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Performance and blood biochemistry profile of broiler chickens fed dietary turmeric (*Curcuma longa*) powder and cayenne pepper (*Capsicum frutescens*) powders as antioxidants

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ABSTRACT

A 56-day experimental trial was conducted to investigate the performance and blood biochemistry profile of broiler chickens fed dietary turmeric (*Curcuma longa*) powder (t) and cayenne pepper (*Capsicum frutescens*) powder (c) as antioxidants. Two hundred and forty three (two-week old) broiler chicks were randomly allotted into nine treatment groups consisting of 27 selected chicks and three replicates of nine birds each. Three levels of t – (0, 200 and 400 g/ 100 kg basal diet) and three levels of c – (0, 100 and 200 g/ 100 kg basal diet) were used to formulate nine dietary treatments (basal diet (B) inclusive) and fed to each groupin two phases, starter (3–4 weeks) and finisher (5–8 weeks) phases in a randomized design. Feed intake and weight gain were highest ($p < 0.05$) in chicks fed B + 100c diet at the starter phase, while feed conversion ratio was best ($p < 0.05$) in chickens fed B + 400t + 200c diet at finisher phase. All chickens fed dietary additives had significantly ($p < 0.05$) decreased serum alanine aminotransferase and low density lipoproteins but increased high density lipoproteins in the starter phase. The hematological count determined indicate poor ($p < 0.05$) profile in groups fed B + 200c diet. Feeding broiler chicks dietary B + 400t + 200c was recommended for optimal growth performance. However, indices measured in the finisher phase allude that the best ($p < 0.05$) lipid profile were for chickens allotted B + 400t and B + 200t + 100c diets, while chicks fed B + 200t + 100c diet had overall a better serum count in the finisher phase.

1. Introduction

Animal and human health are two interwoven fields of research, with recurrent findings attributing health effects to excess fat content in diet, saturated fatty acid and cholesterol content facilitating prevalent diseases of western societies such as cardiovascular diseases, diabetes (Micha, Wallace, & Mozaffarian, 2010) and cancer (Cross et al., 2010; Ferguson, 2010). Reactive oxygen species (ROS) and nitrogen species (RNS) have been implicated in mechanisms of red cells damage (Rao et al., 1970), via the alteration of lipid profile and cellular activity. Consumption of different types of phenolic compounds from natural foods has been emphasized as a means to possibly decrease the risk of serious health problems due to their antiradical and antioxidant activities (Surh, 2003). Cellular activity and performance of broiler chicken reportedly depend on available feed nutrients, utilizable feed ingredients as well as distribution of absorbed nutrients to and through tissues and organs.

Researches have focused on the beneficial effects of phytogenic substances on broiler chickens. Anti-oxidative substances in plantshave been demonstrated to restrict the formation of toxic oxidation products, maintain nutritional quality and possibly stimulate performance. Turmeric powder (*Curcuma longa*) belongs to the ginger (*Zingiberaceae*) family and known to possess phenolic compounds (curcuminoids) that act as antioxidant and anti-inflammatory agent. Curcuminoids such as curcumin, demethoxycurcumin and bisdemethoxycurcumin, are yellowish turmeric pigments that have antioxidative, anticarcinogenic, and anti-inflammatory properties (Nishiyama et al., 2005). Curcumin is the prominently potent curcuminoid, reportedly capable of lowering the activity of reactive oxygen species that elevates the antioxidant enzymes superoxide dismutase, catalase, and glutathione peroxidase levels in the blood. McCarthy, Kerry, Kerry, Lynch, and Buckley (2001) similarly reported curcumin as the active substance in turmeric powder capable of inhibiting the generation of ROS like superoxide anions, H_2O_2 and nitrite radical generation by activated macrophages, which play an important role in inflammation. As reported by Kermanshahi and Riasi (2006) turmeric powder at 0.2% decreased

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Nomenclature

B	Basal diet
c	cayenne pepper powder
t	turmeric powder
Units	
MJ/kg	mega joule per kilogram
%	percentage
G/b	grams per bird
G/b/r	grams per bird per replicate
G/dl	gram per deciliter
Mg/dl	milligram per deciliter
l	Liter

serum triglyceride, total cholesterol and LDL-c concentrations in laying hens.

Pepper is widely cultivated in the tropics principally for its economic and nutritional value. Its fruit is a major source of natural colours and antioxidant compounds. Capsaicinoids in cayenne pepper reportedly exhibit protective coverage against mutagens, carcinogens, cholesterol, obesity and pains (Choi et al., 2004). Capsaicin, the prominent capsaicinoids stimulate metabolism via energy release food catabolism leading to growth stimulation (Govindarajan & Sathyanarayana, 1991). The combination of antioxidants could have a superior effect compared to single antioxidants in facilitating normal physiological activities in chickens (McDonald & Scott, 1996), however, the toxicity of turmeric powder and cayenne pepper when consumed is reportedly dose dependent (Nwaopara, Anyanwu, Oyinbo, & Anaikot, 2004; OdikeIngbenebor, and AdoyeOdikeIngbenebor, and Adoye, 2007 and HMPC, 2009) and specie dependent (Al-Sultan, 2003). Hence, the scope of this study targets the anti-oxidative effects of turmeric (*Curcuma longa*) powder and cayenne pepper (*Capsicum frutescens*) powder on the performance and blood biochemistry of broiler chickens

2. Materials and methods

Fresh Cayenne pepper was purchased from a commercial market in Ibadan which was cleaned, spread in thin layer and dried. To prevent high losses and contamination due to weather exposure, the fruits were regularly stirred daily until constant weight was attained to ensure uniform drying, thereby reducing dis-coloration and fungal growth. The dried crispy pepper was ground into powder via the attrition mill, which was added to basal diet at appropriate levels of inclusion. Dried turmeric rhizomes was also purchased from the same market, milled into powdery form and included into the basal diets at appropriate levels of inclusion.

