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Original Paper

Effects of ginger meal supplementation on performance and meat antioxidative enzymes of broilers fed monosodium glutamate

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The ameliorative effects of ginger meal (GM) on the performance, carcass, and meat qualities of broilers fed diets containing MSG were examined. A total of 360 one-day-old broilers were randomly allotted into four diets: Diet A (control), Diet B (basal + 1.25 g MSG/kg diet), Diet C (Diet B + 1.25 g GM/kg diet) and Diet D (diet B + 2.50 g GM/kg diet). The birds were fed starter and finisher diets and water *ad libitum*. At 6 weeks old, growth performance, carcass and meat qualities were assessed. Broilers on Diets B to D significantly (P <0.05) recorded increased body weight, feed, energy, and protein intakes with those on Diet D having the best feed conversion ratio. The dressed weight and dressing percentage of broilers on the experimental diets were better than the control diet. The inclusion of GM significantly (P <0.05) ameliorated the negative impacts of MSG on relative weights of the heart, liver, and bile. Meat catalase and glutathione peroxidase were significantly (P <0.05) reduced while lipid peroxidation and meat cholesterol were significantly (P <0.05) elevated among the birds fed Diet B when compared with the control. However, the inclusions of GM played a restorative role by significantly (P <0.05) improving the meat antioxidant enzymes and reducing lipid peroxidation and cholesterol. Therefore, the inclusion of MSG at 1.25 g/kg with an inclusion of 1.25 to 2.50 g GM/kg was beneficial for feed palatability enhancement with resultant improvement on performance, carcass, and meat qualities.

Keywords: chickens, carcass qualities, ginger, haematology, lipid peroxidation

1 Introduction

A major constraint to optimum utilization of the highly nutritive and abundant non-conventional feed resources, especially the plant proteins, is palatability (Olarotimi, 2020). Feed palatability largely determines feed acceptability. Despite the rich nutritional contents present in some non-conventional feed resources (Olarotimi and Adu, 2017), they are still underutilized in the feeding of monogastric animals, especially, poultry birds due to the off flavour and/or bitterness. To harness the potentials of these feed resources, the inclusion of flavour-enhancing feed additives such as monosodium glutamate (MSG) will be of special interest. Monosodium glutamate had been reported to be of great importance in enhancing the palatability of feeds (Khalil and Khedr, 2016) due to its capability to boost the appetite centre positively and results in increased body weight gain (BWG) (Gobatto et al., 2002). Feed intake (FI) of broiler chickens fed diets containing MSG between 0.25 to 1.00 g/kg diet was found to be positively enhanced, BWG was increased with an inclusion level up to 0.50 g/kg diet with feed conversion ratio positively influenced (Olateju et al., 2019). In another development, Gbore et al. (2016) observed a significant increase in the average feed intake, body weight gains, and feed conversion efficiency of female rabbits fed increasing levels of MSG. Hewitt and van Barneveld (2012) supplemented 1.15% MSG in gilt lactation diets and reported no deleterious effects on the sow with her FI being maintained and a subsequent significant increase in piglet weight gain was recorded.

Despite the potential of MSG in enhancing the palatability of the most beneficial feed resources, there have been several reports highlighting its negative impacts as feed additives. However, it is the excessive

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inclusion of MSG in the diet that most reports implicated in conferring varying negative effects on animals (Eweka and Om'Iniabohs, 2006). For instance, Diniz et al. (2004) observed induced oxidative stress in the tissues of young rats administered chronic dosage of MSG. The mechanism by which the high inclusion of MSG in the diet caused damage to the animals has been linked to its capability of inducing oxidative stress. Koya et al. (2003) revealed that MSG-induced hyperglycemia caused oxidative stress in the kidney by generating excessive free radicals.

However, the incorporation of feed additives capable of ameliorating the free radicals generation effects of MSG will be a welcomed development in harnessing the potential of MSG to serve as veritable palatability enhancing agent in poultry nutrition. Improved physiological stability and antioxidant status of birds as well as enhanced immunity and performance has been recorded as a result of research focus being shifted in the direction of phytogenic additives as potential feed additives in poultry diets in recent times. The antioxidative status of chickens has been proved to be further enhanced by dietary sources through the incorporation of herbal additives (Gbore et al., 2020). A classical example of a herbal additive that had been researched and reported to be of beneficial effects in poultry nutrition is ginger (*Zingiber officinale*). Significant improvement in the antioxidant status of broilers fed ginger at 5 g/kg diet was also reported by Zhang et al. (2009). Karangiya et al. (2016) equally documented an improvement in the body weight gain of broiler chicks fed varying inclusions of ginger meal. Phytochemical study of ginger has proved that it possesses polyphenolic compounds which are capable of stimulating the digestive enzymes and subsequently improving the overall digestion and body weight gain and also confer an anti-inflammatory, antioxidant, and potential cancer-preventive activity (Hussein et al., 2017). Therefore, the objective of this study was to assess the ameliorative effects of ginger meal on the growth performance, carcass characteristics, intestinal microflora, and meat antioxidative enzymes of broiler chickens fed high dietary monosodium glutamate.

