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The meat quality and growth performance in broiler chickens fed diet with cinnamon powder

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Abstract

The aim of the study was to investigate the feeding effect of diets containing 3, 5 and 7% of cinnamon powder on meat quality and growth performance in broiler chickens. The chicken meat quality and growth performance in broiler chickens fed diets containing cinnamon powder increased significantly ($P < 0.05$) when compared to the control group. However, the TBARS of the meat of chickens fed diets containing cinnamon powder decreased significantly ($P < 0.05$) when compared to the control group. These findings suggest that the cinnamon powder can improve the shelf life and quality of chicken meat with maximize the productivity of broiler chickens.

Key words

Cinnamon powder, Broiler chickens, Growth performance, Meat quality

Introduction

Cinnamon (*Cinnamomi cassiae cortex*) has long been used as a medicinal herb as well as an ingredient in foods such as Sujonggwa (cinnamon flavored persimmon punch in South Korea), rice cakes, cookies, etc. Indeed, cinnamon is one of the oldest herbs known to man, and was mentioned in the Bible and used in ancient Egypt for beverage flavoring and medicine, and as an embalming agent. The essential oils found in cinnamon bark have been found to be primarily composed of cinnamaldehyde and other biologically active substances such as cinnamyl acetate, cinnamyl alcohol, eugenol, carvacrol etc (Qin *et al*., 2003; Broadhurst *et al*., 2000). The essential oil, which is responsible for the cinnamon flavor, promotes antiinflammation activity (Otsuka *et al*., 1982), antibacterial activity (Valero *et al*., 2003; Dickens *et al*., 2000; Ouattara *et al*., 1997) and antioxidant activity (Su *et al*., 2007; Park and Park, 2000). The polyphenolic polymers extracted from cinnamon potentiate insulin action by preventing insulin resistance induced by a high fructose diet and may function as antioxidants (Anderson *et al*., 2004; Qin *et al*., 2004).

Animal feeding experiments have revealed that the degree of decomposition of cinnamon bark by lumen anaerobic fermentation in ruminants (Wohlt *et al*., 1981), the acceptance and preference of cinnamon-flavored diet by Norwegian rats (Bennett *et al*., 1998), and the effects of the addition of cinnamon to the feed provided to weanling pigs (Young *et al*., 2003). Cinnamon powder may also contribute to increased quality of chicken meat and growth performance in broiler chickens. The present study investigated the effects of three different concentrations of cinnamon powder to the diets of broiler chickens on the shelf-life, acceptability, quality of chicken meat and growth performance.

Materials and Methods

Broiler chicken husbandry: All the experimental procedures including the treatment of experimental animals were in pursuant with the scientific and ethical regulations provided in the European Experimental Animal Handling License. In addition, this study was approved by the Institutional Animal Care and Use Committee of Kangwon National

University, South Korea. A total of 480 one-day-old male broiler chicks (Ross×Ross 308) were purchased from a commercial hatchery. The broiler chicks were all randomly allocated into four dietary groups with four replicates each (30 broiler chicks per pen), consisting of a control(no cinnamon powder, (CNP), 3.0% CNP group, 5.0% CNP group, and 7.0% CNP group. The experimental diets were formulated using mostly corn and soybean meal and all nutrient levels, including crude protein and metabolic energy, were the same as those of isocaloric and isonitrogenous diets. The experimental diets met (or marginally exceeded) the nutrient requirements recommended by the National Research Council (1994). The cinnamon was purchased in the form of bark sticks from a traditional market and ground into powder with a particle size of 20 mm using a commercial cutting mill, after which it was added to the feed provided to the cinnamon powder supplemented groups. The cinnamon powder contained crude protein (4.02%), carbohydrate (85.25%), a gross energy of 16.83 MJ kg^{-1} and a metabolizable energy that was calculated to be 15.15 MJ kg^{-1} (Han *et al*., 1982). The mixed experimental diets were stored in a cool place and the water and diet were supplied to the chicks *ad libitum*. The broiler chicks were reared under standard conditions (density: 10 chicks m^{-2}) in a room with a concrete floor covered with chaff with free access to the diets and water for 5 weeks. The room temperature was gradually decreased from 33º to 23ºC during the first 3 weeks, where it was maintained for the remaining experimental period. The relative humidity was maintained at 70% and light was provided continuously throughout the experiment. The growth performance data, including the feed intake (FI), body weight gain (BW) and feed efficiency (FE) of the broiler chickens were determined at 3 weeks and 5 weeks, respectively. FE was calculated by dividing BW during a certain period by FI.

