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# Comparative Effects of Non-Antibiotic Growth Promoters and Antibiotics on the Performance of Broiler Chickens

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## ABSTRACT

This study evaluated the effects of non-antibiotic growth promoters and an antibiotic on the performance of broiler chickens. A total of 150-day-old Lohmann Meat broiler chicks were randomly assigned to five dietary treatments with three replicates per treatment and 10 birds per replicate for 28 days. The treatments were: basal diet without supplementation ($T_0$), phytogenic blend with organic acids at 100 g/ton ($T_1$), lysozyme at 500 g/ton ($T_2$), cinnamon at 500 g/ton ($T_3$), and bacitracin at 500 g/ton ($T_4$). Dietary treatments significantly influenced feed intake, body weight gain, feed conversion ratio, and flock uniformity ($P < 0.05$). Birds fed the phytogenic blend, lysozyme, and cinnamon showed higher feed intake and body weight gain than the control and bacitracin groups. Feed conversion ratio improved in all supplemented groups, with the lowest value observed in the cinnamon group, followed by the phytogenic blend and lysozyme. Weekly results further showed significant treatment effects on body weight gain and feed conversion ratio across different growth stages, particularly in the later phase. Bacitracin supplementation did not confer comparable performance benefits and was associated with reduced overall performance. The findings indicate that phytogenic additives, essential oils, organic acids, and lysozyme can enhance broiler growth performance and feed efficiency, and may serve as effective alternatives to antibiotic growth promoters in broiler production.

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## Introduction

The global poultry industry has experienced rapid expansion over the past few decades to meet rising demand for affordable animal protein. Broiler chickens, in particular, play a crucial role in this sector due to rapid growth rate and efficient feed conversion. Faster growth in the poultry industry lowers egg and meat prices, making these foods more affordable and improving living standards. For this reason, antibiotic growth promoters (AGPs) have been widely used worldwide in poultry production to support bird health and improve feed efficiency, thereby increasing growth rates (Plata et al., 2022). However, the improper use of AGPs has led to the development of pathogens that show resistance to antibiotics such as fluoroquinolones, vancomycin, and third- and fourth-generation cephalosporins, which resulted in a complete ban on AGPs in animal feed across the European Union (Collignon et al., 2009; Huyghebaert et al., 2011). In addition, antibiotic residues contribute to the rise of antimicrobial resistance in both animals and humans, posing serious risks to public health (Shao et al., 2021). Therefore, the development of effective alternatives to AGPs has become essential to meet the growing demand for poultry production while reducing the risk of antimicrobial resistance and its associated impacts on both animal and human health.

Plant extracts and their associated bioactive compounds have long been used in traditional medicine (Savoia, 2012). In recent years, these extracts have received growing attention in animal nutrition due to their positive effects on growth performance and overall health (Diaz et al., 2016). Plant-derived bioactive substances, including those from herbs and spices, exhibit antimicrobial, antifungal, antiparasitic, anti-inflammatory, and antioxidant properties (Lillehoj et al., 2018). Previous studies have shown that plant extracts supplementation can increase immune cells, improve intestinal integrity, and reduce oxidative stress through antioxidative and immunomodulatory effects (Abou-Elkhair et al., 2014).

Essential oils (EOs) derived from plants have attracted considerable attention as potential alternatives to antibiotics due to strong antimicrobial, antiviral, anticoccidial, antifungal, anti-inflammatory, antioxidant, and immunomodulatory properties (Yang et al., 2015; Zeng et al., 2015; El-Shall et al., 2020). In vitro studies have shown that plant-based essential oils (EOs), including thyme, carvacrol, cinnamaldehyde, and citral, can inhibit or eliminate both Gram-negative and Gram-positive bacteria, such as *Salmonella*, *E. coli*, *Campylobacter*, and *Clostridium perfringens*, while maintaining beneficial microorganisms like *Lactobacillus* spp. (Calo et al., 2015; Lopez Romero et al., 2015; Yang et al., 2015). Studies in broiler chickens have further demonstrated that EO-based products with diverse components improve growth performance and intestinal health, and reduce the adverse effects associated with pathogenic infections, including *Salmonella*, *E. coli*, *C. perfringens*, and coccidiosis (Alali et al., 2013; Yin et al., 2017; Liu et al., 2018; Wang et al., 2019; Gordillo Jaramillo et al., 2021).

