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Performance and Carcass Characteristics of Broilers Chickens Supplemented with Organic Acids Enriched Corn Cob Biochar in the Finisher Diets

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The study examined growth performance, nutritional digestibility, carcass traits, and bone mineralization in broiler finisher diets supplemented with increased citric acid and fumaric acid corn cob biochar. For this experiment, a total of 480-day-old Ross 308 broiler chicks were procured from a commercial hatchery and were randomly divided into 6 treatment groups: Control group (basal diet), negative control (without AGPs), CCB1%, CCB1.5%, FCB1%, and FCB1.5%. Each treatment was comprised of 8 replicates with 10 birds in each replicate in a completely randomized design. The performance data of birds, i.e., feed intake (FI), feed conversion ratio (FCR) and body weight gain (BWG) were determined weekly. Nutrient digestibility was calculated by using an external maker (Celite)®. Two birds from each replicate were slaughtered at the end of the trial for bone mineralization and carcass parameters evaluation. The data collected was analyzed by the analysis of variance and the means were compared using Tukey's test. The results showed that the birds supplemented with the different inclusion levels of CCB and FCB exhibited improved growth performance ($P<0.05$). The highest FI was observed in birds receiving diets without AGPs, and the lowest FI was recorded in CCB1% supplemented groups during the $4^{th}/5^{th}$ weeks and overall finisher phase. Moreover, improved BWG and FCR were observed in birds that received a 1% CCB-enriched diet compared to a negative control diet. Similarly, the nutrient digestibility (dry matter, ether extract, and crude protein) was higher in CCB1%. The findings of carcass characteristics also showed the increased proportions of carcass, breast, and thigh weights in CCB1% supplemented birds. However, the weights of giblets (i.e., heart, liver, gizzard) remained the same among all the dietary treatments ($P>0.05$). Furthermore, the minerals (Ca and P) content in the tibia bone was also higher in birds that received a 1% CCB-enriched diet compared with the negative control. In conclusion, it is suggested that the supplementation of CCB1% in the finisher diets improves growth performance, carcass characteristics, and bone mineralization of broilers.

Keywords: Biochar, organic acids, citric acid, fumaric acid, performance.

INTRODUCTION

Broilers are meat-type birds that grow quickly and attain a market weight of 1.80 to 2.25 Kg in 5-6 weeks (Leeson, 1991). Due to its shorter lifespan, broiler meat is a cheaper source of protein and amino acids than red meat (Al-Dawood, 2016). The shorter productive lifespan and higher feed efficiency made poultry products a good animal protein source (Husna *et al.*, 2017). Broilers are fed a customized diet to improve feed efficiency (FE) (Barekatain and Swick, 2016). Broiler feeds generally contain antibiotic growth promoters (AGPs) to boost FE and growth (Hamasalim, 2016).

However, due to the negative consequences of antibiotics, such as cross-resistance, the use of antibiotics as growth promoters has been forbidden in broiler diets (Diarra *et al.*, 2007). Therefore, an alternative to AGPs that improves bird growth without affecting health is needed (Hajati and Rezaei, 2010). Biochar is becoming a popular local growth promoter (Gerlach and Schmidt, 2012). Corn cob (CC), sugarcane bagasse, and chicken litter thermochemically convert into it in an oxygen-limited environment (Evans *et al.*, 2015). Biochar improves poultry feed intake and performance (Kana *et al.*, 2011; Dim *et al.*, 2018). Biochar improves digestion and FE (Gerlach *et al.*, 2014). Prasai *et al*. (2017) found that broilers fed 2-4% biochar from oak, maize cob, coconut shell, and locally available wood had better development and carcass quality (Terry *et al.*, 2020). Biochar in broiler diets