Blood immunoglobulins: At end of the experiment after 5 weeks, 1 ml of blood was obtained from the wing veins of broiler chickens that were scheduled to be sacrificed using a syringe with a Hamilton 22 gauge needle (0.70 mm in diameter) and then stored at room temperature for 30 min. Serum was isolated via the centrifugation of blood at 2,200 × g for 15 min at 4ºC. After the isolated serum was rapidly frozen with gaseous liquid nitrogen, it was stored at -80ºC until immunoglobulin analysis. The blood immunoglobulin levels were assessed via the double antibody sandwich ELISA method using a commercial kit (Bethyl Laboratories, Inc., Montgomery, TX, USA). IgG (chicken IgG ELISA quantitation set, E30-104), IgA (chicken IgA ELISA quantitation set, E30-103) and IgM (chicken IgM ELISA quantitation set, E30-102) were assessed by response and via measurements of their optical density at 450 nm with a precision microplate reader (Molecular Devices, Inc., New York, USA).

Weight analysis and physical evaluation: Diet and water was withdrawn from all broiler chickens 12 hr before being slaughtered. A total of 60 broiler chickens (fifteen from each pen per treatment group) with a body weight similar to the standard one were selected from each treated group. According to the following recommendations for the euthanasia of experimental animals (Close *et al*., 1997), the animals were sacrificed without stress via cervical dislocation. To minimize the stress to the broiler chickens, those that were expected to be slaughtered were selected 2 hr prior to sacrifice and moved to an isolated place out of the sight of the other broiler chickens. Immediately after cervical dislocation, the carotid arteries were cut and the chickens were bled for 100 seconds, after which they were placed in hot water (60ºC) for about 4 min. The feathers were then removed by passing through a rotary drum mechanical picker for 30 sec. After the blood, feathers, feet, heads (cut at the first cervical vertebra) and shanks were removed and evisceration was conducted, the whole carcasses were air-chilled (air flow of 6 m^3 s^{-1}) and stored in a chilling room at 4ºC until the next day. The carcasses were weighed and deboned 24 hr after slaughter, and the breast muscle, thigh meat with skin, liver, gizzard, abdominal fat, spleen, Bursa of Fabricius and thymus were then removed and weighed. The weight of abdominal fat was determined by collecting all fat spreading to the ischium, around the cloaca, and into the neighboring abdominal muscles. The dressing percentage was calculated as the ratio of the carcass weight to the live weight. The weight of the breast muscle and thigh meat were expressed as their rates to the carcass weight and the relative weight of liver, gizzard, abdominal fat, spleen, Bursa of Fabricius, and thymus and are reported as the percentage of live weight. Among the 60 broiler chickens sacrificed without stress via cervical dislocation, the breast muscle and thigh meat from 40 carcasses were utilized for evaluation of the water holding capacity, meat color and lipid oxidation product. The other 20 carcass were used for sensory evaluation. At 24 hr postmortem, 20 carcasses selected from each treatment group were evaluated for the final pH of the breast pectoralis major using a pH meter (520A, Orion Research Inc, USA) by inserting a glass electrode directly in the thickest part of the pectoralis major. The electrode was calibrated in standard buffers at pH 4 and 7 at ambient temperature prior to analysis.

Water holding capacity: The water holding capacity was determined in a breast muscle as the percentage of drip loss over a 48 h period. Approximately 10 g of breast muscle was taken from the carcass using a 25 mm cork borer perpendicular to the muscle fiber direction and immediately weighed. The samples were placed in an airtight container

to avoid evaporation, after which they were stored at 4ºC in a chilling room. After 48 hr, the samples were again weighed. The drip loss was expressed as a percentage of the initial weight (Honikel, 1998).

Meat color: The meat color was measured in the breast muscle using a Minolta reflectance colorimeter (Minolta Chroma Meter CR-300, Minolta Corp, Osaka, Japan). Briefly, the breast muscle was cut and exposed to air for 15 min at room temperature prior to color measurement. The meat color was then measured three times using a white ceramic tile (L*=92.30, a*=0.32 and b*=0.33) as a standard. The meat color was expressed as Hunter values (L*=lightness, a*=redness, b*=yellowness).