Lysozyme (LZ) has emerged as a promising alternative due to broad-spectrum antimicrobial activity, immunomodulatory properties, and environmental safety (Masschalck and Michiels, 2003). The inclusion of exogenous LZ in broiler diets improves growth performance and intestinal health by disrupting the cell walls of pathogenic bacteria, suppressing inflammatory responses, and enhancing innate immunity (Abdel-Latif et al., 2024). Previous studies have reported that LZ, when used as a feed additive, inhibits intestinal pathogenic bacteria such as *Salmonella* and *E. coli*, maintains intestinal microbial balance, and reduces the incidence of diarrhea (Tian et al., 2023).

Organic acids and their salts, applied either individually or in combination, have gained global recognition as promising alternatives to antibiotic growth promoters (Ebeid et al., 2022). These compounds have been incorporated into animal diets for many years due to their antibacterial properties, which lower the pH in the gastrointestinal tract. Organic acids improve growth performance by enhancing nutrient availability in feed, increasing nutrient solubility in the digestive tract, and promoting efficient digestion and absorption (Manvatkar et al., 2022). Organic acids (OAs) can serve as effective alternatives to antibiotics and also act as feed preservatives due to their antimicrobial properties. Previous studies have shown that dietary supplementation with OAs improves growth performance, enhances feed conversion efficiency, and increases protein utilization in broiler chickens (Nava et al., 2009; Adil et al., 2011).

Limited research has evaluated the efficacy of combined secondary plant compounds (such as cinnamon, capsaicin, carvacrol, and cineole), essential oils, and organic acids compared with individual plant-derived compounds and lysozyme on the growth performance of broiler chickens. Therefore, the present study aimed to evaluate the effects of both blended and individual phytogenic compounds on broiler performance, in comparison with lysozyme and antibiotic growth promoters under similar experimental conditions.

## Materials and Methods

### Place of work

The study was conducted at the poultry farm of Sher-e-Bangla Agricultural University, situated in Sher-e-Bangla Nagar, Dhaka-1207, Bangladesh. All experimental procedures were conducted in accordance with established guidelines for the care and use of animals in research.

### Experimental design and birds

A total of 150-day-old Lohmann Meat (Indian River strain) commercial broiler chicks, with an average initial body weight of 49 ± 0.2 g, were used in this experiment. The chicks were randomly assigned to five treatment groups, with three replicates per group and 10 birds per replicate. The study was conducted using a completely randomized design (CRD) over 28 days. The primary objective was to evaluate the potential of non-antibiotic growth promoters (Mixed or single secondary plant compounds, essential oils and lysozyme enzyme) in commercial broiler diets, with particular emphasis on their effects on growth performance.

**Dietary treatments**

Five dietary treatments were applied. The control group ($T_0$) received the basal commercial diet without supplementation. Treatment $T_1$ included 100 g/ton of a blend of secondary plant compounds and essential oils (cinnamon, capsaicin, carvacrol, and cineole) with organic acids. Treatment $T_2$ consisted of 500 g/ton lysozyme enzyme. Treatment $T_3$ included 500 g/ton cinnamon as a single plant compound and essential oil. Treatment $T_4$ received 500 g/ton bacitracin as an antibiotic growth promoter.

**Management practices**

Prior to the experiment, all components of the poultry shed, including the ceiling, walls, floor, feeders, and drinkers, were thoroughly cleaned and rinsed with water to ensure proper sanitation. The floor was then disinfected using an iodophor solution prepared at a rate of 3 ml per liter of water. Standard management practices remained consistent throughout the experimental period to ensure uniform rearing conditions.
At placement, day-old chicks were individually weighed and randomly assigned to electrically heated brooders for a 7-day brooding period. Following this initial phase, the birds were transferred to their respective experimental pens. The ambient temperature inside the broiler house was maintained at 34°C during the first week and subsequently reduced by approximately 3°C each week until it reached 23°C, which was then sustained for the remainder of the study. A lighting schedule of 23 hours of light and 1 hour of darkness was maintained during the brooding stage.