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eliminates digestive tract toxins, stimulates intestinal flora, and improves chicken productivity (Gerlach *et al.,* 2014). Biochar's adsorption qualities make it useful with other feed additives (Shahid *et al.,* 2015). Modern chicken farming optimizes performance and output with feed additives. Herbal, probiotic, and prebiotic feed additives are suggested (Shah *et al.,* 2020; Jabbar, 2021; Chand, 2021; Shahid *et al.,* 2015). Fumaric and citric acids make good feed additives (Khan *et al.,* 2022). Organic acids are proven to improve broiler chicken health and performance and could substitute antibiotics. Organic acids improve food digestion and development performance in broiler chicks by acidifying the gut (Boling *et al.,* 2000). No study has examined the effects of citric acid and fumaric acid-enriched corn cob biochar supplementation on broiler intake, growth performance, nutrient digestibility, bone mineralization, and carcass characteristics. Thus, this study examines the effects of enhanced citric acid corn cob biochar (CCB) and fumaric acid (FCB) on broiler chicken development, nutritional digestibility, bone mineralization, and carcass characteristics from day 22 to 35.

MATERIALS AND METHODS

***Ethical approval*:** The experiment was conducted at the Animal Nutrition Research Centre of the Institute of Animal and Dairy Sciences, University of Agriculture, Faisalabad (UAF) after approval from the Graduate Studies and Research Board, UAF.

***Preparation of biochar and enrichment of citric acid and fumaric acid*:** Biochar was prepared through slow pyrolysis in a portable metallic kiln (CCM-7). Raw materials were burned inside the kiln without oxygen or in an oxygen-limited environment at 450-550ºC temperature for 120-150 minutes. Then, biochar was cooled down by an immediate sprinkling of water. The biochar production yield was 18-25% of the total biomass. To produce enriched CCB and FCB in this study, citric acid and fumaric acid in powdered form were procured from a commercial supplier. These acids' specified amounts (w.r.t. experimental treatments) were added to a premixer along with a designated portion of CC biochar. The resulting mixture was thoroughly blended in a mechanical blender before being added to the rest of the feed.

***Animals, management, and experimental diets*:** The experiment used 480-day-old broiler chicks (Ross-308) from a commercial hatchery that had been brooded on commercial feed for 21 days in floor pens at 30 kg/m2. A nipple drinker, a hand feeder, and wood shavings for litter were all included in the pens. The Ross 308 recommendations were followed in implementing the lighting and room temperature program. On the 22nd day, the birds were weighed (720 ± 3.7 g/bird), and the chicks were randomly divided into six dietary treatments with eight replicates (10 chicks per replicate). Animals had ad libitum access to the experimental diets designated as; Control group (basal diet), negative control (without AGPs-), Enriched citric acid corn cob biochar @ 1% (CCB1 i.e., citric acid+biochar @ 1% each), Enriched citric acid corn cob biochar @ 1.5% (CCB1.5 i.e., citric acid+biochar @ 1.5% each), Enriched fumaric acid corn cob biochar @ 1% (FCB1 i.e., fumaric acid+biochar @ 1% each), and Enriched fumaric acid corn cob biochar @ 1.5% (FCB1.5 i.e., fumaric acid+biochar @ 1.5% each) The ingredient composition and nutritional value of all experimental diets can be seen in Table 1.

Data Collection

***Growth performance*:** Each replicate's FI and BW were recorded every week. Using the following formula, the amount of feed rejected was deducted from the total amount of meal supplied to determine the FI of the birds:

Feed intake = Feed offered – Feed refused

FCR was calculated by the given formula.

$$\text{FCR} = \frac{\text{Feed intake in grams}}{\text{Weight gain in grams}}$$

***Nutrient digestibility*:** The nutrient digestibility of DM, CP, and EE was determined using the indirect marker method. Celite® (a source of acid-insoluble ash) was added @ 1% to the experimental diets. Plastic sheets were spread in each pen under the birds to collect feces. Fecal samples were collected in labeled zipper bags replicate-wise and stored at -10°C till analyzed for acid-insoluble ash (AIA). The following relationship was used to determine the coefficient of digestibility for each nutrient:

$$\text{Coefficient of digestibility \%} = 100 - [100 \times \frac{\text{Marker in feed}(\%)}{\text{Marker in feces}(\%)} \times \frac{\text{Nutrient in feces}(\%)}{\text{Nutrient in feed}(\%)}]$$

***Carcass parameters*:** To gather information on the characteristics of the corpse, two birds from each treatment group were chosen at the conclusion of the trial, weighed separately, and killed. Following the killing, the feathers were taken off, and the animal was then disemboweled to determine the weight of the dressed body, the breast meat, the thighs, and the giblet organs (heart, liver, and gizzard). By dividing the weight of each internal organ by the live weight of the bird and multiplying the result by 100, the relative weight % of the heart, liver, bursa, spleen, and gizzard of the killed birds was determined.

