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Growth response and serum biochemical profiles of broiler chickens fed different sources of biochar supplements

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Abstract

This study evaluated the impact of different biochar sources on the growth performance and serum biochemical profiles of broiler chickens. A total of 120 broilers were used in this experiment. They were randomly assigned to four treatment groups (T1, T2, T3, and T4) in a completely randomized design (CRD). Each treatment was replicated three times with 10 birds per replicate. Treatment 1 served as the control without biochar, while T2, T3, and T4 were supplemented with biochar from mahogany, maize stover, and maize cobs, respectively, at a concentration of 20g/kg of feed. Data collected were subjected to analysis of variance (ANOVA) in CRD. The results showed that broilers in T3 maize Stover biochar (MSB) had the highest body weight gain (BWG) of 3.53 ± 0.155 kg, while the lowest value (2.97 ± 0.06 kg) was recorded in control group (T1). Similarly, T3 (2.32) and T4 (2.87) exhibited the most efficient feed conversion ratios (FCR), which were significantly ($p < 0.05$) better than the control group (3.10). In serum biochemical indices, the highest high-density lipoprotein (HDL) level of 70.33 ± 1.86 mg/dl was recorded in T3, whereas the lowest value of (35.00 ± 0.58 mg/dl) occurred in T1. For low-density lipoprotein (LDL), the control group (T1) had the value of (56.00 ± 1.15 mg/dl), which was significantly ($p < 0.05$) higher than T2 (22.00 ± 1.15), T3 (27.33 ± 1.76), and T4 (25.67 ± 1.86 mg/dl). Furthermore, T3 (MSB) effectively reduced cholesterol levels from 119 mg/dl in the control group to 88 mg/dl. In conclusion, T3 (MSB) demonstrated the most significant improvements in body weight gain, feed conversion ratio, and serum biochemical parameters compared to the other biochar sources.

Keywords: Growth; Serum biochemistry; Broilers; Biochar; Supplement

1. Introduction

Biochar is a carbon-rich material produced through the incomplete combustion of biomass in the absence of oxygen, a process known as pyrolysis (Kutlu *et al.*, 2001). Its highly porous structure makes it an excellent natural filter with a significant capacity to retain water and ions. When compared to other organic materials, biochar has a stronger affinity for ammonia, ions, and other nutrients or irritants. In Japan and China, biochar bokashi is commonly used as a feed supplement, reportedly enhancing digestion and feed conversion ratios (Gerlach and Schmidt, 2012).

When pyrolysis is more complete, biochar production results in charcoal. Studies have shown that dietary supplementation with charcoal can lead to increased live weight gain and improved feed conversion ratios (FCR) in commercial meat chickens and ducks (Kana *et al.*, 2010; Ruttanavut et al., 2009). The proposed benefits of including biochar or charcoal in animal diets include toxin binding, enhanced growth, reduced ammonia emissions, and lower rectal temperatures (Omeje *et al.*, 2023). One potential mechanism behind the improved FCR involves alterations in the gastrointestinal tract (GIT) microbiota.

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Various sources of nutritional biochar have been used in farm animal diets, and the specific source of biochar plays a critical role in determining its nutritional and health benefits. Investigating the effects of different biochar supplements is therefore essential to ascertain biochar supplement with best significant impact. This study was designed to assess the growth performance and some serum biochemical responses of broiler chickens fed varying sources of biochar supplements.

2. Material and methods

2.1. Location of the Study

The study was carried out at the Department of Animal Science Teaching and Research Farm, University of Nigerian, Nsukka. Nsukka lies in the Derived Savannah Region, and is located on longitude 60^0C 25 N and latitude 7^0C 24 E at an altitude of 430m above sea level (Ofiomata, 1975). The climate is a humid tropic setting with a relative humidity range of 56.01%-103%. Average diurnal minimum temperature ranges from 22^0C -24.7^0C while the average maximum temperature ranges from 33^{0c} -37^{0c} (Energy Centre UNN, 2008), the annual rainfall ranges from 1680mm-1700mm (Breinholt *et al*., 1981).

2.2. Duration of the Study

The experiment lasted for eight (4) weeks during which the experimental birds were fed *ad-libitum*.

