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EFFECT OF DIETARY INCLUSION OF BIOCHAR ON GROWTH PERFORMANCE, HAEMATOLOGY AND SERUM LIPID PROFILE OF BROILER BIRDS

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ABSTRACT

One hundred and twenty (120) day-old broiler birds were used to ascertain the effect of dietary inclusion of biochar on the growth, hematology and serum lipid profiles of birds in a 56-day feeding trial. The birds were randomly assigned to 4 groups of 30 birds each, replicated twice with 15 birds per replicate. The groups were randomly assigned to four diets in a completely randomized design involving four levels (0, 2, 4 and 6%) of biochar kg-1. Treatments did not differ significantly (P > 0.05) in final body weight, average daily weight gain, average daily feed intake and feed conversion ratio at the starter phase. However, at the finisher phase, significant differences (P < 0.05) were observed among treatments in final body weight, average daily weight gain and feed conversion ratio. Final body weight, average daily weight gain and feed conversion ratio of birds fed 6% biochar kg-1 were significantly (P < 0.05) higher than other treatment groups. White blood cell counts (WBC) and packed cell volume (PCV) were not affected by treatments at the starter and finisher phases, respectively. Hemoglobin concentration (Hb) and red blood cell count were significantly (P < 0.05) increased by the treatments at both starter and finisher phases. Non-significant difference (P>0.05) was observed in the triacylglycerol (TAG) values of birds at the finisher phase, while cholesterol and low density lipoprotein levels were significantly reduced (P < 0.05, 0.01) at both phases. The result of the present study showed that up to 6% dietary biochar kg-1 improved growth, hematology and serum lipid profiles of broiler birds.

Keywords: biochar, performance, health-status, fat-accretion, broilers.

INTRODUCTION

With global human population projected to increase to 10 billion people by 2050 (FAO 2009a), there is the need for adequate and nutritious food supply for the teeming human population, through sustainable production systems. Poultry production is one sustainable means proposed for the attainment of this goal of global food sufficiency. Sustainable poultry production is also a key measure in alleviating poverty and addressing the menace of protein insufficiency among many households in sub-Saharan Africa, particularly, Nigeria (Ani, 2007a). Poultry are fast growing birds that yield products containing essential amino acids which the body requires for normal metabolic activities (Ibe, 2004). Poultry have potential to give high turnover rate on investment, and are also efficient converters of feed to animal protein (Oluyemi and Roberts, 2000). Over the last few decades, the use of dietary inclusions, majorly, antibiotic growth promoters have been explored with the aim of increasing efficiency of feed utilization in poultry (Hamasalim, 2016). Notwithstanding, numerous health complications are often associated with the use of antibiotic growth promoters in poultry nutrition. Thus, the search for and use of natural and locally available feed additives with no attendant health implication on humans is justified (Hajati and Hazaei, 2010; Saleha *et al*., 2009). In view of these, biochar is gaining attention as a locally sourced feed additive with capacity to improve digestibility, feed efficiency, weight gain, feed conversion ratio and dietary energy absorption in poultry birds (Gerlach and Schmidt, 2012). Inclusion of biochar in poultry nutrition has been reported to rapidly decrease the incidence of diarrhea, eliminate allergies and ameliorate the detrimental effects of mycotoxins in feed (Marie, 2013).