***Bone mineralization*:** After being crushed and defatted for 24 hours with petroleum ether using the Soxhlet apparatus, the tibia samples were oven-dried for another 24 hours at 100 °C. After that, dried samples were burned for 24 hours at 600 °C in a muffle furnace to calculate the percentage of bone ash (dry weight basis, fat-free). The P and Ca contents of the tibia samples were ascertained after the ash was solubilized using a solution of nitric and perchloric acid.

Table 1. Ingredient composition of finisher diets (day 22-35).

Ingredient	Experimental Diets					
	T1	**T2**	**T3**	**T4**	**T5**	**T6**
Maize	65.31	65.38	65.31	65.31	65.31	65.31
SBM	10.34	10.34	10.34	10.34	10.34	10.34
Canola meal	5.83	5.83	5.83	5.83	5.83	5.83
Feather Meal	7.00	7.00	7.00	7.00	7.00	7.00
RSM	5.00	5.00	5.00	5.00	5.00	5.00
CG 60	2.00	2.00	2.00	2.00	2.00	2.00
Fishmeal	2.00	2.00	2.00	2.00	2.00	2.00
Limestone	1.00	1.00	1.00	1.00	1.00	1.00
Lysine	0.63	0.63	0.63	0.63	0.63	0.63
Salt	0.30	0.30	0.30	0.30	0.30	0.30
DLM	0.17	0.17	0.17	0.17	0.17	0.17
Theronine	0.08	0.08	0.08	0.08	0.08	0.08
Arginine	0.05	0.05	0.05	0.05	0.05	0.05
Phytase	0.01	0.01	0.01	0.01	0.01	0.01
XAP	0.01	0.01	0.01	0.01	0.01	0.01
Anti-coc super	0.025	0	0.025	0.025	0.025	0.025
Lincomycine	0.025	0	0.025	0.025	0.025	0.025
Meduramycine	0.025	0	0.025	0.025	0.025	0.025
Premix	0.15	0.15	0.15	0.15	0.15	0.15
Isoleucine	0.05	0.05	0.05	0.05	0.05	0.05
Total	100.00	100.00	100.00	100.00	100.00	100.00
Enriched Biochar	0.00	0.00	1.00	1.50	1.00	1.50

*Per kilogram of diet, one kilogram of premix was given: Contains 10,000 IU of vitamin A, 1100 IU of vitamin D3, 11.0 IU of vitamin E, 1.1 mg of vitamin K, 2.2 mg of thiamin, 5 mg of riboflavin, 12 mg of pantothenate, 2.2 mg of vitamin B6, 0.11 mg of d-biotin, 1.55 mg of folic acid, 12.1 µg of vitamin B12, 250 mg of choline chloride, 44 mg of nicotinic acid, 50 mg of zinc, 60 mg of magnesium, 5 mg of copper, 0.1 mg of cobalt, 0.3 mg of iron, 30 mg Fe, and 1 mg of selenium,
T1=Positive control group (commercial diet), T2=Negative control group (control diet without antibiotic growth promoter), T3=1% CCB supplementation in diets, T4 = 1.5% CCB supplementation in diets, T5=1% FCB supplementation in diets, T6 = 1.5% FCB supplementation in diets.

Table 2. Nutrient composition of finisher diets (22-35 days).