2.1. Proximate composition of test ingredients

Proximate composition (moisture, crude protein (CP), ether extract (EE), carbohydrate and ash content) of turmeric rhizome powder, cayenne pepper, test diets were determined by method described by AOAC (2005)

2.2. Experimental birds and management

2.2.1. Research policy

Animal Ethics Committee guidelines of the Federal University of Agriculture, Abeokuta (FUNAAB, 2014) were strictly adhered to throughout the duration of the experiment.

2.2.2. Experimental site

243-day old broiler (Arbor acres) chicks were sourced from a hatchery in Ibadan. The birds were brooded together for the first two weeks in a deep litter pen. Wood shavings were spread on the floor of the pen as litter material. Vaccinations and medications required were administered following a recommended schedule of an established farm during the experiment. The experiment was carried out at the Poultry Unit of Directorate of University Farms (DUFARMS), Federal University of Agriculture Abeokuta, Ogun State, Nigeria. The site is located in the rain forest vegetation zone of South-Western Nigeria on latitude 7° 13′ 49.46″ N, longitude 3° 26′ 11.98″E and altitude 76 m above the sea level. The climate is humid with a mean annual rainfall of 1037 mm and mean temperature and humidity of 34.7 °C and 83%, respectively (Google Earth, 2013). Feed and water were offered *ad-libitum*.

2.2.3. Experimental diets and layout

At the end of two weeks of collective brooding, the birds were randomly assigned into nine treatment groups, each consisting of 27 birds. Each treatment was further replicated three times containing 9 birds per replicate. Experiment had the starter (3–4 weeks) and finisher (5–8 weeks) phases. All diets were formulated following recommended procedures (NRC, 1994)

Treatment (T) 1- Basal diet (No dietary Supplementation) (B)
T2 - Basal diet + 200 g Turmeric Powder (B + 200t)
T3 - Basal diet + 400 g Turmeric Powder (B + 400t)
T4- Basal diet + 100 g Cayenne Pepper Powder (B + 100c)
T5 - Basal diet + 200 g Cayenne Pepper Powder (B + 200c)
T6 - Basal diet + 200 g Turmeric Powder + 100 g Cayenne pepper powder (B + 200t + 100c)
T7 – Basal diet + 400 g Turmeric Powder + 100 g Cayenne pepper Powder (B + 400t + 100c)
T8 – Basal diet + 200 g Turmeric Powder + 200 g Cayenne pepper Powder (B + 200t + 200c)
T9 – Basal diet + 400 g Turmeric Powder + 200 g Cayenne pepper (B + 400t + 200c)

2.3. Data collection

2.3.1. Performance evaluation

Record of feed intake, weight gain and mortality were taken weekly. Feed conversion ratio (FCR) was obtained by calculation.

$$\text{Total Feed Intake (g)} = \text{Total Feed supplied (g)} - \text{Total feed left over (g)}$$

$$\text{Average feed intake (g/bird)} = \frac{\textit{Total Feed Intake}}{\textit{Number of birds}}$$

$$\text{Total weight gain} = \text{Final weight} - \text{Initial weight}$$

$$\text{Feed conversion ratio} = \frac{\text{Total Feed intake (g)}}{\text{Total weight gain (g)}}$$

$$\%\,\text{Mortality} = \frac{\textit{Number of dead birds}}{\textit{Total number of stocked birds}} \times \frac{100}{1}$$

2.3.2. Blood collection

At weeks 4 and 8, 5 ml of blood was collected from the wing vein of three birds per replicate into heparinized tubes containing anticoagulant (Ethylene diamine tetra-acetate (EDTA)) for haematological indices, while blood serum was collected into plain vials.

2.3.3. Haematological indices

Haematological indices such as erythrocyte count, Packed Cell Volume (PCV), White Blood Cell (WBC), WBC differentials and mean corpuscular haemoglobin were determined. Haemoglobin concentration was determined using van slyke apparatus, and PCV – hacksley haematocrit centrifuge (UK). WBC and its differentials were determined using the Neubaer count chamber following procedure described by Fudge (2000) and Cray and Zaias (2004).

2.3.4. Serum biochemistry profile

At days 28 and 56, blood samples were collected into heparinized tubes from three birds selected per replicate by running the needle through the brachial vein. Serum was determined colorimetrically using Jenway 6405 UV/VIS Spectrophotometer (UK). Serum protein was derived through methodology described by Tietz (1995). Bromo Cresol Green (BCG) method was employed for serum albumin as described by Donmas, Watson, and Briggs (1971), while Alanine Transaminase (ALT), Aspartate Transaminase (AST) (IFCC 1986a, b) and Cholesterol (Gordon & Amer, 1977) values were recorded. Creatinine level was done with beam spectrophotometer (492 nm), while concentration of low density lipoprotein (LDL), high density lipoprotein (HDL) and triglycerides in the serum (Burtis & Ashwood, 1999) were documented.

2.4. Statistical analysis

Data obtained were subjected to one-way analysis of variance and analyzed using the general linear model procedure of SPSS (2011) version 20. Treatment means with significant difference at $p < 0.05$ were compared using Duncan Multiple Range Test (DMRT) of the same statistical package.

