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EFFECT OF DIFFERENT LEVELS OF CHARCOAL IN THE DIET ON THE PRODUCTIVE AND PHYSIOLOGICAL PERFORMANCE OF BROILERS

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Abstract

This study investigated the effect of including different amounts of charcoal in broiler diets on their growth performance, feed conversion ratio (FCR), carcass traits, intestinal microbiota, and blood biochemical traits. A total of 324 unsexed day-old Ross 308 broiler chicks weighing 41.6 g on average were randomly distributed into four groups comprising a control (T1) with a standard diet, and three treatment groups whose diets were supplemented with charcoal at 1.5% (T2), 3% (T3), and 4.5% (T4), respectively. The results showed that the T3 group had the highest average weekly weights and cumulative weight gain, significantly better growth rates and feed efficiency, and the best FCR rates compared to other treatments. Carcass analysis showed that adding charcoal resulted in higher breast and thigh meat percentages, improving fresh meat quality. Moreover, it notably favored an enteric epithelial microbiota by decreasing pathogenic Salmonella and *E. coli* while promoting beneficial *Lactobacillus*. This improvement was clearly seen in their enhanced health status as indicated by higher packed cell volumes, hemoglobin, and total protein levels in the blood. These results suggest that charcoal supplementation in broiler diets improves growth performance, feed efficiency, and health status, supporting its potential as a beneficial supplement for poultry diets.

Keywords: Charcoal, Broiler, Productivity, Physiological performance.

تأثير إضافة الفحم بمستويات مختلفة إلى العليقة في الأداء الإنتاجي والفسيولوجي لفروج اللحم

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الخلاصة

أُجريت هذه الدراسة في حقل الدواجن، قسم إنتاج الحيواني، كلية الزراعة، جامعة البصرة، لمدة 35 يومًا. تم تربية 324 فرخ من هجين Ross 308 غير مجنسة بعمر يوم واحد بمتوسط وزن بلغ 41.6 غرام .هدفت هذه الدراسة إلى معرفة تأثير إضافة مستويات مختلفة من الفحم النباتي إلى علائق فروج اللحم على أداء النمو، كفاءة تحويل العلف (FCR)، خصائص الذبيحة، العد المايكروبي للبكتريا في الأمعاء، وصفات الدم الخلوية والكيماحيوية. حيث تم تقسيم الافراخ إلى أربع معاملات: المعاملة الأولى T1 تحتوي على نظام غذائي قياسي، وثلاث معاملات أضيف إليها الفحم بنسبة 1.5، 3، 4.5% للمعاملات الثانية والثالثة والرابعة على التوالي. أظهرت النتائج أن المجموعة T3 حققت أعلى متوسط وزن الأسبوعي وأكبر زيادة في الوزن التراكمي، مما يعكس التحسن في معدلات النمو وكفاءة تحويل العلف مقارنة بالمعاملات الأخرى. لوحظت ان أفضل نسبة تحويل غذائي في المعاملة الثالثة T3، مما يشير إلى استفادة أفضل من العناصر الغذائية. كما أظهر نتائج التحليل الاحصائي ان إضافة الفحم أدى إلى زيادة الوزن النسبي لقطعيات الصدر والفخذ، مما يعزز الصفات النوعية للذبيحة. كما ساهمت إضافة الفحم بشكل ملحوظ في تحسين توازن بيئة الاحياء المجهرية في الأمعاء من خلال تقليل نسبة بكتيريا السالمونيلا والايشيريشيا القولونية الضارة، وتعزيز نمو بكتيريا *Lactobacillus* المفيدة. كان هذا التحسن واضحًا من خلال الحالة الصحية للقطيع، والتي تمثلت في زيادة حجم الخلايا المرصوصة (PCV)، ومستويات الهيموغلوبين، والبروتين الكلي في دم افراخ فروج اللحم المغذى على علائق مضاف اليها الفحم النباتي. ومن خلال هذه النتائج نؤكد إمكانيته إضافة الفحم كمكمل غذائي معزز للنمو.

كلمات مفتاحية: الفحم النباتي، فروج اللحم، الأداء الإنتاجي، الأداء الفسيولوجي.

Introduction

Broiler chicken production has become archetypical of efficient animal protein production characterised by rapid growth and high feed conversion nowadays, poultry industry is one of the most acknowledged significant global animal protein producers for human consumption (13), and global poultry production is expected to reach historically high level with 107 million tonnes by the year 2025 according to the most recent reports, which emphasizes the role of this sector in providing the required animal protein for the increased demand for food (13). Feed costs eat up a huge portion of the expenses (even 75% of the entire costs). The importance now is on the search for alternative feed sources that are sustainable and cheap (20). Therefore, the research has now inclined toward natural feed additives like enzymes and medicinal herbs because of their safety and potency suggesting no side effects with their use (31). Charcoal is considered one of the most promising alternatives because of its properties. Charcoal could decrease disease rates as. Salmonella which is one of the most serious and significant pathogens responsible for foodborne illnesses globally (42). And even serve to neutralise the toxins in the feed, thus improving the productive performance of chickens, as few recent studies have described. A study, for example, showed that the addition of activated charcoal to the diet improves growth performance via improved digestion, and boost the immunity when challenged by toxins such as deoxynivalenol (18). It also provides beneficial aid, like the impact on animal health. It could possibly promote and help in the development of the intestinal villi, resulting in longer intestinal length as well as improved efficiency of nutrient absorption (17). (32) Discovered that using wood/green waste biochar, bentonite, and zeolite may decrease poultry pathogen levels in laying chickens, preserving microbial diversity and potentially lessening antibiotic usage in the poultry industry. These materials could play a significant role in poultry health management. According to (16) incorporating biochar into broilers' diets did not change colonic pH, SCFA profiles, or bacterial populations within their intestines. The present study was designed to assess the productive performance, carcass quality, and intestinal histology of broiler chickens fed on different levels of charcoal in the diet. This work is a part of this study to develop sustainable nutritional strategies that yield cost-effective production while conserving consumer health.