Ingredients	T1	T2	T3	T4	T5	T6
DM	87.78	87.78	87.78	87.78	87.78	87.78
Crude protein	19.00	19.00	19.00	19.00	19.00	19.00
Crude fat	5.10	5.10	5.10	5.10	5.10	5.10
ME (kcal/kg)*	3200.00	3200.00	3200.00	3200.00	3200.00	3200.00
Calcium (Ca)	0.79	0.79	0.79	0.79	0.79	0.79
Available phosphorus (P)	0.395	0.395	0.395	0.395	0.395	0.395
Sodium (Na)	0.18	0.18	0.18	0.18	0.18	0.18
Chloride (Cl^-)	0.18	0.18	0.18	0.18	0.18	0.18
Digestible lysine	1.16	1.16	1.16	1.16	1.16	1.16
Digestible methionine	0.47	0.47	0.47	0.47	0.47	0.47
Digestible arginine	1.22	1.22	1.22	1.22	1.22	1.22
Digestible threonine	0.78	0.78	0.78	0.78	0.78	0.78
Isoleucine	0.81	0.81	0.81	0.81	0.81	0.81

***Chemical analysis*:** All experimental diets and composite fecal samples were subjected to the following analyses: total ash by a muffle furnace (method 942.05), nitrogen by combustion (method 990.03), ether extract by Soxhlet fat analysis following 3N HCl acid hydrolysis (method 920.39), and dry matter (DM) by oven-drying method (method 930.15) in accordance with AOAC (2007). In accordance with AOAC (2000), the AIA and nutritional composition of the experimental diets were also examined.

Statistical analysis**:** Data on growth performance, carcass characteristics, and bone mineralization were subjected to analysis of variance for a completely randomized design using the Minitab 17. Tukey's test was applied to compare mean values (Steel *et al.*,1997).

RESULTS

Feed intake**:** Table 3 shows the effect of supplementation of different levels of biochar enriched with citric and fumaric acid on the FI of broilers in the finisher phase. The results showed considerable ($p<0.05$) differences in FI of the broiler chickens fed the experimental finisher diets. The increased FI was observed in the Negative control diet (821.38gm) and (966.53gm) during the 4th and 5th week, respectively. Whereas, the decreased FI was recorded in CCB1% in the 4th (804.88gm) and 5th (956.83gm) weeks. During the overall finisher phase (i.e., 22-35 days), a similar trend for the increased FI was seen in the negative control diet (1787.9gm), while the decreased FI was noticed in CCB 1% (1761.9gm).

Body weight gain**:** The current study showed higher live body weight gains (565.58gm) (627.96gm) in the 4th and 5th week, respectively (Table 4) in CCB1% diets. However, lower body weight gains were found in negative control birds during the 4th (544.72gm) and 5th (608.90gm) weeks. Similarly, the overall finisher phase findings showed a higher gain in CCB1% (1192.9gm vs 1153.6gm) compared with the negative control fed group.

Feed conversion ratio**:** The supplementation of different levels of citric and fumaric acid-enriched corn cob biochar improved ($p<0.05$) the FCR of broilers compared with the control diets in the finisher phase (Table 5). The results showed enhanced FCR in CCB1% compared with the birds fed with a negative control diet at the 4th (1.42 vs 1.50) and 5th (1.52 vs 1.58) weeks. During the overall period (22-25 days), the better FCR was also recorded in birds fed with the CCB1% (1.47), and vice versa was observed in in negative control diet (1.55).

Nutrient digestibility**:** The results of digestibility showed that the addition of different levels of citric and fumaric acid-enriched corn cob biochar significantly ($p<0.05$) affected the

Table 3. Effect of supplementation of the effect of enriched citric acid corn cob biochar (CCB) and fumaric acid corn cob biochar (FCB) on feed intake (grams) of broilers in finisher phase.

#	Treatments						SEM	*P*-Value
	T1	T2	T3	T4	T5	T6		
4th Week	813.30^{ab}	819.38^{a}	804.88^{b}	808.50^{b}	806.80^{b}	810.05^{b}	1.656	0.048
5th Week	950.93^{c}	961.53^{a}	956.83^{b}	959.02^{b}	955.10^{bc}	959.07^{b}	1.271	0.003
4th- 5th Week	1766.2^{b}	1768.9^{a}	1761.9^{b}	1764.5^{b}	1763.9^{b}	1765.1^{b}	1.772	0.001

T1=Positive control group (commercial diet), T2=Negative control group (Control diet without antibiotic growth promoter), T3=1% CCB supplementation in diets, T4 = 1.5% CCB supplementation in diets, T5=1% FCB supplementation in diets, T6 = 1.5% FCB supplementation in diets; The values in a row with superscript (a, b, c) are significantly different.