2 Material and methods

2.1 Experimental site

The experiment was carried out at the Poultry Unit of the Teaching and Research Farm, Adekunle Ajasin University, Akungba-Akoko, Nigeria. The study was conduct between the months of March and April when the average temperature was 24 °C and relative humidity was 91% giving temperature humidity index (THI) of 74.34. The research ethics and guidelines of the Animal Science Department of the institution approved the conduct of the experiment (AAUA/ANS/21/050).

2.2 Preparation and phytochemical analysis of ginger powder

Fresh ginger rhizomes and MSG were procured from local market. The fresh rhizomes were washed and sliced into tiny chips for effective drying. The sliced ginger rhizomes were air dried for 14 days in an open ventilated space away from sunlight. Air drying of ginger rhizomes was adopted over sun and thermal processing to avoid degradation of nutritional and phytochemical contents of the ingredient. The air dried ginger rhizomes were milled into fine particles to make ginger meal (GM) using a laboratory hammer mill (Brand: Unimach, Model: WF-130) with 2 mm screen. The GM was stored in an air tight container at room temperature. A sample of the GM was taken and analysed in the laboratory for its proximate, mineral and phytochemical compositions (Table 1). The phytochemical contents were assayed as previously described by Gbore et al. (2020) while the mineral contents such as Zn, Fe, Ca, P and Mg were equally assayed as described by Nunes et al. (2010).

Table 1 Proximate, antioxidant, minerals and phytochemical compositions of ginger meal

Composition	Mean ± SE
Proximate (%)	
Moisture	5.70 ±0.17
Ash	6.20 ±0.34
Fibre	10.96 ±0.22
Fat	13.70 ±0.21
Protein	11.08 ±0.31
Carbohydrate	52.37 ±0.16
Antioxidant properties	
DPPH (%)	55.90 ±0.76
Vitamin C (mg/g)	8.87 ±0.70
Phytochemicals (mg/g)	
Tannins	0.39 ±0.03
Flavonoids	3.43 ±0.15
Phenols	6.07 ±0.16
Saponins	429 ±16.20
Alkaloids	15.70 ±0.35
Phytate	28.70 ±0.08
Minerals (ppm)	
Zn	16.80 ±0.20
Ca	8.78 ±0.07
P	5.70 ±0.10
Mg	1.73 ±0.03

2.3 Experimental animals and diets

Basal starter (0 to 21 days of age) and finisher (21 to 42 days of age) experimental diets were formulated (Table 2) to meet Arbor Acres broiler's manual requirement (Aviagen, 2014). The proximate analyses of the diet samples were carried out according to AOAC (AOAC, 1995). Four (4) experimental diets were prepared for both feeding phases of the experiment. The diets were designated as Diet A (Basal/Control diet), Diet B (Basal + 1.25 g MSG/kg diet), Diet C (Basal + 1.25 g MSG + 1.25 g GM/kg diet) and Diet D (Basal+ 1.25 g MSG + 2.50 g GM/kg). A total of three hundred and sixty (360) one-day-old Arbor Acres broiler chicks were randomly selected and distributed into the four (4) dietary treatments. Each treatment was replicated six (6) times with fifteen (15) birds per replicate in a completely randomized design (CRD). Feed and water were provided *ad libitum* throughout the 6 weeks of the experiment. Recommended vaccination and other medications were administered as at when due.

2.4 Performance, carcass and intestinal microflora of broilers

The weights and feed intake of the birds were recorded weekly throughout the experimental period and the feed conversion ratio was estimated as the ratio of weekly feed intake to weight gain. Protein intake (*PI*), protein utilization (*PU*), energy intake (*EI*) and energy utilization (*EU*) were also estimated as:

$$PI\,(\text{g/bird}) = \frac{feed\ intake\ (\text{g}) \cdot feed\ crude\ protein\ (\%)}{100}$$

$$PU = \frac{crude\ protein\ intake\ (\text{g})}{weight\ gain\ (\text{g})}$$

Table 2 ingredient compositions of the experimental starter and finisher diets (kg)

Ingredients	Starter phase				Finisher phase			
	A	B	C	D	A	B	C	D
Maize	405.00	405.00	405.00	405.00	455.00	455.00	455.00	455.00
Soybean meal	250.00	250.00	250.00	250.00	200.00	200.00	200.00	200.00
Groundnut cake	100.00	100.00	100.00	100.00	55.00	55.00	55.00	55.00
Fish meal (72% CP)	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00
Corn bran	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00
Cassava flakes	100.00	100.00	100.00	100.00	150.00	150.00	150.00	150.00
Wheat bran	15.00	15.00	15.00	15.00	10.00	10.00	10.00	10.00
Bone meal	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00
Limestone	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00
Salt	3.50	3.50	3.50	3.50	3.50	3.50	3.50	3.50
Ginger meal	0.00	0.00	1.25	2.50	0.00	0.00	1.25	2.5
Msg	0.00	1.25	1.25	1.25	0.00	1.25	1.25	1.25
Lysine	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Methionine	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Broiler premix	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
Total	1000.00	1001.25	1002.50	1003.75	1000.00	1001.00	1002.50	1003.75
Analyzed nutrients								
ME (kcal/kg)	3009.51	3009.51	3009.98	3010.06	3104	3104	3104.32	3104.67
Crude protein (%)	23.44	23.44	23.43	23.42	19.80	19.80	19.81	19.80
Fat	4.10	4.10	4.11	4.13	3.91	3.91	3.92	3.93
Calcium (%)	1.17	1.17	1.18	1.19	1.16	1.16	1.17	1.18
Phosphorus (%)	0.52	0.52	0.53	0.53	0.50	0.50	0.51	0.52
Lysine (%)	1.32	1.32	1.34	1.36	1.12	1.12	1.14	1.16
Methionine (%)	0.59	0.59	0.59	0.60	0.55	0.55	0.56	0.56
Crude fibre (%)	3.83	3.83	3.83	3.84	3.46	3.46	3.47	3.48