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Biochar is a carbon-rich charcoal- like substance obtained through the processes of pyrolysis, gasification and hydrothermal carbonization. While pyrolysis which is the first step in biochar production, involves thermal decomposition of organic matter under limited oxygen supply and high temperatures (< 700°C), gasification involves exposing biomass to high temperature coupled with oxygen supply, whereas hydrothermal carbonization (HTC) involves steaming biomass with different types of acids acting as catalysts (Harris, 1999; Almuth, 2011). Biochar production usually begins with biomass (which could be crop residue, wood and wood waste, certain animal manure and/or various other organic materials) being fed into a pyrolin kiln i.e. a furnace that burns with little or no oxygen. The process yields two main products, biochar, constituting 50% of the carbon content of the biomass, and biofuel, often syngas which can be employed in several energy application processes (Anita, 2009; Almuth, 2011). Gerlach *et al*. (2014b) and Van *et al*. (2006a) reported that dietary inclusion of biochar is capable of enhancing the immune status of animals. According to Gerlach and Schmidt (2012) inclusion of biochar in the diet of broiler birds deactivated toxins found in the digestive tract, helped activate intestinal flora and resulted in improved vitality of the birds. Teleb *et al.* (2004) found that supplementation of broiler diets with 0.5% biochar reduced the detrimental effects of aflatoxins, by lowering mortality and improving growth performance. Kutlu *et al*. (2000), Kana *et al*. (2010) and Prasai (2013) observed improved growth performance in broilers fed diets containing 2 and 6% inclusion levels of biochar obtained from oak, maize cob, canarium seed, coconut shell, and locally available wood. Odunsi *et al.* (2007) however reported than at an inclusion level of 7% or more, biochar depressed growth and final body weights in broilers. Doydora *et al.* (2011), Ritz *et al.* (2010) and Marie (2013) noted that dietary biochar obtained from pine chips, peanut hulls and locally available wood have potential to significantly reduce ammonia and phosphorus content of poultry droppings, reduce odour and water runoff from liter piles during rainfall. Apart from its relevance as litter and feed additive, biochar has other agricultural, environmental, electrical, industrial and textile applications, ranging from silage preparation, manure composting, slurry treatment, water treatment in fish farming, bioremediation, biogas production, insulator and air decontaminator in buildings, and a host of other uses (IUCN, 2012; Elad *et al*., 2010; Lin *et al*., 2008; Inthapanya *et al*., 2012). Based on the inherent potentials of biochar, the present study was therefore designed to investigate the effect of varying inclusion levels of biochar on growth performance, hematology and serum lipid profiles of broiler birds.

MATERIALS AND METHODS

The study was carried out at the Department of Animal Science Teaching and Research Farm, University of Nigeria, Nsukka. The duration of the study was eight weeks. Corn Stover served as the organic material used for biochar production through the process of pyrolysis, and was procured from Department of Crop Science, University of Nigeria Nsukka. The Stover was chopped into small pieces and sun-dried for two weeks, after which it was fed into the pyrolysis kiln, to undergo pyrolysis, under serious and careful precautionary measures. The resultant biochar product was then used for the study.

Experimental diets

Four starter diets with biochar (BC) included at 0%BC kg-1(T1), 2%BC kg-1(T2), 4%BC kg-1 (T3) and 6%BC kg-1 (T4) were used during the starter phase of the experiment. Also four finisher diets having biochar (BC) inclusion at 0%BC kg-1(T1), 2%BC kg-1(T2), 4%BC kg-1 (T3), and 6%BC kg-1 (T4) were used during the finisher phase of the study. The percentage compositions of the starter and finisher diets are shown in Table 1.

Management of experimental birds and data collection

A total of one hundred and twenty (120) unsexed day-old commercial broiler chicks were randomly divided into four groups of 30 birds each, replicated twice with 15 birds per replicate. The groups were randomly assigned to four isocaloric (2.80/27. 2Mcal of ME/kg) and isonitrogenuos (23.08/20.10% crude protein/) diets at both starter (0-28 days) and finisher (28-56 days) phases in a completely randomized design with treatment as main effect involving 0%,(control), 2%, 4% and 6% dietary inclusion levels of biochar. The birds were placed in 2.6 × 3 m deep litter pens with fresh wood shavings which were changed on weekly basis. Feed and water were supplied *ad libitum* to the birds from 0 to 56 days of age. The birds were subjected to standard broiler management procedures. The birds were properly vaccinated as and when due following the vaccination protocol for broiler birds by the National Veterinary Research Institute

(NVRI), Vom, Plateau State, Nigeria (unpublished). The birds were weighed at the beginning of the experiment to obtain their initial body weights, and subsequently on weekly basis to determine their growth performance. The birds were finally weighed at the end of the experiment to determine their final live weights. Feed conversion ratio was calculated from these data as quantity (gram) of feed consumed per unit (gram) weight gained over the same period.

