Nigerian J. Anim. Sci. 2026, 28 (1): 85-95

Effects of dietary supplementation of tumeric, black pepper and their combinations on growth response, heamatology, serum biochemistry, gut microbial counts, and meat quality of broiler chickens

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Targeted Audience: Poultry farmers, Feed millers, Researchers

Abstract

This study was conducted to investigate the effects of supplementation of turmeric, black pepper and their combinations on the growth response, haematology, serum biochemistry, gut microbial counts and meat quality of broiler chickens. The broiler chicks were fed one of the six experimental diets. These includes: i) a corn-soybean basal diet without feed additive (T1), ii) The basal diets with 1% black pepper (T2), iii) The basal diets with 1% Turmeric powder (T3), iv) The basal diets with 0.25% black pepper + 0.75% turmeric powder (T4), v) the basal diets with 0.75% black pepper + 0.25% turmeric powder (T5), vi) The basal diet with 0.5% black pepper + 0.5% turmeric powder (T6). In completely randomized design (CRD) and lasted for 6 weeks. Data was collected weekly on weekly growth performance. Blood samples were collected for haematology and serum biochemical indices. At the end of the experiment 2 birds per replicate were sacrificed, opened up, faecal samples were collected from the ileo- caecal junction for gut microbial counts. Results of growth response revealed significant ($p<0.05$) dietary effects on final weight, weight gain and feed conversion ratio (FCR). For blood parameter, white blood cell (WBC), eosinophil, cholesterol, High density lipoprotein (HDL) and low density lipoprotein (LDL) were significant. While all other parameters measured were not significant ($p>0.05$). The meat quality attributes results show that water holding capacity were significantly influenced. The study concluded that supplementing broilers diets with a combination of (0.5% turmeric + 0.5% black pepper) will results in good feed conversion ratio and did not have any detrimental effects on the haematological and serum biochemical indices.

Key words: Black pepper, Turmeric, haematology, Microbial counts, Eimeria oocytes.

Description of problems

Overuse of antibiotics in poultry production has led to the emergence of antibiotics – resistant bacteria, which poses a threat to both animal and human health. Therefore, there is a growing interest in finding alternatives to antibiotics that can promote animal health and welfare without contributing to the development of antibiotics resistance (1,2,3). Many spices and foliar meals have been reported to have positive effects on the performance and health status of egg and meat-type chickens (4, 5, 6, 7, 2). These phytogenic feed additives (PFAs) contains a lot of bioactive compounds such as polyphenols, organic acids, essential oils, terpenoids and aldehydes are known to possess antioxidants and antibacterial properties that can have a positive impacts on productivities (8). In addition, PFAs can stimulate blood circulation and promote the production of digestive secretion, including mucin, amylase, lipase, trypsin, protease, and bile acid (9). Previous studies have shown that PFAs can impact the gut microbiome (10), improve lipid metabolism (11) enhance intestinal mucosal morphology, strengthen

the intestinal functions (12), and boost the immune system of broiler chickens (13).

Turmeric (*Cucuma longa*) is a spice that belongs to the Zingbaracae family and is widely distributed in tropical and subtropical region of the world, particularly in Asian countries (14). As a traditional herbal medicine, turmeric has been used for centuries to treat various ailments, including urinary tract infection, liver disorder, inflammations, menstrual disorders, and digestive issues (15). Both *in vivo* and *in vitro* studies have demonstrated that turmeric possess numerous biological and pharmacological properties such as antioxidants, antibacterial, antifungal, anti-inflammatory, and immune-modulatory effects (16). The pharmacological activities ot turmeric is primarily attributed to the presence of various curcuminoid compounds, including curcumin, demethoxycurcumin, and bisdmethoxycurcumin (15).

Black pepper (*Piper nigrum*) is another significant widely –used spice with therapeutic benefit. In traditional medicine, it is utilized to alleviate symptoms of dizziness, asthma, chronic indigestion, flu, fever, chills, and migraine (17). Piperine, the primary active compound found in black pepper, has been extensively researched in recent years due to its relatively low side effects and a broad range of physiological activities , including antioxidants, antimicrobial, anti-inflammatory, anticacinogenic, and cholesterol lowering effects (18). Other benefits of piperine includes promoting blood circulation, stimulating appetite, and producing saliva and digestive secretions in poultry (19). Although the pharmaceutical activities of turmeric and black pepper in human and various experimental animals have been well-documented, there have been limited studies of these additives in poultry as natural growth promoters.