3. Results

3.1. Composition (%) of basal diet at starter and finisher phases

The determined analysis of the basal diet used at the starter and finisher phases respectively is presented in Table 1. The basal diet was formulated up to 100 kg of feed. At starter phase, basal diet fed chicks contains 23.09% crude protein, while basal diet at finisher phase had 19.11% crude protein. Energy content of basal diet available for metabolism yielded 12.10 and 12.03 MJ/kg value at starter and finisher phases respectively. Crude fiber values of starter and finisher basal diets were 3.47 and 3.50, respectively, while determined analysis of feed ether extract was 4.17 and 3.93 values at starter and finisher phases respectively. Broiler chickens derived calcium and phosphorus from formulated basal diet at starter (1.40 and 0.71) and finisher (0.69 and 1.38) phases, respectively, per kilogram of feed.

3.2. Growth performance of chickens fed dietary additives

The effect of dietary inclusions on growth performance of broiler chicks is presented in Tables 2 and 3 for starter and finisher phases respectively. No significant ($p > 0.05$) effect was observed among performance parameters, except feed intake at starter phase. Feed intake was higher ($p < 0.05$) in groups fed dietary B + 400t and B + 100c than other dietary groups with the basal group and groups fed 400t + 200c least ($p < 0.05$).

At the finisher phase, significant ($p < 0.05$) differences were observed in final weight, weight gain, feed intake and feed conversion ratio indices. Broiler chickens fed basal diet had the least ($p > 0.05$) final weight and weight gain compared to highest ($p < 0.05$) weights (final weight and weight gain) obtained for birds fed dietary B + 100c. Feed intake of birds fed single dietary additive, excluding groups fed B + 200c diet was higher ($p < 0.05$) than intake values recorded for birds fed the basal diet. However, treatments groups fed dietary B + 200c, B + 200c + 200t and B + 200c + 400t dietary additive had significantly ($p < 0.05$) lower intake than the basal group. Feed conversion ratio of chickens fed B + 400t + 200c dietary additive was best ($p < 0.05$). No mortality was recorded at the end of 6 weeks of feeding trial.

3.3. Serum biochemistry of broiler chickens fed dietary additives

Tables 4 and 5 show the effects of feeding dietary ingredients on serum indices of broiler chicks at starter phase. At starter phase, significant ($p < 0.05$) differences were observed in total serum protein, globulin, Alanine amino-transferase (ALT), Aspartate aminotransferase (AST) low density lipoproteins (LDL) and high density lipoprotein (HDL) values. Birds fed no dietary additive had highest ($p < 0.05$) total serum protein and globulin compared to other treatment groups. This same trend was observed in ALT and LDL indices documented, as the basal group had significantly ($p < 0.05$) increased values. For AST, the basal group (B) and groups fed B + 400t + 200c diet were significantly ($p < 0.05$) highest, as opposed to the 141.00 U/L value of birds fed B + 200t diet. However, contrary to the trend above, HDL values recorded show that birds fed B + 400t + 100c, B + 200t + 100c; B + 200t + 200c and B + 400t diets had statistically better ($p < 0.05$) values than the basal group. No significant difference ($p > 0.05$) was observed in creatinine values recorded for broiler chicks.

Significant differences ($p < 0.05$) were recorded across treatments groups for serum parameters, with albumin and AST excludedat finisher phase. Total serum protein value increased for groups fed B + 200t, B + 400t, B + 100c, B + 200c, B + 200t + 200c and B + 400t + 200c diets than the 2.10 g/dl of the Basal group, though statistically similar to values for birds fed B + 200t + 100c and B + 400t + 100c diets.

Chickens fed B + 200c diet had the highest ALT values which contrasts with the 16.50 U/L recorded for birds fed B + 400t + 100c diet. All dietary combinations gave lesser ALT values compared to values documented for chickens in the basal group. Creatinine was least ($p < 0.05$) in groups fed 1 g/kg dietary cayenne pepper but highest in chickens fed B + 200t + 200c diet. Serum LDL of chickens fed B + 200t was higher ($p < 0.05$) than the 18.10 g/dl recorded for groups fed dietary B + 200t + 100c diet. Respectively, groups fed dietary B + 400t and B + 200t + 100c had the highest ($p < 0.05$) HDL levels

Table 1
Composition (%) of the experimental diets at starter and finisher phases for broiler chickens.

Ingredients (%)	Starter phase	Finisher phase
Maize	52.00	58.40
Wheat bran	4.30	10.60
Soybean meal	18.50	10.00
Groundnut cake	17.00	14.00
Fishmeal (72%)	2.20	1.00
Bonemeal	3.00	3.00
Limestone	2.00	2.00
Salt	0.25	0.25
[a]Mineral and vitamin premix	0.25	0.25
Methionine	0.25	0.25
Lysine	0.25	0.25
Total	**100.00**	**100.00**
Determined analysis		
Crude protein (%)	23.09	19.11
M. E (MJ/kg)	12.10	12.03
Crude Fiber	3.47	3.50
Ether extract	4.17	3.93
Calcium	1.40	1.38
Phosphorus	0.71	0.69

[a]Premix composition per kg diet: Vit A: 400,000.00 IU, Vit D3: 800,000.00 IU, Vit E: 9,200.00 mg, Vit k: 800.00 mg, Vit B1: 1000.00 mg, Vit B6: 500.00 mg, Vit B12: 25.00 mg, Niacin: 6000.00 mg, Pantothenic acid: 2000.00 mg, Folic acid: 200.00 mg, Biotin: 8 mg, Mn: 300,000.00 g, Zn: 20,000.00 g, Cobalt: 80.00 mg, I: 40.00 mg, Choline: 80,000.00 g, Antioxidants: 800.00 mg.

Table 2
Effect of dietary additives on growth performance of broiler chicks at starter phase.

