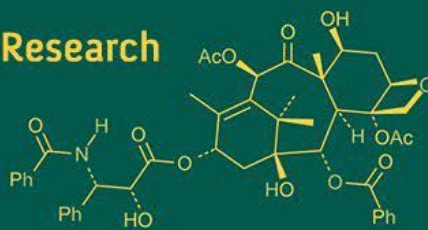
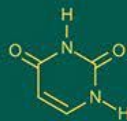
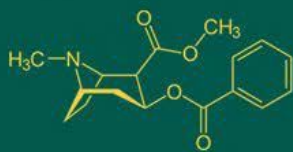


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Studies on growth promoting effects of cinnamon powder and cinnamaldehyde in broilers

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Abstract

The present study was conducted to evaluate the growth-promoting effects of cinnamon powder and cinnamaldehyde as natural alternatives to antibiotic growth promoters in broiler chickens. A total of 144 one-day-old Van-Cobb broiler chicks were randomly allotted to six dietary treatments with four replicates of six birds each for a 42-days feeding trial. The treatments included basal control diet, basal diet supplemented with avilamycin (15 mg/kg feed), cinnamon powder at 5 and 10 g/kg feed, and cinnamaldehyde at 150 and 300 mg/kg feed. Growth performance parameters, feed consumption, feed conversion ratio (FCR) and intestinal histomorphology were evaluated. Dietary supplementation of cinnamon powder (5 and 10 g/kg) and cinnamaldehyde (150 and 300 mg/kg) significantly improved body weight and body weight gain compared to the control group, with performance comparable to the antibiotic-supplemented group. Total feed consumption did not differ significantly among treatments, while FCR was significantly improved in all supplemented groups during the later growth phase (weeks 5-6). Histomorphological examination of the small intestine revealed significant increases in villus height, villus width, and villus height-to-crypt depth ratio, along with reduced crypt depth in the jejunum and ileum of birds receiving cinnamon powder and cinnamaldehyde, indicating enhanced intestinal absorptive capacity. Overall, the results indicated that cinnamon powder, particularly at 5 g/kg feed, and cinnamaldehyde at 300 mg/kg feed showed growth-promoting and gut-health-enhancing effects comparable to antibiotic supplementation, suggesting their potential as safe and effective phytochemical alternatives in broiler production systems.

Keywords: Cinnamon powder, Cinnamaldehyde, Growth performance, Feed conversion ratio, Intestinal histomorphology

Introduction

Hidden hunger, characterized by deficiencies of essential nutrients despite adequate caloric intake, remains one of India's most persistent public health challenges. A large segment of the population consumes diets that are inadequate in crucial micronutrients and high-quality proteins, resulting in widespread malnutrition, impaired immunity, reduced physical productivity, and increased susceptibility to disease. The Indian Council of Medical Research-National Institute of Nutrition (ICMR-NIN) recommends a daily protein intake of 0.83 g/kg body weight for healthy adults, yet studies indicate that the average intake in India is only about 0.6 g/kg, highlighting a significant gap that contributes to the nation's hidden hunger^[1].

Ensuring access to good-quality, nutrient-dense foods is therefore critical to addressing our countries nutritional needs. Among the available solutions, animal-source foods hold particular significance because they offer high biological value protein and essential amino acids that are often lacking in cereal-based Indian diets^[2]. Poultry products, especially broiler meat, stand out as an efficient, affordable, and culturally acceptable option. Broiler meat not only provides a rich source of quality protein but also represents an important livelihood opportunity for small and marginal farmers^[3]. Thus, strengthening the poultry sector can simultaneously improve nutritional security and rural income generation.

Given India's large and growing population, the demand for protein-rich foods continues to rise. To meet this demand, poultry production systems have increasingly relied on growth promoters to enhance feed efficiency, growth rate, and overall performance. Traditionally,

antibiotics have been used for this purpose; however, their widespread and indiscriminate use has raised global concern due to the emergence of antimicrobial resistance (AMR), a major threat to both human and animal health^[4]. As a result, there is an urgent need to transition toward safe, natural, and sustainable alternatives to antibiotic growth promoters.

Organic and plant-derived growth promoters have gained attention in recent years, with spices emerging as promising candidates due to their bioactive compounds and long history of dietary acceptance. Among them, cinnamon (*Cinnamomum zeylanicum*) is particularly noteworthy. India is one of the regions where cinnamon is widely grown, easily accessible, and well incorporated into traditional diets. Its antimicrobial, antioxidant, and digestive stimulant properties make it a valuable natural additive with the potential to enhance poultry growth performance while reducing dependence on synthetic antibiotics^[5].

Therefore, exploring the efficacy of cinnamon as an organic growth promoter in broiler production presents a dual opportunity, *i.e.* improving poultry productivity in an environmentally responsible manner and contributing to the broader national goals of combating hidden hunger and strengthening nutritional security. The study was conducted to compare growth promoting effects of cinnamon powder and cinnamaldehyde with that of standard antibiotic treatment

Materials and Methods

Chicks Housing and Management

Group feeding was applied for animals in each compartment, feed and water were presented *ad libitum*. The birds were maintained at the brooder house of the Poultry Research Station (PRS), College of Veterinary Science and Animal Husbandry, Anand. A deep litter system was used for the rearing of chicks with a well-ventilated brooder house using standard management and health care practices. During night hours, adequate artificial light was provided by using electric bulbs to keep a warm environment inside the house. All birds were vaccinated according to the standard poultry vaccination protocol, which included B1 strain against Ranikhet disease on day 7 (intra-ocular), intermediate strain against Infectious Bursal Disease on day 14 (intra-ocular), and Lasota strain against Ranikhet disease on day 21 (via drinking water).

