Consequences of supplementing duck's diet with charcoal on carcass criteria, meat quality, nutritional composition, and bacterial load

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ABSTRACT The influence of charcoal as feed additives on carcass and meat characteristics was studied in 144 four weeks old Muller ducks. The experimental ducklings were assigned to six groups of 24 birds (Eight per replicates each). The dietary treatments contained 0, 0.5, 1.0, 1.5, 2.0, and 2.5% charcoal for G1 (C), G2 (L1), G3 (L2), G4 (L3), G5 (L4) and G6 (L5), respectively. All experimental birds were raised under similar environmental and managerial conditions. Results indicated that charcoal did not affect most carcass traits significantly except for dressing percentage was higher ($P < 0.05$) in 1.5 and 2 % charcoal included ducks diets compared to control ducks. Charcoal supplementation significantly affected duck meat tenderness, juiciness and water holding capacity. Moreover, charcoal altered ($P < 0.05$) meat components such as crude protein, calcium components, desirable fatty acids, nutritional value and some bacterial counts. Thiobarbituric acid reactive substances reduced in birds fed charcoal at 1.5, 2, and 2.5%, with significant variation among treatments. No significant differences in the number of *Escherichia coli* and *Staphylococcus aureus* were detected among the ducks fed with charcoal and the control group. It could be concluded that charcoal could be included in ducks' diets at 1.5 and 2% with beneficial effects on carcass parameters.

Key words: carcass, duck, charcoal, meat quality, microbiota

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INTRODUCTION

Production and use of biochar have become more common during the last 10 years. Biochar is comparable to charcoal and activated charcoal because they are all pyrogenic carbonaceous compounds formed by pyrolyzing materials rich in organic carbon (Pignatello et al., 2017). Few studies have been done on using biochar in animal feed (Man et al., 2021).

The amount of cellulose, hemicellulose and lignin in the raw materials, as well as other processing variables like activation and drying, have a big impact on the biochar's structural properties, and chemical composition (Amin et al., 2017; Emwas et al., 2019; Chandra et al., 2021a,b). The heating parameters, such as temperature, reaction time, and reactor type, also impact the final products' characteristics (Yu et al., 2019).

According to Gerlach and Schmidt (2012), biochar is advantageous because it helps with digestion, feed efficiency, and consequently energy absorption through the feed. The biochar effectively binds toxins like dioxin, glyphosate, mycotoxins, pesticides, and polycyclic aromatic hydrocarbons, negating any negative effects on the gastrointestinal tract and intestinal flora. Additionally, the animals' health, activity, and balance and the

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yield of meat and eggs will be improved (Gerlach and Schmidt, 2012).

Additionally, chickens and ducks with foot pad dermatitis can get relief (Gerlach and Schmidt, 2012). There have been few studies on the impact of biochar on broiler performance (Evans et al., 2017; Dim et al., 2018). Compared to the control group, egg-laying chickens fed wood-based biochar, produced eggs with higher weights and feed conversion ratio (**FCR**) (Prasai et al., 2018). The digestive system responds to biochar as an antidote by deactivating toxic metabolites (Gerlach and Schmidt, 2012; Khafaga et al., 2019; Mehana et al., 2020). The hematological parameters of chicken given a meal containing 1% rice husk were evaluated by Hien et al. (2018). The biochar lowers blood plasma triglycerides, according to Hien et al. (2018) examination of the hematological parameters in chicken fed 1% biochar derived from rice husk.

Additionally, it was shown that adding 1% wood biochar to ducks' meals caused an increase in their intake of omega-3 fatty acids. Islam et al. (2014) demonstrated that adding 1% biochar to daily feed significantly reduced the low-density lipoprotein levels, increased the high-density lipoprotein levels, and reduced the ratio of omega-6 to omega-3 polyunsaturated fatty acids.

Only a few studies have been carried out to evaluate the effects of adding charcoal to ducks' diet on the meat's bacterial load, amino acid composition, and fatty acid composition. Therefore, the current study aimed to determine how adding charcoal to ducks' diets affects their carcass features, sensory evaluation, the composition of amino acids and fatty acids, the composition of minerals, and the bacterial load of the flesh.

MATERIALS AND METHODS

The current study was conducted at the Poultry Production Department, Faculty of Agriculture, Assiut University, Assiut, Egypt.