Parameters	Basal (B)	B + 200t	B + 400t	B + 100c	B + 200c	B + 200t + 100c	B + 400t + 100c	B + 200t + 200c	B + 400t + 200c	SEM
Initial weight (g/b)	211.11	233.29	216.65	212.97	225.92	218.52	211.10	218.50	212.97	0.40
Final weight (g/b)	616.56	677.43	682.95	668.12	682.93	687.02	634.81	623.69	651.47	27.48
Total weight gain (g/b)	405.44	444.14	466.30	455.15	457.01	468.51	423.71	405.19	438.50	27.24
Total feed intake (g/b)	845.95^{c}	925.91^{b}	1000.22^{a}	972.02^{a}	925.91^{b}	926.28^{b}	925.91^{b}	925.91^{b}	840.17^{c}	10.66
FCR	2.09	2.10	2.17	2.14	2.06	1.99	2.20	2.29	1.94	0.15
Mortality (%)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

$^{a, b, c}$ Means in the same row with different superscripts differ significantly ($p < 0.05$).
c – Cayenne Pepper Powder; t – Turmeric Rhizome Powder; Av – Average.
FCR – Feed Conversion Ratio; g/b – gram per bird.

compared to other treatments groups, though statistically similar with birds fed dietary B + 200t + 200c diet.

3.4. Effect of dietary inclusion of turmeric powder and cayenne pepper powder on hematological indices of broiler chickens

Values recorded on the effects of test substances on hematological indices of broiler chicks at starter phase are presented in Tables 6 and 7. PCV, hemoglobin concentration (HBC), red blood cell (RBC) and white blood cell (WBC) values at starter phase were significantly $p < 0.05$) different among indices measured. PCV recorded was highest ($p < 0.05$) in groups that consume no dietary additives as opposed to least ($p > 0.05$) documented in groups fed B + 200t and B + 200t + 200 dietary inclusions respectively. HBC value was highest ($p < 0.05$) for birds fed the basal diet (11.80 g/dl), though values were similar to birds fed B + 400t + 200c dietary additive (11.35 g/dl). The latter was however similar in value to birds fed B + 400t + 100c (10.15 g/dl). The Basal group maintained its trend with a red blood cell count of 3.14×10^{12}/L which was higher ($p < 0.05$) than other treatment groups. Groups fed B + 200t + 100c additive had the highest ($p < 0.05$) WBC count. Count documented for B + 200t + 100c was higher ($p < 0.05$) than count recorded for birds fed B + 200t and B + 400t diets, although similar in values as groups fed no dietary additives, B + 100c, B + 400t + 100c, B + 400t + 200c and B + 200c + 200t diets. Neutrophil and lymphocyte indices were significantly ($p < 0.05$) highest and lowest in treatment groups fed 100 and 200 g dietary cayenne pepper additive respectively.

In the finisher phase, hematological parameters significant ($p < 0.05$) at starter phase were also significant at finisher phase. PCV, HBC and RBC values of chickens fed dietary B + 200t + 200c additive were high ($p < 0.05$) contrasting documented values for groups fed B + 400t + 200c diet. WBC values ranged from 2.20 to 7.75×10^{3}/L. Birds fed B + 400t + 200c dietary additive had highest ($p < 0.05$) WBC count, but at 200 g dietary cayenne pepper addition to the basal diet, the least ($p > 0.05$) count was recorded. Neutrophil and lymphocyte values were alternately highest ($p < 0.05$) and lowest ($p > 0.05$) for groups fed B + 400t + 100c diet (50.00 and 46.50 %) and basal diet (34.50 and 62.00 %) respectively at the end of the feeding trial.

4. Discussion

The highest feed intake observed in the chicks fed dietary B + 400t and B + 100c may point to antioxidant stimulation of digestive system. Findings from this feeding trial disagree with reports of Al-sultan (2003) and Durrani et al. (2006) whose findings reveal reduced feed intake as dietary consumption of turmeric increased, while feeding 100 g of cayenne pepper with the basal diet likely pointed to optimal tolerance of chicks to capsaicin (the most active and pungent capsaicinoid in pepper) stimulation of digestive system. Significant increase in feed intake in chicks fed 4 g/kg turmeric powder may be due to the optimum antioxidant activity of turmeric (*Curcuma longa*) documented to stimulate enzymatic system of chicks. Curcuma, cayenne pepper and other antioxidants can reportedly stimulate the function of pancreatic enzymes (lipases, amylases and proteases)

Broiler chickens fed B + 100c diet consumed more feed with higher gain and live-weight. Increased activities of digestive enzyme in gastric mucosa possibly enhance the synthesis of bile acids in the liver and their excretion in bile, which beneficially effect lipids digestion and absorption. This was however not the case for chickens fed B + 200c diet, possibly suggesting optimal tolerance of chickens to capsaicinoids present in cayenne pepper. Hence, to balance the fast rate of metabolism, chickens fed B + 100c diet possibly consume more feed, facilitated by the improvement of endogeneous digestive enzyme secretion (Srinivasan, 2005).

Feed conversion ratio was best in chickens fed B + 400t + 200c. A significant ratio of good weight gain to feed intake may be due to optimum activity of curcuminoids in B + 400t diet. Curcumin in turmeric has been demonstrated to improve feed utilization by stimulating protein synthesis through enzymatic system of birds (Al-sultan, 2003), resulting in improved digestion, increased nutrients metabolism and increased weight gain (Durrani et al., 2006). Dietary capsaicins possibly increase satiety and fullness, and its consumption tend to prevent overeating in animals. Hence, 200 g of cayenne pepper added to basal diet show that capsaicin in cayenne pepper prevented minimized fat deposition as digestive juices acts on feed consumed. However, curcumin in B + 400t diet facilitated protein synthesis.

Packed Cell Volume (PCV) is the percentage (%) of Red Blood Cells (RBC) in blood (Purves, Sadava, Orians, & Heller, 2003), and values

Table 3
Effect of dietary additives on growth performance of broiler chickens at finisher phase.