TBARS: Thiobarbituric acid reactive substances (TBARS) was induced by placing 50 g of thigh meat was put into a polypropylene plastic bag and heating the sample in a 70ºC water bath for 10 min. These lipid oxidized samples were then stored in oxygen-permeable polyethylene zipper lock bags at 4ºC for 5 days, after which the lipid oxidation products were measured as thiobarbituric acid reactive substances as described below (Burge and Aust, 1978). Briefly, 0.5 g of thigh meat oxidized was mixed with 15 mL distilled water and then homogenized thoroughly at 2,200 ×*g* for 5 min using a homogenizer (tissue grinder, 1102-1, Japan). Next, 1 mL of the homogenates was mixed with 50 ¼L of butylated hydroxyanisole and 2 mL of 50% trichloroacetic acid solution (TBA/TCA) containing 1.3% (wt/vol) thiobarbituric acid dissolved at 60ºC. For the color reaction, the mixture was heated in a 60ºC water bath for 1 h and then cooled to room temperature, after which it was centrifuged at 2,200 ×*g* for 15 min. The absorbance of the supernatant fluid was then measured at 532 nm using a spectrophotometer (Shimadzu, UV mini-1240, Japan). The results were then compared with those of a blank containing 1 mL of distilled water and 2 mL of TBA/TCA mixture solution, after which the difference was multiplied by the common coefficient 5.88 and the values of TBARS were expressed as the value of MDA (malondialdehyde mg kg^{-1}). To induce the formation of MDA, tetrathoxypropane (Sigma Co. St. Louis, MO, USA) dissolved by itself in water solution was used as the MDA standard.

Sensory evaluation: For the sensory evaluation, the thigh meat with skin was fried in fresh corn oil and the breast muscle was boiled in water as is done for the preparation of Samgyetang (South Korean chicken soup). Sensory evaluation was conducted within 30 minutes of preparation while focusing on the degree of cinnamon taste and flavor. Sensory evaluation was conducted in a sensory evaluation room by a trained 20 member panel (consisting of 10 male and 10 female college students), who scored sensory attributes of taste and flavor, juiciness, tenderness and overall acceptability using a 9-point hedonic scale (1 = dislike extremely; 5 = neither like nor dislike; 9 = like extremely).

Statistical analysis: All data for growth performance and meat quality were analyzed using the SAS software (SAS, 2000). A general linear model procedure was performed and mean values and the standard error were reported. Duncan's multiple range tests were used to compare the mean values and a $P < 0.05$ was considered statistically significant.

Results and Discussion

Growth performance of the broiler chickens fed diets with three different levels of cinnamon powder is presented in Table 1. The BW of the CNP groups observed during the overall experimental period were significantly increased when compared to the control group. The BW of the 5.0% CNP group was significantly higher than the other CNP groups, while there was no significant difference between the 3.0% and 7.0% CNP groups. Thus, the plateau levels required to BW appeared to be attained in the diet containing 5.0% cinnamon powder. The reason for the increased body weight in the CNP groups may have been decreased chick mortality and diarrhea due to increased serum immunoglobulin levels (Table 2) via the heavier weight of the immune organs (Table 3) as well as the antibacterial activity (Hernandez *et al*., 2004; Valero and Salmeron, 2003; Dickens *et al*., 2000; Ouattara *et al*., 1997) and antioxidation activity (Calucci *et al*., 2003; Park and Park, 2000) of CNP in the diets. The FI was also slightly higher in CNP groups than in control group, but there were no significant differences among groups. The FE was significantly higher in 5.0% CNP group than in the other CNP groups, but there were no significant differences among groups. This is the first study to report that the growth performance of broiler chickens could be improved by providing diets containing cinnamon powder. These results suggest that the essential oils contained in cinnamon promote the growth of muscular tissue (Hernandez *et al*., 2004) in broiler chickens. Hernandez *et al*. (2004) reported that the body weight gain, feed intake and feed efficiency of broiler chickens fed a diet supplemented with cinnamon, oregano and pepper oil extracts at 200 ppm were similar to those of broiler chickens fed a diet supplemented with placebo, antibiotics and labiatae extract for 42 days (Hernandez *et al*., 2004). Furthermore, the values reported in their study were lower than the results obtained in the present study. In addition, the acceptance and preference of cinnamon flavored diets was reported to increase in Norwegian rats (Bennett *et al*., 1998), which supports the results of the present study.