$$EI\ (\text{kcal/ME/bird}) = \frac{\text{feed intake (g)} \cdot \text{feed metabolizable energy (kcal/ME)}}{1000}$$

$$EU = \frac{\text{energy intake (kcal/ME/bird)}}{\text{weight gain (g)}}$$

On the last day of the experiment, ten (10) birds per replicate (60 birds/treatment) were randomly selected and humanely slaughtered and eviscerated. The organ (lung, gizzard, heart, kidney, and liver) weights were determined with a sensitive scale and recorded. Dressing percentage was determined as the percentage ratio of the live weight to that of the dressed weight of the birds. The intestinal microflora population was determined as previously described by Oloruntola et al. (2021). To determine the bacteria's growth, caecal contents of the slaughtered broilers were taken for bacterial population's analysis by serial dilution. A day before the caecal content collection, agar plates were prepared aseptically and streaked on the experimental site. The aerobic bacteria, lactic acid-producing bacteria and while the intestinal negative lactose bacteria were cultured in the nutrient agar; Man Rogosa agar and the MacConkey agar, respectively (Seidavi and Simoes, 2015).

As previously described by Gbore et al. (2020), 100 g breast meat samples were collected after dressing and evisceration from the sacrificed birds. The samples were preserved at -18 °C till determination of the extent of lipid peroxidation using the thiobarbituric acid (TBA) assay method; meat catalase activity by measuring the disappearance of H_2O_2, glutathione peroxidase activity, and cholesterol concentrations determined spectrophotometrically by using commercial kits (Asan Pharm. Co., Ltd. Seoul, Korea).

2.5 Statistical analysis

Data collected were subjected to one-way analyses of variance (ANOVA) using GraphPad Prism, software version 6.01. Duncan multiple range test (DMRT) of the same package was used for the post hoc analysis where significant difference occurred at $P < 0.05$.

3 Results and discussion

3.1 Proximate, antioxidant, minerals and phytochemical compositions of GM

The results of the proximate, antioxidant, minerals and phytochemical analyses of GM used for the present study are in Table 2. The proximate analysis of the ginger meal revealed that GM is rich in carbohydrates, crude protein, crude fibre, and fat. It equally showed that ginger meal is rich in antioxidants such as 2,2-diphenyl-1-picrylhydrazy hydrate (DPPH) and vitamin C. Ginger meal is also a reservoir of phytochemicals such as alkaloids, saponins, phenols, flavonoids and phytate and tannins in low quantity. The GM also is also rich in inherent mineral contents such as Zinc, Magnesium, calcium and phosphorus. Ginger meal, apart from its proven nutritional richness in carbohydrates, crude protein, fat and fibre as well as minerals such as Zn, Ca, P and Mg (Nour and Yap, 2017) as highlighted further in the present study, is also an indisputable source of natural antioxidants such as DPPH and vitamin C and phytochemicals such as tannins, flavonoids, phenols, saponins, alkaloids and phytate which are bioactive non-nutritive plant chemicals. The great antioxidant activities of GM had been reported to be responsible for its use as therapeutic, anti-bacterial and anti-cancer agents as well as serving as enzymes and hormones stimulant (Akinmoladun et al., 2007). Ginger meal can, therefore, be considered as veritable alternative to antibiotic growth promoters (AGPs) in broiler chicken production as the functions and potentials of phytogenic compounds as phytobiotics and immunomodulatory agents were previously documented (Rehman et al., 2018). The free radical scavenging activity of the antioxidant contents of ginger meal in the present study could be said to have protected the broilers against possible oxidative stress unlike birds on the diet containing MSG without ginger meal. It has been previously explained that phyto-antioxidants play a significant role in enhancing the well being of poultry birds, especially the broiler chickens (Gbore et al., 2020). The antioxidant contents of GM, when used as nutritional supplement in broiler feeding, would reinforce the defence mechanisms of the birds and prevent the possible damaging effects of free radicals on the cells and organs of the body, thereby, enhancing their physiological balance and making them resistant to infections and degenerative diseases that could have spelt a pronounced economic loss to the farmers.