Birds were reared in floor pens measuring 3 ft × 2 ft, each provided with fresh rice husk litter at a uniform depth of approximately 3 cm to ensure proper bedding. Environmental parameters, including room temperature and relative humidity, were monitored daily using a digital thermometer and an automatic thermo-hygrometer. A standard vaccination program was followed: vaccines against Newcastle disease and infectious bronchitis were administered via eye drops on day 3, while vaccination against infectious bursal disease was provided through drinking water on days 9 and 17. Clean drinking water was supplied *ad libitum*, and feed was offered according to the age-specific nutritional requirements recommended for the Lohmann Meat strain. Each pen contained one feeder and one round drinker, adequately serving a group of 10 birds.

Commercial Kazi broiler starter and grower diets were procured from the local market. Feed was provided four times daily following the Indian River management guidelines, while drinking water was made available *ad libitum* and supplied twice daily. The feeding program was divided into two phases: starter (0-10 days) and grower (11-28 days). The experimental treatments involved supplementing the basal commercial feed with non-antibiotic growth promoters, including mixed or single secondary plant compounds, essential oils, and the enzyme lysozyme. The composition of the experimental diets for the respective treatment groups are presented in Table 1.

### Data Collection

Body weight (BW) was measured at weekly intervals on days 7, 14, 21, and 28. Body weight gain was determined by subtracting the initial body weight from the final body weight. Feed intake (FI) was estimated as the difference between the amount of feed provided and the residual feed. Feed conversion ratio (FCR) was calculated as the ratio of feed intake to body weight gain per pen.

**Table 1.** Nutrient Composition of Commercial Broiler Starter and Grower Ration

| **Broiler Starter Ration** | | **Broiler Grower Ration** | |
|---|---|---|---|
| **Name of nutrients** | **Percent present** | **Name of nutrients** | **Percent present** |
| Protein | 21.0% | Protein | 19.0% |
| ME (kcal/kg) | 3050 | ME (kcal/kg) | 3150 |
| Fiber | 5.0% | Fat | 6.0% |
| Ash | 8.0% | Lysine | 1.10% |
| Lysine | 1.20% | Methionine | 0.47% |
| Methionine | 0.49% | Cystine | 0.39% |
| Cystine | 0.40% | Tryptophan | 0.18% |
| Tryptophan | 0.19% | Threonine | 0.75% |
| Threonine | 0.79% | Arginine | 1.18% |

### Statistical analysis

The data were analyzed using one-way ANOVA in SPSS (version 27). Differences among means were assessed with Duncan's Multiple Range Test, while significance was set at $P < 0.05$. The results are presented as standard error of the mean (SEM).

## Results and Discussion

### Growth performance

The effects of different dietary treatments on growth performance and feed efficiency parameters of broiler chickens were presented in Table 2. Dietary supplementation significantly influenced all measured variables ($P < 0.05$). Feed intake (FI) was significantly higher in birds receiving the phytogenic blend ($T_1$), lysozyme ($T_2$), and cinnamon ($T_3$) compared to the control ($T_0$) and antibiotic group ($T_4$). The lowest FI was observed in $T_4$, while $T_1$ showed the highest intake. Body weight gain (BWG) followed a similar trend, where $T_1$, $T_2$, and $T_3$ exhibited significantly greater body weight gains than $T_0$ and $T_4$. Among the treatments, $T_1$ achieved the highest BWG, indicating improved growth performance with the phytogenic blend. Feed conversion ratio (FCR) was significantly improved (lower values) in all supplemented groups compared to the control. The best FCR was recorded in $T_3$, followed by $T_1$ and $T_2$, whereas the control group showed the poorest feed efficiency. Flock uniformity (%) also differed significantly among treatments. The highest uniformity was observed in $T_0$ and $T_3$, while $T_4$ showed the lowest value, indicating greater variation among birds in the antibiotic-treated group. Overall, the results demonstrate that non-antibiotic growth promoters, particularly phytogenic compounds and essential oils, enhanced growth performance and feed efficiency compared to both the control and antibiotic treatments**.**