Parameters	Basal (B)	B + 200t	B + 400t	B + 100c	B + 200c	B + 200t + 100c	B + 400t + 100c	B + 200t + 200c	B + 400t + 200c	SEM
Initial weight (g/b)	616.56	677.43	682.95	668.12	682.93	687.02	634.81	623.69	651.47	27.48
Final weight (g/b)	1543.85^{b}	1740.73^{ab}	1662.97^{ab}	1760.17^{a}	1648.12^{ab}	1637.93^{ab}	1675.04^{ab}	1639.85^{ab}	1725.68^{ab}	59.50
Total weight gain (g/b)	927.29^{b}	1063.30^{ab}	980.01^{ab}	1092.05^{a}	965.19^{ab}	950.91^{ab}	1040.23^{ab}	1016.16^{ab}	1074.21^{ab}	43.41
Total feed intake (g/b)	3298.86^{f}	3475.91^{b}	3385.17^{c}	3542.20^{a}	3233.32^{g}	3333.30^{e}	3367.02^{d}	3233.32^{g}	3207.39^{h}	2.74
FCR	3.56^{b}	3.27^{ab}	3.45^{ab}	3.24^{ab}	3.35^{ab}	3.51^{ab}	3.24^{ab}	3.19^{ab}	2.99^{a}	0.14
Mortality (%)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

$^{a, b, c, d, e, f, g, h}$ Means in the same row with different superscripts differ significantly ($p < 0.05$).
c – Cayenne Pepper Powder; t – Turmeric Powder; Av. – Average.
FCR – Feed Conversion Ratio; g/b – gram per bird.

Table 4
Effect of dietary additives on serum indices of broiler chicks at starter phase.

Parameters	Basal (B)	B + 200t	B + 400t	B + 100c	B + 200c	B + 200t + 100c	B + 400t + 100c	B + 200t + 200c	B + 400c + 200c	SEM
Total protein (g/dl)	4.35^{a}	2.75^{b}	2.50^{b}	2.30^{bc}	2.85^{b}	2.75^{b}	2.25^{c}	2.50^{b}	2.50^{b}	0.32
Globulin (g/dl)	2.85^{a}	1.35^{b}	1.30^{b}	1.15^{b}	1.60^{b}	1.55^{b}	0.85^{b}	1.30^{b}	1.25^{b}	0.27
Albumin (g/dl)	1.50^{a}	1.40^{ab}	1.20^{ab}	1.15^{b}	1.25^{ab}	1.20^{ab}	1.40^{ab}	1.20^{ab}	1.25^{ab}	0.09
ALT (U/L)	78.50^{a}	10.50^{b}	9.50^{b}	4.50^{b}	13.50^{b}	3.50^{b}	12.00^{b}	15.00^{b}	4.00^{b}	3.61
AST (U/L)	177.00^{a}	141.00^{b}	158.00^{ab}	158.00^{ab}	152.50^{ab}	165.00^{ab}	160.00^{ab}	154.00^{ab}	171.50^{a}	98.51
Creatinine (Mg/dl)	0.30	0.35	0.25	0.4	0.30	0.35	0.40	0.40	0.35	0.06
LDL(mg/dl)	50.55^{a}	12.75^{b}	25.70^{b}	19.60^{b}	26.15^{b}	12.75^{b}	17.15^{b}	19.35^{b}	18.10^{b}	6.14
HDL (mg/dl)	18.95^{d}	79.85^{ab}	91.35^{a}	66.25^{b}	40.60^{c}	88.45^{a}	86.55^{a}	90.60^{a}	63.65^{b}	6.01
Total Cholesterol (Mg/dl)	91.15	117.60	126.30	95.75	92.75	117.60	127.50	125.75	103.70	10.69

$^{a, b, c, d}$ Means in the same row with different superscripts differ significantly ($p < 0.05$).
c – Cayenne Pepper Powder; t – Turmeric Rhizome Powder; U/L units per liter.
HDL – High Density Lipoprotein; LDL – Low Density Lipoprotein; g/dl – gram/deciliter.
mg/dl – milligram/deciliter.

Table 5
Effect of additives on serum indices of broiler chickens at finisher phase.

Parameters	Basal (B)	B + 200t	B + 400t	B + 100c	B + 200c	B + 200t + 100c	B + 400t + 100c	B + 200t + 200c	C + 400t + 200c	SEM
Total protein (g/dl)	2.10^{b}	3.65^{a}	4.00^{a}	3.55^{a}	3.95^{a}	2.95^{ab}	3.25^{ab}	4.15^{a}	4.35^{a}	0.42
Globulin (g/dl)	1.10^{b}	2.55^{a}	2.90^{a}	2.35^{a}	2.75^{a}	1.80^{ab}	2.15^{ab}	3.05^{a}	3.15^{a}	0.40
Albumin (g/dl)	1.00	1.10	1.10	1.20	1.20	1.15	1.10	1.15	1.20	0.15
ALT (U/L)	41.50^{c}	18.50^{ef}	55.50^{b}	28.50^{d}	80.50^{a}	26.5^{de}	16.50^{f}	21.50^{def}	24.50^{def}	2.54
AST (U/L)	104.50	112.50	140.00	145.50	177.50	120.00	132.00	139.50	127.00	22.50
Creatinine (Mg/dl)	0.35^{ab}	0.45^{a}	0.45^{a}	0.20^{b}	0.25^{ab}	0.35^{ab}	0.30^{ab}	0.45^{a}	0.35^{ab}	0.07
LDL (Mg/dl)	28.55^{abc}	36.70^{a}	20.65^{bc}	30.20^{abc}	33.20^{ab}	18.10^{e}	31.10^{abc}	26.30^{abc}	26.60^{abc}	3.81
HDL (Mg/dl)	36.25^{f}	45.70^{de}	75.95^{a}	31.55^{ef}	44.00^{de}	75.05^{a}	60.20^{bc}	66.25^{ab}	53.00^{cd}	3.52
Total Cholesterol (Mg/dl)	103.25^{ab}	88.10^{b}	118.65^{a}	93.15^{ab}	98.05^{ab}	100.55^{ab}	98.35^{ab}	107.40^{ab}	101.65^{ab}	8.36