Table 4. Effect of supplementation of enriched citric acid corn cob biochar and fumaric acid corn cob biochar on body weight gain (grams) in broilers in starter phase.

#	Treatments						SEM	*P*-Value
	T1	T2	T3	T4	T5	T6		
4th Week	551.40^{c}	549.72^{d}	561.58^{a}	557.18^{b}	560.23^{a}	558.15^{b}	1.187	0.001
5th Week	618.27^{c}	615.90^{d}	625.96^{a}	620.13^{b}	623.25^{ab}	621.65^{b}	1.094	0.003
4th- 5th Week	1175.7^{c}	1170.6^{d}	1182.9^{a}	1177.3^{b}	1180.5^{a}	1179.8^{b}	1.380	0.002

T1=Positive control group (commercial diet), T2=Negative control group (Control diet without antibiotic growth promoter), T3=1% CCB supplementation in diets, T4 = 1.5% CCB supplementation in diets, T5=1% FCB supplementation in diets, T6 = 1.5% FCB supplementation in diets. The values in a row with superscript (a, b, c) are significantly different.

Table 5. Effect of supplementation of enriched citric acid corn cob biochar and fumaric acid corn cob biochar on feed conversion ratio in broilers in finisher phase.

#	Treatments						SEM	*P*-Value
	T1	T2	T3	T4	T5	T6		
4th Week	1.48^{b}	1.50^{a}	1.43^{d}	1.47^{b}	1.45^{c}	1.44^{cd}	4.249	0.048
5th Week	1.54^{b}	1.57^{a}	1.48^{d}	1.53^{c}	1.51^{c}	1.52^{cd}	3.584	0.020
4th- 5th Week	1.51^{b}	1.54^{a}	1.45^{d}	1.50^{c}	1.48^{cd}	1.48^{cd}	2.205	0.001

T1=Positive control group (commercial diet), T2=Negative control group (Control diet without antibiotic growth promoter), T3=1% CCB supplementation in diets, T4 = 1.5% CCB supplementation in diets, T5=1% FCB supplementation in diets, T6 = 1.5% FCB supplementation in diets. The values in a row with superscript (a, b, c) are significantly different.

DM, CP, and EE digestibility in broilers (Table 6). The highest DM digestibility was observed in CCB 1% (85.56%), and the lowest digestibility was observed in negative control (80.20%) diets. Similarly, the EE digestibility was maximum in CCB 1% (84.84% vs 78.53%) compared with the negative control. The results of ether extract digestibility were also substantially significant, where maximum ether extract digestibility was observed in CCB 1% (84.84%), while the minimum ether extract digestibility was observed in the negative control diet (78.53%). The findings of CP digestibility also showed a similar trend of increased digestibility in CCB1% (86.42%) compared with all the dietary treatments.

***Carcass parameters*:** The addition of different levels of citric and fumaric acid-enriched corn cob biochar in the finisher diets significantly ($p<0.05$) affected the carcass parameters (table 7). The highest carcass (63.48%), dressing (98.23%), thigh (25.76%), and breast (33.82%) were observed in CCB 1% diets compared with the control groups. However, citric and fumaric acid-enriched corn cob biochar supplementation

Table 6. Effect of supplementation of enriched citric acid corn cob biochar and fumaric acid corn cob biochar on nutrient digestibility in broiler in finisher phase.

	Treatments							
#	T1	T2	T3	T4	T5	T6	SEM	*P*-Value
Dry matter	83.29^{c}	80.20^{d}	85.56^{a}	84.36^{b}	85.54^{a}	84.26^{b}	0.1249	0.001
Ether extract	80.43^{c}	79.30^{cd}	82.27^{a}	81.08^{b}	80.90^{b}	80.60^{c}	0.1430	0.002
Crude protein	81.50^{c}	78.76^{d}	83.68^{a}	81.74^{b}	83.20^{a}	81.47^{b}	0.1112	0.001

T1=Positive control group (commercial diet), T2=Negative control group (Control diet without antibiotic growth promoter), T3=1% CCB supplementation in diets, T4 = 1.5% CCB supplementation in diets, T5=1% FCB supplementation in diets, T6 = 1.5% FCB supplementation in diets. The values in a row with superscript (a, b, c) are significantly different.