Materials and Methods

This 35-day study was conducted from 1/11/2023 to 5/12/2023 at a poultry field of the Department of Animal Production, College of Agriculture, University of Basrah. A total of 324 unsexed day-old Ross 308 broiler chicks with an initial average weight of 41.6 g were used. The chicks were reared on litter, and feed was provided *ad libitum*. Their chambers were illuminated with 18 h light per day at 100 W lamps per square meter. Brooding was conducted in groups in the first week with the veterinary unit conducting a biosecurity prophylactic vaccination program in the field. At the end of the first week, the chicks were randomly assigned to one of four treatments each containing three replicates: T1 - control diet (no carbon); T2, T3, and T4 standard diets + 1.5%, 3%, and 4.5% carbon kg feed, respectively. The chicks were previously fed a starter diet which was substituted with a grower diet following the recommendations of (30).

The starter and finisher dietary crude protein percentage contents were 22.11% and 20.20% while the metabolisable energy values were 2910.10 and 2860.1 kcal/kg, respectively. The charcoal obtained from the local market was made from local eucalyptus trees, ground using an electric grinder and incorporated in the diet. Weekly growth parameters (weight gain, feed intake, and feed conversion efficiency) were recorded. At the end of the trial, live weight and carcass characteristics were determined, and an additional 54 birds (2M, 2F) were randomly selected within each treatment, replicated three times, and slaughtered for further analysis. For the haematological analysis, blood samples were collected in sterile tubes with EDTA, and the biochemical parameters were collected into different tubes. The carcasses were dressed, weighed, and eviscerated, and the different traits (dressed carcass weight, edible organ weights, and abdominal fat weight) were measured for dressing percentage.

The carcasses were subsequently sectioned by structure, i.e., primary (breasts and thighs) and secondary (backs, wings, and necks), and the weight of each type calculated in relation to the total weight of the carcass. During the fifth week, the factors of production index, as important economic indicators of the productivity of strains and hybrids were examined. The birds were slaughtered and eviscerated at 35 days of age for intestinal content analysis (1 of 6 birds selected from each treatment) for the microbial content analysis. Culture media (Salmonella agar, MacConkey agar and *Lactobacillus* agar) were made and 0.1 ml of 1/10 up to 1/10000 dilutions from the intestinal content was spread on the culture medium using a glass spreader aseptically. The plates were incubated at 37 °C for 48 hours and removed for counting of colonies (4). The data were subjected to statistical analysis through a complete randomized design (CRD), using the statistical software SAS (37). Duncan's new multiple range test (10) was used to compare the means, and differences between treatments were identified as significant at $P \leq 0.05$.

Table 1: Chemical composition of the starter feed for chicks based on the formulated dietary composition.

Components	Group charcoal content			
	T1 (0%)	**T2 (1.5%)**	**T3 (3.0%)**	**T4 (4.5%)**
Corn	50.00	50.00	40.00	42.60
Peanut Meal	3.50	3.00	3.00	18.00
Charcoal	0.00	1.50	3.00	4.50
Soybean Meal	30.00	30.00	28.20	12.00
Wheat Bran	6.00	5.00	4.00	10.00
Fish Powder (72%)	2.40	2.00	2.00	7.00
Vegetable Oil	1.90	0.80	0.80	3.00
Salt	0.00	0.00	1.00	1.00
***Premix**	2.00	2.00	2.00	1.00
Lysine	2.00	2.00	2.00	0.45
Methionine	2.20	2.20	2.20	0.45
Total	100	100	100	100
Total Protein (%)	22.48	22.92	22.51	22.50
Energy (kcal/kg)	2910.10	2836.12	2801.01	3043.33

Vitamin and mineral mix at a concentration of 0.1%, with vitamins forming 0.02% of the total. Choline is added at 0.05%, and the mix also includes a significant portion of salt and other minerals, totaling 0.3%. Specifically, it contains 300 mg magnesium (Mg), 55 mg manganese (Mn), 0.4 mg iodine (I), 56 mg iron (Fe), 30 mg zinc (Zn), and 4 mg copper (Cu). The vitamin mix is fortified with 8250 International Units (IU) vitamin A, 1200 IU vitamin D3, 1 mg vitamin K, and 40 IU vitamin E. Additionally, it provides 2 mg vitamin B1, 4 mg vitamin B2, 10 micrograms vitamin B12, 60 mg niacin, 10 mg pantothenic acid, and 500 mg choline.

Table 2: Chemical composition of final broiler feed based on the diet plan.