Birds, Diets, and Experimental Design

For this investigation, 144 native ducklings that were 1 day old in total were used. The experimental ducklings were divided into six groups, each with 24 birds. The dietary regimens for G1 (C), G2 (L1), G3 (L2), G4 (L3), G5 (L4), and G6 (L5), respectively, contained charcoal concentrations of 0, 0.5, 1, 1, 5, 2, and 2.5%. Under the direction of a professional veterinarian, vaccinations and a medical program were carried out in accordance with the various stages of age. Charcoal has the following chemical compositions: dry matter, crude protein (CP), crude fiber, oil, and ash, with respective values of 99.02, 1.98, 11.22, 0.00, and 2.08.

Throughout the experiment, the birds had ad libitum access to feed and fresh water. The experimental birds were fed a diet that included 20% CP and 3,000 kcal kg^{-1} until they were 16 weeks old and acceptable quantities of the nutrients as recommended by NRC (1994). Throughout the experimental period, birds were exposed to a consistent 16L:8D photoperiod at 10−20 lux/m^2. All experimental birds were grown on deep litter with an 8−10 cm thickness in floor pens that were each 2 square meters in size.

Investigated Measurements

Carcass Traits Three birds per treatment were slaughtered at the age of 16 weeks. The carcasses were carefully dissected, and the weights of the liver, heart, gizzard and abdominal fat were recorded, along with the dressing % (carcass weight + giblets weight)/live body weight multiplied by 100.

Sensory Evaluation The sensory evaluation was conducted, in which a test panel of five panelists graded the samples of meat on a scale of 1 to 10 for color, flavor, tenderness, and juiciness according to Sudha et al. (2007). The panelists rated meat on its general acceptability, color, texture, elasticity, and flavor.

Water Holding Capacity Based on the percentage of free water in the meat, the Grau and Hamm (1953) method, as modified by Pohja and Niinivaara (1957), was used to calculate water holding capacity (WHC) and plasticity. Ground meat samples were placed on Whatman No. 1 filter paper (Whatman, Maidstone, England) and pressed less than 2 kilograms of pressure for 5 minutes between two glass plates.

Each sample of ground beef weighed precisely about 0.001 grams. Two spots created by extruded meat juice and flesh were measured using a planimeter in cm^2. To determine the percentage of free water in the meat, the infiltrate area, represented in cm^2 was acquired from the difference between the areas of these two places, and was divided by the sample weight.

Cooking Loss and pH Cooking loss and pH were calculated using the method developed by Zaika et al. (1976) 24 h after slaughtering in distilled water with a 1:1 meat-to-water ratio (w:v). Cooking loss was determined as recommended by Barbanti and Pasquini (2005).

Meat Chemical Composition

The chemical composition of meat was analyzed on a mix of breast and thigh meat stored at −18°C. Dry matter, CP, crude fat, and ash contents were determined according to the methods described by AOAC (1999). The basic chemical composition of breast and leg muscles was determined using the standard methods. CP (N × 6.25) was determined by the Kjeldahl method using a Kjeltec system (2200 Kjeltec Auto Distillation Foss Tecator—Foss Trecator AB, Höganäs, Sweden). Fat content was determined using a Soxtec System HT 1043 Extraction Unit (Foss Trecator AB, Höganäs, Sweden). Samples were analyzed in triplicates per each carcass per each determination.

Determination of Mineral Content To determine the content of minerals (Na, P, Ca, Fe), meat samples were freeze-dried, and wet mineralized in a Milestone

Table 1. Carcass traits of Muller ducks as affected by dietary charcoal supplementation as a feed additive.

Traits	Charcoal levels					SEM	*P* value
	C 0.0%	L1 0.5%	L2 1.0%	L3 1.5%	L4 2.0%	L5 2.5%		
Carcass appearance								
Conformation	4.06	4.01	3.79	3.92	4.11	4.20	0.12	0.3261
Fatness	3.92	3.88	4.02	3.78	3.91	3.66	0.15	0.1485
Breast circumference	18.55	18.32	19.14	18.69	18.46	19.08	1.51	0.3444
Breast irritation	2.74	2.16	2.88	2.01	1.95	2.36	1.04	0.8254
Carcass traits (cut parts %)								
Dressed carcass, %	75.22[b]	75.35[b]	76.69[ab]	77.81[a]	77.71[a]	76.87[ab]	0.69	0.0132
Heart, %	0.53	0.52	0.51	0.54	0.53	0.55	0.06	0.8651
Liver, %	2.49	2.48	2.35	2.23	2.58	2.29	0.26	0.3126
Gizzard, %	2.15	2.26	2.31	2.35	2.21	2.34	0.22	0.5686
Giblets, %	5.17	5.26	5.17	5.12	5.32	5.18	0.29	0.8712
Abdominal fat, %	1.66	1.59	1.52	1.56	170	1.68	0.15	0.2563