3.2 Performance of broilers fed diets containing MSG and GM

The results of the performance of broiler chickens fed diets containing high inclusion of MSG with varied levels of GM are in Table 3. There were no significant ($P < 0.05$) differences in the body weight gain (BWG) of the birds on diets A, B and C in the starter phase of the experiment. However, birds on diet D displayed a significant ($P < 0.05$) increase in BWG when compared with those on other diets in the starter phase. In the finisher phase, BWG of the birds on diets other than the control were significantly ($P < 0.05$) enhanced. There was statistical similarity ($P > 0.05$) in the BWG of the broilers on diets B, C and D in this phase of the experiment. However, the

overall effects of the starter and finisher diets revealed significantly (P <0.05) lower BWG among the birds on the control diet when compared with birds on other diets. Chickens on diet C showed statistical similarity (P >0.05) with birds on diets B and D while those on diet D recorded the significantly (P <0.05) higher values. For the feed in take (FI), inclusion of 1.25 g MSG/kg diet, at the starter phase, significantly (P <0.05) enhanced the FI of birds on diet B when compared with those on the control but was statistically similar (P >0.05) to what were recorded among birds on diet C and D. Though chickens on diets C and D recorded higher values in FI when compared with birds on the control diet, the differences, however, were not significantly (P >0.05) pronounced. For the finisher phase, the FI among birds on diets B, C and D were similar (P >0.05) but were higher significantly (P <0.05) when compared with those of the birds on the control diet. For the overall effects of the two phases, inclusion of 1.25 g MSG/kg diet significantly (P <0.05) had a pronounced effect on the feed intake when compared with birds on diets A and D.

The feed conversion ratios (FCR) of the birds at the finisher phase were not influenced at all by the inclusion of MSG and ginger supplement. However, the FCR of the birds at starter phase and the overall effect followed the same trend as birds on diets A and D were statistically similar (P >0.05) and had the best FCR compared with those on diets B and C which were also similar. The protein intake (PI), energy intake (EI) and energy utilization (EU) of the birds on diets C and D in the starter phase of the present study were not significantly (P >0.05) different from what were recorded by those on the control diet, whereas, birds on diet B displayed a significantly (P <0.05) higher values for these parameters when compared with the control birds but were not statistically (P >0.05) different when compared with the birds on diets C and D except

Table 3 Performance of broilers fed diets containing MSG and ginger powder

Parameters	A	B	C	D	SEM	*P*-value
Starter phase (1 to 21 days)						
Initial body weight (g/bird)	35.04	34.19	34.21	33.81	0.45	0.14
Body weight gain (g/bird)	620.38^{b}	619.42^{b}	625.98^{b}	671.09^{a}	30.70	0.03
Feed intake (g/bird)	1418.22^{b}	1826.14^{a}	1587.43^{ab}	1566.86^{ab}	94.30	0.04
Feed conversion ratio	2.29^{b}	2.95^{a}	2.54^{ab}	2.33^{b}	0.17	0.01
Protein intake (g/bird)	332.43^{b}	428.05^{a}	371.93^{ab}	366.96^{ab}	15.89	0.04
Protein utilization	0.54	0.69	0.59	0.55	0.08	0.17
Energy intake (kcal/ME/bird)	4268.15^{b}	5495.79^{a}	4778.13^{ab}	4716.34^{ab}	167.45	0.01
Energy utilization	6.88^{b}	8.87^{a}	7.63^{ab}	7.03^{b}	1.49	0.03
Finisher phase (22 to 42 days)						
Body weight gain (g/bird)	1507.09^{b}	1668.89^{a}	1675.81^{a}	1775.10^{a}	67.51	0.02
Total feed intake (g/bird)	3220.76^{b}	3671.87^{a}	3770.67^{a}	3752.76^{a}	145.01	0.01
Feed conversion ratio	2.14	2.20	2.25	2.11	0.07	0.26
Protein intake (g/bird)	637.71^{b}	727.03^{c}	746.97^{a}	743.05^{a}	30.19	0.03
Protein utilization	0.42	0.44	0.45	0.42	1.03	0.64
Energy intake (kcal/ME/bird)	9997.24	11397.48	11705.37	11651.08	171.72	0.31
Energy utilization	6.63	6.83	6.98	6.56	1.22	0.22
Overall (1 to 42 days)						
Total weight gain (g/bird)	2127.47^{c}	2288.31^{b}	2295.79^{ab}	2446.19^{a}	77.3	0.01
Total feed intake (g/bird)	4638.98^{c}	5498.01^{a}	5358.10^{ab}	5318.62^{b}	173.21	0.19
Feed conversion ratio	2.18^{b}	2.40^{a}	2.33^{a}	2.17^{b}	0.05	0.01
Protein intake (g/bird)	970.14^{b}	1155.08^{a}	1118.91^{a}	1110.01^{a}	216.20	0.02
Protein utilization	0.96	1.13	1.04	0.97	1.32	0.09
Energy intake (kcal/Me/bird)	14265.9^{b}	16893.27^{a}	16483.5^{a}	16367.4^{a}	198.21	0.01
Energy utilization	13.51^{b}	15.70^{a}	14.62^{ab}	13.59^{b}	2,.12	0.04