**Table 2.** Effect of Dietary Treatments on Growth Performance and Feed Efficiency of Broiler Chickens

| Parameters | Treatments | | | | | P-value |
|---|---|---|---|---|---|---|
| | $T_0$ | $T_1$ | $T_2$ | $T_3$ | $T_4$ | |
| Feed intake (g/bird) | $2196.67^{b}\pm9.17$ | $2266.00^{a}\pm10.39$ | $2242.50^{a}\pm17.96$ | $2242.50^{a}\pm10.86$ | $2154.67^{c}\pm15.09$ | <0.001 |
| Body weight gain (g/bird) | $1530.33^{b}\pm9.52$ | $1658.67^{a}\pm14.31$ | $1627.00^{a}\pm11.84$ | $1650.33^{a}\pm9.95$ | $1548.67^{b}\pm14.26$ | <0.001 |
| Feed conversion ratio (FCR) | $1.44^{a}\pm0.00$ | $1.37^{cd}\pm0.01$ | $1.38^{bc}\pm0.00$ | $1.36^{d}\pm0.01$ | $1.39^{b}\pm0.00$ | <0.001 |
| Flock uniformity (%) | $72.33^{a}\pm3.28$ | $68.00^{ab}\pm3.51$ | $66.00^{ab}\pm1.00$ | $71.67^{a}\pm4.41$ | $58.33^{b}\pm0.33$ | 0.044 |

Here, $T_0$ = Control; $T_1$ = 100 g/ton phytogenic blend + OA; $T_2$ = 500 g/ton lysozyme; $T_3$ = 500 g/ton cinnamon; $T_4$ = 500 g/ton bacitracin. Values are expressed as mean ± standard error of the mean (SEM). Different superscripts (a-d) within the same row indicate statistically significant differences among treatments at $P < 0.05$.

The findings of the present study indicate that non-antibiotic growth promoters positively influenced growth performance and feed efficiency in broiler chickens. These findings are consistent with previous studies reporting that phytogenic additives and essential oils (EOs) can enhance broiler performance by improving nutrient digestion and absorption (Elmowalid et al., 2022). The improved performance may be attributed to the stimulatory effects of these additives on digestive enzyme activity and gut health, which enhance nutrient retention and utilization. Although some studies have reported no significant effects of EO supplementation on growth traits such as ADG, ADFI, and FCR (Pham et al., 2023), the current results align with the majority of literature demonstrating significant improvements in growth performance and feed efficiency with phytogenic supplementation (Bendary et al., 2022; Hashem et al., 2022; Ibrahim et al., 2022). Similarly, the combined use of organic acids and essential oils has been shown to improve growth and feed utilization (Polycarpo et al., 2017), which is consistent with the enhanced performance observed in the phytogenic blend-supplemented group. The variation observed among studies may be due to variations in the type, dosage, dietary composition, environmental conditions, management practices, and age of birds (Zeng et al., 2015). In contrast to previous findings that reported no significant effect of phytogenic supplementation on feed intake (Oso et al., 2019), the present study observed a significantly higher feed intake in birds receiving phytogenic and enzyme-based additives, which may be associated with enhanced feed palatability and improved digestive function. Furthermore, the relatively lower performance and poorest flock uniformity observed in the antibiotic-treated group indicate that non-antibiotic alternatives may provide more consistent growth responses. Overall, the findings of this study confirm that phytogenic compounds, lysozyme, and cinnamon can effectively enhance growth performance and may serve as viable alternatives to antibiotic growth promoters in broiler production.

**Weekly feed intake**

Weekly feed intake differed among dietary treatments at specific growth stages (Table 3). In the first week, birds receiving $T_1$ (100 g/ton phytogenic blend + organic acids), $T_2$ (500 g/ton lysozyme), and $T_3$ (500 g/ton cinnamon) showed higher feed intake compared with the control ($T_0$) and $T_4$ (500 g/ton bacitracin). During the second week, no statistically significant differences appeared among treatments (P = 0.149). In the third week, marked differences were observed (P < 0.001). The highest feed intake occurred in $T_1$, followed by $T_2$, $T_3$, and $T_4$, whereas the control group recorded the lowest intake. By the fourth week, $T_1$, $T_2$, and $T_3$ maintained feed intake levels comparable to the control, while $T_4$ exhibited a significantly lower intake than all other treatments (P < 0.001). Overall, phytogenic supplementation combined with organic acids ($T_1$) consistently supported higher feed intake, particularly during the later growth phase, whereas bacitracin supplementation ($T_4$) reduced feed intake during the final week. These findings indicate that dietary interventions have time-dependent effects on feed intake in broiler chickens.