Blood collection for haematological and lipid profile evaluation

At weeks 4 and 8 of the experiment, blood was collected with a sterile needle from the wing veins of two birds per replicate (32 birds in all for both phases). The blood was collected into properly labeled sterile bottles containing ethylene diamine tetra acetic acid (EDTA) and cooled at 4°C using icepacks. The samples were transferred to the Laboratory of Faculty of Veterinary Medicine, University of Nigeria Nsukka for determination of hematological parameters of the birds. The packed cell volume (PVC) was determined using the micro hematocrit centrifuge method (Coles, 1986). A 0.5 ml of blood was centrifuged at approximately 10,000 revolutions for 5 min in a micro hematocrit centrifuge. The PCV was subsequently determined by measuring the height of the erythrocyte column and expressing this as a fraction of the height of the total blood column. PCV - Height of packed cell column divided by height of whole blood column. Haemoglob in concentration was determined spectrophoto metrically (Perkin-Elmer) by the cyanomethaemoglob in method (Higgins *et al*., 2008). A 0.5 ml of blood was diluted in a buffered solution of potassium ferricyanide and potassium cyanide to yield the stable haemoglob in derivative cyanmethaemoglob in. The potassium ferricyanide converted the haemoglob in to methaemoglob in which was further converted to cyanmethaemoglob in by the action of potassium cyanide. Cyan-methaemoglob in produced a color which was measured in a spectrophotometer. The color relates to the concentration of hemoglobin in the blood. The absorbance of this solution was read in a colorimeter at a wavelength of 540 nm. Erythrocyte count (RBC) and leukocyte count (WBC) were determined using Neubarhemocy to meter after the appropriate dilution (Mitruka and Rawnsley, 1977; Thrall and Weiser, 2002). Blood samples for serum analysis were centrifuged at 3000×g for 15min and serum was separated. Determination of serum total triacylglycerol (TAG), total cholesterol (TC), high density lipoprotein-cholesterol (HDL-C) and low density lipoprotein-cholesterol (LDL-C) concentrations were done with Randox kits (BT294QY, Randox, United Kingdom). The lipoproteins LDL-C and HDL-C were fractionated by a dual precipitation technique (Jacob *et al*., 1990). After fractional precipitation, lipoprotein cholesterol was estimated.

Proximate and statistical analyses

Samples of diets were analyzed for proximate composition using the methods of AOAC (1990). Data collected were subjected to analysis of variance as described for completely randomized design (Steel and Torrie, 1980), and differences between treatment means were separated using Duncan's New Multiple Range Test (Duncan, 2003) as outlined by Obi (2002).

RESULTS AND DISCUSSION

Growth performance of broilers fed varying dietary levels of biochar

Table 2 shows the proximate composition of experimental diets, while growth performance of broiler birds (starter and finisher phases) to the experimental diets is shown in Table 3. Treatments did not differ significantly ($P > 0.05$) in final body weight, average daily weight gain, average daily feed intake and feed conversion ratio at the starter phase. However, at the finisher phase, significant differences ($P<0.05$) were observed among treatments in final body weight, average daily weight gain and feed conversion ratio. Broilers fed 4 and 6 % biochar kg-1 were similar in final body weight but heavier ($P < 0.05$) than those fed 2% biochar kg-1 and those on the control diet (0% biochar kg-1). For average daily weight gain, birds without biochar supplementation (control group) gained the least weight, and this was comparable to the weight gained by those on 2% biochar kg-1. Birds on 4 and 6% biochar kg-1 had the highest but similar weight gain. Similar trend was observed in feed conversion ratio (FCR), where birds on 4 and 6% biochar kg-1 had comparable but the least FCR. Birds fed 0% biochar kg-1 had the highest FCR, and this was comparable to the FCR of birds with 2% biochar kg-1 in their diets. As shown in Table 3, it is evident that at the starter phase, the effect of treatment on performance traits of chicks was not significant.