values are means and SEM (standard error of means); means in a row without a common superscript letter differ significantly (P <0.05); diets: A – control/basal; B – basal + 1.25 g MSG/kg; C – diet B + 1.25 g ginger kg^{-1}; D – diet B + 2.50 g ginger/kg

for EU where a statistical difference occurred between birds on diets B and D. A different scenario played out entirely in the finisher phase of this experiment as the EI, EU and protein utilization (PU) of the birds were not significantly (P >0.05) across all the treatment diets when compared. However, the PI were significantly (P <0.05) higher among the birds fed diets C and D while those on diet B showed a significantly (P <0.05) lower PI when compared with birds on other diets. Furthermore, at the overall stage, the PI and EI among the birds fed diets B, C and D were significantly (P <0.05) higher than what were recorded among those on the control diet and were not different (P >0.05) when they were compared among one another. The EU and PU of the overall stage followed the same trend with what were recorded among the birds on the starter phase. The PU were not influenced (P >0.05) by the inclusions of MSG and GM in the broilers' diets. However, inclusion of MSG at 1.25 g/kg diet as used in the present study significantly (P <0.05) increased the EU when compared with birds on the control and diet but a similarity (P >0.05) were observed among birds on diets B and C.

Parameters such as BWG, FI, FCR, PI and PU as well as EI and EU are among the reliable indicators of measuring productive performance in poultry production. The significant increase in BWG, FI and PI in the finisher phase, giving rise to overall significant increase in these parameters, among the broilers on Diet B as against birds on Diet A indicated the potentials of dietary MSG in enhancing the productive performance of broiler chickens. However, the BWG at the starter phase of these birds was not significantly (P >0.05) influenced by the inclusion of MSG in the diet. This could be due to the fact that the breed of birds used in the experiment will only attain the optimum physiological growth and development of their tissues at an age above four weeks or the rate of conversion of feed to meat is higher at the finisher phase than the starter phase as clearly indicated by their FCR and PU which were far better at the finisher phase than the starter phase across all the experimental diets. The significant increase in EI and EU at the starter phase among birds on Diet B when compared with those on Diet A showed that MSG enhances energy metabolism in broiler chickens at the early stage of life which will eventually determine the overall performance of the birds as shown by the overall EI and EU in the present study. Our result on BWG enhancement of MSG was in agreement with the findings of Nosseir et al. (2012) who had reported that rats treated with MSG showed a significant increase in weight compared with those in the control. The increase in FI among birds on Diet A as observed in this study is indicative that MSG improves feed palatability and acceptability among the birds, and therefore, stimulates the orosensory receptors and positively influenced the appetite, thereby, inducing BWG as a result of increased overall feed, protein and, energy intakes when compared with birds on the control diet.

Furthermore, the highest starter, finisher as well as overall BWG recorded among the birds on the containing 2.5 g GM/kg diet could be attributed to the mechanism of action of the inherent bioactive compounds and supplemental energy in GM contributing to promoting broiler chickens' growth performance. A previous study (Athanasiadou et al., 2007) has stressed the potentials of phyto-additives with inherent bioactive compounds are capable of stimulating and enhancing the performance of livestock through the improvement of FI and digestibility, nutrient absorption, and elimination of pathogens that have colonized the gastrointestinal tract of the animal and enhance the secretion of endogenous digestive enzymes and enlargement of villi diameters in the small intestine, thereby improving the broiler chickens' overall BWG, PI, EI, and FCR. The antibacterial, antiviral, antioxidant, anti-cholesterolemic, and anticancerous characteristics of ginger have a strong stimulating effect on the immune and gastrointestinal systems in birds.

3.3 Carcass characteristics of broilers fed high MSG supplemented with GM

The dressing percentage, relative organ weights and intestinal microflora of broilers fed high inclusion of MSG supplemented with GM are shown in Table 4. The live and dressed weights of the birds on diets B, C and D were significantly (P <0.05) higher than the mean live and dressed weights of the birds on the control diet. However, there were no significant (P >0.05) differences in the live and dressed weights of the birds on diets B, C and D when compared with each other. Furthermore, the inclusions of MSG and GM did not significantly (P >0.05) affect the dressing percentage of the birds across all the experimental diets. Among the relative organ weights, heart, liver and bile of the birds on diet B were significantly (P <0.05) higher than what were recorded among birds on all other experimental diets. It was also obvious that varied inclusions of GM in the diets of birds in groups C and D significantly (P <0.05) lowered the relative weights of heart, liver and bile when compared with those in group B. Spleen, gizzard, proventiculus and lungs of the birds across all the experimental diets were not influenced significantly (P >0.05) by the experimental diets when compared with the control. The inclusions of MSG and GM did not cause significant difference (P >0.05) in the aerobic bacteria, lactic-acid producing bacteria and intestinal negative bacteria populations in the chickens' intestine.