2.3. Experimental Material (Biochar)

Figure 1 Biochar Supplement

Three different biomasses were collected and prepared into biochar using the normal process i.e. (pyrolysis). They are maize Stover, maize cobs and mahogany. They were pulverized into powdered form after burning them in a kiln and were included at the level of 20g/kg of the diet.

2.4. Experimental diets

Broiler finisher diet was formulated and used to feed the experimental birds. The compositions of the diets are as shown in table 1 below.

Table 1 Percentage composition of the broiler finisher diet

Ingredients	%composition
Maize	53.0
Wheat offal	10.0
P K C	5.5
G N C	15.0
Fish meal	1.5
S B M	10.0
Bone meal	4.0
Salt	0.25
Lysine	0.25
Methionine	0.25
Vitamin premix	0.25
Total	100
Calculated composition	
Crude protein (%)	20.1
Gross energy (Mcal/kg)	2.72

2.5. Experimental Procedure

The experiment, which spanned eight weeks, involved a total of 120 broiler chicks. The chicks were randomly assigned to four treatment groups, each consisting of three replicates. Treatment 1 served as the control and did not include any biochar. Treatment 2 included 20 g/kg of biochar derived from mahogany, Treatment 3 contained 20 g/kg of biochar produced from maize stover, and Treatment 4 consisted of 20 g/kg of biochar made from maize cobs. Standard poultry routine management practices were consistently implemented throughout the experiment.

2.6. Management of Experimental Birds

Day-old chicks in each replicate were brooded in a deep litter pen measuring 1.50 x 1.50 meters within the experimental house until they reached four weeks of age. The poultry house was open-sided and divided into individual pens separated by wire gauze, with fresh wood shavings used as litter material. Heat was supplied using charcoal stoves placed under metal hovers. The birds were provided with feed and water, and additional lighting was supplied at night using rechargeable lamps to illuminate the pens.

The chicks were vaccinated against Newcastle disease on day one via the intraocular route and again at three weeks. They were also vaccinated against Gumboro disease at weeks two and four. All other standard routine poultry management practices were meticulously followed throughout the study.

2.7. Experimental parameters measured

The experimental parameters measured were; initial body weight, final bodyweight, weight gain, feed intake and feed conversion ratio for growth response and cholesterol, high density lipoprotein (HDL), low density lipoprotein (LDL), triglycerides (TAG), aspartate aminotransferase (AST), alanine aminotransferase (ALT), alkaline phosphatase (ALP), Albumin, bilirubin, Urea and Creatinine for the serum biochemical profiles.

2.8. Growth Performance Evaluation

Body weight, feed intake, and feed-to-gain ratio were monitored weekly throughout the experimental period. Key parameters calculated at the end of the experiment included, body weight gain, final weight, feed intake, feed conversion ratio (FCR), feed cost/kg and feed cost per kilogram of weight gain.

All birds in each replicate were individually weighed using a 5 kg top-loading Salter weighing scale. Weighing was conducted weekly in the morning before feeding. Initial body weights were recorded at the start of the experiment and used to calculate weight gain as follows:

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

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

Daily feed intake was determined by subtracting the leftover feed from the total feed supplied. Feed cost per kilogram of weight gain was calculated by multiplying the price of a kg of feed by the feed conversion ratio.

2.9. Serum biochemical analysis

At the end of the week 8, one bird from each replicate was randomly selected and blood samples were collected from their wing veins with sterile needles to determine the serum biochemical indices of the broiler birds using randox kit.

Table 2 Normal range of blood chemistry indices of domestic fowl

Parameters	**Values**
Total protein (g%)	3.3-5.5
Albumin (g%)	1.3-2.8
Globulin (g%)	1.5-4.1
Creatinine (mg%)	0.9-1.8
Uric acid (mg%)	2.5-8.1
Glucose (mg%)	227-300
Cholesterol (mg%)	86-211
Ca (mg%)	13.2-23.7
P (mg%)	6.2-7.9
Na (mEq/L)	131-171
K (mEq/L)	3.0-7.3

Source: Aiello and Mays (1998)

3. Results

Table 3 Growth Response of Finisher Broilers Fed Varying Sources of Biochar Supplements