Table 1: Percentage Composition of broiler starter diets (%)

Ingredients	Starter	Finisher
Maize	51.00	53.00
Wheat offal	6.00	10.00
Palm kernel cake	5.20	5.50
Groundnut cake	21.00	15.00
Soybean meal	10.00	10.00
Fish meal	1.80	1.50
Bone meal	4.00	4.00
Salt	0.25	0.25
Lysine	0.25	0.25
Methionine	0.25	0.25
*Vitamin premix	0.25	0.25
Total	100	100
Calculated composition (%)		
Crude protein	23.08	20.10
Crude fibre	4.02	5.28
Gross energy (Mcal/kg)	2.80	2.72

*Each 2.5kg of starter premix used contained: Vit A (I. U) 100,00000; Vit D3 (I. U) 2,000000; Vit E (mg) 23000; Vit K3(mg) 2000; Vit B1 (mg) 1800; Vit B2 (mg) 5500; Vit B6 (mg) 3000;Vit B12 (mg) 15;Niacin (mg) 27500;Panthotenic acid (mg) 7500; Folic acid (mg) 750; Biotin (mg) 60; Chlorine (mg) 300000; Co (mg) 200;Mn (mg) 40000; Fe (mg) 20000; Zn (mg) 30000; I (mg) 1000; Cu (mg) 3000; Se (mg) 200; Antioxidant (mg) 1250.

This may be attributed to the fact that at this stage, the gut system of the birds was yet to adjust to the test ingredients. According to Kleyn, (2013), birds' digestive tract is usually not fully developed at an early stage of life. As the birds advanced in age (finisher phase), they became capable of absorbing nutrients effectively and thus competed equally. As a feed supplement, the use of biochar is capable of improving performance traits such as weight gain, nutrient digestibility and feed efficiency in broiler chickens and ducks (Gerlach and Schmidt, 2012; Kana *et al*., 2010; Ruttanavut *et al*., 2009). The significantly higher growth performance (final live weight, average daily weight gain and feed conversion ratio) observed for birds fed 4 and 6% dietary biochar kg-1 compared to those in the control suggest that dietary inclusion of biochar improved the performance of the birds. The result of the present study on growth performance are similar to the reports of Kutlu *et al*. (2000) Kana *et al*. (2010) Prasai (2013) and Jiya *et al*. (2013)whose studies showed that at 0.2-0.6% levels of inclusion, dietary biochar resulted in improved performance of broiler birds. Kana *et al*., (2014) also reported that dietary inclusion of born charcoal and canarium charcoal at 0.4% and 0.2% led to an improvement in body weight and weight gain of broilers fed diets containing aflatoxin (AFB1) contaminated diets. The results however contrast the findings of Odunsi *et al*. (2007) Kana *et al*. (2010) and Jiya *et al*. (2013) who reported that from 2% and higher levels of inclusion, dietary biochar is capable of depressing growth rates and final body weights of broiler chickens. The superior growth performance observed in the birds on biochar inclusions can be attributed to the adsorbent features of the biochar in the gut of inclusions can be attributed to the adsorbent features of the biochar in the gut of the birds, arresting toxins and anti-nutritional factors that will interfere with aborption of nutrients by the birds' intestinal walls. Hence, the birds had ample supply of nutrients from the feed with minimal obstruction in their absorption. Notable among the growth enhancing potentials of biochar in the present study is the fact that at 4 and 6% kg-1, the feed conversion ratio of birds were significantly improved. Prasai *et al*. (2016) noted that a probable mechanism of action by which biochar improves FCR is by changing the microbiota constitution in the digestive tract of birds.

