# EFFECTS OF DIETARY CINNAMON POWDER SUPPLEMENTS ON THE GROWTH PERFORMANCE, MEAT YIELD, AND PHYSIOLOGICAL AND BIOCHEMICAL BLOOD PARAMETERS OF BROILERS

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## ABSTRACT

The study was conducted on hybrid male chickens $F_1$(♂Dong Tao x ♀Luong Phuong) from 7 to 13 weeks of age to evaluate the effects of cinnamon powder supplementation on the growth performance of broilers and the biochemical and physiological parameters of chicken blood. A total of 90 chickens were randomly divided into three groups of 30 chickens per group. From 7 weeks of age, chickens of group 1 (control group) had no supplemental cinnamon powder, group 2 (CT1) had 2.0 grams of supplemental cinnamon powder/kg feed, and group 3 (CT2) had 2.5 grams of supplemental cinnamon powder/kg feed. The growth performance and meat yield of the two groups eating diets supplemented with cinnamon powder were greater than the control group ($p<0.01$). The total cholesterol and low density lipoprotein cholesterol (LDL-cholesterol) in the two treatment groups (CT1 and CT2) were lower than those in the control group ($P <0.05$), while the high density lipoprotein cholesterol (HDL-cholesterol) values of the CT1 and CT2 groups were higher than that in the control group ($P <0.05$). The aspartate aminotransferase (AST) and alanine transaminase (ALT) values in the two treatment groups (CT1 and CT2) were lower than those in the control group ($P <0.05$). The leukocyte, lymphocyte, and monocyte levels in the chicken blood in the CT1 and CT2 groups were lower than those in the control group ($P <0.05$). Chickens receiving the CT1 diet had a lower cost of production per 1 kg of chicken as compared to the control and CT2 groups.

Keywords: Blood physiology, blood biochemistry, chicken.

## Ảnh hưởng của việc bổ sung bột quế trong khẩu phần ăn đến khả năng sinh trưởng, năng suất thịt và các chỉ tiêu sinh lý, sinh hoá máu gà thịt

## TÓM TẮT

Nghiên cứu này được thực hiện trên gà trống lai F1(♂Đông Tảo x ♀Lương Phượng) từ 7 đến 13 tuần tuổi nhằm đánh giá ảnh hưởng của bổ sung bột quế đến khả năng sinh trưởng và một số chỉ tiêu sinh hoá, sinh lý máu gà. Tổng số 90 con gà được chia ngẫu nhiên vào 3 lô, mỗi lô 30 con. Từ 7 tuần tuổi gà được nuôi bằng các khẩu phần ăn thí nghiệm gồm: lô đối chứng không bổ sung bột quế, lô 2 (CT1) bổ sung 2 gam bột quế/kg thức ăn và lô 3 (CT2) bổ sung 2,5 gam bột quế/kg thức ăn. Khả năng sinh trưởng, năng suất thịt của gà ở 2 lô bổ sung bột quế cao hơn so với lô đối chứng ($P <0,01$). Chỉ tiêu cholesterol toàn phần, LDL-cholesterol ở lô CT1 và lô CT2 thấp hơn so với lô đối chứng ($P <0,05$), trong khi HDL-cholesterol của lô CT1 và lô CT2 cao hơn so với lô đối chứng ($P <0,05$). Chỉ tiêu AST và ALT ở lô CT1 và lô CT2 thấp hơn so với lô đối chứng ($P <0,05$). Tế bào lympho và bạch cầu trong máu gà ở lô CT1 và lô CT2 thấp hơn so với lô đối chứng ($P <0,05$). Gà được nuôi bằng khẩu phần ăn của lô CT1 có chi phí để sản xuất 1kg gà thấp hơn so với lô đối chứng và lô CT2.

Từ khóa: Sinh lý máu, sinh hóa máu, gà.