Components	Group charcoal content			
	T1 (0%)	T2 (1.5%)	T3 (3.0%)	T4 (4.5%)
Corn	58.40	55.40	53.40	40.00
Peanut Meal	25.40	25.90	26.40	23.00
Charcoal	0.00	3.00	1.50	4.50
Soybean Meal	0.00	1.50	2.00	10.00
Wheat Bran	2.50	2.50	3.50	10.00
Fish Powder (72%)	10.00	8.00	6.50	7.00
Vegetable Oil	3.00	3.00	3.00	3.00
Salt	0.25	0.25	1.25	1.00
Methionine	0.20	0.20	1.20	1.00
*Premix	0.25	0.25	1.25	0.50
Total	100	100	100	100
Total Protein (%)	21.38	21.33	21.30	21.20
Energy (kcal/kg)	2861.1	2850.02	2840.1	2833.01

Vitamin and mineral mix at a concentration of 0.1%, with vitamins forming 0.02% of the total. Choline is added at 0.05%, and the mix also includes a significant portion of salt and other minerals, totaling 0.3%. Specifically, it contains 300 mg magnesium (Mg), 55 mg manganese (Mn), 0.4 mg iodine (I), 56 mg iron (Fe), 30 mg zinc (Zn), and 4 mg copper (Cu). The vitamin mix is fortified with 8250 International Units (IU) vitamin A, 1200 IU vitamin D3, 1 mg vitamin K, and 40 IU vitamin E. Additionally, it provides 2 mg vitamin B1, 4 mg vitamin B2, 10 micrograms vitamin B12, 60 mg niacin, 10 mg pantothenic acid, and 500 mg choline.

Results and Discussion

During the experimental period, Table 3 shows the weekly weight gain of broiler chickens in the different groups with various levels of coal incorporated into the diet. We separately evaluated the treatments T1, T2, T3, and T4 for their impact on the average weekly weight of broilers. Data show a statistical difference at ($P < 0.05$). In the first week, treatment T3 had the highest weight (an average of 160.41 grams), followed by T2 with 150.44 grams, while T1 and T4 had lower weights (averages of 146.9 and 146.33 grams, respectively). Similarly, in the second week, T3 significantly outperformed T2 with an average weight of 464.47 g, while T1 and T4 had the lowest averages at 408.89 and 403.75 g, respectively. During the third week, the weights of T1 and T4 remained consistently the lowest at 917.63 and 917.47 grams, respectively. T3 outperformed the others with an average of 997.05 g, while T2 followed in second place with 949.44 g.

Regarding the weight gain (Table 3), the most significant weight gains occurred in week 4 and, on average, were 1597.38, 1524.53, 1485.97, and 1506.15 g for T3, T2, T1, and T4, respectively. The experiment's fifth week revealed that T3 had the heaviest package with an arithmetic average of 2092.24 g, T2 came in second with 1998.39 g, and T1 and T4 had the lightest packages with arithmetic averages of 1951.52 and 1990.15 g, respectively. Concentrates with a selected dose of coal (T3) had significantly the heaviest bodyweights of broiler chickens in relation to the other treatments. This means that there may be some fast-growing birds on Charcoal, likely because Charcoal increases the conversion of energy and subsequently improves the absorption efficiency of nutrients. Through its highly porous structure, adsorbs toxins and harmful microbes, thereby reducing their detrimental effects in the intestines. This process optimizes the gut environment, enhances digestion and nutrient absorption, and ultimately improves feed conversion rates in broiler (43).

The results of this experiment were in accordance with the available evidence that a dietary source of Charcoal could be favourable to gut wellness and reduce BA levels, which might result in increased growth and productive performance of the birds. These results confirm those established by (26), who have found that feeding 3% Charcoal to broilers caused an increment of 4% of its weight within a 6-week rearing period compared to the control batch. Also, researchers Edrington et al (1997) pointed out that feeding 0.5% of Charcoal to broilers caused an increase in weight of approximately 4.4% after 21 days of feeding on Charcoal compared to that of a control treatment. (21) investigated growth performance, intestinal morphology, and intestinal flora by adding bamboo vinegar and Charcoal powder to the feed.

The results indicated that supplementation significantly enhanced growth performance of loaches and also improved intestinal morphology and the gut microbial community. Studies have shown that adding bamboo vinegar and Charcoal powder to feed can promote intestinal development, improve the structure of the flora in intestines, and raise the survival and growth rates of loaches.

Table 3: Effect of different levels of coal in diet on average weekly weight of broiler chickens (mean ± SE).

Treatments	Week 1 (g)	Week 2 (g)	Week 3 (g)	Week 4 (g)	Week 5 (g)
T1	146.9 ± 2.70^{b}	408.89 ± 5.00^{c}	917.63 ± 2.41^{c}	1485.97 ± 1.44^{d}	1951.52 ± 2.40^{c}
T2	150.44 ± 2.28^{b}	432.64 ± 3.75^{b}	949.44 ± 2.37^{b}	1524.53 ± 2.17^{b}	1998.39 ± 5.70^{b}
T3	160.41 ± 3.31^{a}	464.47± 3.55^{a}	997.05 ± 4.19^{a}	1597.38 ± 6.29^{a}	2092.24 ± 2.42^{a}
T4	146.33 ± 1.46^{b}	403.75 ± 3.20^{c}	917.47 ± 2.45^{c}	1506.15 ± 2.39^{c}	1990.15 ± 3.70^{b}
P<0.05	*	*	*	*	*

Different letters (a, b, c) among treatments indicate significant differences at P<0.05. T1: Control group (standard diet without additives), T2, T3, and T4, addition of 1.5%, 3%, and 4.5% charcoal per kg of feed, respectively.