Hematology and serum lipid profiles of broilers fed varying dietary levels of biochar hematological traits

The hematological traits and serum lipid profile of broilers fed the experimental diets are shown in Table 4. At the starter phase, treatment did not differ significantly ($P > 0.05$) in white blood cell count. There were however, significant differences ($P < 0.05$) among treatments in packed cell volume (PCV), haemoglobin concentration (HC) and red blood cell (RBC) count. Broiler chicks fed 6% biochar kg-1 had the highest PCV value, and this was comparable to the PCV values of chicks on 4% biochar kg-1 diets. Broiler chicks fed 0 (control dietary group) and 2% biochar kg-1 had similar PCV values. Broiler chicks fed 6% biochar kg-1 had the highest HC value, and this was statistically higher ($P < 0.05$) than the HC value of chicks on the control diet. Broiler chicks fed 2 and 4% biochar kg-1 had similar HC values. Broiler chicks fed 2% biochar kg-1 had the least RBC value, and this was statistically lower ($P < 0.05$) than the RBC values of chicks on other treatments. At the finisher phase, PCV and WBC values of broilers were not significantly ($P > 0.05$) affected by treatments. There were significant differences ($P < 0.05$) in haemoglobin concentration and red blood cell counts, however similar trend as was the case at the starter phase was also observed. Blood analysis is a readily available tool for assessing the clinical and nutritional status of animals on a feeding trial (Olabanji *et al*., 2009). Usually, animals that have good blood composition tend to possess records of improved performance

(Isaac *et al*., 2013). The result of the present study on haematology (Table 4) shows that treatment significantly affected red blood cell count, packed cell volume and haemoglobin concentration at the starter phase, and only red blood cell count and haemoglobin concentration at the finisher phase. The result agrees with the findings of Iheukwumere *et al*. (2002) who reported significant differences in PCV, Hb concentration and red blood corpuscles values among birds who were feed restricted. However, broilers in the present study were not feed restricted. The physiological implication of the above result obtained in the present study can be attributed to the ability of the birds on biochar treatment to maximize the vitamin-mineral premix of the diet (especially iron and B-complex vitamins) better than birds on the control group. This is because of the probable binding of the biochar with toxins and anti-nutritional factors in the gut of the birds which would have impeded the utilization of the said vitamins and minerals for the production of the birds' RBC. This consequently influenced their Hb concentration. The results however contrasts the findings of Majewska *et al*. (2009) whose study showed that dietary supplementation of 0.3% charcoal did not have significant effect on hematological indices of turkey. Kana *et al*. (2014) reported that bio-charcoals had no significant effect on RBC, WBC, haemoglobin and hematocrit values of broilers fed aflatoxin B1- contaminated diets. The study of Boonanuntanasarn *et al*. (2014) also showed that dietary inclusion of activated charcoal (bioachar) did not significantly affect RBC, hemoglobin or hematocrit values of Nile tilapia in a 28-day feeding trial. Boonanuntanasarn *et al*. (2014) attributed the immune enhancing potentials of activated charcoal (biochar) to its role as a non-specific detoxifier, capable of improving overall health conditions of animals. From the study, it was observed that the RBC values of birds on the 2% biochar kg-1 diets were significantly decreased compared to those on other treatments. Low levels for haematological parameters as reported by Bawala *et al*. (2007) could be due to harmful effects of high dietary contents. Kana *et al*. (2014) also associated decrease in red blood cell count values with poor quality feeds.

Serum lipid profiles

As shown in Table 4, there were no significant differences ($P > 0.05$) observed for high density lipoprotein (HDL) and triacylglycerol (TAG) across the various treatment means at the starter phase. However, significant differences ($P<0.01$) existed among treatments in cholesterol and low density lipoprotein (LDL) values. Birds fed 6% biochar kg-1 had the least cholesterol value, and this was statistically different from the cholesterol values of birds fed 0 and 2% biochar kg-1. The cholesterol values of birds fed 0, 2 and 4% biochar kg-1 were comparable. Birds fed 0, 4 and 6% biochar kg-1 had comparable LDL values. Birds on 2% biochar kg-1 diets had the least LDL value. Treatment significantly ($P < 0.01$) affected cholesterol, TAG, and LDL values of finisher birds. Birds fed 6% biochar kg-1 had the least cholesterol value and this was statistically lower than the cholesterol value of birds on control diet. Birds fed 0, 2 and 4% biochar kg-1 had comparable cholesterol values. Birds fed 4 and 6% biochar kg-1 had similar LDL values, and these were significantly lower than the LDL of birds fed 0 and 2% biochar kg-1. For TAG values, birds fed 0 and 6% biochar kg-1 had similar values, and these were significantly higher than the TAG values of birds fed 2 and 4% biochar kg-1.