Experimental Design

A total of 144 one day old Van-cobb broiler chicks were used for this experiment. Chicks were purchased from commercial hatchery (Venky's India Limited). Experimental animals were randomly divided into 6 groups with 4 replicates having 6 birds each. Treatment 1 (T1) was fed control (basal) diet, Treatment 2 (T2) was fed basal diet supplemented with avilamycin antibiotic at 15 mg/kg feed as standard antibiotic. Treatment 3 (T3) was fed basal diet supplemented with cinnamon powder at 5 g/kg feed. Treatment 4 (T4) was fed basal diet supplemented with cinnamon powder at 10 g/kg feed. Treatment 5 (T5) and treatment 6 (T6) were fed basal diet supplemented with cinnamaldehyde at 150 and 300 mg/kg feed, respectively. Rations used in the study were prepared in accordance with nutrient requirements stated in BIS (2007). All the birds received broiler feed according to the age of birds *i.e.*, 1-7 days (pre-starter), 8-21 days (starter) and 22-42 (finisher) during the entire experimental period. Commercially sold

synthetic 98 % cinnamaldehyde was used for the purpose of this experiment. The inclusion levels of cinnamon powder and cinnamaldehyde in this experiment were selected based on previously reported effective doses in poultry studies.

Parameters Studied

Growth Performance

To evaluate the growth-promoting effect of the dietary treatments, weekly body weight, body weight gain, feed consumption and feed conversion ratio (FCR) were recorded throughout the 42-day experimental period. Body weight was measured in the morning before feeding using a digital balance at hatch (BW_0) and subsequently at weekly intervals up to the 6th week (BW_1 - BW_6). Weekly body weight gain (BWG_{0-1} to BWG_{5-6}) was determined by subtracting the previous week's weight from the current week's weight, and overall body weight gain (BWG_{0-6}) was also calculated. Feed consumption was measured on a group basis by recording the amount of feed offered and subtracting the residual feed at the end of each week to obtain weekly (FC_1 - FC_6) and total feed intake (FC_{0-6}). Feed conversion ratio, an indicator of feed efficiency, was computed weekly and cumulatively using the ratio of total feed consumed to total body weight gained by each group. Mortality was recorded daily, and cumulative mortality for each treatment group was calculated for the entire experimental period.

Histomorphology Study of Small Intestine

At the end of the experimental period, eight birds from each treatment group were sacrificed for evaluation of histomorphology of small intestine. Distal segments of the duodenum, jejunum, and ileum were collected to measure villus height, villus width, crypt depth, and villus height-to-crypt depth ratio. After evisceration, 2-3 cm intestinal segments were excised, rinsed with phosphate-buffered saline (PBS), and trimmed into 1 cm cross-sections, which were then fixed in 10 % neutral buffered formalin. Tissues were processed using the paraffin-embedding method, sectioned at 4-5 μ m thickness using an automatic microtome (Leica, Germany), and stained with hematoxylin and eosin following the method of Luna (1968)^[6]. Stained slides were examined under a light microscope, and measurements were taken using image analysis software (Quasmo Industry Pro).

Statistical Analysis

All the data were presented as Mean $\pm$ S.E. Completely randomized design and one-way analysis of variance (ANOVA) was used to compare the mean values of different experimental groups using IBM SPSS software (version 26.0). Significant difference ($p < 0.05$) between different experimental groups were analysed by Duncan's multiple range test.

Results

Growth Performance

Body weight

As presented in Table 1, no significant differences were observed in body weight among the experimental groups at day-old, 1st week, and 3rd week of age. However, significant differences appeared at the 2nd, 4th, 5th, and 6th weeks of the experiment. At 2nd week, birds supplemented with cinnamon powder at 5 g/kg feed and cinnamaldehyde at 150 mg/kg exhibited significantly higher body weights compared to the antibiotic-treated group, while remaining comparable to the

control. No significant differences in third-week for body weight across the experimental groups may be explained by comparable heat stress encountered by all birds, potentially masking treatment-related responses. By 4th week, birds receiving 5 g/kg cinnamon powder recorded significantly higher body weight than those fed 10 g/kg, although all treatment groups remained statistically similar to both the control and antibiotic groups. At the 5th week, body weight increased significantly in birds supplemented with the standard antibiotic and with 5 g/kg cinnamon powder, compared to the control group. By the 6th week, all treatment groups including cinnamon powder (5 and 10 g/kg), cinnamaldehyde (150 and 300 mg/kg), and the antibiotic showed significantly higher body weight than the control, and the performance of cinnamon and cinnamaldehyde treatments was comparable to the antibiotic group.