Given the pharmacological properties of turmeric and black pepper documented in previous in vitro studies, the current research postulated that these phytogenic products would work synergistically to enhance each other's beneficial effects. Therefore this present study is aimed at investigating the effect of turmeric, black pepper, and their combinations on the growth response, heamatology, serum biochemistry, gut microbial counts, gut morphometry and meat quality of broiler chickens.

Materials and Methods

Source of Plant material and processing

Black pepper and turmeric rhizomes were purchased from local market in Ibadan, Nigeria. The samples were cleaned dried, ground to a fine powder and stored in an air tight container until when needed for formulation.

Experimental design, and diets

In a 42 –days study, 300 1 day –old unsexed broilers chickens were purchased from a local commercial hatchery. On arrival the broilers chickens were brooded together for 7 days during this time they were fed with basal diet, after which they were weighed and randomly assigned to one of the six experimental diets with five replicate pens (10 birds per replicate) in a completely randomized design. The birds were housed in deep litter pen in with continuous day light and were allowed to *ad libitum* access to feed and water throughout the experiment. The nutritional requirements of the growing broilers were adapted from (20) tables, and a basal diets was formulated (Table 1). The broiler chicks were fed one of the six experimental diets. These includes: i) a corn-soybean basal diet without feed additive (T1), ii) The basal diets with 1% black pepper (T2), iii) The basal diets with 1% Turmeric powder (T3), iv) The basal diets with 0.25% black pepper + 0.75% turmeric powder (T4), v) the basal diets with 0.75%

black pepper + 0.25% turmeric powder (T5), vi) The basal diet with 0.5% black pepper + 0.5% turmeric powder (T6).

Table 1: Experimental diets

Ingredients (%)	Starter phase	Finisher phase
Maize	50.00	55.00
Groundnut cake	6.40	3.80
Soyabean meal	30.00	30.00
Fish meal (72% CP)	2.00	1.00
Wheat offals	7.30	5.00
Bone meal	2.00	2.50
Limestone	1.50	2.00
Salt	0.25	0.25
Vitamin/mineral premix*	0.25	0.25
Lysine	0.20	0.10
Methionine	0.10	0.10
Total	**100.00**	**100.00**
M.E	2831.25	2861.10
Determined analysis %		
Dry matter (%)	91.43	92.18
Crude protein (%)	23.03	19.89
Ether extract (%)	3.68	3.54
Crude fibre (%)	3.56	3.75
Ash (%)	5.16	5.35

*Vitamin-mineral premix (2.5kg/1000kg); vitamin A (11,000,000IU), vitamin D3 (3,000,000IU), vitamin E (30,000IU), vitamin K (2.3gm), vitamin B1 (1.7gm), Riboflavin (5.2gm), Pyridoxin (3.7gm), vitamin B12 (18mg), Biotin (76mg), Niacin (37gm), panthotenic acid (9.2gm), folic acid (0.9gm),manganese (85gm), zinc (50gm), iron (25gm), copper (6gm), iodine (1gm), selenium (120gm), cobalt (220mg),antioxidant (126gm), choline chloride (180gm). M.E = Metabolizable energy.

Sampling and measurement

The initial individual body weight of the broiler chickens were measured on day 7 and thereafter on weekly bases, and the mean was calculated for each replicate. The feed intake (FI) were recorded on replicate bases. The body weight gain (BWG), FI, and feed conversion ratio (FCR) were calculated for a total period of 35 days.

On day 35, two (2) birds with body weight close to the average of the replicate were randomly selested. Blood samples was collected from the brachial vein into heparinized tubes for haematological parameters evaluation such as packed cell volume (PCV), Heamoglobin concentration (Hb), Red blood counts (RBC) and white blood counts (WBC), while the blood constants and white blood cell differential counts were calculated. Another blood samples was collected into non- heparinized tube and centrifuged at 2,500g for 15 min at 4^{o}C to obtain the serum. The serum concentration of glucose, total protein, Albumin, globulin, Aspartate aminotransferase (AST), Alanine aminotransferase (ALT) Alkaline phosphatase (ALP), total cholesterol low density lipoprotein (LDL) and high desity lipoprotein (HDL) were all determine using an automatic biochemical analyser (Clima, Rai.Co, Spain), and commercial laboratory kits (Pars Azmoon kits, Pars Azmoon, Tehran, Iran).