## 1. INTRODUCTION

Vietnam is situated in Southeast Asia and has a tropical monsoon climate, so the risk of disease outbreaks in livestock is high. According to Nguyen Mau Dung *et al.* (2020), chicken farming in Vietnam often suffers from significant diseases such as avian influenza, Newcastle, Gumboro, coccidiosis, and respiratory diseases. According to Coyne *et al.* (2019), Vietnamese chicken farmers often use antibiotics to prevent and control diseases in chickens to reduce mortality and improve breeding efficiency. For chicken production in the Red River Delta, 29.5% of laying chicken farms were reported to use antibiotics periodically to prevent diseases, and for broiler farms, 16.2% of the farms used them to improve growth performance, 13.3% used them for disease prevention, and 9.5% used them to treat diseases (Kim *et al.*, 2013). Uncontrolled usage of antibiotics can lead to antibiotic resistance and antibiotic residues in livestock products. According to Lan *et al.* (2016), *Ornithobacterium rhinotracheale (*ORT), which causes asthma dyspnea in chickens, was resistant to eight out of 14 antibiotics tested, namely erythromycin (100% of samples), gentamycin (100% of samples), enrofloxacin (100% of samples), norfloxacin (100% of samples), kanamycin (93.33% of samples), tylosin (83.33% of samples), colistin (96.67% of samples), and lincomysin (70% of samples).

Using herbal products to replace synthetic antibiotics is a new approach in livestock production in Vietnam. According to Neeta *et al.* (2011), alkaloids, flavonoids, saponins, and tannins in herbs can have antibacterial functions. According to Al-Kassie (2009), the supplementation of cinnamon in the diet improved the growth performance and feed conversation rate of chickens.

The goal of this study was to evaluate the effects of different levels of cinnamon powder supplementation in broiler chicken diets on their growth performance, meat yield, and the physiological and biochemical parameters of their blood.

## 2. MATERIALS AND METHODS

The experiment was carried on hybrid male chickens $F_1$ (♂Dong Tao x ♀Luong Phuong) from June 2020 to April 2021 in Hai Duong province. From 1 day to 6 weeks of age, the chicks were fed commercial compound feed. At 6 weeks of age, 90 healthy broilers were selected based on their initial weight, and each individual's wings were marked with a number before being randomly divided into three lots with 30 birds per lot. From 7 to 13 weeks of age, the lots used the same basal dietary (Table 1) supplemented with cinnamon powder at different levels. The basic, self-mixed dietary powder can be referenced according to TCVN: 2265-2020 on animal feed-compound feed for chickens. The diet lots were as follows: lot 1 had no supplemental cinnamon powder (control group), lot 2 had 2.0 grams of supplemental cinnamon powder/1 kilogram of complete feed (CT1), and lot 3 had 2.5 grams of supplemental cinnamon powder/1 kilogram of complete feed (CT2). All the experimental broilers were raised in the same housing system with the floor of the housing covered with rice husks and the birds had access to garden enhancements. Feed and water were offered ad libitum, and the birds could go to the garden freely. The housing was illuminated 24 hours a day. The density was 8 chickens/$m^2$ in the housing and 1 head/$m^2$ in the playground. All the birds were cared for utilizing the procedures outlined in the framework of the VietGAHP standards (Ministry of Agriculture and Rural Development, 2017) to support normal growth and prevent diseases.

The diet was analyzed at the Central Laboratory of the Faculty of Animal Science, Vietnam National University of Agriculture, and the nutrient composition was as follows: dry matter (DM) was analyzed according to the instructions of TCVN 4326:2001, crude protein (CP) was analyzed according to the instructions of TCVN 4328: 2007, calcium (Ca) was analyzed according to the instructions of TCVN 1526: 2007, phosphorus (P) was analyzed according to the instructions of TCVN 1525:2001, lipids were analyzed according to the instructions of TCVN 4331:2001, and crude fibers (CF) were analyzed according to the instructions of TCVN 4329:2007.

**Table 1. Ingredient and chemical composition of the basal diet for of the broiler chickens from 7 to 13 weeks of age**

| Feed ingredients | Percentage |
|---|---|
| Yellow corn | 55.00 |
| Soybean meal | 25.00 |
| Wheat bran | 5.00 |
| Rice bran | 9.20 |
| Limestone powder | 2.00 |
| Dicalcium phosphate | 1.00 |
| Mineral premix | 1.00 |
| DL-Methionine 98% | 0.50 |
| Salt powder (NaCl) | 0.30 |
| L-Lysine HCl 70% | 0.50 |
| L-Threonine 98% | 0.50 |
| Calculated composition | Percentage |
| Dry matter | 87.94 |
| Crude protein | 16.01 |
| Lipids | 4.77 |
| Crude fiber | 3.49 |
| Calcium | 1.17 |
| Phosphorus | 0.76 |

### 2.1. Evaluation of the growth performance and cost of raising broilers

Broilers were individually weighed each week in the morning before feeding on a mechanical balance (clock scale) with an accuracy of ± 30 grams. Live body weights of the experimental flocks were recorded for calculating the average daily gain. The amount of feed consumed and the number of broilers were recorded daily for each lot.