Body Weight Gain (BWG)

As presented in Table 2, body weight gain (BWG) did not differ significantly among groups during the 0-1 and 2-3 week periods. A significantly higher BWG was observed during 1-2 weeks in birds supplemented with cinnamon powder (5 g/kg) and cinnamaldehyde (150 mg/kg) compared with the antibiotic group and higher cinnamaldehyde dose (300 mg/kg), while remaining comparable to the control. No significant differences in third-week for body weight gain across the experimental groups may be explained by the comparable heat stress encountered by all birds, potentially masking treatment-related responses. During 3-4 weeks, BWG was significantly higher in birds fed 5 g/kg cinnamon powder than those receiving 10 g/kg, although all groups were statistically similar to the control. At 4-5 weeks, antibiotic supplementation produced the greatest BWG, followed by significantly higher gains in birds receiving 10 g/kg cinnamon powder and 300 mg/kg cinnamaldehyde relative to the control. By 5-6 weeks, all supplemented groups, cinnamon powder (5 and 10 g/kg), cinnamaldehyde (150 and 300 mg/kg), and the antibiotic demonstrated significantly higher BWG than the control, with performance in the cinnamon and cinnamaldehyde groups comparable to the antibiotic. Overall BWG (0-6 weeks) was significantly improved in all supplemented groups relative to the control, indicating that cinnamon powder and cinnamaldehyde were equally effective as the standard antibiotic in promoting sustained growth.

Feed Consumption (FC)

A significant effect of dietary treatment was observed only during the fifth week as shown in Table 3, where birds supplemented with cinnamon powder at 10 g/kg and cinnamaldehyde at 150 mg/kg exhibited reduced feed intake compared to those receiving cinnamon powder at 5 g/kg. However, these reductions did not persist through the sixth week, and total feed consumption over the entire experimental period (0-6 weeks) remained statistically similar across all dietary groups.

Feed Conversion Ratio (FCR)

FCR remained statistically similar among treatment groups during the first four weeks of the trial, indicating that early growth performance was not influenced by supplementation with cinnamon powder, cinnamaldehyde, or the standard

antibiotic (Table 4). Differences emerged during the fifth and sixth weeks, where birds receiving cinnamon powder at 5 and 10 g/kg, cinnamaldehyde at 150 and 300 mg/kg, and the standard antibiotic exhibited significantly improved FCR compared to the control group. Importantly, the FCR performance of all phytochemical-supplemented groups was comparable to that of the antibiotic-treated birds, indicating their potential as effective natural alternatives for improving feed utilization.

Intestinal Histomorphology

The mean villus height (VH), villus width (VW), crypt depth (CD), and villus height-to-crypt depth ratio (VH/CD) of the duodenum, jejunum, and ileum of broilers at 42 days of age are presented in Table 5 and graphically illustrated in Figures 1 - 6.

Duodenum

Duodenal VH increased significantly in all supplemented groups cinnamon powder (5 and 10 g/kg), cinnamaldehyde (150 and 300 mg/kg), and standard antibiotic compared with the control. The highest VH was recorded in the standard antibiotic group, followed by cinnamaldehyde at 300 mg/kg. VW followed a similar trend, the standard antibiotic group showed the greatest VW, with cinnamaldehyde at 300 mg/kg ranking next. CD did not differ significantly among treatments. VH/CD ratio was significantly higher in the standard antibiotic group than in cinnamon powder (5 and 10 g/kg), cinnamaldehyde 150 mg/kg, and control, but comparable to cinnamaldehyde 300 mg/kg.

Jejunum

Jejunal VH was significantly higher in all treatment groups than in the control, with the standard antibiotic group showing the highest values. This was followed by supplementation of cinnamaldehyde at 300 mg/kg. VW was significantly highest in the antibiotic group, followed by cinnamaldehyde 300 mg/kg. CD values were highest in the control group and significantly reduced in all supplemented groups. VH/CD ratio was significantly higher in all supplemented groups than in control. The highest ratios were seen in birds fed the antibiotic, cinnamon powder 5 g/kg, and cinnamaldehyde 300 mg/kg.

Ileum

Ileal VH was significantly higher in all treatment groups than in the control, highest value was noted in the antibiotic group, followed by cinnamaldehyde 300 mg/kg.

VW exhibited patterns consistent with VH, the antibiotic group showed the highest VW, followed by cinnamaldehyde 300 mg/kg. Cinnamon powder at 5 g/kg was significantly higher than the 10 g/kg group, cinnamaldehyde 150 mg/kg, and control. Cinnamon powder at 10 g/kg exceeded cinnamaldehyde 150 mg/kg and control. No difference was found between cinnamaldehyde 150 mg/kg and control.

CD was significantly lowest in the cinnamaldehyde 300 mg/kg group. CD values of the antibiotic group were comparable to cinnamon powder at 5 g/kg but significantly lower than cinnamon powder at 10 g/kg, cinnamaldehyde 150 mg/kg, and control. Cinnamon powder at 10 g/kg showed lower CD than cinnamaldehyde 150 mg/kg and control, and cinnamaldehyde 150 mg/kg produced lower CD than control.