$^{a, b, c, d, e, f}$ Means in the same row with different superscripts differ significantly ($p < 0.05$).
c – Cayenne Pepper Powder; t – Turmeric Rhizome Powder; mg/dl – milligram/deciliter.
HDL – High Density Lipoprotein; LDL – low density lipoprotein; g/dl – gram/deciliter.
U/L units per liter.

Table 6
Effect of dietary treatments on hematological indices of broiler chicks at starter phase.

Parameters	Basal (B)	B + 200t	B + 400t	B + 100c	B + 200c	B + 200t + 100c	B + 400t + 100c	B + 200t + 200c	B + 400t + 200c	SEM
Packed cell volume (%)	35.50^{a}	26.50^{c}	34.00^{ab}	28.00^{bc}	28.00^{bc}	28.50^{bc}	30.50^{abc}	26.00^{c}	34.00^{ab}	1.94
Hemoglobin (g/dl)	11.80^{a}	8.85^{c}	9.65^{c}	9.35^{c}	9.35^{c}	9.50^{c}	10.15^{bc}	8.65^{c}	11.35^{ab}	0.48
Red blood cell (10^{12}/L)	3.14^{a}	2.33^{bc}	2.60^{bc}	2.51^{bc}	2.51^{bc}	2.51^{bc}	2.68^{abc}	2.33^{c}	2.97^{ab}	0.14
Mean corpuscular hemoglobin (Pg)	37.63	38.12	37.18	37.37	37.23	37.84	37.97	37.22	38.35	0.66
Mean corpuscular hemoglobin concentration (g/dL)	33.24	33.40	33.27	33.40	33.40	33.33	33.28	33.27	33.38	0.05
Mean corpuscular volume (FI)	11.32	11.41	11.17	11.34	11.80	11.35	11.41	11.19	11.49	0.19
White Blood Cell (10^{3}/L)	5.70^{abc}	3.15^{c}	3.90^{bc}	6.25^{abc}	3.95^{bc}	8.35^{a}	5.75^{abc}	6.70^{ab}	6.55^{abc}	1.00
Neutrophil (%)	36.50^{ab}	36.50^{ab}	37.00^{ab}	41.00^{a}	42.50^{a}	37.50^{ab}	38.00^{ab}	36.00^{ab}	30.50^{b}	2.24
Lymphocyte (%)	59.50^{ab}	59.00^{ab}	59.00^{ab}	55.50^{b}	53.00^{b}	58.50^{ab}	57.50^{b}	60.50^{ab}	66.50^{a}	2.39
Eosinophil (%)	3.50	4.00	3.50	3.00	3.50	4.00	3.50	3.00	2.50	0.60
Monocyte (%)	0.50	0.50	0.50	0.50	1.00	0.00	1.00	0.50	0.50	0.41
Basophil (%)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

$^{a,b, c}$ Means in the same row with different superscripts differ significantly ($p < 0.05$).
c – Cayenne Pepper Powder; t – Turmeric Powder; g/dl – gram per diluents.
g/dl – gram per deciliter; L – liter.

obtained fall within the normal range of 25–41% reported by Mitruka and Rawnsley (1997) in broiler chickens. PCV is the quickest indirect way of assessing values of red blood cells in circulation and is often used as a simple screening test for anaemia (Coles, 1978; Bashar, Tukur, Sekoni, & Hassan, 2010). Red blood cell is produced in the long bones of the body, and adequate production is dependent on the amount of iron absorbed from food digested. Additionally, Reece (2009) reveals the main component of erythrocytes as haemoglobin, as it forms about one-third red blood cell content, which, according to Sugiharto, Widiastuti, and Prabowo (2011) generated increased haemoglobin (HB) concentration by possibly signaling production of haemoglobin. The basal group had the highest value for these parameters (PCV, RBC, and HB).

Cayenne pepper (capsaicinoids) has been reported to contain phenol compounds. According to Siriporn, Kunchit, Crustopher, and Ermorn (2006) can inhibit iron absorption. Galib, Al-Kassie, Mamdooh, Al-Nasrawi, and Saba (2011) corroborate this report when reporting significant decline in haemoglobin levels as consumption of dietary pepper in broiler chick diet increased at the third weeks of feeding trial. This possibly explains why chicks fed the basal diet had the highest circulating erythrocytes and haemoglobin levels.

Values obtained at the finisher phase were within the normal range of $5.5 \times 10^{3}mm^{3}$ (Micha et al., 2010) and $5.5–12.5 \times 10^{3}mm^{3}$ (Mcdonald and Scott, 1996), excluding chickens fed B + 200t, B + 400t and B + 100c diet groups. Highest immunity value recorded for birds fed B + 200t + 100c group possibly suggests cayenne pepper and

Table 7
Effect of dietary treatments on hematological indices of broiler chickens at finisher phase.