[a,b]Means within rows followed by different superscripts are significantly different ($P < 0.05$). C (L0), L1, L2, L3, L4 and L5 = Birds fed graded levels of charcoal at 0, 0.5, 0.1, 1.5, 2.0, and 2.5 %, respectively.

microwave digestion system (Milestone Ethos Plus microwave system, Sorisole, Italy). Samples were analyzed by atomic absorption spectrometry (AAS, Thermo Scientific ICE 3000 unit, Cambridge, UK). Samples were also colorimetrically analyzed for phosphorus content using a Marcel Media Eko spectrometer (Marcel, Warsaw, Poland).

Determination of Essential Amino Acids Content The amino acid content in the meat samples was assessed according to the method of Ceylan and Aksu (2011).

Determination of Fatty Acids Content Fatty acid composition was determined according to the fatty acid methyl ester method (Satchithanandam et al., 2001). Nutritive value was determined according to Caneque et al. (2005) method. The cholesterol content of meat was determined by a 405 nm spectrophotometer in the residuals (AOAC, 1999).

Measurement of* Escherichia coli *and* Staphylococcus aureus *in Duck's Meat The carcasses parts of the left side (breast, thigh, and wing) after being removed and dissected, was prepared for the determination of *E. coli* and *S. aureus* in the meat tissues using the dilution plate method (Johnson and Curl, 1972).

The bacterial count was carried out after 96 hours postmortem for each part for each group. A total number of 45 samples (nine samples were taken from each group) were used. Aliquots (0.2 ml) were spread with a sterile glass rod over the surface of eosin methylene blue selective agar medium (EMB agar) (Product Code: LAB061) (Lab M Limited, Lancashire, UK) for the determination of the population of *E. coli* and mannitol salt selective agar medium (Product Code: LAB007) (Lab M Limited) for the determination of the population of *S. aureus*. Plates were dried in a laminar flow-cabinet for 20 min before incubation at 37°C in the dark for 3 days and colony counts were carried out. Six plates per dilution were made for each sample for each replicate.

Measurement of Thiobarbituric Acid Reactive Substances in Duck's Meat The thiobarbituric acid reactive substances (**TBARS**) value was measured according to Gómez et al. (2012) method. TBARS was expressed as μmol of malondialdehyde kg^{-1} meat. It was calculated using tetraethoxypropane malonic aldehyde as a standard.

Statistical Analysis

Data were subjected to statistical analysis using SAS software's General Linear Model Procedure (SAS Institute, version 9.2, 2009). Duncan (1955) was used to find variations in group mean values. The proportions of the investigated parameters were converted to Arcsine values.

For the analysis of variance, the following model was utilized:

$$Y_{ij} = \mu + S_i + e_{ij}$$

Where: Y_{ij} = an observation, μ = overall mean, S_i = treatment effect and e_{ij} = experimental error.

RESULTS AND DISCUSSION

Data of ducks' carcass and meat quality traits that received different levels of charcoal are listed in Tables 1 and 2. Results revealed that carcass conformation, fatness, breast circumference and irritation were not significantly affected ($P > 0.05$) by the variation of charcoal levels in ducks diet. Moreover, most carcass traits such as heart, liver, gizzard, giblets and abdominal fat percentages were not significantly affected by supplementing ducks' diet with different levels of charcoal (Tables 1 and 2).

On the other hand, ducks who received diets with 1.5 and 2 % charcoal showed a significant increase in dressed carcass % compared to control birds (Table 1). Results partially agreed with those obtained by Kana et al. (2011), who found that there was a significant ($P < 0.05$) decrease in gizzard weight for broilers supplemented with charcoal 0.2% but dressing percentage, abdominal fat and liver weight were not significantly ($P > 0.05$) affected by charcoal supplementation. Emadi

Table 2. Meat quality traits of Muller ducks as affected by dietary charcoal supplementation as a feed additive.