VH/CD ratios were significantly highest in the antibiotic and cinnamaldehyde 300 mg/kg groups. Cinnamon powder at 5 g/kg produced higher VH/CD than cinnamon powder 10 g/kg, cinnamaldehyde 150 mg/kg, and control. Cinnamon powder 10 g/kg showed higher VH/CD than cinnamaldehyde 150 mg/kg and control. Cinnamaldehyde 150 mg/kg exceeded control

Discussion

These findings on growth enhancement align with several earlier reports. Toghyani *et al.* (2011)^[7] observed significant improvement in body weight of birds supplemented with 2 g/kg cinnamon powder. Reis *et al.* (2018)^[8] supplemented essential oils containing cinnamaldehyde and Mondal *et al.* (2025)^[9] supplemented 100-200 mg/kg essential oil containing cinnamaldehyde and observed a significant improvement in weight gain in broilers. Conversely, some studies have reported no significant effects. Jamroz *et al.* (2006)^[10] and Hernandez *et al.* (2004)^[11] found no improvement in body weight with plant extracts or essential oils containing cinnamaldehyde. Similarly, Koochaksaraie *et al.* (2011)^[12] and Chowlu *et al.* (2019)^[13] reported non-significant differences in body weight at various inclusion levels of cinnamon powder. Ipcak and Alcicek (2019)^[14] and Yang *et al.* (2021)^[15] reported non-significant differences in body weight at various inclusion levels of cinnamaldehyde. The present results on body weight gain agree with those of Bravo *et al.* (2014)^[16] and Pirgozliev *et al.* (2015; 2019)^[17, 18] supplemented plant extract (100 g/ton) containing 3% cinnamaldehyde. Qaid *et al.* (2021)^[19] supplemented 2 g/kg cinnamon bark powder, Khan *et al.* (2023)^[20] supplemented cinnamon powder at 0.5% and 1.0%, Liu *et al.* (2024)^[21] supplemented essential oil at 300 and 450 mg/kg feed containing cinnamaldehyde, Doneria *et al.* (2025)^[22] supplemented 400 mg/kg cinnamon oil, and Mondal *et al.* (2025)^[9] supplemented 100 and 200 mg/kg of essential oil containing cinnamaldehyde, also reported significant improvements in BWG in broilers. However, the findings contrast with reports by Jamroz *et al.* (2003)^[23] who supplemented plant extract (150 and 300 ppm cinnamaldehyde), Bravo *et al.* (2011)^[24] supplemented cinnamaldehyde at 100 mg/kg feed, Pathak *et al.* (2016)^[25] supplemented essential oils (500 mg/kg feed) containing cinnamaldehyde, Chowlu *et al.* (2019)^[13] supplemented cinnamon powder at 2.5, 5 and 7.5 g/kg and Ipcak and Alcicek (2019)^[14], who observed no significant effects of cinnamon or cinnamaldehyde supplementation on BWG. The overall findings on feed consumption by broilers in the present study align with Chowlu *et al.* (2019)^[13] who supplemented cinnamon powder at 2.5, 5 and 7.5 g/kg and Qaid *et al.* (2021)^[19] supplemented cinnamon bark powder at 2, 4 and 6 g/kg feed. Pathak *et al.* (2016)^[25] supplemented essential oils (500 mg/kg feed) containing cinnamaldehyde, Pirgozliev *et al.* (2019)^[18] supplemented phytogetic feed additives (PA), containing 3% cinnamaldehyde, Ipcak and Alcicek (2019)^[14] and Yang *et al.* (2021)^[15] supplemented cinnamaldehyde at a dose range of 50 to 150 mg/kg feed, and Mondal *et al.* (2025)^[9] supplemented essential oil (containing cinnamaldehyde) at 100 and 200 mg/kg feed, all of whom documented non-significant effects on broiler feed

consumption. In contrast, only a few studies have documented significant alterations in feed intake, such as Pirgozliev *et al.* (2015)^[17] using plant extract (100 g/ton) containing 3% cinnamaldehyde (C + XT), and Khan *et al.* (2023; 2025)^[20, 26] who supplemented cinnamon powder at 0.5% and 1.0% of feed. Collectively, these findings suggested that cinnamon-based phytogetic additives generally do not influence feed consumption under standard management conditions.

The improvements in FCR in the present study were supported by findings of Singh *et al.* (2014)^[27] who supplemented cinnamon powder at 0.5% and 1.5% of feed, Pirgozliev *et al.* (2015)^[17] supplemented plant extract (100 g/ton) containing 3% cinnamaldehyde, Qaid *et al.* (2021)^[19] supplemented cinnamon bark powder at 2 g/kg, Khan *et al.* (2023; 2025)^[20, 26] supplemented cinnamon powder at 0.5% and 1.0%, Liu *et al.* (2024)^[21] supplemented with essential oil containing cinnamaldehyde at 300 and 450 mg/kg feed and Mondal *et al.* (2025)^[9] supplemented with essential oils at 100 and 200 mg/kg feed (containing cinnamaldehyde) across various dosages and phytogetic formulations. However, other researchers including Chowlu *et al.* (2019)^[13] supplemented cinnamon powder at 2.5, 5 and 7.5 g/kg, Ipcak and Alcicek (2019)^[14] supplemented with 150 mg/kg feed cinnamaldehyde, Pirgozliev *et al.* (2019)^[18] supplemented with phytogetic feed additives (PA), containing 3% cinnamaldehyde, Qaid *et al.* (2021)^[19] supplemented with cinnamon bark powder at 4 and 6 g/kg and Yang *et al.* (2021)^[15] supplemented cinnamaldehyde at 50 and 100 mg/kg feed reported non-significant effects on FCR. These improvements suggest that the feed-efficiency-enhancing effects of cinnamon-based additives become more prominent during later growth phases when nutrient demand and metabolic load increase.