After blood sample collection, the same birds were euthanized by cervical dislocation to evaluate carcass characteristic, meat attributes, ileo caecal microbial population, and the small intestine morphological characteristics. After removing the feathers, carcass weight, breast, thighs, and all other carcass parameters were weighed and expressed as a percentage of live body weight.

For histological measurement, a 3 cm segment was first removed from the middle point of the duodenum, jejumum, and ileum; then flushed with distil water and fixed in 10% neutral buffer formalin for 48 hours. The fixed samples were dehydrated, cleared, and embedded in paraffin. Tissue samples (5µm thickness) were cut by a microtome, stained with haematoxylin-eosin and scanned using a light microscope. The morphological parameters including villi height (VH: from the top of the villus to the top of lamina propria), cryptal depth (CD: the depth of the

invagination between adjacent villi), and villi width (VW: at the middle point of the villus) were measured on each slide.

For meat quality measurement, samples of breast muscle (pectoralis major) were taken from each carcass for meat quality measurements. All measurements were performed after the breast meat has been chilled (4°C) for 24 hours postmortem. The ultimate muscle pH was determined using a calibrated glass electrode pH meter. A 5g sample of breast muscle was homogenized with 45 mL of deionized water, and the pH probe was inserted into the homogenate to measure ph. Measurements were taken in triplicate and averaged. Thermal shortening was assessed by evaluating carcass handling temperature prior to the onset of rigor mortis. Immediately after slaughter and evisceration, carcasses were monitored for internal muscle temperature using a calibrated digital thermometer. Carcasses were exposed to controlled temperature conditions above 20°C before chilling to determine the degree of muscle fiber contraction attributable to thermal shortening. Muscle samples from the breast (Pectoralis major) were excised and their sarcomere length measured using a ruler, as shorter sarcomere lengths are indicative of greater shortening. Cold Shortening was determined in carcasses subjected (breast muscle) to rapid chilling at temperatures below 10°C before the onset of rigor mortis. Sarcomere length and tenderness (Warner–Bratzler shear force) were recorded to quantify the extent of shortening. A reduction in sarcomere length compared to control samples indicated cold shortening, which is typically associated with tougher meat texture.

Breast muscle samples were weighed before freezing and after thawing at 4°C for 24 hours for the evaluation of thaw loss. The samples were weighed (W_1) prior to freezing, the samples were then thawed at 4°C for 24 hours and reweighed (W_2). Thaw loss percentage was calculated as:

$$\text{Thaw loss \%} = \frac{\text{Wt before thawing (W1)} - \text{Wt after thawing (W2)}}{\text{Wt before thawing (W1)}} \times 100$$

Cooking Loss was measured as per standard gravimetric methods. Breast muscle samples (pectoralis major) were collected from each carcass, trimmed of visible fat and connective tissue, and individually weighed to obtain the raw weight. Each sample (approximately 100 g) was sealed in a heat-resistant polyethylene bag and cooked in a water bath at 80°C until the internal temperature reached 75°C. After cooking, the samples were removed, cooled to room temperature (approximately 25°C), blotted with filter paper to remove surface moisture, and reweighed to determine the cooked weight.

$$\text{Cooking Loss (\%)} = \frac{\text{Wt before cooking (W1)} - \text{Wt after cooking (W2)}}{\text{Wt before cooking (W1)}} \times 100$$

All meat quality tests were replicated (at least in triplicate) for accuracy. Care was taken to ensure uniform sample handling and temperature control during analysis.

Statistical Analysis

Data collected on bird performance, haematology and weights were subjected to one way analysis of variance procedure (ANOVA) of SAS institute Inc (21). The treatment means were compared using the (22) multiple range test.

Results

The results of the growth response of broiler chicken fed diets supplemented with Turmeric, Black pepper, and their combinations is presented in Table 2. Final weight, weight gain, feed conversion ratio (FCR) were significantly ($p<0.05$) influenced by the dietary treatments while all other parameters were not significantly ($p>0.05$) influences. Highest final weight, and weight was recorded for birds on T6 (0.50% turmeric

and 0.50% black pepper), while those on T3 (1% Turmeric) had the least values for both parameter. Birds fed diet supplemented with 0.50 black pepper and 0.50% Turmeric (T6) had the least FCR compared to other treatment groups.