Traits	Charcoal levels					SEM	*P* value
	C 0.0%	L1 0.5%	L2 1.0%	L3 1.5%	L4 2.0%	L5 2.5%		
Meat quality (sensory traits)								
Color	8.53	8.60	8.60	8.73	8.48	8.56	0.71	0.2654
Flavor	7.90	7.92	8.52	8.50	7.96	8.42	0.92	0.5264
Tenderness	7.66[b]	7.95[ab]	8.58[a]	8.45[a]	8.56[a]	7.92[ab]	0.78	0.0342
Juiciness	7.60[b]	7.62[b]	7.96[ab]	8.54[a]	8.48[a]	8.04[ab]	0.69	0.0256
Susceptibility	7.92	8.02	8.42	8.56	8.37	8.24	0.48	0.5625
Physical traits								
Texture	8.25	8.14	7.82	7.58	7.61	8.00	0.75	0.4564
WHC	6.55[b]	6.58[b]	7.21[ab]	7.54[a]	7.49[a]	7.52[a]	0.45	0.0315
pH0	6.40	6.35	5.96	6.19	6.22	6.31	0.53	0.6154
pH24	5.62	5.70	5.58	5.32	5.41	5.60	0.49	0.2635

Abbreviations: WHC, water holding capacity; pH0, pH at zero time; pH24, pH after 24 hours.
[a,b]Means within rows followed by different superscripts are significantly different ($P < 0.05$). C (L0), L1, L2, L3, L4 and L5 = Birds fed graded levels of charcoal at 0, 0.5, 0.1, 1.5, 2.0, and 2.5%, respectively.

and Kermanshahi (2006) confirmed our results, and they reported non-significant effects of using turmeric rhizome powder on relative weights of broiler organs. Additionally, Abdel-Fattah et al. (2008) demonstrated that carcass yield and live weight of broilers were unaffected by dietary organic acids.

Our results also do not agree with those of Jiya et al. (2014) and Yunana et al. (2019), who recorded significant effects of charcoal inclusion in broiler diets on broiler organ weight and abdominal fat. The results of our study on organs weight and abdominal fat may be attributed to the lowest nutritional factors for charcoal as suggested by Yunana et al. (2019). The improvement of dressing percentages of ducks received diets supplemented with 1.5 and 2% charcoal in our study may be attributed to charcoal which is a prebiotic that enhances FCR and improves digestion and consequently improving growth and muscle formation (Kutlu et al., 2000; Majewska et al., 2011).

Sensory parameters due to the inclusion of different levels of charcoal in duck diets did not vary significantly compared to control diets for meat color, flavor and susceptibility (Table 2). However, ducks that received 1, 1.5, and 2% charcoal levels had significantly higher tenderness than those of the control group. Moreover, juiciness was higher ($P < 0.05$) in ducks fed with diets with 1.5 and 2% charcoal than in the control ducks (Table 2). Sensory analysis of poultry meat, including aroma, flavor, and texture mostly were affected by their diets (Escobedo Del Bosque et al., 2020).

The non-significant effect of charcoal on duck's meat color is a good factor because the color is one of the important parameters influencing consumer acceptability (Pathare and Roskilly, 2016). Concerning texture, pH0 (at zero time) and pH24 (after 24 hours); non-significant differences were recorded due to feeding different levels of charcoal in ducks' diets, but WHC significantly increased in the meat of ducks fed diets supplemented with 1.5, 2, and 2.5 % charcoal levels compared to control and ducks fed 0.5 % charcoal diet (Table 2).

The improvement of juiciness, tenderness and WHC of charcoal-included diets at certain levels may be attributed to its fiber content. Afzal and Zahid (2004), and Jiya et al. (2014) concluded that dietary fiber could affect some foods' functional properties as increasing oil holding capacity, WHC, gel formation and/or emulsification, modifying textural properties and improving shelf-life.

The chemical and mineral compositions of the meat of ducks fed diets supplemented with different levels of charcoal are presented in Table 3. The moisture, crude ether extract and crude ash percentages did not differ significantly ($P > 0.05$) between ducks fed charcoal, including diets and control ones (Table 3). While ducks received diets supplemented with 1.5, 2, and 2.5 %

Table 3. Meat mineral composition of Muller ducks as affected by dietary charcoal supplementation as a feed additive.