The results on histomorphology of small intestine in the present study were consistent with earlier reports demonstrating the beneficial effects of cinnamaldehyde and cinnamon-based phytogetic additives in broilers. Pathak *et al.* (2016)^[25] reported a significant increase in ileal villus height in birds supplemented with essential oils containing cinnamaldehyde compared to the control. Similarly, Reis *et al.* (2018)^[8] observed a significant increase in jejunal villus height in birds fed a phytogetic feed additive (1%) containing cinnamaldehyde compared to the control; however, they also reported a significant increase in crypt depth in birds receiving a standard antibiotic diet. Qaid *et al.* (2021)^[19] reported a significant increase in duodenal villus height and VH/CD ratio in birds supplemented with cinnamon powder at 2 g/kg feed compared to the control. Yang *et al.* (2021)^[15] also reported a significant increase in the VH/CD ratio of the duodenum and jejunum in birds fed cinnamaldehyde at 50 and 100 mg/kg compared to the control. Furthermore, Doneria *et al.* (2025)^[22] observed significantly increased villus height in the duodenum and jejunum of birds supplemented with cinnamon oil (400 mg/kg), while Ibigbami *et al.* (2025)^[28] reported significant increases in villus height and villus width at various cinnamon inclusion levels, along with a significant reduction in crypt depth at higher supplementation rates.

Table 1: Effect of dietary supplementation of cinnamon powder and cinnamaldehyde on body weight (BW) of broilers

Group	BWG 0-1	BWG 1-2	BWG 2-3	BWG 3-4	BWG 4-5	BWG 5-6	BWG 0-6
Group I	84.27 ± 2.86	175.80 ± 5.39	226.87 ± 9.50	360.83 ± 16.91	415.57 ± 22.81	626.35 ± 12.16	1889.69 ± 41.09
Group II	86.33 ± 2.87	160.80 ± 6.55	243.04 ± 10.60	374.41 ± 22.14	589.61 ± 17.73	711.20 ± 13.16	2165.38 ± 38.31
Group III	86.55 ± 3.54	186.75 ± 6.33	246.05 ± 12.16	373.80 ± 19.50	459.00 ± 15.49	747.50 ± 18.21	2127.63 ± 48.05
Group IV	83.95 ± 3.37	170.90 ± 7.68	236.90 ± 6.84	330.50 ± 16.66	527.00 ± 24.68	698.75 ± 36.05	2048.38 ± 31.67
Group V	89.64 ± 2.89	193.11 ± 4.57	260.63 ± 10.72	362.66 ± 11.25	431.68 ± 15.52	743.49 ± 26.32	2062.38 ± 36.61
Group VI	88.24 ± 3.17	162.06 ± 7.95	250.65 ± 11.19	381.02 ± 15.52	489.65 ± 18.01	762.24 ± 32.42	2124.57 ± 51.47

Values (Mean ± S.E., n=24) bearing different superscripts (a, b, c) within a same column differ significantly from each other (P<0.05).

Group I - Control; Group II- Positive control; Group III- cinnamon powder @ 5.0 g/kg feed; Group IV- cinnamon powder @ 10 g/kg feed; Group V- cinnamaldehyde @ 150 mg/kg feed; Group VI - cinnamaldehyde @ 300 mg/kg feed

Table 2: Effect of dietary supplementation of cinnamon powder and cinnamaldehyde on weekly body weight gain (BWG) of broilers

Groups	BWG 0-1	BWG 1-2	BWG 2-3	BWG 3-4	BWG 4-5	BWG 5-6	BWG 0-6
Group I	84.27 ± 2.86	175.80 ± 5.39ab	226.87 ± 9.50	360.83 ± 16.91ab	415.57 ± 22.81a	626.35 ± 12.16a	1889.69 ± 41.09a
Group II	86.33 ± 2.87	160.80 ± 6.55a	243.04 ± 10.60	374.41 ± 22.14ab	589.61 ± 17.73d	711.20 ± 13.16b	2165.38 ± 38.31b
Group III	86.55 ± 3.54	186.75 ± 6.33b	246.05 ± 12.16	373.80 ± 19.50b	459.00 ± 15.49abc	747.50 ± 18.21b	2127.63 ± 48.05b
Group IV	83.95 ± 3.37	170.90 ± 7.68ab	236.90 ± 6.84	330.50 ± 16.66a	527.00 ± 24.68c	698.75 ± 36.05b	2048.38 ± 31.67b
Group V	89.64 ± 2.89	193.11 ± 4.57b	260.63 ± 10.72	362.66 ± 11.25ab	431.68 ± 15.52ab	743.49 ± 26.32b	2062.38 ± 36.61b
Group VI	88.24 ± 3.17	162.06 ± 7.95a	250.65 ± 11.19	381.02 ± 15.52ab	489.65 ± 18.01bc	762.24 ± 32.42b	2124.57 ± 51.47b

Values (Mean ± S.E., n=24) bearing different superscripts (a, b, c) within a same column differ significantly from each other (P<0.05).