The results in Table 4 describe how the different proportions of Charcoal added to the broiler diet affect the relative weight gained by the birds during the experimental period. On the weight basis, the birds resumed with different weights in the first week; group T3 showed maximum gain in weight, followed by T2, T1, and T4. Significant weight gain of chicks under T3 treatment was evident compared to other treatments throughout the experiment period (P < 0.05) Weight increased constantly in the case of T2 treatment, but both T1 and T4 showed less increase. Extra weight, according to (11) is added due to increased rates of bird growth positively influenced by ingested Charcoal in the form of supplementary energy and nutrient provision. Results to the detoxifying effects of charcoal, thereby lowering the surface tension of the intestinal digest to support liver function with respect to fat digestion. More so, the adsorption properties of charcoal act curatively on the gastrointestinal tract (GIT), adsorbing gases such as hydrogen sulphide and ammonia that are formed there, including bacterial toxins and mycotoxins produced by fungi (41).

The improvement in the feed conversion efficiency in the supplemented groups especially in group T3 could be attributed to the ability of the birds fed Charcoal to maximally utilize the vitamin-mineral premix especially iron and B-complex vitamins in the diet probably due to the binding of Charcoal with toxins and anti-nutritional factors in the gut (39). This evidence shows an additive effect of Charcoal on feed utilisation, digestion, and absorption mechanisms, with an eventual outcome of weight gain. (27 and 40) Have said that the inclusion of 3 kg of Charcoal per tonne of feed increased performance in broilers with a 3.5% gain in body weight and a 2.0% betterment in the feed conversion ratio. Similar results were observed by (28) who found an increase in broiler weight upon the addition of 0.3% Charcoal. The live final weight of broilers had increased by 5.32% or 127 g and decreased by 0.50% or 11 g, mainly due to enhanced nutrient absorption by the gastrointestinal tract. In 2015, Fu et al showed that body weight in broilers indicated a remarkable increase while supplementing the Charcoal in the diets at levels of 1%, 5%, and 10%.

Table 4: Relative weight gain of broiler chickens from adding different levels of charcoal to their diet (mean ± SE).

Treatments	Week 1 (g)	Week 2 (g)	Week 3 (g)	Week 4 (g)	Week 5 (g)	Cumulative Increase (g)
T1	104.94 ± 2.70^{b}	261.95 ± 6.50^{c}	508.75 ± 5.79^{b}	568.34 ± 0.99^{c}	465.55 ± 0.99^{c}	1909.52 ± 2.42^{c}
T2	108.44 ± 2.28^{b}	282.19 ± 4.07^{b}	516.80 ± 2.04^{b}	575.08 ± 3.36^{c}	473.87± 3.66^{bc}	1956.39 ± 5.70^{b}
T3	118.41 ± 3.31^{a}	304.06 ± 5.12^{a}	532.58 ± 2.99^{a}	600.33± 2.18^{a}	501.86 ± 4.40^{a}	2057.24 ± 2.42^{a}
T4	104.33 ± 1.46^{b}	257.42 ± 4.67^{c}	513.72 ± 2.90^{b}	588.68 ± 0.24^{b}	483.99 ± 3.32^{b}	1948.15 ± 3.71^{b}
P<0.05	*	*	*	*	*	*

Different letters (a, b, c) among treatments indicate significant differences at P<0.05. T1: Control group (standard diet without additives), T2, T3, and T4, addition of 1.5%, 3%, and 4.5% charcoal per kg of feed, respectively.

Table 5 shows that adding different levels of Charcoal to diets significantly influenced FCR at all stages (P < 0.05). A statistical analysis of the tabulated data presented below shows that the second treatment recorded the highest FCR of 1.53 as compared to the control treatment, with the lowest FCR standing at 1.59. Indeed, this significant improvement in FCR following a period of adaptation to the Charcoal added to diet is known to be due to a reduction in metabolic rate and an increase in the volume of the digestive system, Activated charcoal works in broiler intestines through multiple mechanisms including physical and chemical adsorption, utilising its high surface area to absorb and filter harmful molecules.

It is characterized by its electrochemical effect through ion attraction and modification of ionic balance, which improves digestive enzyme activity and reduces harmful oxidative reactions, thereby contributing to improved digestive system health and nutritional efficiency. And may be contribute to modifying or stabilizing the pH level in the digestive tract, providing a suitable environment for digestive enzymes to function. This helps enhance the breakdown of proteins, fats, and carbohydrates more efficiently (5, 6, 7, 9, 32 and 33). The adsorption qualities of activated carbon from Charcoal are well-known for their ability to improve gut quality and absorb toxins and other toxic materials. It also enhances digestion and all metabolic processes.

Table 5: Feed conversion ratios at different charcoal levels in the diet (mean ± SE).