Table 2: Growth response of broiler chicken fed diets supplemented with black pepper, turmeric and their combination

Parameters	T1	T2	T3	T4	T5	T6	±SEM
Initial weight (Kg/bird)	0.13	0.13	0.13	0.13	0.13	0.13	0..00
Final weight (Kg/bird)	2.36^{ab}	2.35^{ab}	2.28^{b}	2.30^{ab}	2.34^{ab}	2.57^{a}	0.03
Weight gain (Kg/bird)	2.24^{ab}	2.22^{ab}	2.16^{b}	2.17^{ab}	2.21^{ab}	2.45^{a}	0.03
Feed intake (Kg/bird)	4.64	4.49	4.42	4.48	4.60	4.57	0.07
Feed conversion Ratio	2.07^{b}	2.02^{b}	2.05^{b}	2.06^{b}	2.09^{a}	1.85^{ab}	0.04
Protein efficiency ratio	0.49	0.54	0.48	0.49	0.48	0.56	0.01

The results of haematology and serum biochemistry of broilers fed diets supplemented with turmeric, black pepper and their combinations are presented in Tables 3 and 4. All haematological indices parameters measured were not significantly ($p>0.05$) influenced by the dietary treatments except white blood cells (WBC) and Eosinophils which were significantly influenced ($p<0.05$). Birds on T1 (control) and T4 (0.5% turmeric +0.5% black pepper) had highest values for (WBC) while the least values were recorded by birds on T5 (0.75% turmeric + 0.25% black pepper). Eosinophil was highest in birds in T6 (0.25 turmeric + 0.75% black pepper) while bird in T4 (0.5% turmeric+ 0.5% black pepper) had the least values. Among the serum biochemical indices evaluated, cholesterol, high density lipoprotein (HDL), and low density lipoprotein (LDL) were significantly ($p<0.05$) influenced by the dietary treatments, while all other parameters were not significantly ($p>0.05$) influenced. Highest cholesterol value was recorded for birds in T5, with lowest value recorded for birds in T1. However, birds on T4 and T5 had the highest values for both HDL and LDL, while those on T1 had the least values for these parameters.

Table 3: Haematological indices of broiler chicken feed diets supplemented with black pepper, tumeric and their combinations

Parameter	T1	T2	T3	T4	T5	T6	±SEM
Packed cell volume (%)	34.33	32.67	35.33	33.00	33.00	32.33	0.62
Red blood cells	3.54	3.37	3.39	3.31	3.41	3.35	0.07
Haemoglobin	11.30	10.53	11.63	10.80	10.73	10.70	0.90
Mean cell volume	97.10	96.60	104.46	99.67	99.86	96.89	1.04
Mean corpuscular concentration	31.96	31.25	34.39	32.68	31.50	32.12	0.42
MCHC	33.25	32.23	31.93	32.72	32.84	33.12	1.62
White blood cell	2.17^{a}	1.69^{b}	1.45^{b}	2.14^{a}	1.85^{ab}	1.57^{b}	0.08
Lymphocytes (%)	66.67	64.67	67.00	65.00	65.00	64.00	0.72
Heterophil (%)	24.33	27.33	26.33	29.00	29.00	27.67	0.82
Monocytes (%)	2.67	2.67	3.00	3.67	2.67	2.67	0.18
Eosinophil (%)	4.33^{ab}	5.00^{ab}	3.33^{ab}	2.33^{b}	3.00^{ab}	6.00^{a}	0.44
Basophil (%)	0.33	0.33	0.33	0.00	0.33	0.33	0.04

Note: MCHC – Mean corpuscular haemoglobin concentration

Table 4: Serum Biochemical indices of broiler chicken feed diets supplemented with black pepper, turmeric and their combinations.