Parameters	Basal (B)	B + 200t	B + 400t	B + 100c	B + 200c	B + 200t + 100c	B + 400t + 100c	B + 200t + 200c	B + 400t + 200c	SEM
Packed cell volume (%)	30.00^{ab}	27.00^{ab}	27.00^{ab}	27.00^{ab}	26.00^{ab}	29.00^{ab}	28.00^{ab}	30.50^{a}	25.00^{b}	1.46
Hemoglobin (g/dl)	10.00^{ab}	9.00^{ab}	9.00^{ab}	9.00^{ab}	8.65^{ab}	9.65^{ab}	9.35^{ab}	10.15^{a}	8.35^{b}	0.49
Red blood cell (10^{12}/L)	2.64^{ab}	2.38^{ab}	2.38^{ab}	2.39^{ab}	2.30^{ab}	2.54^{ab}	2.47^{ab}	2.68^{a}	2.19^{b}	0.13
Mean corpuscular hemoglobin (Pg)	37.89	37.90	37.81	37.65	37.70	37.99	37.86	37.95	38.13	0.16
Mean corpuscular hemoglobin concentration (g/dl)	33.24	33.34	33.33	33.33	33.27	33.27	33.39	33.28	33.40	0.08
Mean corpuscular volume (Fl)	11.37	11.37	11.34	11.30	11.33	11.42	11.34	11.40	11.41	0.04
White Blood Cell (10^{3}/L)	4.85^{cd}	5.05^{cd}	6.70^{ab}	4.55^{d}	2.20^{e}	6.15^{bc}	5.15^{cd}	5.30^{cd}	7.75^{a}	0.38
Neutrophil (%)	34.50^{b}	45.00^{ab}	45.00^{ab}	45.50^{ab}	41.50^{ab}	40.50^{ab}	50.00^{a}	38.50^{ab}	40.50^{ab}	3.79
Lymphocyte (%)	62.00^{a}	51.50^{ab}	51.50^{ab}	50.00^{ab}	54.50^{ab}	56.00^{ab}	46.50^{b}	58.00^{ab}	56.00^{ab}	3.92
Eosinophil (%)	2.50	3.50	2.50	4.00	3.00	3.50	2.50	3.50	3.00	0.53
Monocyte (%)	1.00	0.00	1.00	0.50	0.50	0.00	1.00	0.00	0.50	0.29
Basophil (%)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

$^{a,b,\ c,\ d,\ e}$Means in the same row with different superscripts differ significantly ($p < 0.05$).
c – Cayenne Pepper Powder; t – Turmeric; Powderg/dl – gram per diluent; g/dl – gram per deciliter; L – liter.

turmeric at this level facilitated immunity of the birds through stem cell production of white blood cells. Capsaicin when consumed in excess destroys nerve fibres that transmit information from gut to the brain (Stearns et al., 2012). However, at moderate level, it has been shown to boost immunity as cayenne pepper contains vitamin A or beta-carotene that can protect against invading pathogens. This explains how cayenne pepper inclusion in basal diet at 100 g had better white blood cell count than groups fed B + 200c diet. Curcumin on the other hand has been reported to promote brain health, courtesy its potent antioxidant and anti-inflammatory properties. Curcumin can affect signaling molecules (Subash et al., 2011), and it has been demonstrated to work in a similar way as vitamin D by modulating large numbers of animal genes. But unlike vitamin D, curcumin influences about 700 genes. According to Barry et al. (2009) curcumin acts by inserting itself into cells' membranes where it changes the physical properties of the membrane itself, making it more 'orderly'. Akram et al. (2010) further described curcumin exertion on anti-inflammatory activity by inhibiting a number of different molecules that play an important role in inflammation.

All values obtained for PCV at the finisher phase were within the normal range of 22–35% reported by Jain (1993). Present trial show treatment groups fed B + 200t + 200c diet had highest ($p < 0.05$) effect on PCV, HB and RBC count. Adaptation of chickens to antioxidants fed, as well as proper absorption of iron from feed at the finisher phase may explain high values for circulating red blood cells in treatment group mentioned above. Hence, at an inclusion ratio of 1:1 in this experiment, capsaicinoids and curcuminoids may have individually contributed optimally to stimulate iron absorption, utilization and subsequent production of RBC by stem cells.

Chickens fed B + 200c had low documented values for white blood cell count (2.2×10^{3} mm) at the finisher phase. This is lesser than the $4.25–5.13 \times 10^{3}$ mm recorded by Clement, Ibrahim, Joseph, and Iro (2010). A low level of white blood cell in the blood could be as a result of no disease condition or low production from bone marrow (Clement et al., 2010). Findings documented on capsaicin reveals long-term inhibitory effects on sensory neurons, which involve the release of neuropeptides such as substance P (Holzer, 1990). De Simon et al. (1989) stated that this chemical is found in the brain and intestinal tissues, capable of modulating inflammation and immune response of host. Capsaicin has been found to reduce "substance P" (a neurotransmitter) by stimulating the release or exhaust of signals until no more is produced. Galib et al. (2011) also observed that feeding dietary hot red peppers to broiler chickens resulted in lower values for WBC count at finisher phase. Additionally, Vicente et al. (2007) posited that substance P can stimulate enzyme release from lysosomes, ingest cells by phagocytes and increases the natural killer of cell activity. Feeding mice 10% dietary capsicum annum for eight-weeks led to aggregation of white blood cells (Anderson, 2007). Hence, at B + 200c dietary inclusion, capsaicin damaged some nerve cells connected to the production of white blood cells in bone marrow. Contrary to findings above,birds fed B + 400t + 200c had improved WBC count at the end of 6 weeks of feeding trial. Hucklenbroich et al. (2014) suggests that a bioactive compound in turmeric called aromatic-turmerone can increase neural stem cell growth in the brain by as much as 80% at certain concentrations. Neural stem cells differentiate into neurons and play an important role in self-repair, suggesting aromatic-turmerone may help in the recovery of brain function in neurodegenerative diseases. This was further clarified by findings of Anthony, Kuttan, and Kuttan (1999) and Al-sultan (2003) who reported turmeric inclusion in diet increased WBC count in Balb/c mice and broiler chickens. This possibly alludes to groups fed B + 400t + 200c diet utilizing absorbed curcumin, which suppressed degenerative effect of capsaicin via nerve stem cells regeneration, as well as bone marrow stimulation and leukocytes synthesis.