Treatments	First Week	Second Week	Third Week	Fourth Week	Fifth Week	Cumulative FCR
T1	1.05 ± 0.03[a]	1.37 ± 0.03[a]	1.28 ± 0.00[a]	1.59 ± 0.00[a]	2.19 ± 0.02[a]	1.59 ± 0.00[a]
T2	0.94 ± 0.04[b]	1.25 ± 0.01[b]	1.25 ± 0.01[b]	1.57 ± 0.00[a]	2.06 ± 0.00[b]	1.53 ± 0.00[c]
T3	0.87 ± 0.00[b]	1.16 ± 0.01[c]	1.21 ± 0.00[c]	1.47 ± 0.01[b]	1.98 ± 0.01[b]	1.45 ± 0.00[d]
T4	1.03 ± 0.02[a]	1.36 ± 0.04[a]	1.29 ± 0.00[a]	1.56 ± 0.00[a]	2.06 ± 1.97[b]	1.56 ± 0.00[b]
P<0.05	*	*	*	*	*	*

Different letters (a, b, c, d) among treatments indicate significant differences at P<0.05. T1: Control group (standard diet without additives), T2, T3, and T4, addition of 1.5%, 3%, and 4.5% charcoal per kg of feed, respectively.

The effect of adding various ratios of Charcoal inclusion with the diet is expressed in the results presented in Table 6 about feed intake rate (g) during the entire study period. Feed consumption within the first week: T1 treatment was found to consume the highest amount of feed with a mean value of 109.72 g; the consumption decreased towards T2 and T3 treatments, and T4 was at moderate performance, with a value of 107.41 g. During the second week of the trial period, these variables did not show any significant difference between them, and feed was consumed in the range of 349.72 g-357.91 g. In the third week, treatment T4 exhibited the highest average of 662.44 g, while treatments T2 and T3 gave lower averages of 647.50 g and 643.19 g, respectively. In the fourth week, treatments T1 and T4 led in feed consumption with an average of 903.97 g and 917.56 g, respectively, and the average was lowest for treatment T3 at 884.24 g. During the fifth week, it was observed that the T1 treatment consumed the highest feed, with an average of 1018.14 g, as compared with the T2 and T3 treatments, with an average of 977.85 g and 992.18 g, respectively.

Cumulative feed consumption, it was highest in the T1 treatment, having a mean of 3040.95 g, followed by the T4 treatment, having a mean of 3034.89 g, and lastly, the T2 and T3 treatments, with lower means of 2984.91 g, and 2974.63 g, respectively. The results show that Charcoal contributed significantly to feed consumption in most of the weeks, which was associated with the impact on digestion and nutrient absorption processes by the birds. These results confirm those obtained by (27), who attested that supplementation of the broilers' diets with 1%, 2%, 4 % and 6% Charcoal significantly caused an improvement in feed consumption and an overall body weight increase compared to the control group. Similarly, (22) found that up to 2% charcoal inclusions in broiler diets could result in similar improvements in feed consumption and weight gain.

On the other hand, the level of 3% helped in the digestion process and reduced the pressure on the feed, which ultimately led to improved feed conversion and a positive effect on the final weight (1). A study conducted by (24) indicated that there is no increase in feed intake and weight gain but somewhat decreases due to adverse effects of high doses of Charcoal on digestive health. It has been reported by (35) that when low levels of activated charcoal were added, the feed conversion efficiency of the fish was significantly improved with no considerable effect on feed intake, suggesting that the right concentration of Charcoal is crucial to attaining the desired benefits without side effects.

Table 6: Effect of different proportions of charcoal in diets on feed consumption rates (g) (mean ± SE).

Treatments	First Week (g)	Second Week (g)	Third Week (g)	Fourth Week (g)	Fifth Week (g)	Cumulative Feed Consumption (g)
T1	109.72 ± 2.18^{a}	357.91± 1.97	651.22± 7.13^{ab}	903.97± 3.13^{a}	1018.14± 9.44^{a}	3040.95± 16.16^{a}
T2	101.41± 2.27^{b}	354.02± 6.44	647.50 ± 5.04^{b}	904.13± 7.60^{a}	977.85± 6.26^{b}	2984.91± 17.41^{b}
T3	102.50± 3.02^{b}	352.52± 4.96	643.19 ± 1.57^{b}	884.24± 4.56^{b}	992.18 ± 3.09^{b}	2974.63± 7.99^{b}
T4	107.41 ± 1.86^{b}	349.72± 3.14	662.44 ± 1.67^{a}	917.56± 4.94^{a}	997.76± 10.47^{ab}	3034.89± 8.89^{a}
P<0.05	*	NS	*	*	*	*

Different letters (a, b) among treatments indicate significant differences at P<0.05. T1: Control group (standard diet without additives), T2, T3, and T4, addition of 1.5%, 3%, and 4.5% charcoal per kg of feed, respectively.

Table 7 presented the effect of supplementing varying levels of charcoal on overall mortality, vitality rate, and production index of broilers. There was no significant difference in percentage mortality between the overall treatments. All the treatments fell within 6.33% and 6.67%. These indicated that the inclusion of Charcoal did not significantly alter the death rate. On the other hand, when it came to the vigour rate, the rates were too close between treatments, with no significant differences, ranging from 93.33 to 96.67%. This affirms findings similar to those by (22), who also found that adding as much as 0.6% charcoal does not significantly affect mortality and vitality rates in broilers. Still, on the production index, treatment T3 presented the highest with 395.69, with a significant difference found at the $P \leq 0.05$ level, meaning an increment in Charcoal added to the broiler diet improved the production index compared to other treatments. T1 and T4 showed much lower values. One can interpret from the results that Charcoal may have contributed to improved digestion or nutrient adsorption, thus, better performance in treatment T3.