Parameters	T1	T2	T3	T4	T5	T6	±SEM
Glucose (mg/dl)	181.33	217.33	216.33	256.00	213.00	208.86	8.47
Total protein (mg/dl)	3.73	4.13	4.03	3.34	4.20	3.90	0.09
Albumin (mg/dl)	0.07	0.63	0.77	0.77	0.37	0.67	0.03
Globulin (mg/dl)	3.03	3.50	3.27	3.60	3.47	3.23	0.08
AST (IU/L)	188.33	194.67	191.67	200.67	193.67	167.33	4.19
ALT (IU/L)	24.67	32.67	28.00	33.00	29.00	26.33	1.30
Cholesterol (mg/dl)	125.00^{c}	165.00^{abc}	147.00^{bc}	190.00^{ab}	196.33^{a}	162.00^{abc}	7.68
HDL (mg/dl)	73.00^{b}	79.00^{ab}	76.00^{ab}	92.00^{a}	90.00^{a}	81.67^{ab}	2.50
LDL (mg/dl)	34.47^{b}	65.27^{ab}	50.00^{ab}	76.33^{a}	64.87^{ab}	61.73^{ab}	5.01
Creatinine (mg/dl)	0.40	0.47	0.43	0.50	0.50	0.47	0.01
Urea (mg/dl)	1.73	2.67	2.13	2.20	2.03	2.00	0.11

ALT – Alanine aminotransferase, AST – Aspartate aminotransferase, HDL – High density lipoprotein, LDL – Low density lipoprotein

The results of gut microbial counts of broilers fed diets supplemented with turmeric, black pepper and their combinations is presented in Table 5. All parameters measured were not significantly ($p>0.05$) influenced by the dietary treatments. TBC x 10^6 cfu/ml = Number of viable bacteria count x serial dilution ratio/volume of inoculum used.

Table 5: The gut microbial counts of broiler chicken fed diet supplemented with black pepper, turmeric and their combination

Parameter (CFU/g)	T1	T2	T3	T4	T5	T6	±SEM
Total Bacteria count	1.07	1.17	1.03	1.03	1.25	1.03	0.06
Bacillus spp.	0.10	0.13	0.00	0.07	0.00	0.03	0.02
Streptocuccus spp.	0.20	0.17	0.03	0.00	0.20	0.07	0.05
Salmonella spp.	0.10	0.43	0.07	0.17	0.20	0.10	0.04
Escherichia spp.	0.27	0.17	0.27	0.03	0.20	0.27	0.05
Klebsiella spp.	0.10	0.13	0.00	0.03	0.20	0.03	0.03
Streptococcus faecalis	0.07	0.00	0.00	0.20	0.00	0.17	0.04
Staphylococcus auerus	0.00	0.00	0.13	0.00	0.20	0.10	0.03

Table 6 present the meat quality attributes of broiler chickens fed diets supplemented with Turmeric, black pepper, and their combinations. Among all meat quality attributes evaluated, cooking loss was significantly ($p<0.05$) influenced by the dietary treatments, while all other parameters were not significant ($p>0.05$).The values obtained for cooking loss ranged from (22.22 to 24.00) with birds on T1 having the highest values while those in T6 had the least values.

Table 6: Meat Quality Attributes of Broiler Chickens Fed Diets Supplemented With Black Pepper, Turmeric and Their Combinations

Parameters	T1	T2	T3	T4	T5	T6	±SEM
Thermal shortening	28.04	35.06	23.23	31.75	35.48	31.75	2.33
Cold Shortening	24.00	20.97	12.22	8.01	9.17	13.86	2.89
Cooking loss	39.72^{a}	33.71^{ab}	33.33^{ab}	36.07^{ab}	34.92^{ab}	22.22^{b}	2.10
Thermal Loss	31.45	36.18	38.19	36.15	32.82	35.20	1.65

Discussion

The use of phytogenic feed additives (PFAs) has become increasingly popular in the post-antibiotics ere due to their various properties including antibacterial, antioxidants, and, anti-inflammatory effects. Phenolic and flavonoid compounds, which are secondary metabolites of plants, are primarily responsible for their antioxidants and antimicrobial activities. The feeding trial results indicate that broilers fed diets supplemented with a combinations of 0.50% black pepper and 0.05% Turmeric recorded the highest values for final weight, weight gain, and had the lowest feed conversion ratio (FCR). However adding turmeric, black pepper and most especially their combinations did enhance growth response across the dietary treatments. Likewise, (23) reported that Turmeric powder at 0.1% inclusion level increased body weight gain and reduced FCR of broilers. Furthermore, prior research has demonstrated that adding different PFAs to broiler diets, such as *Pullicaria gnaphalode* powder and *Achryrabthes japonica* extracts can improve FCR, nutrient digestibility, gut micrbiota, and intestinal morphology (24, 25)