The blood immunoglobulin levels are presented in Table 2. The IgG, IgA and IgM levels of the CNP groups were significantly higher than those of the control group.

Specifically, the IgG, IgA and IgM levels increased by 245.08, 165.75 and 214.90%, respectively, in the 5.0% CNP group which represented the greatest increase when compared to control. The higher blood immunoglobulin levels in broilers fed CNP were considered to be due to broilers in the CNP groups having greater proliferation of cells in immune organs when compared to the control group (Table 3). The thymus, spleen and Bursa of Fabricius are important antibody producing organs in birds. In a previous study, the increased weight of the thymus in response to cinnamon powder was believed to occur via enhanced growth of the thymocytes and treatment with cinnamon powder was found to maintain a consistent increase in serum immunoglobulin production (Wang *et al*., 2000).

The carcass characteristics and weight of immune organs in the birds fed cinnamon powder are shown in Table 3. The dressing percentage and the weight of thigh meat with skin and breast muscle were significantly higher in the CNP groups than the control group. The highest levels were observed in the 5.0% CNP treatment groups, while no significant difference was observed between 3.0% and 7.0% CNP groups. These results were likely related to the body weight gain, which appeared higher in CNP groups than control group (Table 2). The weight of the gizzard, liver and abdominal fat did not differ significantly among groups, which is similar to the results obtained by Hernandez *et al*. (2004), who found no change in the weights of liver, stomach, and digestive tract of broiler chicks fed a diet supplemented with cinnamon extract (Hernandez *et al*., 2004). The CNP groups showed significantly heavier weights of the thymus, Bursa of Fabricius, and spleen when compared to the control group. The weight of the immune organs was significantly higher in the 5.0% CNP group than the other groups, while there was no significant difference between 3.0% and 7.0% CNP groups. The thymus and Bursa of broilers increase as the birds mature, and the immune responses of birds are dependent on the spleen and the peripheral lymph nodes. The Bursa of Fabricius tends to be consistent in birds, and is thus often utilized for studies of the development and functional maturity of B-lymphocytes (Wang *et al*., 2000). Based on the results of the present study, cinnamon powder may prevent the harmful inflammation caused by immune system response. In addition, the increased weight of the immune organs observed in this study was considered to promote the ability of broilers to grow by suppressing inflammation (Otsuka *et al*., 1982).

The pH, water holding capacity, and TBARS of chicken meat from birds fed cinnamon powder are shown in Table 4. The pH of the chicken meat did not differ significantly among groups. However, the water holding capacity was significantly higher in the CNP groups than the control group, while the TBARS was significantly lower

Table 1 : Effect of dietary cinnamon powder for 5 weeks on growth performance in broiler chickens

Weeks	Diets containing cinnamon powder				PSE†
	0	3.0%	5.0%	7.0%	
		Body weight (g)			
0-3	797^{c}	815^{b}	857^{a}	819^{b}	5.0990
4-5	993^{b}	1,017^{ab}	1,038^{a}	1,017^{ab}	17.778
0-5	1,790^{c}	1,832^{b}	1,895^{a}	1,839^{b}	9.7553
		Feed intake (g)			
0-3	1,033	1,033	1,040	1,044	5.6911
4-5	1,837	1,840	1,850	1,846	8.6843
0-5	2,870^{b}	2,873^{b}	2,890^{a}	2,890^{a}	5.2360
		Feed efficiency			
0-3	0.77^{b}	0.78^{b}	0.82^{a}	0.78^{b}	0.0058
4-5	0.54^{b}	0.55^{b}	0.56^{a}	0.55^{b}	0.0050
0-5	0.62^{b}	0.63^{b}	0.65^{a}	0.63^{b}	0.0050

PSE, Pooled standard error of mean values; $^{a-c}$ Mean values with different superscripts are significantly different at $p < 0.05$

Table 2 : Effect of dietary cinnamon powder for 5 weeks on serum immnuoglobulins from broiler chickens (Unit: ¼g m l^{-1})

Items	Diets containing cinnamon powder				PSE†
	0	3.0%	5.0%	7.0%	
IgG	47.07^{d}	89.84^{c}	115.36^{a}	95.11^{b}	2.6558
IgA	33.35^{d}	35.71^{c}	55.28^{a}	45.92^{b}	0.3198
IgM	40.19^{c}	55.21^{b}	86.37^{a}	80.03^{a}	0.2409