These are all based on the earlier hypothesis that Charcoal could be a supporting agent, and these results conform to the study of (19) indicating that the inclusion of 0.3% activated charcoal in the diet improved the feed conversion ratio and production index of broilers. There were no significant differences in the overall mortality and vitality rates among all the treatments. Still, they showed a remarkable difference in the production index for broilers at some level of addition. This means that the possibility of the Charcoal supplement being a performance enhancer in broiler diets is considerable

Table 7: Effect of different levels of charcoal in broiler diets on overall mortality and vitality rates, and production index (mean ± SE).

Treatments	Mortality Rate (%)	Vitality Rate (%)	Production Index
T1	6.67 ± 6.67	93.33 ± 6.67	326.92± 24.18[b]
T2	6.67 ± 3.33	93.33 ± 3.33	349.20 ± 11.46[b]
T3	6.33 ± 3.33	96.67 ± 3.33	395.69 ± 12.39[a]
T4	6.67 ± 3.33	93.33 ± 3.33	340.67 ± 12.08[b]
P<0.05	NS	NS	*

Different letters (a, b) among treatments indicate significant differences at P<0.05. T1: Control group (standard diet without additives), T2, T3, and T4, addition of 1.5%, 3%, and 4.5% charcoal per kg of feed, respectively. *NS indicates no significant differences between treatment means at P≤0.05.

The results shown in table 8 illustrate effect of adding different proportions of Charcoal to the diet on the cellular blood traits of broiler chickens. The results revealed that most of the studied cellular traits had significant differences between the treatments at a significance level of (P<0.05). Treatment T2 (1.5% Charcoal) showed a significant decrease in packed cell volume (PCV), haemoglobin level (HB), and red blood cell count (RBC) compared to all other treatments. By contrast, T4-treated 4.5% Charcoal significantly reduced the total white blood cell count (WBC) compared to all other treatments (18).

The percentage of lymphocytes was significantly higher in treatments T3 (3% Charcoal) and T4 compared to other treatments; treatment T4 recorded the lowest rate of heterophils (HETRO) and the highest rate of eosinophils (ESO) (3). This is probably due to Charcoal, which positively affects nutrient absorption and has a role in the minimisation of oxidative stress by the birds, contributing to improved health (23). This is because activated charcoal is capable of improving the quality of the intestine, amplifying the absorption of nutrients essential for the production of several types of blood cells. These might explain the higher values of HB, PCV, and RBC in some treatments. (38) Suggested that activated charcoal can absorb toxins while also enhancing nutrient absorption; and hence has several health benefits including improvement of gut and blood health. In addition, it means that the immune system is affected by the beneficial effect of charcoal on the gut environment and reduction of overall systemic inflammation. This may also clarify different WBC, LYMPH, and MONO values. Improving the intestinal environment enhances the distribution of lymphocytes and monocytes while reducing the activity of heterophils in cases of overall improved health.

Charcoal can boost immune responses by enhancing the distribution of immune cells and reducing inflammation (34). On the other hand, activated charcoal can help reduce oxidative stress by absorbing toxins and heavy metals (7 and 36). Charcoal treatments can explain the lower HETRO values by reducing oxidative stress on cells. Charcoal can mitigate oxidative stress through its absorptive properties. The use of activated charcoal in broiler diets may provide benefits to cellular blood traits by improving bowel conditions, improving nutrient utilisation, and reducing oxidative stress. Nonetheless, the combination of the right dosages and context can substantially optimise benefit and minimise negative effects (32).

Table 8: Effect of different levels of charcoal in diets on the cellular blood traits of broilers (mean± SE).

Values / Treatments	T1	T2	T3	T4	P<0.05
PCV	33.12 ± 0.96[a]	27.43 ± 0.16[b]	32.28 ± 0.31[a]	32.00 ± 0.34[a]	*
Hb	11.07 ± 0.96[a]	10.11 ± 0.22[b]	11.86 ± 0.33[a]	10.40 ± 0.44[b]	*
RBC	3.33 ± 0.84[a]	2.44 ± 0.21[b]	3.16 ± 0.32[ab]	3.51 ± 0.32[a]	*
WBC	19.01 ± 0.36[a]	18.60 ± 0.31[a]	18.88 ± 0.43[a]	17.52 ± 0.31[b]	NS
LYMPH	64.55 ± 0.45[b]	64.24 ± 0.11[b]	67.05 ± 0.35[a]	67.65 ± 0.32[a]	*
HETRO	30.53 ± 0.56[a]	29.02 ± 0.12[b]	28.43 ± 0.34[b]	26.66 ± 0.37[c]	*
MONO	3.76 ± 0.98[a]	3.66 ± 0.42[a]	2.43 ± 0.31[b]	3.23 ± 0.34[ab]	*
ESO	2.29 ± 0.78[b]	3.03 ± 0.42[a]	3.96 ± 0.32[a]	3.77 ± 0.37[a]	*

Different letters (a, b, c, d) among treatments indicate significant differences at P<0.05. T1: Control group (standard diet without additives), T2, T3, and T4, addition of 1.5%, 3%, and 4.5% charcoal per kg of feed, respectively. *NS indicates no significant differences between treatment means at P≤0.05. PCV: Packed Cell Volume, HB: Hemoglobin, RBC: Red Blood Cells, WBC: White Blood Cells, LYMPH: Lymphocytes, HETRO: Heterophils, MONO: Monocytes, ESO: Eosinophils.