Table 4 Carcass traits and intestinal microflora of broilers fed MSG and ginger meal

Parameters	A	B	C	D	SEM	*P*-value
Carcass characteristics						
Live weight (g/bird)	2100^{b}	2570^{a}	2500^{a}	2600^{a}	76.6	0.01
Dressed weight (g/bird)	1650^{b}	2150^{a}	2080^{a}	2190^{a}	68.8	0.01
Dressing percentage (%)	78.57	83.66	83.20	84.23	2.71	0.10
Relative organ weights						
Heart	2.99^{c}	3.93^{a}	2.84^{c}	3.33^{bc}	0.11	0.01
Liver and bile	11.30^{b}	17.00^{a}	12.60^{b}	12.10^{b}	0.49	0.02
Gizzard and proventiculus	16.80	16.70	17.30	17.10	0.69	0.11
Lungs	4.16	3.99	4.11	4.17	0.17	0.19
Spleen	0.87	0.86	0.88	0.97	0.03	0.13
Intestinal microflora						
Aerobic bacteria	7.57	7.78	7.24	7.29	0.234	0.58
Intestinal negative bacteria	7.44	7.59	6.49	6.42	0.223	0.12
Lactic acid-producing bacteria	6.91	6.37	6.55	6.93	0.162	0.25

values are means and SEM (standard error of means); means in a row without a common superscript letter differ significantly (P <0.05); diets: A – control/basal; B – basal + 1.25 g MSG/kg; C – diet B + 1.25 g ginger/kg; D – diet B + 2.50 g ginger/kg

From the present study, the significant increase observed in live and dressed weights of birds fed 1.25 g MSG/kg diet proved that MSG has the potential of increasing the carcass value of broiler chickens. Increased carcass breast meat quantity and reduced-fat are among key factors considered to adjudge the profitability of broiler production (Adetunji et al., 2019). Furthermore, the fact that the inclusion of GM at the inclusion rates used in this study did not adversely affect the carcass traits such as dressing percentage and dressed weight indicated that GM is a veritable additive to enhance the meat quality of broiler chickens fed MSG for better feed palatability without compromising the carcass quality of the chickens. The significant increase in the relative organ weights of the heart, liver, and bile among the birds fed diet B indicated the potential of high inclusion of MSG in causing heart and liver hypertrophy in broiler chickens. Our finding was consistent with an earlier report which indicated that a significant increase in heart weight among rats fed high MSG (Okon et al., 2013). This could be a pointer to the fact that the gross weight of the heart of domestic chicken could significantly be enlarged with continuous high MSG in broilers' diet. Usually, the hypertrophy of the heart results in an increased thickness of the heart muscle and in most cases cardiac enlargement is accompanied by cardiovascular problems. Also, the enlarged liver and bile weight recorded among birds on diet B gave credence to the hepatotoxicity of high inclusion of MSG in broilers' diets. A previous study suggested that dilatations of the central hepatic vein with lysed erythrocytes and distorted hepatocytes due to impaired membrane permeability could be responsible for liver hypertrohphy (Eweka et al., 2011). However, the inclusion of GM in diets C and D proved the antioxidant and anti-inflammatory properties of the additive as there was a significant reduction in the weights of the heart, liver, and bile. This reduction in liver and heart relative weights of broiler chickens fed GM could be an indication that ginger exhibits hepatoprotective and anti-inflammatory properties when added as dietary supplements in broilers fed MSG. Since phyto-additives are reservoirs of natural antioxidants; they are capable of scavenging the reactive oxygen species (ROS) generated by the high inclusion of MSG thereby protecting the vital organs of the body against oxidative stress. Similarly, the addition of phyto-additive in broiler feed was noted to lower the cholesterol concentrations in the meat and liver (Oloruntola et al., 2018). It could be that the lowered cholesterol concentration in the liver was, therefore, responsible for its lower weight among birds fed diets supplemented with GM. There is also an additional health benefit to the inclusion of GM in broiler diets because consumption of cholesterolemic meat could predispose humans to hypercholesterolemia implicated in causing atherosclerosis and coronary heart diseases (Shen et al., 2019). It was generally observed in this study that the gut integrity of the birds was not compromised as indicated by the insignificant effects of the MSG and GM on the intestinal microflora of the birds. The result of the total aerobic bacteria, lactic acid-producing bacteria, and intestinal negative bacteria counts was statistically similar across the treatments thereby suggesting that MSG

and GM did not interfere with the intestinal microflora throughout the experimental period. The role of non-pathogenic intestinal bacteria in inhibition of pathogen proliferation, enhancement of growth performance, and reduction of morbidity and mortality of poultry has been stressed (Oluwafemi et al., 2018).

3.4 Meat cholesterol and antioxidative enzymes of broilers fed MSG and GM

The inclusion of high MSG in the diet of broiler chickens (Figure 1) significantly (P <0.05) reduced the meat catalase when compared with those on the control diet. However, an inclusion of 1.25 g/kg diet GM significantly enhanced the meat catalase content among birds on diet C when compared with those on diet B. A doubling effect of GM was recorded among the birds on diet D as a significant (P <0.05) increase was noted when compared with birds on diet A, B and C. Furthermore, there was a significant (P <0.05) reduction in glutathione peroxidase (GSH) activity (Figure 2) of the meat samples from birds on diet B when compared with those on the control diet. However, inclusion of 1.25 g GM/kg diet marginally ameliorated the effect of MSG on this enzyme, though not significantly (P >0.05) relevant. The activity of GSH was significantly (P <0.05) increased among the chickens on diet D containing 2.5 g GM/kg diet when compared with those on diet B. the means recorded by birds on diet D was statistically comparable with those on diets A and C. The meat lipid peroxidation (Figure 3) and cholesterol (Figure 4) observed among the birds fed diet B, containing 1.25 g MSG/kg diet, were significantly (P <0.05) higher than what were recorded among birds fed diets A, C and D, respectively. Though