Group I - Control; Group II- Positive control; Group III- cinnamon powder @ 5.0 g/kg feed; Group IV- cinnamon powder @ 10 g/kg feed; Group V- cinnamaldehyde @ 150 mg/kg feed; Group VI - cinnamaldehyde @ 300 mg/kg feed

Table 3: Effect of dietary supplementation of cinnamon powder and cinnamaldehyde on weekly feed consumption (FC) of broilers

Groups	FC1	FC2	FC3	FC4	FC5	FC6	TFC 0-6
Group I	199.96 ± 2.03	374.58 ± 8.85	593.13 ± 6.91	962.46 ± 2.54	909.33 ± 28.46ab	1072.92 ± 5.71	4112.38 ± 33.04
Group II	204.00 ± 2.49	367.88 ± 8.45	577.80 ± 6.18	951.50 ± 12.84	886.42 ± 45.67ab	1075.00 ± 85.43	4062.58 ± 112.47
Group III	202.83 ± 3.83	399.29 ± 2.33	591.25 ± 3.68	957.42 ± 5.18	952.67 ± 31.63b	1039.17 ± 84.55	4142.63 ± 119.10
Group IV	202.33 ± 2.85	382.38 ± 16.31	560.13 ± 21.27	932.17 ± 16.34	822.25 ± 33.03a	1032.50 ± 55.44	3931.75 ± 90.40
Group V	197.50 ± 4.28	374.08 ± 10.49	578.50 ± 25.46	933.42 ± 14.67	842.55 ± 54.14a	963.75 ± 69.23	3889.80 ± 66.54
Group VI	197.96 ± 4.09	368.58 ± 5.25	575.29 ± 13.30	935.13 ± 18.62	859.33 ± 33.62ab	1033.33 ± 25.27	3969.63 ± 74.16

Values (Mean ± S.E., n=24) bearing different superscripts (a, b, c) within a same column differ significantly from each other (P<0.05).

Group I - Control; Group II- Positive control; Group III- cinnamon powder @ 5.0 g/kg feed; Group IV- cinnamon powder @ 10 g/kg feed; Group V- cinnamaldehyde @ 150 mg/kg feed; Group VI - cinnamaldehyde @ 300 mg/kg feed

Table 4: Effect of dietary supplementation of cinnamon powder and cinnamaldehyde on feed conversion ratio (FCR) of broilers

Groups	FCR 0-1	FCR 0-2	FCR 0-3	FCR 0-4	FCR 0-5	FCR 0-6
Group I	1.58 ± 0.02	1.90 ± 0.04	2.21 ± 0.05	2.40 ± 0.08	2.34 ± 0.11b	2.13 ± 0.05b
Group II	1.58 ± 0.06	1.97 ± 0.04	2.16 ± 0.02	2.32 ± 0.07	2.00 ± 0.06a	1.84 ± 0.05a
Group III	1.57 ± 0.08	1.91 ± 0.08	2.10 ± 0.06	2.25 ± 0.09	2.18 ± 0.06ab	1.91 ± 0.08a
Group IV	1.58 ± 0.01	1.95 ± 0.06	2.13 ± 0.08	2.38 ± 0.08	2.08 ± 0.06a	1.88 ± 0.05a
Group V	1.51 ± 0.08	1.80 ± 0.05	2.01 ± 0.09	2.27 ± 0.09	2.15 ± 0.05ab	1.85 ± 0.03a
Group VI	1.53 ± 0.06	1.97 ± 0.06	2.13 ± 0.07	2.28 ± 0.06	2.09 ± 0.05a	1.84 ± 0.05a

Values (Mean ± S.E., n=24) bearing different superscripts (a, b, c) within a same column differ significantly from each other (P<0.05).

Group I - Control; Group II- Positive control; Group III- cinnamon powder @ 5.0 g/kg feed; Group IV- cinnamon powder @ 10 g/kg feed; Group V- cinnamaldehyde @ 150 mg/kg feed; Group VI - cinnamaldehyde @ 300 mg/kg feed

Table 5: Effect of dietary supplementation of cinnamon powder and cinnamaldehyde on Villi height (VH), Villi width (VW), Crypt depth (CD) and Villus height to Crypt depth (VH/CD) ratio of Duodenum, Jejunum and Ileum in broilers at 42nd day (µm)

Groups	Duodenum VH (µm)	Duodenum VW (µm)	Duodenum CD (µm)	Duodenum VH/CD	Jejunum VH (µm)	Jejunum VW (µm)	Jejunum CD (µm)	Jejunum VH/CD	Ileum VH (µm)	Ileum VW (µm)	Ileum CD (µm)	Ileum VH/CD
Group I	1564.94 ± 9.34a	142.91 ± 0.78a	199.01 ± 1.08	7.86 ± 0.05a	1505.07 ± 5.19a	143.52 ± 0.55a	214.65 ± 2.20c	7.02 ± 0.08a	1294.55 ± 2.32a	181.72 ± 1.12a	216.16 ± 1.30e	5.99 ± 0.03a
Group II	2044.45 ± 11.56c	199.54 ± 2.61f	209.77 ± 4.60	9.78 ± 0.20d	1899.99 ± 2.11f	186.86 ± 0.98f	205.35 ± 5.71bc	9.31 ± 0.27d	1566.13 ± 7.31f	234.96 ± 1.11e	182.92 ± 3.16b	8.58 ± 0.16c
Group III	1826.67 ± 8.74c	165.22 ± 1.16d	203.79 ± 5.88	9.03 ± 0.28c	1684.26 ± 8.03d	170.44 ± 0.59d	187.94 ± 5.39a	9.02 ± 0.27cd	1444.29 ± 4.99d	213.71 ± 1.39c	183.72 ± 0.94b	7.86 ± 0.05d
Group IV	1664.85 ± 10.76b	156.27 ± 0.67c	194.03 ± 6.55	8.65 ± 0.27bc	1596.18 ± 15.12c	159.85 ± 0.71c	190.68 ± 5.86ab	8.43 ± 0.23bc	1405.44 ± 3.65c	202.27 ± 0.87b	196.82 ± 1.78c	7.15 ± 0.08c
Group V	1656.56 ± 5.75b	150.37 ± 0.77b	205.76 ± 4.18	8.08 ± 0.18ab	1535.16 ± 4.41b	153.95 ± 0.63b	184.12 ± 0.97a	8.34 ± 0.06b	1345.37 ± 7.47b	180.54 ± 3.32a	210.88 ± 1.21d	6.38 ± 0.05b
Group VI	1941.06 ± 6.16d	183.72 ± 1.82e	208.91 ± 6.07	9.36 ± 0.28cd	1823.66 ± 8.50e	178.58 ± 1.03e	196.55 ± 5.80ab	9.33 ± 0.24d	1503.28 ± 2.04e	227.28 ± 0.74d	175.59 ± 0.78a	8.56