Table 9 levels of glucose, cholesterol, total protein, globulin, and albumin in the blood of broilers after using different charcoal levels in the diet. Presentation of results Glucose Levels, overall, indicate an increase in glucose levels as a percentage of charcoal in the diet increased. The lowest glucose level was observed in T1 group (without charcoal which recorded 170.3 mg/100 ml), and the highest was observed in T4 group (4.5% charcoal which recorded 212.3 mg/100 ml). Results revealed that feeding with charcoal cellular digestion and absorption of carbohydrates, leading to a rise in the blood glucose level. Lipid profile: The highest cholesterol level, with 180.2 mg/100 ml was observed in control group (T1), and the lowest, with 123.3 mg/100 ml in T2 group. The addition of charcoal to the feed could lead to a reduction in this way with the better digestion and binding of fats in the small intestines. In combination with this the fats absorbed become less, it is possible.

Total Protein: There was a significant increase in the level of total protein in the group treated by added charcoal (T2, T3, and T4) compared to the control group as shown in detail in the table. The inclusion of charcoal aids in good gut health and the enhanced nutrient absorptions and feed efficiency. The treatment groups (T2, T3, and T4) showed higher globulin compared to the control. All this chalks up to a healthier immune response, a healthier gut, and a reduction of oxidative stress described earlier with charcoal.

The charcoal had no effect on albumin or made such little effect that it was not detectable, as all the charcoal-treated groups were almost similar to all boxes. The results obtained in the current table 9 revealed that charcoal has the potential to improve some biochemical traits of broiler chicken. These metabolic parameters need to be followed in future studies, but normalisation (Regularisation) of glucose concentration, and an increase in total protein and therefore globulin levels point to the hypothesis that this high amount of charcoal may enhance the digestion and absorption of essential nutrients and gut health.

The results have supported the notion that charcoal can be a beneficial dietary component to increase health levels and nutrient utilisation of broiler chickens. Despite these changes, albumin showed no significant differences between groups, with the data indicating that this indicator may be stabilizing. This could suggest that it has no negative impact on the blood levels of albumin, a fact that might corroborate the safety of its usage as an additive. It is concluded that the optimal level of charcoal to be added to the broiler chicken diet and its potential beneficial health effects should be further studied (18).

Table 9: Effect of different levels of charcoal in broiler diets on some biochemical traits (mean ± SE).

Treatments	Glucose (mg/100 ml)	Cholesterol (g/100 ml)	Total Protein (g/100 ml)	Globulin (g/100 ml)	Albumin (g/100 ml)
T1	170.31 ± 9.72^b	180.2 ± 5.91^a	5.18 ± 0.24^b	2.05 ± 0.16^b	3.13 ± 0.10
T2	202.62 ± 7.70^a	123.3 ± 3.58^b	6.87 ± 0.34^a	2.97 ± 0.19^a	3.89 ± 0.15
T3	190.21 ± 3.57^a	136.1 ± 6.74^b	6.62 ± 0.14^a	2.93 ± 0.18^a	3.69 ± 0.19
T4	212.31 ± 5.88^a	140.0 ± 7.79^b	6.63 ± 0.29^a	2.73 ± 0.16^a	3.90 ± 0.12
P<0.05	*	*	*	*	NS

Different letters (a, b, c, d) among treatments indicate significant differences at a P<0.05. T1: Control group (standard diet without additives), T2, T3, and T4, addition of 1.5%, 3%, and 4.5% charcoal per kg of feed, respectively. *NS indicates no significant differences between treatment means at P≤0.05.

The Effect of supplementing diet with charcoal at different levels on carcass Traits in broiler at 35 Days, the data presented in Table 10 showed that there was a significant effect on carcass traits when the birds were fed diets supplemented with charcoal as indicated above and slaughtered at 35 days. Live body weight in the 3% charcoal-supplemented T3 group was highest (2092.24 g) and it was statistically significant (P<0.05). This was reflected in the paper by (39). The presence of charcoal might improve digestion and nutrient absorption that leads to improved growth. On the other hand, although the T3 group showed a mild increase, the differences in chilled carcass weight among different treatments were found to be indistinguishable, which is similar to what has been observed with some improvement in gut health and nutrient absorption reported by (14), Several factors impact the cut-up yield of broiler, including the feeding regimen and additive (44), feed withdrawal practices (44), and various other conditions. However, in terms of dressing percentage.

The highest average was recorded when the animals were fed 1.5% charcoal (80.23%) and it was significantly ($P<0.05$) higher than those estimated for the other treatments. This increase was driven by improved feed conversion efficiency to meat. However, (27) Lend support to the damage caused by over-dosing, as further increases in charcoal up to 4.5% (T4) led to a decrease in dressing percentage (76.68%). Thus, it could be deduced that incorporating a low dose of charcoal (1.5% and 3%) into the diet of broiler chickens might improve live body weight and dressing percentage through its attributes enhancing digestion and nutrient absorption as shown in this study (25).

Nonetheless, it is extremely important that one avoids excessively high proportions as they can create unfavourable effects. (29) Found that adding charcoal at 1.5% and 2% increased the carcass yield and also improved the tenderness, freshness, and water-holding capacity of the meat. Moreover, adding charcoal made good changes in the chemical and nutritional composition of the meat. Compared to the base diet with no additives, charcoal supplementation at 1.5% and 3% significantly increased both breast and thigh percentages (table 11). Treatment T2 had the highest breast percentage 33.91 and treatment T3 had the highest thigh percentage 27.69.