	T_1 Control	**T_2 (M)**	**T_3 (MSB)**	**T_4 (MC)**	**P value**
Initial Body Weight (kg)	0.05±0.00	0.05±0.00	0.05±0.00	0.05±0.00	1.00
Final Body weight (kg)	2.56±0.00^{d}	2.79±0.02^{b}	2.95±0.02^{a}	2.72±0.03^{c}	0.00
Total weight gain (kg)	2.51±0.00^{d}	2.74±0.02^{b}	2.90±0.02^{a}	2.67±0.03^{c}	0.00
Av. Daily weight gain(g)	44.94±0.15^{d}	49.04±0.47^{b}	51.78±0.40^{a}	44.79±0.55^{c}	0.00
Total feed intake (kg)	7.81±0.05^{a}	7.63±0.04^{b}	6.72±0.04^{c}	7.69±0.05^{ab}	0.00
Av. Daily feed intake (g)	139.49±0.96^{a}	138.28±0.88^{b}	120.14±0.85^{c}	137.42±0.95^{ab}	0.00
Feed conversion ratio	3.10±0.01^{a}	2.78±0.00^{b}	2.32±0.00^{d}	2.87±0.01^{c}	0.00
Feed cost/kg	960.00^{b}±1.73	978.00^{a}±0.53	963.00^{b}±0.33	963.67^{b}±1.15	0.00
Feed cost/kg wt. gain	2,976.00^{a}±2.31	2,718.84^{b}±2.89	2,234.16^{d}±2.89	2,765.73^{c}±2.30	0.00

^{abcd}: Means on the same row with different superscripts are significantly different ($P \leq 0.05$ or $P \leq 0.01$). Key: M= Mahogany, MSB= Maize Stover Biochar, MC= Maize cob.

The results indicated that broilers on T_3 (MSB) achieved the highest final body weight of 2.95 ± 0.02 kg, which was significantly higher than the values recorded for treatments T_2 (2.79 ± 0.02 kg), T_4 (2.72 ± 0.03 kg), and the control group T_1 (2.56 ± 0.00 kg). Total weight gain followed a similar trend, with T_3 showing the highest value of 2.90 ± 0.02 kg. Birds on T3 also had the highest average daily weight gain of 51.78 ± 0.40 g, which was significantly ($p<0.05$) higher than the values recorded for T_2 (49.04 ± 0.47 g), T_1 (44.94 ± 0.15 g), and T_4 (44.79 ± 0.55 g).

In feed intake, the control group (T_1) recorded the highest total feed intake of 7.81 ± 0.05 kg, which was significantly ($p<0.05$) higher than the values for T_4 (7.69 ± 0.05 kg), T_2 (7.63 ± 0.04 kg), and T_3 (7.63 ± 0.04 kg). Similarly, in feed cost/kg weight gain, T1 had the highest feed cost/kg weight gain of ₦2,976.00±2.31 which was significantly ($p<0.05$) higher than the values of ₦2,718.84±2.89 and ₦2,765.73±2.30 recorded for T2 and T4 respectively. T3 had the least feed cost/kg weight gain of ₦2,234.16±2.89 which was significantly lower than the other treatment groups.

For feed conversion ratio (FCR), birds on T_1 recorded the poorest (highest) FCR of 3.10 ± 0.01, which was significantly ($p<0.05$) different from the values obtained from T_4 (2.87 ± 0.01), T_2 (2.78 ± 0.00), and $T_{3,}$ which had the best FCR of 2.32 ± 0.00.

Table 4 Serum Biochemistry indices of finisher broilers fed varying sources biochar supplements