PSE, pooled standard error of mean values; $^{a-d}$ Mean values with different superscripts are significantly different at $p < 0.05$

Table 3 : Effect of dietary cinnamon powder for 5 weeks on carcass characteristics and weight of immune organ in broiler chickens

Items	Diets containing cinnamon powder				PSE†
	0	3.0%	5.0%	7.0%	
Dressing percentage[a]	77.08^{c}	78.13^{b}	78.87^{a}	77.85^{b}	0.2127
Proportion (%) of tissue weight[b]					
Breast muscle	22.13^{c}	22.72^{b}	23.79^{a}	22.73^{b}	0.0980
Thigh meat	18.05^{c}	18.71^{b}	19.85^{a}	18.75^{b}	0.1271
Gizzard	1.71	1.76	1.74	1.71	0.0474
Liver	2.57	2.52	2.51	2.59	0.0871
Abdominal fat	1.65	1.68	1.67	1.60	0.0714
Bursa of Fabricius	0.11^{c}	0.15^{b}	0.20^{a}	0.16^{b}	0.0071
Spleen	0.03^{c}	0.07^{b}	0.11^{a}	0.08^{b}	0.0050
Thymus	0.13^{c}	0.15^{b}	0.20^{a}	0.16^{b}	0.0071

[a] Dressing percentage (carcass weight/live weight); [b] % of breast muscle and thigh meat against carcass weight., % of organ tissues against live weight; [c] PSE, pooled standard error of mean values; $^{a-c}$ Mean values with different superscripts are significantly different at $p < 0.05$

in the CNP groups when compared with the control group, although there were no differences observed in these values among CNP groups. This is the first study to report that the shelf life of chicken meat and the water holding capacity can be improved by providing diets containing CNP to broiler chickens. The increase in the water holding capacity of the breast muscle appeared to be attributable to improvement of the antioxidant activity via inhibition of TBARS (Young *et al.,* 2003). Drip loss or water loss percentage is a widely investigated approach used to measure the water holding capacity, which in turn influences savoriness, tenderness, color, fragrance, and nutrient content in the muscle. A lower water holding capacity in muscles can induce liquid out flow, loss of soluble nutrients and flavor. Therefore, the muscle becomes dry, hard and tasteless, and the meat quality is decreased (Barbut, 1996). Lipid oxidation is a factor that reduces meat quality and malondialdehyde is a soluble degraded product of lipids and an indicator that can be widely used to reflect the extent of lipid oxidation in meat (Raharjo and Sofos, 1993). The finding that TBARS was lower in CNP groups is related to the effects of herbs such as cinnamon, which may help animals to be healthy, improves the defensive reaction against insects, fungi, bacteria or viruses, and boosts the antibacterial effect of chemicals in the body of animals fed cinnamon (Dickens *et al*., 2000). The numerous essential oils found in cinnamon are primarily cinnamaldehyde and cinnamyl acetate, cinnamyl alcohol, eugenol, and carvacrol (Hernandez *et al*., 2004; Qin *et al*., 2003; Broadhurst *et al*., 2000; Kim and Kim, 2000), which have been shown to have strong antibacterial activity (Hernandez *et al*., 2004; Valero and Salmeron, 2003; Ouattara *et al*., 1997), and antioxidation activity (Su *et al*., 2007; Calucci *et al*., 2003; Park and Park, 2000).

Therefore, the essential oils contained in cinnamon likely inhibited TBARS by inducing a sparing effect on tocopherol or supporting the regeneration of tocopherol in feed (Young *et al*., 2003). Since the increased antioxidant activity results in increased protection against the stresses caused by lipid oxidation, the TBARS inhibiting effect caused by CNP supplementation observed in this study implies that the shelf life was improved by CNP supplementation.

The meat color of the breast muscle of birds fed with cinnamon powder is presented in Table 5. The L^* (lightness) value was significantly higher in th e CNP groups than the control group, but there was no significant difference in the a^* (redness) and b^* (yellowness) values among groups. The meat color is a major criterion that is used by consumers to

Table 4 : Effect of dietary cinnamon powder for 5 weeks on pH, water holding capacity and TBARS in chicken meats

Weeks	Diets containing cinnamon powder				PSE[b]
	0	3.0%	5.0%	7.0%	
pH	5.79	5.82	5.79	5.80	0.0584
Water holding capacity (%)	57.08[b]	59.63[a]	60.29[a]	59.80[a]	0.5729
TBARS[a]	0.75[a]	0.51[c]	0.55[bc]	0.57[b]	0.0214