Traits	Charcoal levels					SEM	*P* value
	C 0.0%	L1 0.5%	L2 1.0%	L3 1.5%	L4 2.0%	L5 2.5%		
Chemical composition (%)								
Moisture	71.52	72.33	71.93	71.38	71.19	71.41	1.35	0.8564
Crude protein	21.19[b]	20.92[b]	22.84[ab]	23.59[a]	23.55[a]	23.46[a]	0.66	0.0262
Crude ether extract	3.04	2.78	2.82	2.71	3.02	2.91	0.81	0.8254
Crude ash	1.92	1.89	2.19	2.10	2.26	1.78	0.51	0.1652
Mineral composition (%)								
Calcium	10.71[b]	10.65[b]	11.49[ab]	12.33[a]	12.27[a]	11.53[ab]	1.18	0.0165
Phosphorus	49.92	49.53	51.32	49.78	50.15	50.11	3.02	0.8254
Sodium	59.26	59.42	61.06	60.52	60.90	61.00	3.12	0.6351
Iron	3.11	3.01	2.98	3.24	3.18	3.20	1.01	0.1652

[a,b]Means within rows followed by different superscripts are significantly different ($P < 0.05$). C (L0), L1, L2, L3, L4 and L5 = Birds fed graded levels of charcoal at 0, 0.5, 0.1, 1.5, 2.0, and 2.5%, respectively.

Table 4. Some essential amino acids content in Muller ducks' meat as affected by dietary charcoal supplementation as a feed additive.

	Charcoal levels							
Traits	C 0.0%	L1 0.5%	L2 1.0%	L3 1.5%	L4 2.0%	L5 2.5%	SEM	*P* value
Essential amino acids								
Histidine, (mg 100 g^{-1})	0.192	0.214	0.191	0.223	0.215	0.231	0.092	0.4261
Cystine, (mg 100 g^{-1})	0.295	0.311	0.325	0.295	0.319	0.400	0.085	0.8156
Threonine, (mg 100 g^{-1})	0.388	0.356	0.400	0.385	0.406	0.410	0.096	0.1523
Valine, (mg 100 g^{-1})	2.041	2.022	2.003	1.954	1.882	2.114	0.063	0.7821
Phenylalanine, (mg 100 g^{-1})	0.600	0.582	0.655	0.595	0.700	0.752	0.058	0.1526

C (L0), L1, L2, L3, L4 and L5 = Birds fed graded levels of charcoal at 0, 0.5, 0.1, 1.5, 2.0, and 2.5%, respectively.

charcoal levels had meat higher in the percentage of CP than control and those fed 0.5 % charcoal level (Table 3). These results from the present study, partially agreed with those obtained by Islam et al. (2014), who found that including different levels of charcoal in broiler diets does not affect broiler meat's chemical composition. Charcoal is an inert material, so it does not affect most of the meat composition parameters, but it catalyzes to improve the efficiency of feed utilization in poultry (Islam et al., 2014).

Moreover, charcoal had higher values of crude fiber, which led to an improved FCR that might lead to an increase in muscle formation, which may cause increased the percentage of CP in the muscle, as demonstrated in the current study. Mineral meat contents such as phosphorus, sodium and iron did not vary significantly between ducks fed different charcoal levels and control ones (Table 3). Still, it was obvious that ducks fed diets that included 1.5 and 2% charcoal had meat with higher calcium levels than control and ducks fed diets containing 0.5% charcoal. Due to charcoal diets, few reports are concerned with duck meat's mineral analysis. In our opinion, the non-significant difference in most mineral compositions indicates the safety effect of charcoal on electrolyte balance in ducks' blood and meat. Moreover, further investigations are needed to assess the mineral composition of duck meat and possible mechanisms of their detected concentrations.

Nutritional components of duck meat, such as essential amino and fatty acids, are listed in Tables 4 and 5. It was clear that non-significant variations were recorded for essential amino acids (histidine, cysteine, threonine, valine and phenylalanine) between charcoal supplemented ducks and the control group (Table 4). Concerning fatty acids, saturated fatty acids, unsaturated fatty acids **(UFA**) and cholesterol levels do not differ significantly in charcoal supplemented group and control ducks (Table 5). However, desirable fatty acids were increased ($P < 0.05$) in 2 and 2.5% charcoal included groups compared to control and 0.5 and 1 % charcoal-fed birds (Table 5).

Moreover, the nutritional value was increased ($P < 0.05$) in 1.5 and 2% charcoal included groups compared to the 0.5% charcoal group. These results partially agreed with those obtained by Islam et al. (2014) who found no variations in the total concentration of saturated fatty acids, UFA, and monounsaturated fatty acids between the treatments and between ducks fed diets containing various amounts of charcoal and the control group. Islam et al. (2014) also observed that adding 1% wood biochar to ducks' meals increased levels of omega-3 fatty acids.