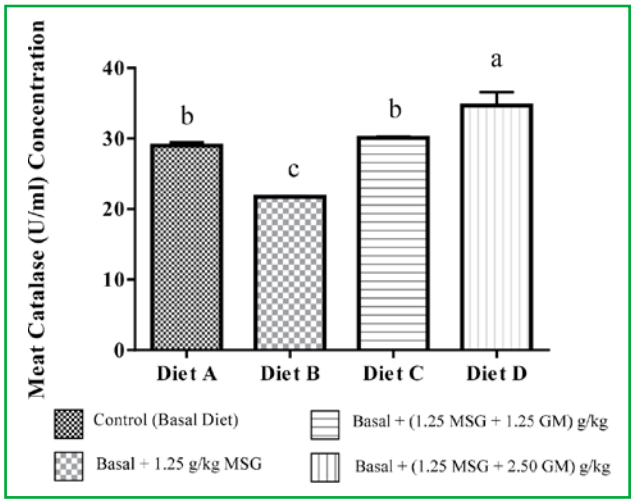

Figure 1 Effects of MSG and ginger meal on meat catalase

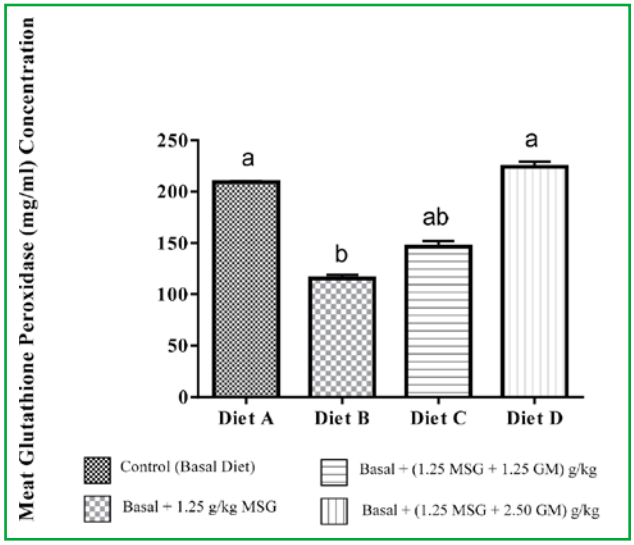

Figure 2 Effects of MSG and ginger meal on meat glutathione peroxidase

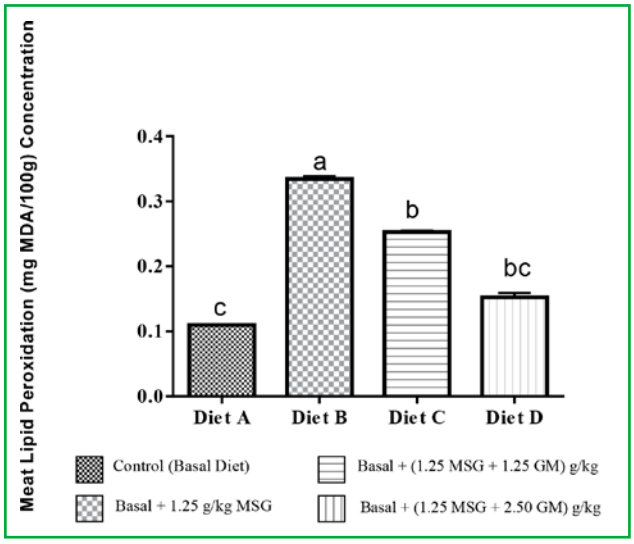

Figure 3 Effects of MSG and ginger meal on meat lipid peroxidation

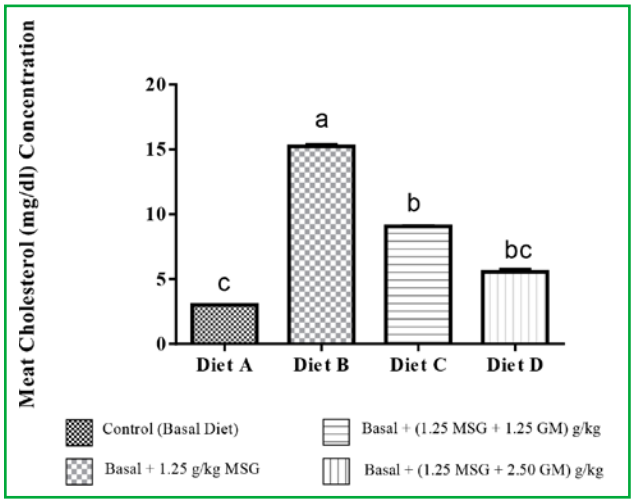

Figure 4 Effects of MSG and ginger meal on meat cholesterol

inclusion of 1.25 g GM/kg diet significantly (P <0.05) lowered the meat lipid peroxidation and cholesterol among birds on diet C as compared with birds on diet B, higher (P <0.05) lipid peroxidation and cholesterol were still observed when compared with meat from the birds on the control diet. However, inclusion of 2.5 g GM/kg diet reduced the meat lipid peroxidation and cholesterol significantly (P <0.05) among the birds on diet D to be comparable with values recorded among birds on the control diet.