The non- significant effects of PFAs on haematological values reported in this study could infer that the haematological indices were within the safety limits for broilers. The observed PCV and Hb values were within the reference range 24.9 – 45.2% for healthy birds reported by (26). The significant difference observed in the mean WBC and Neutrophil could be due to differences in the intrinsic body defense system (27). The normal haematological values portrayed the nutritional status of the broiler chickens and thus indicating adequate nourishment of the birds (28). The serum biochemistry profile of broiler chickens provides valuable information about their metabolic status, health, and overall physiological condition. In this study, *Piper nigrum* and *Curcuma longa* significantly increase total cholesterol, LDL, and HDL in the blood serum. The serum concentration of cholesterol and triglyceride can reflect the lipid metabolism (29). The increase in these parameter was at variant (30) who reported significant reduction in rats fed and excessive fat diet supplemented with cucumin. The increase in the value of HDL is in agreement with (31) who reported that ginger and black pepper at the 0.25% + 0.25% inclusion level notably increased HDL in broiler chickens. However, this result corroborate the reports of (32 and 33).

The phytogenic materials (Turmeric, Black pepper and their combination), did show any significant effects on the gut microbial population. This finding corroborate the work of (34), who reported reduction in gut microbial counts when Thyme and cinnamon were fed to broiler chickens. (35) also observed decrease in the mean bacterial counts with increased Turmeric concentration in broilers diets. He also reported strong inhibition of pathogenic

bacterial when diets supplemented with 1% turmeric powder were fed to broiler chickens.

Turmeric-based treatments (T3 and T4) significantly reduced thermal shortening and cold shortening, which are key indicators of postmortem muscle contraction and tenderness. This effect is likely due to the antioxidant activity of curcumin in maintaining muscle cell membrane integrity during chilling (36, 37). Cooking loss was markedly lower in supplemented groups, especially T6, indicating improved water-holding capacity a critical quality attribute affecting juiciness and consumer acceptability (36). Although thaw loss differences were not statistically significant, numerical trends showed that balanced combinations of turmeric and black pepper (T5 and T6) tended to minimize moisture loss during frozen storage. This supports previous findings that natural antioxidants in spices can slow protein and lipid degradation, thereby maintaining water retention (37).

Conclusion and application

It can be concluded that;

1. Supplementing broilers diets with a combination of (0.5% turmeric + 0.5% black pepper) will bring about good feed conversion ratio and did not have any detrimental effects on the haematological and serum biochemical indices.

References

1. Aderemi, F. A., M. A. Olufemi, A. Magret, G. A. Adenike, and O. A. Mathew. (2018). (2018). Utilization of duckweed meal as replacement for fish meal by broiler chickens. *Insight Poultry Research*, 8: 1-9.

2. Ruelas, E. P. F., A. W. Canaza-Cayo, F. H. R. Huanca, U. H. P. Guerra, R. Churata-Salehi, B., Stojanovic-Radic, Z., Matejic, J., Shariffi-Rad, M.J., Kumar, N.V.A and Martins, N (2019) The Threapeutic potential of curcumin. A review of clinical trials. *European Journal of Medical Chemistry* 163, 527-545.

3. Soisuwan, K., Plaimast, H., Hongnum, A., Chotnipat, S and Nopparatmaitree, M. (2023). Effect of Natural Multi-Enzyme Supplementation on Growth Performance, Gut Microflora, Carcass Characteristics, and Meat Quality of Broilers Reared in Tropical Climates. *Journal Animal Health and Production* 11(2): 129-138

4. Aderemi, F. A., M. A. Olufemi, O. A. Mathew, and O. O. Loveth. (2017). Evaluation of fermented Locust Bean Meal (*Parkia biglobosa*) as a replacement to soybean meal on production performance, blood profile and gut morphology of broiler chicken. *Journal Animal Science and Veterinary Medicine.* 2:23–28.

5. Alabi Olufemi, M., O. Ojo John, F. A. Aderemi, T. E. Lawal, A. O. Oguntunji, M. O. Amalraj, A., Pius, A., Gopi, S, and Gopi, S. (2017) Biological activities of curcuminoids, other biomolecules from turmeric and their derivatives – A review *Traditional Complementary Medicine* 7. 205-233

6. Liu, M., Y. Lu, P. Gao, X. Xie, D. Li, D. Yu, and M. Yu. (2020). Effect of curcumin on laying performance, egg quality, endocrine hormones, and immune activity in heat-stressed hens. *Poultry Science.* 99:2196–2202.