[a] TBARS, mg of malondialdehyde kg^{-1} meat; [b] PSE, pooled standard error of mean values; [a,b] Mean values with different superscripts are significantly different at $p < 0.05$

Table 5 : Effect of dietary cinnamon powder for 5 weeks on meat color in chicken meats

Items[a]	Diets containing cinnamon powder				PSE[b]
	0	3.0%	5.0%	7.0%	
L^*	55.76[b]	60.17[a]	60.72[a]	60.42[a]	0.6230
a^*	4.67[a]	3.94[ab]	3.29[b]	3.53[b]	0.5345
b^*	16.15	15.98	16.37	15.73	0.5568

[a] L^* (lightness), a^* (redness), b^* (yellowness); [b] PSE, pooled standard error of mean values; [a,b] Mean values with different superscripts are significantly different at $p < 0.05$

Table 6 : Influence of dietary cinnamon powder for 5 weeks on sensory score in fried chicken meats

Items	Diets containing cinnamon powder				PSE[a]
	0	3.0%	5.0%	7.0%	
Color	7.55[c]	8.02[b]	8.74[a]	8.13[b]	0.2403
Flavor	7.67[c]	7.53[c]	8.74[a]	8.01[b]	0.2003
Taste	7.38[c]	8.07[b]	8.64[a]	8.16[b]	0.1921
Texture	7.51[c]	8.05[b]	8.52[a]	8.07[b]	0.1331
Acceptability	7.55[c]	8.24[b]	8.74[a]	8.17[b]	0.1061

[a] PSE, pooled standard error of mean values; [a-c] Mean values with different superscripts are significantly different at $p < 0.05$

Table 7 : Influence of dietary cinnamon powder for 5 weeks on sensory score in boiled chicken meats

Items	Diets containing cinnamon powder				PSE[a]
	0	3.0%	5.0%	7.0%	
Color	7.75[c]	8.45[b]	8.74[a]	8.37[b]	0.1394
Flavor	7.17[c]	8.07[b]	8.74[a]	8.16[b]	0.1655
Taste	7.50[c]	8.12[b]	8.65[a]	8.06[b]	0.1436
Texture	7.44[c]	8.27[b]	8.65[a]	8.23[b]	0.1063
Acceptability	7.75[c]	8.37[b]	8.76[a]	8.20[b]	0.1339

[a] PSE, pooled standard error of mean values; [a-c] Mean values with different superscripts are significantly different at $p<0.05$

judge meat quality. The L* value is especially important in white muscles and is correlated with drip loss and pH (Barbut, 1997).

Table 6 and Table 7 show the results obtained from the sensory evaluation on the acceptability of the cooked chicken meat from broilers that were stably sacrificed after being fed a diet containing CNP. The overall acceptability index of the taste and flavor of the fried or boiled chicken meats was significantly improved in the CNP groups when compared with the control group. The score of the 5.0% CNP group was significantly higher than that of the other treatment groups, while the scores of the 3.0% and 7.0% CNP groups did not differ significantly. The increase in the scores of the taste and flavor of the cinnamon treated groups was likely due to the presence of essential oils of CNP in the muscle tissues of the meat. However, the essential oils existing in the meat were not analyzed; therefore, further studies are necessary. Nevertheless, the results of this study indicate that the taste and flavor of chicken meats could be improved by providing a diet containing CNP to broiler chickens. Cinnamic aldehyde is the major essential oil contained in cinnamon, comprising 89.47% of cinnamon powder, 94.80% of water extract and 73.31% of ethanol extract (Kim and Kim, 2000). The essential oils contained in cinnamon may prevent cardiovascular diseases and arteriosclerosis (Ensminger and Esminger, 1986), a swell as reduce the risk of type 2 diabetes and cardiovascular disease (Khan *et al*., 2003; Babu *et al*., 2007) by lowering blood cholesterol and adjusting blood sugar and insulin secretion.

In conclusion, the results of the study showed that feeding dietary cinnamon powder to broiler chickens improved the shelf life and quality of chicken meats with increasing growth performance via stimulation of the growth of cells of major immune organs and boosting the immunoglobulin IgG content. Additionally, the results of this study indicated that amending the diet of broilers with 5.0% cinnamon powder can improve the quality of chicken meat and maximize the production yields of broiler chickens.

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