Table 7. Effect of supplementation enriched citric acid corn cob biochar and fumaric acid corn cob biochar on carcass parameters of broiler in finisher phase.

	Treatments							
#	T1	T2	T3	T4	T5	T6	SEM	*P*-Value
Dressing	97.08^{b}	96.54^{c}	98.23^{a}	97.88^{ab}	98.16^{bc}	97.71^{ab}	0.161	0.001
Carcass	60.43^{cd}	59.18^{d}	63.48^{c}	61.25^{bc}	62.33^{b}	61.19^{bc}	0.323	0.003
Breast	32.42^{bc}	31.87^{c}	33.82^{a}	32.71^{b}	33.66^{a}	32.61^{b}	0.132	0.001
Thigh	24.53^{d}	24.28^{cd}	25.76^{a}	25.25^{b}	25.64^{ab}	25.21^{bc}	0.110	0.002

T1=Positive control group (commercial diet), T2=Negative control group (Control diet without antibiotic growth promoter), T3=1% CCB supplementation in diets, T4 = 1.5% CCB supplementation in diets, T5=1% FCB supplementation in diets, T6 = 1.5% FCB supplementation in diets. The values in a row with superscript (a, b, c) are significantly different.

Table 8. Effect of supplementation of enriched citric acid corn cob biochar and fumaric acid corn cob biochar on giblet parameters (heart, liver and gizzard) of broiler in finisher phase.

	Treatments							
#	T1	T2	T3	T4	T5	T6	SEM	*P*-Value
Heart	0.42	0.47	0.48	0.46	0.47	0.45	0.029	0.233
Liver	2.57	2.54	2.65	2.61	2.63	2.6	0.034	0.186
Gizzard	1.35	1.24	1.64	1.43	1.61	1.39	0.045	0.112

T1=Positive control group (commercial diet), T2=Negative control group (Control diet without antibiotic growth promoter), T3=1% CCB supplementation in diets, T4 = 1.5% CCB supplementation in diets, T5=1% FCB supplementation in diets, T6 = 1.5% FCB supplementation in diets. The values in a row with superscript (a, b, c) are significantly different.

Table 9. Effect of supplementation of enriched citric acid corn cob biochar and fumaric acid corn cob biochar on bone mineralization (Ca, P) of broiler in finisher phase.

	Treatments							
#	T1	T2	T3	T4	T5	T6	SEM	*P*-Value
Calcium	4.95bc	4.56c	5.75a	5.48a	5.68a	5.39ab	0.113	0.041
Phosphorus	19.39	16.87	25.66	19.87	25.34	19.69	0.106	0.452

T1=Positive control group (commercial diet), T2=Negative control group (Control diet without antibiotic growth promoter), T3=1% CCB supplementation in diets, T4 = 1.5% CCB supplementation in diets, T5=1% FCB supplementation in diets, T6 = 1.5% FCB supplementation in diets. The values in a row with superscript (a, b, c) are significantly different.

in the finisher diets did not affect ($p>0.05$) the giblet organ proportions (table 8). The proportions of the giblets, i.e., liver, gizzard, and heart, remained the same in all the experimental diets.

***Bone mineralization*:** The effect of supplementation of citric and fumaric acid-enriched corn cob biochar on bone mineralization % (Ca, P) of broilers is presented in Table 9. A higher calcium concentration (5.75 vs 4.56%) was observed in CCB1% compared with the negative control. Similarly, the P was also higher in CCB1% (25.66%), while the lower P was found in negative control (16.87%) diets.