Table 2: Proximate Composition of Experimental Diets (%) on DM Basis

Starter Phase				
Parameters	T1 (0% biochar)	T2 (2% biochar)	T3 (4% biochar)	T4 (6% biochar)
Dry Matter	83.50	83.70	83.85	83.97
Crude protein	22.48	22.48	22.48	22.48
Crude fibre	11.10	11.23	11.45	11.60
Ash	17.45	17.50	17.74	17.86
Ether extract	1.20	1.20	1.20	1.20
Nitrogen free extract (NFE)	31.27	31.29	30.98	30.83
Finisher Phase				
Dry Matter	83.57	83.78	83.90	83.99
Crude protein	20.80	20.80	20.80	20.80
Crude fibre	11.00	11.50	11.65	11.89
Ash	18.20	18.34	18.57	18.72
Ether extract	0.86	0.86	0.86	0.86
Nitrogen free extract (NFE)	32.71	32.28	32.o2	31.72

DM- dry matter

Table 3: Performance characteristics of broilers fed varying dietary levels of biochar

Starter Phase					
		Treatments			
Parameters	T1 (0% biochar)	T2 (2% biochar)	T3 (4% biochar)	T4 (6% biochar)	p-value
Initial body weight (kg)	0.10±0.00	0.10±0.00	0.10±0.00	0.10±0.00	0.73 NS
Final body weight (kg)	0.87±0.01	0.85±0.01	0.89±0.02	0.87±0.01	0.23 NS
Av. daily weight gain (g)	27.50±0.36	27.50±0.36	26.61±0.18	28.22±0.72	0.23 NS
Av. daily feed intake (g)	37.86±0.36	38.57±0.36	38.57±0.36	38.39±0.18	0.44 NS
Feed conversion ratio	1.38±0.01	1.45±0.00	1.37±0.02	1.40±0.01	0.07NS
Finisher Phase					
Initial body weight (kg)	0.87±0.01	0.85±0.01	0.89±0.02	0.87±0.01	0.23 NS
Final body weight (kg)	1.93±0.08b	2.19±0.12b	2.65±0.05a	2.63±0.08a	0.05*
Av. daily weight gain (g)	37.86±3.22b	48.04±4.47b	62.68±2.50a	62.86±3.93a	0.02*
Av.daily feed intake (g)	114.38±1.07	123.94±3.75	123.83±0.54	118.80±2.13	0.36
Feed conversion ratio	3.02±0.23a	2.58±0.17ab	1.97±0.09b	1.89±0.19b	0.03*

a, b, c, means on the same row with different superscripts are statistically different (P>0.05). Av: average.

Table 4: Haematological and serum lipid profile of broilers fed varying dietary levels of biochar