The lack of significant differences during the second week is consistent with the findings of Pham et al. (2023), Adewole et al. (2021), and Yang et al. (2018), who reported no effect of essential oils and organic acids on feed intake during the early growth phase (1-21 days). This consistency suggests that such additives may have a limited influence on feed intake during this period. However, significant differences in feed intake during the first, third, and fourth weeks suggest that responses to dietary treatments vary across growth stages. The increased feed intake in birds receiving phytogenic additives and organic acids may reflect improved gut health and nutrient utilization. Huang et al. (2024) also reported significant effects of essential oils and organic acids on feed intake during early growth, partially supporting the present findings. Furthermore, the significant variation across weeks aligns with Chen et al. (2025), who observed that lysozyme supplementation influenced feed intake at different growth stages. The reduced feed intake in the bacitracin group during the fourth week suggests differential responses between antibiotic and non-antibiotic additives. Overall, these results indicate that the effects of dietary additives on feed intake vary across growth phases and are more pronounced in later stages of development.

**Table 3.** Effect of Dietary Treatments on Weekly Feed Intake of Broiler Chickens

| Weeks | Treatments | | | | | P-value |
|---|---|---|---|---|---|---|
| | $T_0$ | $T_1$ | $T_2$ | $T_3$ | $T_4$ | |
| 1st weeks | $228.33^{b}\pm4.05$ | $245.67^{a}\pm4.97$ | $241.33^{a}\pm2.33$ | $248.33^{a}\pm4.40$ | $236.00^{ab}\pm2.08$ | 0.024 |
| 2nd week | $404.67^{a}\pm3.75$ | $388.33^{a}\pm1.45$ | $394.50^{a}\pm5.05$ | $387.83^{a}\pm6.64$ | $397.50^{a}\pm5.25$ | 0.149 |
| 3rd Week | $678.33^{d}\pm4.25$ | $726.00^{a}\pm3.00$ | $708.67^{b}\pm1.76$ | $696.00^{c}\pm2.51$ | $697.33^{bc}\pm5.69$ | <0.001 |
| 4th Week | $885.33^{a}\pm4.80$ | $906.00^{a}\pm6.65$ | $898.00^{a}\pm12.22$ | $910.33^{a}\pm4.40$ | $823.83^{b}\pm8.85$ | <0.001 |

Here, $T_0$ = Control; $T_1$ = 100 g/ton phytogenic blend + OA; $T_2$ = 500 g/ton lysozyme; $T_3$ = 500 g/ton cinnamon; $T_4$ = 500 g/ton bacitracin. Values are expressed as mean ± standard error of the mean (SEM). Different superscripts (a-d) within the same row indicate statistically significant differences among treatments at P < 0.05.

### Weekly body weight gain

Table 4 summarizes the weekly body weight gain (BWG) of broiler chickens subjected to five different dietary treatments ($T_0$ -$T_4$). During the first week, dietary treatments showed a significant effect on BWG (P = 0.005). The highest BWG was observed in $T_1$ (233.67 ± 5.55 g), which remained statistically similar to $T_3$ (229.33 ± 5.61 g), while $T_2$ (220.33 ± 2.91 g) occupied an intermediate position. The control group $T_0$ (204.33 ± 4.06 g) recorded the lowest BWG. In the second week, no significant differences were found among treatments (P = 0.431), with BWG values ranging narrowly between 291.33 ± 3.18 g ($T_3$) and 300.00 ± 1.53 g ($T_0$). A significant effect of dietary treatment was evident in the third week (P < 0.001). The highest BWG was observed in $T_1$ (561.00 ± 1.73 g), followed by $T_3$ (550.67 ± 2.33 g). Intermediate values were recorded for $T_2$ (534.00 ± 3.79 g) and $T_4$ (526.00 ± 2.52 g). In contrast, the control group ($T_0$) showed the lowest BWG (501.33 ± 4.18 g) and differed significantly from all supplemented treatments. In the fourth week, significant differences among treatments were observed (P < 0.001). Higher BWG was recorded in $T_1$ (566.67 ± 8.82 g), $T_2$ (577.33 ± 7.22 g), and $T_3$ (579.00 ± 2.08 g), with no significant differences among these groups. In contrast, $T_4$ (511.00 ± 8.50 g) showed lower BWG, while the control group ($T_0$; 524.67 ± 2.67 g) recorded lower values than most supplemented treatments. Overall, $T_1$ and $T_3$ resulted in improved growth performance, particularly during the later growth phase.