7. Ramachandraiah, K., and G. P. Hong. (2022). Polymer based nanomaterials for strategic applications in animal food value chains. *Food Review International* 38:1577–1606.

8. Shirani, V., Jazi., V., Toghyani, M., Ashayerizadeh, A., Sharifi, F., and

Barekatain, R. (2019). *Pulicaria gnaphalodes* powder in broiler diets; Consequences for performance, gut health, antioxidant enzyme activity, and fatty acid profile. *Poultry Science.* 98, 2577 – 2587.

9. Mohebodini, H., Jazi, V., Ashayerizadeh, A., Toghyani, M., and Tellez-Isaias, G (2021). Productivity parameter, caecal microflora, nutrient digestibility, antioxidant status, and thigh muscle fatty acid profile in broiler chickens fed with *Eucalyptus globulos* essential oil. *Poultry Science*. 100, 100992. doi:10.1016/j.psj.2020.12.020.

10. Barbarestani, S.Y., Mohebodini, H., Ashayerizadeh, A, Shabadani, A., and Tughyani, M. (2020) Effect of dietary lavender essential oil on growth performance, intestinal functions, and antioxidants status of broiler chickens. *Livestock Science.* 253. 103958

11. Mohebodini, H., Jazi, Y., Bakhshalinejad, R., Shabani, A, and Ashyerizadeh. A (2019). Effect of dietary resveratrol supplementation on growth performance, immune response, serum biochemical indices, caecal microfloral and intestinal morphology of broiler chickens challenge with *Escherichia coli*. *Livestock Science.* 229, 13-21

12. Oso, A.O., Suganthi, R.U., Reddy, G.M., Malik, P.K., Thirumalaisamy,G., Awachat, V.B (2019). Effect of dietary supplementation with phytogenic blend on growth performance, apparent ileal digestibility of nutrients, intestinal morphology, and caecal microflora of broiler chickens. *Poultry Science.* 98.4755 4766

13. Pigoxliev, V., Mansbridge, S.C., Rose, S.P., Lillebog, H.S, and Bravo, D (2019) Immune modulation, growth performance, and nutrient retention in broiler chickens fed a blend of phytogenic feed additives. *Poultry Science*. 98, 3445- 3449.

14. Almaraj, A., Pius, S., Gopi, S., (2017). Biological activities of Curcuminoids, other biomolecules from turmeric and their derivatives: A review. *Journal of. Traditional Complementry Medicine*. 7:205 - 233

15. Salehi, B., Lopez-Jornet, P., Pons-Fuster Lopiz, E., Calma, D., Sharifi-Rad, D., and Ramirez-Alarcon, K. (2019). Plant derived bioactives in oral mucosal lesion: A key emphasis to curcumin, lycopene, chamomile, Aloe-vera, green tea, and coffee properties. *Biomolecules.* 106 (6): 9-23

16. Mizzael, H., Shakeri, A., Rashidi, B., Jalili, A., Banikazemi, Z and Sahebkar, A (2017) Phytosomal curcumin: A review of pharmacokinetic, experimental and clinical studies. *Journal of Biomedicine and pharmacotheraphy*. 85: 102-112

17. Gogani, I., Mohammad, M., Najafpour, G.D, and Nikzad, M. (2017). Piperine-the bioactive compound of black pepper: from isolation to medicinal formulation. *Compr. Rev. Food Sci*. 16, 124 – 140.

18. Shityakov, S., Bigdelian, E., Hussein, A.A., Hussein, M.B., Tripathi, Y.C and Khan, M.U (2019) Phytochemical and pharmacological attributes of piperine,. A bioactive ingredient of black pepper. *European Journal Medicinal. Chemistry.* 176. 149- 152

19. Ogbuewu, I.P., Okoro, V.M, and Mbajiorgu, C.A. (2020). Meta-analysis of the influence of phytobiotic (pepper) supplmemtation in broiler chicken performance. *Tropical Animal Health and Production.* 6, 17-30.

20. National Research Council. (1994). Nutritional Requirement of Poultry 9th Revision Ed. National Academy Press Washington DC.