Values (Mean ± S.E., n=8) bearing different superscripts (a, b, c) within a same column differ significantly from each other (P<0.05).

Group I - Control; Group II- Positive control; Group III- cinnamon powder @ 5.0 g/kg feed; Group IV- cinnamon powder @ 10 g/kg feed; Group V- cinnamaldehyde @ 150 mg/kg feed; Group VI - cinnamaldehyde @ 300 mg/kg feed

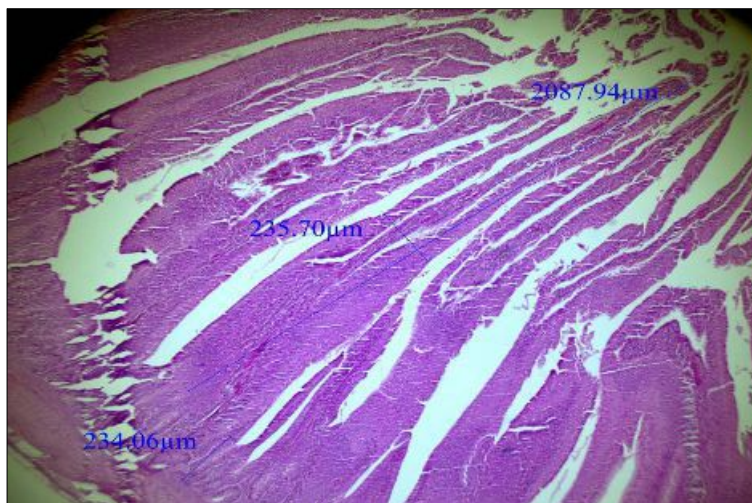


Fig 1: Section of Duodenum of Avilamicin group showing morphology of villi height, villi width and crypt depth in broilers on 42nd day (H & E Stain, 10X)

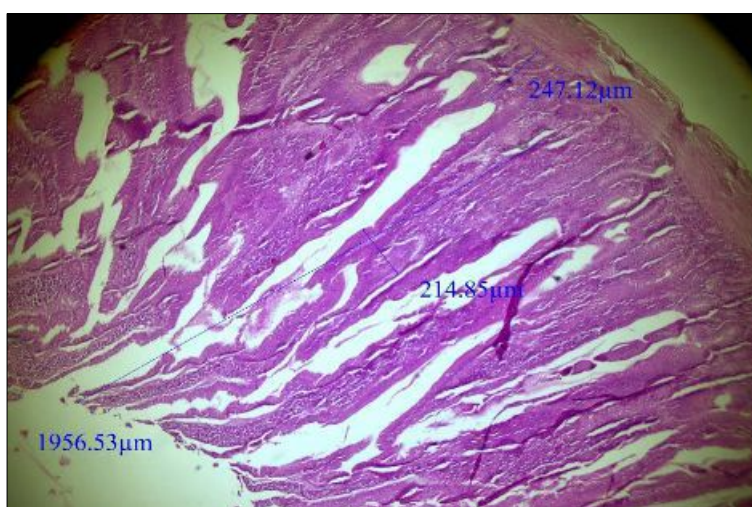


Fig 2: Effect of dietary supplementation of cinnamaldehyde (300 mg/kg feed) on morphology of villi height, villi width and crypt depth of Duodenum in broilers on 42nd day (H & E Stain, 10X)