Parameters	**T_1 Control**	**T_2Mahogany**	**T_3 MSB**	**MC**	**P. value**
Cholesterol (mg/dl)	119.00±2.64^a	95.33±3.53^b	88.00±1.15^b	86.00±2.52^b	0.00**
HDL(mg/dl)	35.00±0.59^d	62.67±1.76^c	70.33±1.86^b	81.00±1.50^a	0.00**
LDL (mg/dl)	56.00±1.15^a	22.00±1.15^b	27.33±1.76^c	25.67±1.86^b	0.00**
TAG (mg/dl)	111.67±1.45^a	95.00±3.79^b	91.67±0.88^b	90.00±0.58^b	0.00**
AST (IU/L)	62.33±2.85^a	62.00±2.31^a	53.00±2.08^b	62.33±1.86^a	0.00**
ALT (IU/L)	30.67±1.76^c	36.67±2.73^a	33.67±1.20^b	29.33±2.40^c	0.00**
ALP (IU/L)	86.00±.15	82.00±1.00	84.00±2.85	85.67±0.88	0.05*
Albumin (mg/dl)	4.19±0.04	4.60±0.31	4.71±0.33	4.41±0.11	0.00**
Bilirubin (mg/dl)	3.17±0.35	3.17±0.47	2.91±0.51	3.36±0.15	0.00**
Urea (mg/dl)	42.33±1.45^b	44.67±2.91^a	44.00±1.00^a	45.00±3.21^a	0.00**
Creatinin (mg/dl)	4.84±0.39	4.39±0.11	4.22±0.17	4.99±0.52	0.00**

^{abc}: Means on the same row with different superscripts are significantly different ($P \leq 0.05$ or $P \leq 0.01$) M= Mahogany, MSB= Maize stover biochar, MC= Maize Cob, HDL= High density lipoprotein, LDL= Low density lipoprotein, TAG= Triglycerides, AST= Aspartate Aminotransferase

In triglycerides (TAG), the results showed that birds on control diet (T_1) had the highest value of 111.67 ± 1.45 which was significantly ($p<0.05$) different from the values of 95.00 ± 3.79, 91.67 ± 0.88 and 90.00 ± 0.58 recorded for $T_{2,}$ T_3 and T_4 respectively. For Aspartate Aminotransferase (AST) levels, birds on the control diet (T_1) had the highest value of 62.33 ± 2.85, which did not differ significantly from 62.00 ± 2.31 (T_2) and 62.33 ± 1.86 (T_4). However, these values were significantly higher than the value of 53.00 ± 2.08 recorded for T_3. Alanine Aminotransferase (ALT) levels were highest in birds on T_1 (36.67 ± 2.73), while the lowest value of 29.33 ± 2.40 was observed in birds on T_4. However, there were no significant differences in ALT levels across the treatment groups. For Alkaline Phosphatase (ALP), birds on the control diet (T_1) recorded the highest value of 86.00 ± 1.15, while the lowest value of 82.00 ± 1.00 was observed in birds on T_2. Similar to ALT, there were no significant differences in ALP levels across the treatment groups.

4. Discussion

4.1. Growth Performance of finisher Broilers Fed Varying Sources of Biochar Supplements

The inclusion of biochar in broiler feed has significant benefits, including enhanced digestion, improved growth rate, better feed conversion ratio (FCR), and increased feed efficiency, which maximizes the energy absorbed from feed. Biochar effectively binds toxins, mitigating their adverse effects on the digestive system and intestinal flora (Sivaranjanee *et al.*, 2024). These properties were evident in this study, where birds supplemented with biochar from maize stover (T_3) demonstrated superior performance in final body weight, body weight gain, and average daily weight gain. Furthermore, birds on T3 had lower total feed intake, average daily feed intake, and FCR, suggesting that the inclusion of maize stover biochar enabled better energy utilization from the feed, leading to higher weight gain compared to other biochar treatments and the control group.

The findings align with previous studies, such as Kana *et al.* (2010) and Jiya *et al*. (2013), who reported that while dietary biochar at levels of 2% or higher can sometimes suppress growth rates and final body weights, it can also enhance growth performance when used at appropriate levels. Mongo *et al*. (2020) demonstrated the growth-promoting potential of coconut shell charcoal in broilers, while Dim *et al*. (2018) showed that broilers fed with 4% and 6% corn stover biochar achieved similar final body weights, significantly exceeding those fed with 2% biochar and the control diet (0% biochar).

Additionally, Omeje *et al*. (2023) reported improved growth performance and reduced ammonia emissions in broilers fed diets supplemented with 1.5% inclusion level of maize stover biochar. Chu *et al*. (2013) observed better growth performance, immune response, and fecal microflora populations in fattening pigs supplemented with bamboo charcoal and bamboo vinegar as antibiotic alternatives.

Contrastingly, Kajethan *et al.* (2020) found that adding 1–2% beech wood biochar to laying hen feed increased daily feed intake and FCR while reducing body weight. Similarly, Dim *et al.* (2018) noted improved growth rates, hematological profiles, and serum lipid profiles in broilers supplemented with 6% biochar.