The feed conversion ratio (FCR) was calculated by the proportion of the total feed consumption and total weight gain of that lot.

Total costs included the costs for the rearing chickens period from 1 day to 6 weeks of age and costs for the period from 7 to 13 weeks of age, including feed, veterinary support, housing's bed litter, lighting and water pumping, housing depreciation costs, and labor costs (work for taking care of the chickens and feed preparation).

### 2.2. Assessing chicken meat performance

At 13 weeks of age, six individual birds were randomly selected from each lot to assess meat performance. The meat performance criteria were live weight (g), carcass weight (g), carcass percentage (%), breast meat weight (gram), breast meat percentage (%), thighs meat weight (g), and the percentage of thigh meat (%), and were completed according to the guidance of Bui Huu Doan *et al.* (2011). The percentage weights of the heart, liver, gizzard, and spleen (%) of the broilers were also measured.

### 2.3. Evaluating the physiological and biochemical characteristics of the chickens' blood

At 13 weeks of age, three individual birds were randomly selected from each lot to evaluate the physiological and biochemical characteristics of the chickens' blood. Two milliliters of blood was taken from each broiler's wing vein and then stored in a test tube containing anticoagulant

solution (EDTA-Ethylene-Diamine Tetra-Acetic acid) for analysis of protein, total cholesterol, HDL-cholesterol, LDL-cholesterol, AST and ALT, red blood cells, white blood cells, hemoglobin, MCV, MCHC, DRW, lymphocytes, and monocytes, which were determined by using an automated analyzer Technicon RA 1000 (Technicon Instruments Corporation), Tarrytown, New York, USA at the Veterinary Teaching Hospital, Vietnam National University of Agriculture.

### 2.4. Statistical analysis

The data were analyzed using SAS 9.1 software. The mean differences of the body weight, ADG (average daily gain), and meat yield criteria among the different lots were analyzed by one-way ANOVA statistical analysis, testing the mean differences among the lots by Ducan's multiple range test with the significance level of $P < 0.05$. The statistical parameters included mean (Mean) and standard error of mean (SE).

## 3. RESULTS AND DISCUSSION

The growth performance of broiler chickens is presented in Table 2. No birds died during the trial. The chickens' weights at the beginning of the experiment were not different among treatments. From 8 weeks of age to the end of the trial, the growth performances of the two lots supplemented with cinnamon powder (CT1 and CT2) were higher than that of the control group ($P < 0.05$). However, growth performance was not different between the two cinnamon powder treatments ($P > 0.05$). The results of this study are similar to results of Lee *et al.* (2004), Toghyani *et al.* (2011), and Vidanagamage *et al.* (2016) who reported that cinnamon supplementation in commercial broilers' diets improved their growth performance and reduced the stress of the broilers. According to Windisch *et al.* (2008), substances such as alkaloids, phenolic compounds, polyphenolic compounds, terpenoids, saponins, and flavonoids in herbs have anti-oxidant and antibacterial properties, enhance palatability, regulate intestinal function, and stimulate the growth of broilers.

The average daily gains of the broilers in the different dietary treatments over the weeks of the experiment are presented in Table 3. The average daily gains (ADG) of the broilers in the CT1 and CT2 lots were higher than the broilers in the control group at 8 to 12 weeks of age. This parameter gradually increased until the birds were 10 weeks of age, and then tended to decrease gradually from 11 weeks of age until selling age (13 weeks of age). These results are similar to those of Nguyen Van Duy *et al.* (2020) who demonstrated that crossbred chickens (3/4 DT × 1/4 LP) fed complete industry-standard diets had ADG values that increased gradually from 1 to 11 weeks of age and then decreased.