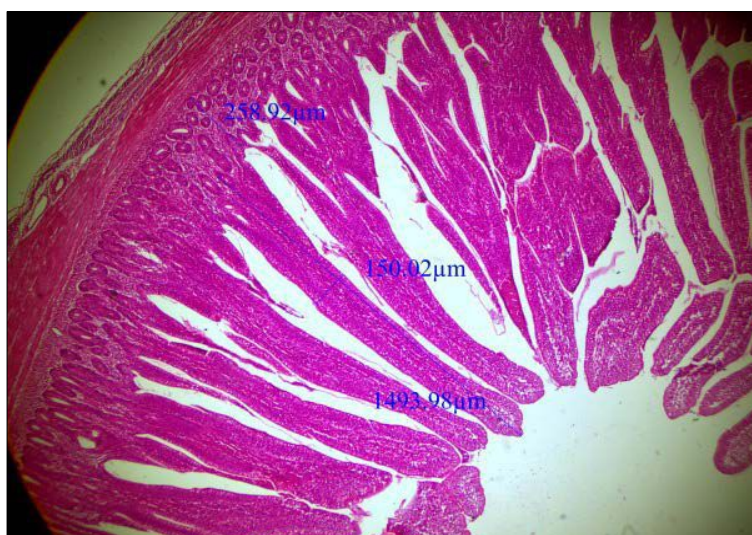


Fig 3: Section of Jejunum of control group showing normal architecture of villi height, villi width and crypt depth of Jejunum in broilers on 42nd day (H & E Stain, 10X)

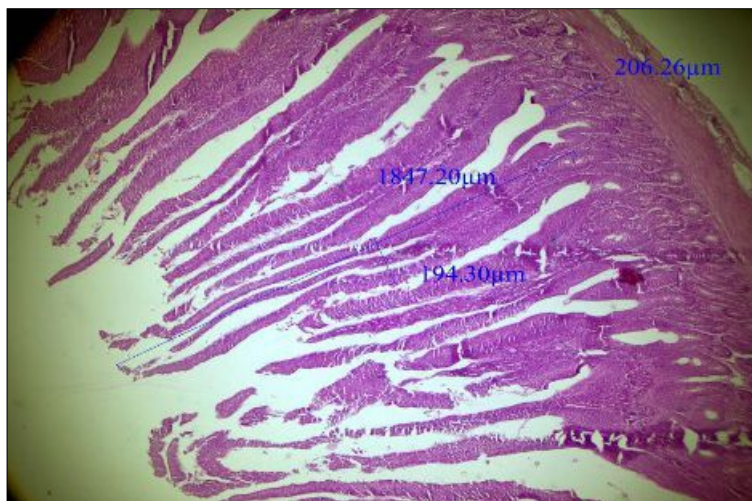


Fig 4: Effect of dietary supplementation of cinnamaldehyde (300 mg/kg feed) showed significant increase in villi height and villi width and decrease in crypt depth of Jejunum in broilers on 42nd day (H & E Stain, 10X)



Fig 5: Section of Ileum of control group showing normal architecture of villi height, villi width and crypt depth in broilers on 42nd day (H & E Stain, 10X)

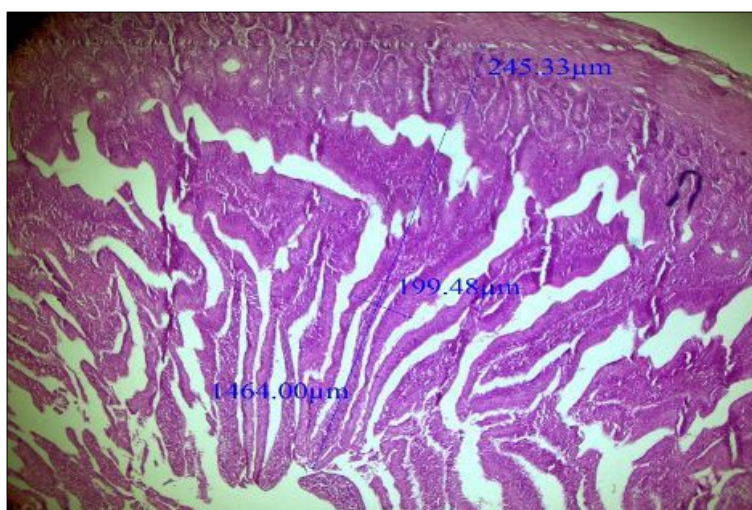


Fig 6: Effect of dietary supplementation of cinnamon powder (5 g/kg feed) showed significant increase in villi height and villi width and decrease in crypt depth of ileum in broilers on 42nd day (H & E Stain, 10X)

Conclusion

Dietary supplementation of cinnamon powder (5 and 10 g/kg feed) and cinnamaldehyde (150 and 300 mg/kg feed) for 42 days resulted in a significant increase in body weight

and body weight gain of broilers compared to the control group, with performance comparable to that of birds receiving the standard antibiotic growth promoter avilamycin. Total feed consumption of birds supplemented

with cinnamon powder and cinnamaldehyde did not differ significantly from the control and was also comparable to the antibiotic-supplemented group, indicating that these phytogetic additives had no adverse effect on feed intake. Feed conversion ratio was significantly improved in birds supplemented with cinnamon powder and cinnamaldehyde compared to the control and was similar to that observed in the avilamycin-supplemented group. Intestinal histomorphological analysis revealed that supplementation with cinnamon powder and cinnamaldehyde significantly increased villus height, villus width, and villus height-to-crypt depth (VH/CD) ratio in the duodenum, jejunum, and ileum. Additionally, a significant reduction in crypt depth was observed in the jejunum and ileum at 42 days of age, which may have contributed to improved nutrient absorption and growth efficiency in broilers. Overall, cinnamon powder at 5 g/kg feed and cinnamaldehyde at 300 mg/kg feed demonstrated growth-promoting effects comparable to those of standard antibiotic supplementation. Therefore, these phytogetic additives may be considered effective and safe alternatives to antibiotic growth promoters in broiler production.

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