DISCUSSION

Biochar improves poultry feed intake and production (Kana *et al.*, 2011; Dim *et al.*, 2018). Biochar improves digestion and feed efficiency (Gerlach *et al.*, 2014). Our study examined the effects of adding citric and fumaric acid to corn cob charcoal. In the 4th and 5th weeks and overall finisher phase, the Negative control diet had the highest FI and the CCB 1% diet the lowest. Dim *et al*. (2018) found that larger levels of organic acid-enriched biochars (2% and 4%) reduce feed consumption. Kana *et al*. (2011) found that broiler diets with biochars reduced feed consumption. Prasai *et al*. (2017) found that broilers given 2% and 4% maize cob biochar ate more, contrary to our findings. Biochar's adsorbent properties may reduce surface tension in the gastrointestinal system by eliminating gases, toxins, and unpleasant substances, which may lower digesta viscosity and improve nutrient absorption across cell membranes. Our study indicated that broilers' diets with citric and fumaric acid-enriched corn cob charcoal digested nutrients better. Evans *et al*. (2017) found that broilers' nutritional digestibility increased with more than 1% biochar in their diets. Biochar may have increased nutritional digestibility by binding pollutants including dioxin, glyphosate, and mycotoxins, preventing digestive system damage (Gerlach and Schmidt, 2012). Biochar slows gastrointestinal passage, prolonging nutrient digestion, improving nutritional digestibility. In the finisher phase, broilers' FCR was higher with citric and fumaric acid-enriched corn cob biochar than with control diets. Kana *et al*. (2011) discovered that adding 0.6% biochar to broiler diets enhanced FCR. After adding 0.5% citric acid to broiler chick diets, Islam *et al*. (2008) found enhanced FCR. The reduced passage rate of biochar-supplemented meal in the bird's gastrointestinal tract may lower FI and FCR (Majewska *et al.*, 2011). In the 4th and 5th weeks of the trial, broilers fed citric and fumaric acid-enriched corncob biochar gained more live body weight. According to Skinner *et al*. (1991), adding fumaric acid to diet dramatically boosted BWG in broiler chicks. Dim *et al*. (2018) also recorded a higher weight gain in birds fed corn cob biochar due to the adsorbent features of the biochar in the gut of birds. This property facilitates the biochar to bind with the toxins and anti-nutritional factors that interfere with the absorption of nutrients by the bird's intestinal walls. However, in contrast to our findings, Dim *et al.* (2018) reported that supplementing poultry manure biochar @ 4% decreased weight. This is because of the possible arsenic contamination of poultry manure biochar. These heavy metal toxins could cause gastrointestinal issues and depress growth in birds (Evans *et al.*, 2015). The addition of different levels of citric and fumaric acid enriched corn cob biochar in the finisher diets significantly affected the carcass parameters. Our findings align with the study of (Majewska *et al.*, 2011), who found a significant increase in dressed carcass % compared to control birds offered with 1.5 and 2 % charcoal. The improvement in dressing percentages of poultry birds may be attributed to charcoal, which is a prebiotic that enhances FCR and improves digestion, consequently improving growth and muscle formation (Majewska *et al.*, 2011). However, citric and fumaric acid enriched corn cob biochar supplementation in the finisher diets did not affect the giblets organs (i.e., liver, gizzard, and heart) proportions. Xu and Chen (2015) found no significant effect of organic acids on heart, liver, and gizzard weights, supporting our findings. Biochar in broiler diets did not impact carcass metrics, according to Kana *et al.* (2011). The current study found that citric and fumaric acid-enriched corn cob charcoal increased Calcium and Phosphorus concentrations. According to Evans *et al*. (2015), broiler diets with more biochar increased bone mineralization. The greater mineral content of biochar may promote bone mineralization, according to Xu and Chen (2015).

***Conclusion*:** In broiler chickens, corn cob biochar supplemented with citric acid (CCB1%) and fumaric acid (FCB) improves development, nutritional digestibility, carcass characteristics, and bone mineralization. The study found that broilers fed the CCB1% diet had higher body weight increase, FCR, and nutrient digestibility than those on adverse diets. The biochar supplementation also raised dressed body, breast, and thigh weights. The CCB1% diet also increased the mineral content in birds' tibia bones, indicating better bone mineralization. It is suggested that the supplementation of CCB1% in the finisher diets improves growth performance, carcass characteristics, and bone mineralization of broilers.

***Authors' contributions*:** AAR executed the research and wrote the manuscript draft, AA assisted in the lab analysis, MFAC- manuscript reviewing, editing, and finalization.

***Conflict of Interest*:** The authors declare no conflict of interest.

***Availability of data and material*:** The data presented in this study is available upon the request to the corresponding author.

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SDGs addressed**:** Zero Hunger, Good Health, and Well-Being.

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