A significant improvement in BWG during the first week and the absence of differences in the second week suggest a variable response during the early growth phase. This observation partially agrees with Pham et al. (2023), who reported no significant effect of essential oils and organic acids (EOA) on average daily gain (ADG) during 1-21 days. Similarly, the lack of differences in the second week in the current study supports the findings of Yang et al. (2018), who observed no effect of EOA supplementation during the early period. In contrast, Zhang et al. (2021) reported enhanced ADG during 1-21 days and across the entire rearing period with essential oil supplementation, which aligns with the present results showing improved BWG in the first, third and fourth weeks. However, the absence of differences in the second week indicates that the response to dietary additives may not be consistent throughout the starter phase. Adewole et al. (2021) reported a reduction in BWG during the starter phase (0-14 days) with supplementation of organic acids and essential oils, which contrasts with the higher BWG observed in supplemented groups during the first week in the present study. During the later growth stages, the improved BWG observed in supplemented groups corresponds with the findings of Li et al., 2025, who reported enhanced ADG during the finisher phase following essential oil supplementation. Huang et al. (2024) reported significant effects of essential oils and organic acids on BWG during 1-21 days but not thereafter, whereas the present results showed significant differences reappearing in the third and fourth weeks. This variation may reflect differences in additive combinations or dosage levels. Furthermore, the response observed with lysozyme supplementation in the present study is largely consistent with that reported by Chen et al. (2025), who found significant effects on BWG across different weeks; however, the absence of significance during the second week in the current study suggests a transient period of reduced responsiveness. Overall, the findings suggest that non-antibiotic growth promoters, particularly phytogenic additives, improve growth performance, though their efficacy varies across growth phases.

**Table 4.** Effect of Dietary Treatments on Weekly Body Weight Gain of Broiler Chickens

| **Weeks** | **Treatments** | | | | | **P-value** |
|---|---|---|---|---|---|---|
| | **$T_0$** | **$T_1$** | **$T_2$** | **$T_3$** | **$T_4$** | |
| 1st week | $204.33^{c}$±4.06 | $233.67^{a}$±5.55 | $220.33^{ab}$±2.91 | $229.33^{a}$±5.61 | $213.67^{bc}$±3.48 | 0.005 |
| 2nd week | $300.00^{a}$±1.53 | $297.33^{a}$±2.19 | $295.33^{a}$±4.63 | $291.33^{a}$±3.18 | $298.00^{a}$±3.61 | 0.431 |
| 3rd week | $501.33^{d}$±4.18 | $561.00^{a}$±1.73 | $534.00^{c}$±3.79 | $550.67^{b}$±2.33 | $526.00^{c}$±2.52 | <0.001 |
| 4th week | $524.67^{b}$±2.67 | $566.67^{a}$±8.82 | $577.33^{a}$±7.22 | $579.00^{a}$±2.08 | $511.00^{a}$±8.50 | <0.001 |

Here, $T_0$ = Control; $T_1$ = 100 g/ton phytogenic blend + OA; $T_2$ = 500 g/ton lysozyme; $T_3$ = 500 g/ton cinnamon; $T_4$ = 500 g/ton bacitracin. Values are expressed as mean ± standard error of the mean (SEM). Different superscripts (a-d) within the same row indicate statistically significant differences among treatments at P < 0.05.

### Weekly Feed Conversion Ratio

The weekly feed conversion ratio (FCR) of broiler chickens under different dietary treatments ($T_0$-$T_4$) is presented in Table 5. In the first week, dietary treatments had a significant effect on FCR (P = 0.001). The lowest FCR was recorded in $T_1$ (1.05 ± 0.00), followed by $T_3$ (1.08 ± 0.01). Intermediate values were observed in $T_2$ (1.09 ± 0.00) and $T_4$ (1.10 ± 0.01), while the highest FCR occurred in the control group ($T_0$; 1.11 ± 0.00). In the second week, significant differences were also observed (P = 0.033). $T_1$ (1.30 ± 0.01) showed a lower FCR compared to $T_0$ (1.35 ± 0.01), $T_2$ (1.33 ± 0.00), and $T_4$ (1.33 ± 0.00), while $T_3$ (1.33 ± 0.01) did not differ significantly from $T_2$ and $T_4$. During the third week, the effect of treatments was highly significant (P < 0.001).