**Table 2. Effects of cinnamon supplementation on the body weights (g) of broiler chickens from 6 to 13 weeks of age**

| Week of age | Dietary treatments (n=30) | | | P |
|---|---|---|---|---|
| | Control group | CT1 | CT2 | |
| 6 | 951.66 ± 11.02 | 950.00 ± 18.95 | 951.67 ± 16.36 | 0.97 |
| 7 | 1,178.00 ± 14.15 | 1,177.33 ± 18.24 | 1,179.33 ± 15.04 | 0.97 |
| 8 | $1,408.00^{b}$ ± 14.15 | $1,431.00^{a}$ ± 16.42 | $1,439.33^{a}$ ± 15.27 | 0.0002 |
| 9 | $1,668.67^{b}$ ± 15.52 | $1,703.00^{a}$ ± 16.57 | $1,714.67^{a}$ ± 16.22 | <0.0001 |
| 10 | $1,932.67^{b}$ ± 14.22 | $1,972.33^{a}$ ± 14.54 | $1,993.33^{a}$ ± 17.01 | <0.0001 |
| 11 | $2,182.00^{b}$ ± 16.12 | $2,246.90^{a}$ ± 14.73 | $2,260.67^{a}$ ± 15.61 | <0.0001 |
| 12 | $2,411.33^{b}$ ± 16.60 | $2,495.86^{a}$ ± 16.81 | $2,510.00^{a}$ ± 17.14 | <0.0001 |
| 13 | $2,633.67^{b}$ ± 17.74 | $2,726.55^{a}$ ± 15.77 | $2,741.67^{a}$ ± 15.83 | <0.0001 |

*Note: $^{a, b}$: Means in the same row without a common letter are significantly different at $P < 0.05$.*

**Table 3. Effects of cinnamon supplementation on the average daily gains (g) of broiler chickens at different ages**

| Week of age | Dietary treatments (n = 30) | | | P |
|---|---|---|---|---|
| | Control group | CT1 | CT2 | |
| 6-7 | 32.33 ± 0.56 | 32.47 ± 0.47 | 32.52 ± 0.47 | 0.96 |
| 7-8 | 32.85$^{b}$ ± 0.30 | 36.23$^{a}$ ± 0.81 | 37.14$^{a}$ ± 0.64 | < 0.0001 |
| 8-9 | 37.23$^{b}$ ± 0.41 | 38.85$^{a}$ ± 0.46 | 39.33$^{a}$ ± 0.67 | 0.01 |
| 9-10 | 37.71$^{b}$ ± 0.47 | 39.90$^{a}$ ± 0.67 | 39.81$^{a}$ ± 0.59 | 0.01 |
| 10-11 | 35.61$^{b}$ ± 0.52 | 37.88$^{a}$ ± 0.59 | 38.19$^{a}$ ± 0.55 | 0.002 |
| 11-12 | 32.76$^{b}$ ± 0.35 | 35.56$^{a}$ ± 0.67 | 35.62$^{a}$ ± 0.50 | 0.0002 |
| 12-13 | 31.76 ± 0.41 | 32.95 ± 0.56 | 33.09 ± 0.72 | 0.21 |

*Note: $^{a, b:}$ Means in the same row without a common letter are significantly different at P <0.05.*

**Table 4. Effects of cinnamon supplementation on the feed consumption (g/bird/day) and feed conversation rates (g) of broiler chickens at different ages**

| Week of age | Dietary treatments | | | | | |
|---|---|---|---|---|---|---|
| | Control group | | CT1 | | CT2 | |
| | Daily feed intake | FCR | Daily feed intake | FCR | Daily feed intake | FCR |
| 6-7 | 86.67 | 2.68 | 86.43 | 2.66 | 86.86 | 2.67 |
| 7-8 | 96.90 | 2.95 | 87.62 | 2.42 | 103.57 | 2.79 |
| 8-9 | 113.10 | 3.04 | 110.71 | 2.85 | 121.43 | 3.09 |
| 9-10 | 121.67 | 3.23 | 124.76 | 3.13 | 127.86 | 3.21 |
| 10-11 | 128.33 | 3.60 | 126.19 | 3.33 | 122.86 | 3.22 |
| 11-12 | 139.29 | 4,25 | 131.90 | 3.71 | 139.05 | 3.90 |
| 12-13 | 145.00 | 4,57 | 145.00 | 4.40 | 142.14 | 4.30 |
| 7-13 | 118.71 | 3.46 | 116.09 | 3.20 | 120.54 | 3.30 |