Table 10: Effect of different levels of charcoal in diets on the carcass traits of the broilers at 35 days of age.

Treatments	Live Body Weight (g)	Chilled Carcass Weight (g)	Dressing Percentage (%)
T1	1951.52 ± 2.40^{d}	1882.11 ± 115.13	77.62 ± 0.12^{d}
T2	1998.39 ± 5.70^{b}	1893.63 ± 102.32	81.23 ± 0.158^{a}
T3	2092.24 ± 2.42^{a}	1994.87 ± 116.46	78.12 ± 1.26^{b}
T4	1966.12 ± 2.54^{c}	1896.87 ± 116.53	76.68 ± 0.16^{c}
P<0.05	*	NS	*

Different letters (a, b, c, d) among treatments indicate significant differences at $P<0.05$. T1: Control group (standard diet without additives), T2, T3, and T4, addition of 1.5%, 3%, and 4.5% charcoal per kg of feed, respectively. *NS indicates no significant differences between treatment means at $P\leq0.05$.

Compared to the base diet with no additives, charcoal supplementation at 1.5% and 3% significantly increased both breast and thigh percentages (Table 11), with treatment T2 registering the highest breast percentage (33.91%) and T3 the highest thigh percentage (27.69%). No other treatment in this study resulted in significant differences in the rate of back and wings.

Table 11: Effect of different levels of charcoal in diets on percentage of carcass cuts (mean ± SE).

Treatments	Breast (%)	Thigh (%)	Back (%)	Wings (%)
T1	27.84±0.54^{d}	23.12±0.21^{c}	18.27±0.40	10.65±0.64
T2	33.91±0.98^{a}	25.86±0.32^{b}	17.90±0.32	11.41±0.23
T3	32.72±1.32^{b}	27.69±0.54^{a}	18.03±0.52	10.73±0.31
T4	30.45±1.77^{c}	24.44±0.41^{c}	18.29±0.44	10.66±0.25
P<0.05	*	*	NS	NS

Different letters (a, b, c, d) among treatments indicate significant differences at $P<0.05$. T1: Control group (standard diet without additives), T2, T3, and T4, addition of 1.5%, 3%, and 4.5% charcoal per kg of feed, respectively. *NS indicates no significant differences between treatment means at $P\leq0.05$.

The study showed that adding different ratios of charcoal to the diet significantly affects the intestinal microbiota of poultry. A decrease in the numbers of harmful bacteria such as Salmonella and *Escherichia coli*, and an increase in the numbers of beneficial bacteria such as *Lactobacillus*, were observed. The control treatment (T1) recorded the highest numbers of Salmonella 4.66 and Escherichia coli 3.19 and the lowest percentage of *Lactobacillus* 1.09. Meanwhile, the other treatments (T2, T3 and T4), which included the addition of charcoal at different ratios (1.5%, 3%, and 4.5%, respectively), showed a significant decrease in the numbers of *Salmonella* and Escherichia coli and a significant increase in the numbers of *Lactobacillus*.

These findings are consistent with the idea that supplementing the diet with charcoal improves beneficial gut bacteria and, in doing so, may be more protective while reducing harmful bacteria. This is in agreement with the findings of (2), which showed that the addition of a compound extracted from charcoal and herbs (CHC) had a positive effect on the growth performance and carcass weight of broiler chickens. This indicates that using charcoal as a feed additive can have multiple benefits for poultry health and production performance (12 and 15). Al so (29) found that adding charcoal at 1.5% and 2% reduced harmful substances such as substances that interact with thiobarbituric acid, all without affecting the number of harmful bacteria.

Table 12: Effect of different levels of charcoal in diets on intestinal microbiota content (mean ± SE).

Treatments	Intestinal Bacteria Count (10^4 bacterial cells/gram)		
	Salmonella	***E. coli***	***Lactobacillus***
T1	4.66 ± 0.16^{a}	3.19 ± 2.81^{a}	1.09 ± 1.05^{c}
T2	3.01 ± 1.05^{c}	1.93 ± 1.06^{c}	2.31 ± 0.27^{b}
T3	3.63 ± 0.17^{b}	2.44 ± 1.08^{b}	2.79 ± 1.75^{a}
T4	2.16 ± 0.02^{d}	2.00 ± 0.21^{b}	1.58 ± 0.32^{ab}
P<0.05	*	*	*

Different letters (a, b, c, d) among treatments indicate significant differences at P<0.05. T1: Control group (standard diet without additives), T2, T3, and T4, addition of 1.5%, 3%, and 4.5% charcoal per kg of feed, respectively. *NS indicates no significant differences between treatment means at P≤0.05.

Conclusions

Based on this study, adding different ratios of charcoal to poultry feed will not adversely affect the growth performance or blood health of broiler chickens. Charcoal supplements also improved productive performance, such as final weight, weekly weight gain, feed conversion efficiency, and feed consumption. It also decreased production costs and enhanced carcass traits. Moreover, charcoal alleviated harmful bacteria and microorganisms while improving cellular and immune blood indicators. In summary, charcoal supplementation in diets can effectively enhance carcass traits and production performance and offer considerable economic benefits to the broiler chicken industry.

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The authors declare no conflict of interest.

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