The lowest FCR was recorded in $T_3$ (1.27 ± 0.01), followed by $T_1$ (1.29 ± 0.00). $T_2$ (1.33 ± 0.01) and $T_4$ (1.32 ± 0.00) showed higher values, whereas the control group ($T_0$; 1.35 ± 0.00) showed the highest FCR. In the fourth week, significant differences among treatments were observed ($P < 0.001$). The lowest FCR was recorded in $T_2$ (1.55 ± 0.03), followed by $T_3$ (1.57 ± 0.00) and $T_1$ (1.60 ± 0.01). $T_4$ (1.61 ± 0.01) exhibited a higher FCR, while the control group ($T_0$; 1.69 ± 0.01) showed the highest value. Dietary treatments resulted in lower FCR than the control, with reductions observed at $T_1$ and $T_3$ across several growth periods.

The present study demonstrated that dietary treatments significantly influenced FCR throughout all growth periods, with improved efficiency observed in supplemented groups compared to the control. This finding contrasts with Adewole et al. (2021), who reported no significant effect of dietary additives on FCR, indicating possible variation due to differences in feed composition, additive type, or experimental conditions. The improvement in FCR observed in the current study is consistent with the findings of Pham et al. (2023), who reported improved FCR with supplementation of essential oils and organic acids, particularly during the later growth phase. Similarly, Zhang et al. (2021) reported improved FCR during 1-21 days in essential oil-supplemented groups compared to control and antibiotic treatments, which agrees with the present results, in which improved FCR was observed from the first week and continued through the third and fourth weeks.

Huang et al. (2024) observed significant effects of essential oils and organic acids on FCR during 1-21 days but no effect thereafter, whereas the present findings show significant differences across all weeks. In contrast, Greene et al. (2022) and Yang et al. (2018) reported no effect of essential oils or organic acids on FCR during the early growth phase (1-21 days), which is inconsistent with the current results. Furthermore, the response to lysozyme supplementation in the present study is supported by Chen et al. (2025), who reported significant differences in FCR across different growth periods. Overall, the results indicate that non-antibiotic growth promoters, particularly phytogenic additives and enzymes, improve feed efficiency in broiler chickens, although responses vary with dietary formulation and management conditions.

**Table 5.** Effect of Dietary Treatments on Weekly Feed Conversion Ratio of Broiler Chickens

| Weeks | Treatments | | | | | P-value |
|---|---|---|---|---|---|---|
| | $T_0$ | $T_1$ | $T_2$ | $T_3$ | $T_4$ | |
| 1st week | $1.11^{a}$±0.00 | $1.05^{c}$±0.00 | $1.09^{ab}$±0.00 | $1.08^{b}$±0.01 | $1.10^{ab}$±0.01 | 0.001 |
| 2nd week | $1.35^{a}$±0.01 | $1.30^{b}$±0.01 | $1.33^{a}$±0.00 | $1.33^{ab}$±0.01 | $1.33^{a}$±0.00 | 0.033 |
| 3rd week | $1.35^{a}$±0.00 | $1.29^{c}$±0.00 | $1.33^{b}$±0.01 | $1.27^{d}$±0.01 | $1.32^{b}$±0.00 | <0.001 |
| 4th week | $1.69^{a}$±0.01 | $1.60^{bc}$±0.01 | $1.55^{d}$±0.03 | $1.57^{cd}$±0.00 | $1.61^{b}$±0.01 | <0.001 |

Here, $T_0$ = Control; $T_1$ = 100 g/ton phytogenic blend + OA; $T_2$ = 500 g/ton lysozyme; $T_3$ = 500 g/ton cinnamon; $T_4$ = 500 g/ton bacitracin. Values are expressed as mean ± standard error of the mean (SEM). Different superscripts (a-d) within the same row indicate statistically significant differences among treatments at $P < 0.05$.

## Conclusion

The present study demonstrates that non-antibiotic growth promoters, including phytogenic compounds, essential oils, and lysozyme, enhance growth performance and feed efficiency in broiler chickens compared to both control and antibiotic-treated groups. The phytogenic blend and cinnamon showed significant improvements in body weight gain and feed conversion ratio, particularly during the later growth phase. Lysozyme supplementation also enhanced growth performance, although responses varied across growth stages. In contrast, antibiotic supplementation did not provide comparable benefits and showed lower overall performance. These findings confirm that non-antibiotic alternatives can serve as effective substitutes for antibiotic growth promoters in broiler production.

## Conflict of interest

We declare that we have no financial or personal relationships with any other individuals or organizations that could inappropriately influence our work. We confirm that the manuscript has been read and approved by all named authors. The manuscript has not been published previously.

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