21. SAS, (2003). SAS?STAT User's Guide: Version 8 for Windows. SAS Institute Inc., Cary, NC., USA

22. Duncan, D.B. 1955. Multiple Range and Multiple F-test. Biometrics. 11- 1-42

23. Khan, K., and Ahmad, N. (2022). Using Cinamom (*Cinnamomum zeylanicum*) and Turmeric (*Curcuma longa*) powder as an antibiotic growth promoter substitution in broiler chicken's diets. *Animal. Biotechnology.* 1: 1-8.

24. Church, J.P., Judd, J.I., Yong, C.W., Kebay, J.L. and Kin, W.W. 1984. Relationship among dietary constituents and specific serum clinical components of subject eating self-selected diets. *American Journal Clinical Nutrition.* 40: 1338-1344.

25. Park, J.H, and Kim, I.H. (2020). Effects of dietary *Achyranthes japonica* extract supplementation on the growth performance, total tract digestibility, ceacal microflora, excreta noxious gas emission , and meat quality of broiler chickens. *Poultry Science*. 99:463 - 470

26. Mitruka, B.M and Rawnsley, H (1977). Clinical biochemistry and heamatological reference values in normal experimental Animals. Ist edition, Masson Publishing Inc. New York, USA. Pp54-55

27. Ganomg, J.E (1991). *A review of Medicinal Physiology*. Lang Medical Publication. Pp 115

28. Church, J.P., Judd, J.T., Yomg, C.W., Kabay, T.l., and Kim, W.W (1984). Relationship among dietary constituents and specific serum clinical components of subjects eating self-selecting diets. *American Journal of Clinical Nutrition* 40: 1338- 1344.

29. Sharifi-Rad, M., Lanketillake, C., Dias, D.A., Cocea, A.O., Mohomoodally, M.F and Lobine, D. (2023). Lifestyle, Oxidative stress, and Antioxidant: Back and Fort in Pathophysiology of chronic diseases. *Frontier in Physiology*. 11:694. Doi;103389/fphys.00694.

30. Akira, A and Teru, O.M (2021). Dietary Curcuminoids Prevent High Fat Diet-Induced Lipid Accumulation in Rat Liver, Epididymal Adipose Tissue. *American Society of Nutritional Sciences.* 131 (11): 2932-2935

31. Aikpitanyi, K.U. and Egweh, N.O. (2020). Haematological and biochemical profile of broiler chickens fed diets containing ginger and black pepper additives. *Nigerian Journal of Animal Science*. 22 (2):114-125.

32. Akbarian A, Golian A, Kermanshahi H, Gilani A, and Moradi S (2012). Influence of turmeric rhizome and black pepper on blood constituents and performance of broiler chickens. *African Journal Biotechnology*. 11(34): 8606-8611

33. Alagawany M., Salah A.S., Mahmoud M.A, and Reda, F.M.(2020) Dietary cold-pressed red and black pepper oil mixture enhances growth, carcass, blood chemistry, antioxidant, immunity and caecal pathogens of quails. *Animal Physiology and Nutrition.* 104 (6):1712–1718.

34. Ahmed, I., El-Rayes, T, and Ahmed, A.I (2018). Assessment of dietary supplementation of Turmeric (*Curcuma longa*) as a phytobiotic on broiler performance and bacterial count. *Egyptian Journal of Nutrition and Feeds*. 21(2): 519-528.

35. Ayoola,and O. Oladejo. (2021). Antilipemic effect of *Moringa oleifera* leaf powder on blood serum cholesterol fractions in broiler finishers. *Int. J. Livest. Produc.* 12:49–52.

36. Wang, D., Huang, H., Zhou, L., Li, W., Zhou, H., Hou, G., Liu, J, and Hu, L (2015). Effects of dietary supplementation with Turmeric rhizome

extract on growth characteristics, antioxidant capability, and meat quality of Wenchang chickens. *Italian Journal of Animal Science.* 14(3): 344-34

37. Qureshi, A.A., Z.Z. Din, N. Abuirmeileh, W.C. Burger, Y. Ahmad, and C.E. Elson. (2015). "Suppression of Avian Hepatic Lipid Metabolism by Solvent Extracts of Garlic: Impact on Serum Lipids." *The Journal of Nutrition* 113:1746–55.