It was clearly evident by the result of this study that high MSG inclusions in broilers' diet adversely affect the oxidative stability of the meat as meat catalase and glutathione peroxidase were both significantly lowered among the birds on diet B while lipid peroxidation and meat cholesterol significantly increased. The antioxidative enzymes which are present in the meat function primarily in preservation against oxidative decomposition (Gbore et al., 2020). The reduction in the activities of these enzymes and elevation of lipid peroxidation and meat cholesterol as observed among the broilers fed diet B in this study would definitely subject the meat to cellular damage coordinated by the absorption of superoxide and hydrogen peroxide. The significantly higher meat malondialdehyde (MDA) and cholesterol concentrations observed among birds in group B indicated that high inclusion of MSG favours higher meat lipid peroxidation and cholesterol deposition. Though a previous study opined that the addition of MSG up to 1.00 g/kg in broiler diet did not affect any meat quality parameters such as malondialdehyde (MDA) of meat and antioxidative enzymes (Adetunji et al., 2019), the present study disagreed with this claim as meat quality parameters were adversely affected. This could be due to the fact the inclusion used in this study was higher than what was used in the report. Lipid peroxidation and antioxidant capacity of meat are usually inversely correlated; this explained why there was an elevation in lipid peroxidation of the breast meat in the face of reducing antioxidative enzymes activities and this will surely lead to meat quality deterioration among the birds on diet B. Lipid peroxidation has also been established as a major factor of health risks to the consumers (Gbore et al., 2020). The reduction of sensory and nutritional quality of meats are usually midwived by a series of biochemical reactions in which polyunsaturated fatty acid reacts with reactive oxygen species (ROS) leading to degradation of lipids and development of oxidative rancidity, thereby, adversely impacting the general acceptance of the meat by the consumers.

However, the inclusion of GM at 1.25 and 2.5 g/kg diet restored the quality of the meat from the broilers as observed among the chickens fed diets C and D respectively. The ameliorative effect of GM observed on meat antioxidative enzymes of chickens in groups C and D was an indication that ginger has an enhancement effect on the concentration of catalase and glutathione peroxidase which in turn have an effect on the antioxidant status of the body of the birds. This study shows that the higher inclusion of GM, as observed among the birds on diet D proved to better enhance the antioxidant enzymes of the birds against oxidative stress occasioned by the high inclusion of MSG. This result has also shown the cholesterolemic effects of MSG and the anticholesterolemic potency of ginger. The presence of gingerols in ginger has been explained to be responsible for its use as a potent antioxidant due to stimulation of superoxide dismutase, catalase, and glutathione peroxidase activities (Chakraborty, 2012) and its use to reduce cholesterol levels. Furthermore, the high composition of phytochemicals and antioxidants in the ginger meal sample (Table 2) was responsible for the reduction in the level of lipid peroxidation in the breast meat samples of chickens fed diet B. Previous studies have also established the potency of phyto-additives in reducing meat lipid peroxidation of animals fed varied inclusions of different herbs and spices (Oloruntola et al., 2018; Gbore et al., 2020). The significantly reduced meat cholesterol concentration in response to an increasing level of GM is indicative that ginger meal has hypocholesterolemic potency. Furthermore, the improved meat catalase and glutathione peroxides concentration in the meat

4 Conclusions

It could be concluded from the results of this study that high dietary inclusion of MSG (1.25 g/kg diet and above) in broilers' diets improved feed palatability and thereby increasing feed intake and improving the carcass traits of the chickens but could also predispose them to oxidative stress, thereby, adversely affecting the productive performance of the birds and compromising the quality of the meat from such chickens. However, the inclusion of GM at 1.25 and 2.5 g/kg diet was potent enough in masking the detrimental effects of high MSG on the productive performance, meat antioxidative enzymes and cholesterol concentration. The quality of the meat from the chickens on diets containing 1.25 and 2.50 g GM/kg diet was far better with improved antioxidant enzymes activities and lowered lipid peroxidation and cholesterol unlike those on diet containing 1.25 g MSG/kg diet. The increased meat catalase and glutathione peroxidase concentrations of chickens in groups fed 1.25 and 2.50 g GM/kg diet as well as the lowered meat lipid peroxidation and cholesterol could translate to an improved shelf life

of the meat. However, further research is required to ascertain the correlation between meat shelf life and the lowered meat lipid peroxidation and cholesterol on one hand and meat shelf life and increased meat catalase and glutathione peroxidase concentrations on the other hand. If a positive correlation is obtained, this would have been a novel approach to producing safer meat for the consumers.

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