The amount of feed consumption and the feed conversion rate of broilers over the weeks of the experiment are presented in Table 4. The feed intake was the greatest in the CT2 lot (2.5 g cinnamon/kilogram of the feed), followed by the control diet and then the CT1 treatment (1.0 g of cinnamon/kilogram of the feed). The feed conversion ratio (FCR) was the best in the CT1 lot (3.21), followed by the CT2 lot (3.31) and then the control lot (3.47). Thus, adding supplemental cinnamon powder to the diets improved the FCR of the broilers. Our research results were similar to those of Lee *et al.* (2004) who reported that cinnamon contains cinnamaldehyde and eugenol substances that stimulate digestion and improve the feed efficiency of chickens. However, Shirzadegan (2014) reported that cinnamon supplements in the diet improved the growth performance of chickens but did not improve the FCR. According to Koochaksaraie *et al.* (2011), adding cinnamon powder to the diet reduced blood sugar in chickens while increasing their appetite. Cinnamon contains cinnamaldehyde, which stimulates appetite and stimulates digestion in chickens (Tabak *et al.*, 1999).

According to Cabuk *et al.* (2003), cinnamon also contains carvacrol, which is a phenol monoterpenoid that stimulates digestion and improves FCR in growing broilers. Similar results were obtained by Jamroz *et al.* (2003) and Al-Kassie (2009) who reported that dietary cinnamon supplementation improved the feed efficiency and growth performance of broilers.

**Table 5. Effects of cinnamon supplementation on meat yield and the inner organs of broiler chickens at 13 weeks of age**

| Criteria | Unit | Dietary treatments (n = 6) | | | P |
|---|---|---|---|---|---|
| | | Control group | CT1 | CT2 | |
| Body weight | gram | 2,650.00$^{b}$ ± 15.43 | 2,730.00$^{a}$ ± 4.87 | 2,715.00$^{a}$ ± 9.12 | 0.0001 |
| Carcass weight | gram | 1,919.52$^{b}$ ± 6.13 | 2,018.21$^{a}$ ± 9.68 | 1,971.63$^{a}$ ± 19.71 | 0.001 |
| Carcass percentage | % | 72.43 ± 0.25 | 73.92 ± 0.23 | 72.62 ± 0.74 | 0.07 |
| Breast meat weight | gram | 338.40$^{b}$ ± 8.69 | 370.47$^{a}$ ± 4.61 | 365.70$^{a}$ ± 4.05 | 0.003 |
| Breast meat ratio | % | 17.63 ± 0.48 | 18.35 ± 0.14 | 1 8.55 ± 0.25 | 0.14 |
| Thigh meat weight | gram | 540.57$^{b}$ ± 1.70 | 584.18$^{a}$ ± 5.12 | 566.78$^{a}$ ± 6.95 | < 0.0001 |
| Thigh meat ratio | % | 28.17 ± 0.23 | 28.94 ± 0.25 | 28.74 ± 0.26 | 0.10 |
| Heart | % | 0.81 ± 0.02 | 0.78 ± 0.01 | 0.80 ± 0.01 | 0.67 |
| Liver | % | 2.70$^{a}$ ± 0.07 | 2.59$^{ab}$ ± 0.05 | 2.4$^{b}$ ± 0.06 | 0.01 |
| Gizzard | % | 2.15$^{b}$ ± 0.06 | 2.24$^{b}$ ± 0.03 | 2.53$^{a}$ ± 0.08 | 0.001 |
| Spleen | % | 0.37 ± 0.04 | 0.31 ± 0.01 | 0.28 ± 0.03 | 0.10 |

*Note: $^{a, b}$: Means in the same row without a common letter are significantly different at P <0.05.*

**Table 6. Effects of cinnamon supplementation on broiler production costs**

| Criteria | Unit | Dietary treatments | | |
|---|---|---|---|---|
| Cost of raising broilers from 1 day to 42 days | VND/head | | 32,122 | |
| Cost from 43 to 91 days | | Control group | CT1 | CT2 |
| Total feed consumption | kg/head | 5.82 | 5.68 | 5.90 |
| Feed price | VND/kg | 8,638 | 8,726 | 9,448 |
| Cost of feed | VND/head | 50,244.40 | 49,636.37 | 55,803.01 |
| Cost of veterinary | VND/head | 8,000 | 8,000 | 8,000 |
| Cost for rice husk (bed litter) | VND/head | 3,000 | 3,000 | 3,000 |
| Cost of electronic | VND/head | 5,000 | 5,000 | 5,000 |
| Housing depreciation | VND/head | 457 | 457 | 457 |
| Labor cost | VND/head | 5,208 | 5,208 | 5,208 |
| Total cost | VND/head | 104,031.51 | 103,423.48 | 109,590.12 |
| Cost to produce 1 kg of live body weight | VND | 39,500.59 | 37,855.35 | 39,947.84 |