Haematological values					
Starter phase					
	Treatments				
Parameters	T1 (0% biochar)	T2 (2% biochar)	T3(4% biochar)	T4 (6% biochar)	p-value
Packed cell volume (%)	31.75±1.70bc	30.75±1.70c	33.75±1.25ab	35.75±1.70a	0.04
Haemoglobin Conc.(g/dl)	10.40±0.34c	11.60±0.75b	11.55±0.19b	12.45±0.25a	0.00
RBC (x106/mm)	10.05±0.57a	9.21±0.53b	10.60±0.19a	10.78±0.56a	0.03
WBC (x106/mm)	8850.00±525.99	8925.00±573.73	8725.00±750.00	9150.00±580.22	0.79
Finisher phase					
Packed cell volume (%)	34.75±1.70	35.25±2.50	37.25±0.95	38.50±1.29	0.31
Haemoglobin Conc. (g/dl)	10.70±0.39c	11.92±0.74b	11.82±0.17b	12.70±0.21a	0.00
RBC (x106/mm)	10.36±0.43a	9.51±0.51b	10.78±0.21a	10.97±0.63a	0.05
WBC(x106/mm)	9125.00±457.34	9200.00±522.81	9400.00±365.14	9525.00±525.19	0.62
Serum lipid profiles (mg/dl)					
Starter phase					
Total cholesterol	83.75±5.18a	84.00±3.74a	76.75±8.99ab	68.00±2.94b	0.00
HDL cholesterol	65.00±4.16	71.75±5.56	69.75±3.77	68.75±2.50	0.18
LDL cholesterol	37.50±4.50b	46.50±7.00a	35.75±5.67b	34.00±4.83b	0.03
Triacylglycerol	104.50±4.12	100.75±9.56	98.00±6.53	106.50±4.04	0.29
Finisher phase					
Total cholesterol	83.75±4.19a	80.50±4.12ab	74.00±8.04b	63.00±2.16c	0.00
HDL cholesterol	68.50±4.50	68.50±5.74	70.75±4.11	72.75±2.75	0.48
LDL cholesterol	40.50±4.04a	41.25±6.99a	31.00±6.05b	28.25±4.11b	0.01
Triacylglycerol	108.50±2.64a	99.00±4.16b	99.75±2.62b	107.75±3.86a	0.00

a, b, c, means on the same row with different superscripts are significantly different (P > 0.05). RBC: red blood cell; WBC: white blood cell; Conc.: Concentration; HDL: high density lipoprotein; LDL: low density lipoprotein.

The result of the present study on serum lipid profile is in tandem with the findings of Boonanuntanasarn *et al*. (2014) whose study showed that dietary supplementation of 20g/kg activated charcoal had a significant effect on blood cholesterol levels in 4-weeks old Nile Tilapia. The study of Yoo *et al.* (2005) also revealed that dietary inclusion of a mixture of charcoal and wood vinegar in the diet of flounders not only improved fatty acid composition, but also decreased saturated fatty acid levels. Earlier report (Neuvonen *et al*., 1989) has shown that intake of biochar (activated charcoal) has potential to interfere with the enterohepatic circulation of bile acids and cholesterol, thereby lowering serum cholesterol levels in hypercholesterolemic conditions. It was observed that there was a significant ($P < 0.01$) decrease in cholesterol levels of birds fed the highest inclusion levels of biochar (6% kg-1) compared to birds on other treatments at both the starter and finisher phases of the experiment. This finding is similar to the result of Boonanuntanasarn *et al*. (2014) who observed that significant differences existed in cholesterol values of Nile Tilapia fed dietary activated charcoal, which appeared to decrease as the level of activated charcoal increased in the diets. The result of the study however disagrees with the reports of Majewska *et al*. (2009) whose study showed that no significant differences existed in triglycerides and total cholesterol levels and other biochemical indices of 20-week old turkeys fed diets containing charcoal, silica grit and hardwood ash. Edrington *et al*. (1997) who fed broilers diets containing super activated carbon, and Majewska *et al*. (2002) who used charcoal feed additives also reported non-significant differences in the biochemical indices of the birds and turkeys.

It is also evident from the result of the study that dietary biochar significantly ($P < 0.05$) lowered the low density lipoprotein (LDL) levels of birds fed 6% biochar kg-1 at finisher

phase. There was also a significant ($P < 0.05$) reduction in triglyceride levels of broilers fed 2 and 4% dietary biochar kg-1 at the finisher phase. Chu *et al*. (2013) reported that dietary supplementation of 0.6% bamboo charcoal decreased the concentration of LDH, triglyceride and bilirubin levels in fattening pigs. Shabani *et al.* (2010) opined that when plasma cholesterol and triglyceride levels are reduced, there is an accompanying reduction in lipogenesis and damaged lipid transport, and prevention of hepatic cholesterol biosynthesis in broiler chickens.

CONCLUSION

The result of the present study showed that up to 6% dietary inclusion of biochar kg-1 led to improvement in growth performance, haematology and serum lipid profiles of broiler birds. However, at 2% level of inclusion kg-1, dietary biochar may not have a lowering effect on cholesterol and triglyceride concentrations of broiler birds.

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