Additionally, Islam et al. (2014) found that 1% biochar added to a daily diet might balance the ratio of omega-6 to omega-3 polyunsaturated fatty acids, lower low-density lipoprotein levels, and increase high-density lipoprotein levels ($P < 0.05$). The findings from the current study align with those of Kim et al. (2011) who reported that although there was no statistically significant differences between the two, chickens fed bamboo charcoal or bamboo leaves tended to have greater ratios of UFA.

Among the ducks fed charcoal-supplemented diets and the control group, there were no significant differences in

Table 5. Fatty acids content in Muller ducks' meat as affected by dietary charcoal supplementation as a feed additive.

	Charcoal levels							
Traits	C 0.0%	L1 0.5%	L2 1.0%	L3 1.5%	L4 2.0%	L5 2.5%	SEM	*P* value
Fatty acids (mg 100 g^{-1})								
Saturated fatty acids	33.65	34.08	32.42	31.11	32.36	32.92	2.65	0.1265
Unsaturated fatty acids	64.45	67.25	65.64	64.81	65.82	65.15	4.88	0.4251
Desirable fatty acid	73.66^{b}	74.00^{b}	73.72^{b}	76.51^{ab}	76.74^{a}	76.80^{a}	0.88	0.0123
Nutritive value	2.44^{ab}	2.25^{b}	2.49^{ab}	2.74^{a}	2.69^{a}	2.49^{ab}	0.40	0.0182
Cholesterol	63.56	64.15	62.25	62.02	62.31	64.02	2.06	0.8512

^{a,b}Means within rows followed by different superscripts are significantly different ($P < 0.05$). C (L0), L1, L2, L3, L4 and L5 = Birds fed graded levels of charcoal at 0, 0.5, 0.1, 1.5, 2.0, and 2.5%, respectively.

Table 6. The bacterial load in Muller ducks' meat as affected by dietary charcoal supplementation as a feed additive.

	Charcoal levels							
Traits	C 0.0%	L1 0.5%	L2 1.0%	L3 1.5%	L4 2.0%	L5 2.5%	SEM	*P* value
Escherichia coli (CFU/cm^2)	3.37	3.44	3.16	3.06	3.11	3.22	0.34	0.2261
Staphylococcus aureus (CFU/cm^2)	0.075	0.076	0.074	0.069	0.069	0.070	0.039	0.1025
TBARS (μmol kg^{-1})	2.54^{ab}	2.80^{a}	2.52^{ab}	2.20^{b}	2.19^{b}	2.18^{b}	0.09	0.0157

Abbreviation: TBARS, Thiobarbituric acid reactive substances.

^{a,b}Means within rows followed by different superscripts are significantly different ($P < 0.05$). C (L0), L1, L2, L3, L4 and L5 = Birds fed graded levels of charcoal at 0, 0.5, 0.1, 1.5, 2.0, and 2.5%, respectively.

the number of *E. coli* (CFU) and *S. aureus* (CFU) (Table 6). However, TBARS was likely to be reduced in birds fed charcoal at 1.5, 2 and 2.5%, with significant variation among treatments (Table 6). According to certain theories, charcoal particles' high surface area and small pores play a key role in bacterial adhesion to the particles during pathogen management (Naka et al., 2001).

Pathogens were discovered to be more thoroughly absorbed than natural gut microflora by Watarai and Tana (2005). Bond Brown Layer pullets (Rhode Island Red cockerel and Rhode Island White hen) had lower levels of harmful bacteria (*Campylobacter jejuni*) in their gut microbiome after consuming 4% wood-based biochar daily. Toxins in the digestive tract can be neutralized by adding biochar to broilers' meals, which can also help to activate and revitalize the intestinal flora (Gerlach and Schmidt, 2012).

CONCLUSIONS

On the vast majority of carcass parameters, charcoal has no negative impact. Inclusion of charcoal in duck diets at levels 1.5 and 2 % produces significant effects on dressing percentage, some sensory parameters and bacterial load. Further studies on the chemical and mineral meat composition and the mechanism of alteration in their values are recommended. Finally, charcoal as feed additives for ducks could be recommended.

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Ethical Approval: The present study was carried out at the research poultry farm of the Poultry Production Department, Faculty of Agriculture, Assiut University, Assiut. This work was carried out and approved by the Local Experimental Animal Care and Ethics Committee at the Poultry Production Department, Faculty of Agriculture, Assiut University, Egypt.

Data Availability Statement: The data that support the findings of this study are available from the author, Farghly, M.F.A., upon reasonable request.

DISCLOSURES

The authors declare no conflicts of interest.

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