The weights of the body, carcass, breast meat, and thigh meat from the two lots whose feed was supplemented with cinnamon powder (CT1 and CT2) were higher than those of the control lot (P <0.05). However, there were no differences in these parameters between the CT1 and CT2 lots. There were also no differences in organ weights except for the liver and gizzards. The liver ratio of the control group was higher than that of CT2, and there was no difference in this parameter between the CT2 and CT1 lots. The gizzard ratio of the CT2 lot was higher than that of the CT1 lot and the control group (P <0.05). The results of our study are similar to the results of Al-Kassie (2009) who reported that dietary cinnamon supplementation improved the meat yield of chickens. According to Naderi *et al.* (2014), diets supplemented with cinnamon powder did not affect chicken heart weight.

The effects of the dietary treatments on livestock production efficiency are presented in

Table 6. From 1 day to 6 weeks of age, all the chickens were raised and cared for using the same procedures and feed, and the cost during this period was 32,122 VND/kg of weight (1 USD = 22,765 VND). In the period from 7 to 13 weeks of age, the feed price was different among lots: it was the highest in CT2, followed by CT1, and then lowest in the control group. However, the cost to produce 1kg of broilers from 7 to 13 weeks of age was the lowest in the CT1 lot (37,855.25 VND), followed by the control group (39,500.59 VND, and then the CT2 lot (39,947.84 VND). Thus, it can be seen that the CT1 lot supplemented with 2.0 grams of cinnamon in their diet had a better broiler raising efficiency than the control group and the CT2 lot (2.5 grams of cinnamon supplement/kilogram of feed).

The biochemical indicators in the blood of the experimental broilers are presented in Table 7. The amount of protein in the blood did not differ among lots (P >0.05). However, the total cholesterol and LDL-cholesterol in the blood of the control group birds was higher than that of the two lots supplemented with cinnamon powder (P <0.01 and P <0.001, respectively). The HDL-cholesterol parameters of the chickens eating diets supplemented with cinnamon powder were higher than that of the chickens in the control group. However, there were no differences between the two levels of cinnamon supplementation on total cholesterol, HDL-cholesterol, or LDL- cholesterol (P >0.05). The results of our study are similar to the results of AL-Kassie (2009), who showed that broilers fed a diet supplemented with cinnamon powder had lower cholesterol compared to the control group. They are also similar to Paryad and Mahmoudi (2008) and Kim *et al.* (2006) who reported that chickens fed a diet supplemented with cinnamon essential oil resulted in reduced total cholesterol and increased blood HDL-cholesterol compared with the control group. According to Shirzadegan *et al.* (2012), cinnamon has active ingredients that reduce lipogenesis, and antioxidants in cinnamon work to prevent lipid peroxidation, leading to a decrease in blood fat.

The amounts of aspartate aminotransferase (AST) and alanine aminotransferase (ALT) in the blood of the broilers from the control group were higher than those of the two cinnamon-supplemented lots at P <0.01 and P <0.001, respectively, while there were no significant differences in these parameters between the CT1 and CT2 lots. This shows that when chickens were supplemented with cinnamon powder, their liver function improved. According to Langhout (2000), phytogenic products have the effect of improving liver function.

The results of the physiological indicators in the blood of the experimental broiler chickens are presented in Table 8. The number of red blood cells, mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), mean corpuscular hemoglobin concentration (MCHC), and red cells distribution width (DRW) in the blood were not impacted by the dietary treatments (P >0.05).