Broilers chicks fed the basal diet had significantly better blood total protein, globulin and albumin than the other dietary groups for serum protein at chick phase. Adedeji (1992) reported serum protein to be a means of replacement of tissue proteins, buffer in acid-base balance and transporter of constituents of blood such as vitamins, iron, copper, hormones, lipids and enzymes. At this phase, acclimatization of chicks to antioxidants fed may be well in process. As such, curcuminoids and capsaicinoids in dietary turmeric powder and cayenne pepper powder may not be fully absorbed and utilized compared to chicks fed the basal diet since specific vitamins and proteins are essential for stem cell formation of serum protein and albumin.

Alanine amino-transferase (ALT) and aspartate amino-transferase (AST) was significantly influenced at the starter phase, with high values recorded for chicks in the basal group. This may possibly be a genetic condition of the chicks inherited from the parent stock. AST is a very sensitive, non-specific bio-marker of liver disease in birds, while ALT is more specific to the liver and can be an indicator to detecting liver injury. However, ALT is still of poor diagnostic value in birds due to its existence in many tissues (Perelman, 1999; Harr, 2002). Hence, since no mortality was recorded at the starter phase, it may be right to assume that the extent of liver damage was tolerable at starter phase. All dietary inclusion of turmeric and cayenne pepper significantly reduce ALT values than the Basal group, pointing to the ability of test ingredients to possibly treat damage to the liver. Akram et al. (2010) reported turmeric and curcumin reversal of biliary hyperplasia, fatty changes, and necrosis of affected liver of rats. Additionally, sodium curcuminate, a salt of curcumin, was found to exert choleretic effects by increasing biliary excretion of bile salts, cholesterol, and bilirubin, as well as increasing bile solubility. Similar trend in ALT was observed in serum low density lipoproteins (LDL) values. Curcumin helps liver cells continue to do their work of taking LDL "bad" cholesterol out of the

bloodstream, but without taking in other fatty acids that "burn out" the mitochondria of the cell. Liver cells protected from fatty acid damage make the liver produce more bile salts, which carry excess LDL out of the body into the waste matter of the large intestine. Hence, curcumin possibly stops the progress of fatty liver and enhances cardiovascular health (Kang et al., 2010). Overall lipoprotein profile was best ($p < 0.05$) in groups fed B + 200t + 100c diet, possibly revealing curcumin and capsaicin influence on liver health at specific inclusion level (200t + 100c) in the basal diet.

Proteins furnish the body with amino acids that are used for the synthesis of body proteins including blood proteins (Bashar et al., 2010). Addass, David, Edward, Zira, and Midau (2012) postulated blood protein content as a product of nutritional status and age. At the finisher phase, chickens fed single diet additives and combination of turmeric and cayenne at ratios 1:2 and 2:1 were best for serum total protein and globulin. It is more likely that at finisher phase, chickens absorbed antioxidants fed more efficiently, thereby facilitating absorption, utilization and subsequent production of serum protein. Serum protein for broiler chickens fed B + 400t + 200c diet indicate high circulating protein that contribute to the immunity status and growth performance of broiler chickens at the finisher phase.

High ($p < 0.05$) ALT recorded for birds fed B + 200c diet at finisher phase was a trend from the starter phase. Red pepper is reportedly harmful if consumed in excess (Nwaopara et al., 2004, 2007). Dkhil and Al-Quraishy (2010) alarmed that hot red pepper possesses some chemical and pharmacological properties similar to the classes of drugs that are capable of inducing liver damage, thus explaining its influence on histological activity observed in the liver when consumed in excess.

Result obtained also show that LDL and HDL were best ($p < 0.05$) suppressed and elevated respectively in groups fed B + 200t + 100c diet. High ($p < 0.05$) HDL documented for chicken in groups fed B + 200t + 100c and B + 400t diet agrees with findings of Akbarian, Golian, Kermanshashi, Gilani, and Moradi (2012), but disagree with experiment conducted by Kermanshahi and Riasi (2006). Kermanshahi and Riasi (2006) reported that turmeric supplementation at 0.5–1.5 g/kg decreased HDL-cholesterol, and increased LDL cholesterol (LDL-cholesterol) in laying hens, thereby revealing antioxidant facilitation of reverse cholesterol transport (green pathway), as cholesterol is eliminated from the body via its conversion to bile salts by the liver. Lower content of cholesterol may result from high body activity and high need of energy in broiler chickens.Significant ($p < 0.05$) serum cholesterol of present study is within the range of 49.2–118 mg/dl reported by Albokhadaim et al. (2012). This point to increased transport of cholesterol to the liver brought about by curcumin in B + 400t diet possibly improve liver and vessels health. Ideal level of cholesterol is of great benefit to welfare Ademola, Farinu, and Babatunde (2009).

5. Conclusion

Blood measures can act as pathological indicators of chicken response to toxic substance exposure as well as organ function. It is widely documented that birds with good (normal) blood composition are likely to show good performance. However, contrary to previous studies, findings from the research we conducted show that broiler chicken groups fed B + 400t + 200c diet had the best indices for growth performance, but not for blood composition. Additionally, feeding chickens the B + 200t + 100c diet effected better blood biochemistry profiles among all of the dietary treatments. Conclusively, our research demonstrates that all dietary additives can positively influence organ and system health at demonstrated levels of inclusion.

Conflict of interest statement

None of the authors has any financial or personal relationships that could inappropriately influence or bias the content of the paper.

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