These findings reinforce the potential of biochar as an effective feed additive when used at optimal inclusion levels and sources, contributing to improved growth performance and overall health in poultry and other livestock animals.

4.2. Serum Biochemical Profiles of finisher broilers fed varying sources of biochar supplements

Blood is a complex fluid composed of various dissolved and suspended inorganic and organic substances (Jurado, 2013), functioning as a specialized circulating tissue. It carries oxygen from respiratory organs to body cells, distributes nutrients and enzymes, and removes waste products, thereby maintaining internal homeostasis (Baker and Silverton, 1985). The functions of blood are facilitated by its constituents, and the biochemical properties of blood are influenced by the quality and composition of feed, including the presence of anti-nutritional factors (Akinmutimi, 2004). These biochemical components can serve as indicators of protein quality in feed and are often used to establish diagnostic baselines for managing farm animals (Tambuwal *et al.,* 2002).

In the present study, dietary biochar supplementation positively influenced serum biochemical parameters in broilers. Birds on biochar diets exhibited lower cholesterol levels and higher HDL values when compared to birds T_1 (control diet)., while LDL and triglyceride (TAG) levels were significantly higher in birds on T1 (control diet). These findings align with Odunitan-Wayas *et al*. (2018) and Rao and Shen (2002), who reported that carotenoid-rich diets reduce serum cholesterol in chickens. The cholesterol-modulating effects of dietary components depend on factors such as breed, sex, age, and feed composition (Toghyani *et al*., 2010). TAG, synthesized in the liver from fatty acids, proteins, and glucose when energy demands are met, is stored in adipose tissue (Esubonteng, 2011).

The results from this study on serum lipid profiles are consistent with Boonanuntanasarn *et al.* (2014), who observed significant reductions in blood cholesterol in Nile tilapia fed 20g/kg of activated charcoal. Similarly, Yoo *et al*. (2005) reported improvements in fatty acid composition and reductions in saturated fatty acids in flounders supplemented with charcoal and wood vinegar while Neuvonen *et al.* (1989) found that activated charcoal could interfere with enterohepatic bile acid circulation, lowering cholesterol levels.

However, these findings are in contrast with the work of Majewska *et al*. (2009), who reported non-significant differences in triglycerides, cholesterol, or other biochemical indices in turkeys fed charcoal-containing diets. Edrington *et al.* (1997) and Majewska *et al*. (2003) similarly found no significant ($p>0.05$) biochemical changes in birds fed charcoal feed additives, which may be attributed to differences in biochar sources and their processing methods. Interestingly, this present study is in consonance with the earlier work of Chu *et al.* (2013) who reported decreased LDH, TAG, and bilirubin concentrations in pigs supplemented with bamboo biochar.

In Aspartate Aminotransferase (AST), the control group (T1) exhibited an elevated AST values when compared to the treatment groups. Report has it that Vitamin A deficiency is associated with an increase in AST and ALT levels (Roodenburg *et al*., 1996) thus, suggesting that the presence of vitamin A in the biochar may have resulted in normal AST levels as reported in this present study. Liver enzymes such as ALT, ALP, and AST are critical markers of liver function, with increased concentrations indicating potential liver damage or disease (Ambrosy *et al.,* 2015).

Reduced serum albumin levels in the control group may reflect impaired protein utilization, as reported by Kakade and Evans (1966). This is further supported by the reduced weight gain in birds on the control diet compared to those on biochar-supplemented diets. Improved serum albumin levels in birds fed biochar diets indicate enhanced amino acid absorption and utilization, contributing to improved growth performance.

5. Conclusion

The research has revealed the beneficial effects of biochar as a dietary supplement in finishing broiler production. From the results obtained, T_3 (MSB) had the best growth response, cheaper feed cost per kg weight gain and better feed conversion ratio (FCR). In serum biochemistry, T_3 (MSB) performed better than the control and some other sources of biochar supplements as it was able to reduce the cholesterol level and improved the content of high density lipoprotein (HDL).

Recommendation

It is recommended that T_3 maize stover biochar (MSB) should be used as preferred biochar supplement for finisher broiler chickens for increased marginal profit.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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