**Table 7. Effects of cinnamon supplementation on the blood biochemical parameters of broiler chickens**

| Criteria | Unit | Dietary treatments (n = 3) | | | P |
|---|---|---|---|---|---|
| | | Control group | CT1 | CT2 | |
| Protein | mg/100 ml | 4.09 ± 0.24 | 4.24 ± 0.25 | 4.20 ± 0.33 | 0.93 |
| Total cholesterol | mg/100 ml | $200.66^{a}$ ± 1.88 | $191.34^{b}$ ± 3.00 | $190.67^{b}$ ± 4.25 | 0.001 |
| HDL-cholesterol | mg/100 ml | $138.23^{b}$ ± 1.72 | $167.00^{a}$ ± 1.57 | $169.66^{a}$ ± 1.20 | <0.0001 |
| LDL-cholesterol | mg/100 ml | $47.33^{a}$ ± 1.87 | $37.00^{b}$ ± 2.00 | $37.33^{b}$ ± 1.38 | 0.002 |
| AST | IU/L | $379.94^{a}$ ± 2.04 | $366.10^{b}$ ± 2.59 | $366.77^{b}$ ± 2.91 | 0.005 |
| ALT | IU/L | $26.89^{a}$ ± 0.39 | $18.00^{b}$ ± 1.52 | $17.66^{b}$ ± 0.33 | 0.001 |

*Note: $^{a, b}$: Means in the same row without a common letter are significantly different at P <0.05.*

**Table 8. Effects of cinnamon supplementation on the blood physiological parameters of broiler chickens**

| Criteria | Unit | Dietary treatments (n=3) | | | P |
|---|---|---|---|---|---|
| | | Control group | CT1 | CT2 | |
| Red blood cells | $10^6$/µl | 2.88 ± 0.14 | 2.67 ± 0.21 | 2.51 ± 0.15 | 0.39 |
| Hemoglobin | mg/ml | 133.66$^a$ ± 2.72 | 137.33$^a$ ± 2.40 | 144.66$^b$ ± 2.74 | 0.0003 |
| MCV | fl | 98.80 ± 2.11 | 95.23 ± 3.09 | 96.13 ± 2.08 | 0.54 |
| MCH | pg | 46.60 ± 1.45 | 45.93 ± 1.48 | 45.66 ± 0.96 | 0.87 |
| MCHC | mg/ml | 471.66 ± 1.52 | 472.66 ± 1.76 | 475.33 ± 1.85 | 0.30 |
| DRW | % | 12.63 ± 0.35 | 11.76 ± 0.33 | 12.16 ± 0.83 | 0.57 |
| White blood cells | $10^3$/µl | 33.70$^a$ ± 1.96 | 25.80$^b$ ± 1.86 | 23.76$^b$ ± 1.29 | 0.0004 |
| Lymphocyte | % | 96.06$^a$ ± 1.04 | 84.86$^b$ ± 1.59 | 84.93$^b$ ± 1.22 | 0.0003 |
| Monocyte | % | 6.87$^a$ ± 0.66 | 1.66$^b$ ± 0.55 | 1.95$^b$ ± 0.41 | 0.001 |

*Note: $^{a, b:}$ Means in the same row without a common letter are significantly different at P <0.05.*

However, the amount of hemoglobin in the control group was lower than that of the CT1 and CT2 lots (P <0.01). The results of this study are similar to those of Al-Kassie (2009) and Soltan *et al.* (2008) who reported that the number of red blood cells and amount of hemoglobin in the blood of chickens fed cinnamon powder were higher than that of the control group.

The number of of white blood cells, lymphocytes, and monocytes in the control lot were higher than those of the two lots fed diets supplemented with cinnamon powder (P <0.001) but did not differ between the two levels of cinnamon powder supplementation (P >0.05). According to Windisch *et al.* (2008), phytogenic products have antibacterial effects. According to Chang *et al.* (2001), cinnamon possesses cinnamaldehyde and eugeno, which have antibacterial functions with gram-negative bacteria (such as *Escherichia coli*, *Pseudomonas aeruginosa*, *Salmonella* sp., and *Parahemolyticus*) and gram-positive bacteria (such as *Enterococcus faecalis, Staphylococcus aureus,* and *Staphylococcus epidermidis*).

## 4. CONCLUSIONS

Supplemental cinnamon powder in the diets (2.0 and 2.5 g/kg feed) of broilers from 7 to 13 weeks of age improved their growth performance, meat yield, and liver function, reduced their total cholesterol and LDL-cholesterol, and increased their HDL-cholesterol and the antibacterial ability of the birds. However there was no significant difference between two levels of supplementation (2.0 and 2.5g cinnamon powder per 1 kg feed).

In terms of production costs, the broiler chicken diet supplemented with 2.0g of cinnamon powder per 1kg feed had the lowest cost of production per 1 kilogram of broiler chicken body weight from 7 to 13 weeks of age.

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