International Journal of Advanced Biochemistry Research

ISSN Print: 2617-4693
ISSN Online: 2617-4707
NAAS Rating (2025): 5.29
IJABR 2025; 9(10): 664-670
www.biochemjournal.com
Received: 19-08-2025
Accepted: 20-09-2025

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Effect of supplementing combination of natural thiosulfinate, cinnamaldehyde and naphthoquinones on growth performance in commercial broilers

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DOI: https://www.doi.org/10.33545/26174693.2025.v9.i10i.6145

Abstract
An experiment was conducted for a period of 42 days to study the effect of supplementing herbal extract combination of natural thiosulfinate, cinnamaldehyde and naphthoquinones (TCN) on growth performance of commercial broilers. A total of 200, day-old commercial broiler chicks of uniform weight were selected and grouped into four treatments *viz.*, T_1 (Control- basal diet), T_2 (basal diet with standard antibiotic – 250mg/kg of feed), T_3 (basal diet with combination of natural thiosulfinate, cinnamaldehyde and naphthoquinones – [TCN combination] supplemented at 250 mg/kg diet) and T_4 (basal diet with TCN supplemented at 500 mg/kg diet). Diets and supplements were analyzed for nutrient composition as per AOAC (2005) method. Birds were reared on deep litter system under standard managemental practices. The results indicated that the TCN combination supplemented at 250 mg/kg (T_3) and 500 mg/kg (T_4) diet revealed significantly ($P \leq 0.05$) increased cumulative body weight compared to control group (T_1), whereas cumulative body weight was non-significant with antibiotic supplemented group (T_2). While higher body weight was observed in group supplemented with combination of herbal extracts at 500 mg/kg diet (T_4) than group supplemented with 250 mg/kg (T_3). The herbal extract combination of TCN at 250 mg/kg (T_3) and 500 mg/kg (T_4) in broilers diet showed non- significant ($P > 0.05$) difference in cumulative feed consumption (g) compared to T_1 and T_2 groups. Feed conversion ratio (FCR) for the TCN supplementation at 250 mg/kg (T_3) and 500 mg/kg (T_4) diet revealed significantly ($P \leq 0.05$) better cumulative feed conversion ratio values when compared to control group (T_1) whereas non-significant with antibiotic supplemented group (T_2). While better FCR was observed in group supplemented with combination of herbal extracts at 500 mg/kg diet (T_4) than the group supplemented with 250 mg/kg (T_3). Based on the results of the experiment, it was concluded that the supplementing herbal extracts combination of natural thiosulfinate, cinnamaldehyde and naphthoquinones {TCN} at 500 mg/kg broiler diets was beneficial with respect to cumulative body weight and feed conversion ratio in broilers.

Keywords: Broilers, herbal extracts natural thiosulfinate, cinnamaldehyde and naphthoquinones, growth performance

Introduction
The poultry industry plays important role in livestock sector for human food consumption as protein source and has a major role in poverty alleviation ensuring food security and generating family income (Mack *et al*., 2005) [20]. The modern intensive farming, high stocking densities, impressive genetic improvement and high yield requirements make commercial broilers vulnerable to different stressors, especially immunological stress. In livestock feeding, increased use of antibiotic growth promoters has led to significant risk of microbial resistance. Hence, complete ban on antibiotics in poultry feeds was brought into force on 1st January, 2006 by the European Union, so all of the antibiotic growth promoters (AGP's) used at sub-therapeutic levels for growth promotion were withdrawn and its use is only permitted for healing purposes (Windisch *et al*., 2008) [34].
With restrictions on antibiotics, the industry is increasingly adopting alternative feed additives to maintain bird health and growth. Herbal feed extracts or photobiotic are usually safe natural plant derivatives from herbs, spices, essential oils and oleoresins are drawing much attention because of ban on antibiotics in poultry industry. *Allium sativum* commonly

known as Garlic, is a species in the genus *Allium*. belongs to the plant family *Liliaceae* is a source particularly rich in organosulfur compounds called thiosulfinates also called allicin which are responsible for its flavor, aroma, therapeutic properties and potential health benefits (Lanzotti, 2006) [17]. Biological and health properties of garlic are derived from its organosulfur compounds, particularly thiosulfinates in which the allicin is major sulfur-containing compound in intact garlic which represents 70 - 80 per cent of the total thiosulfinates (Ozolin *et al*., 1990) [23]. Garlic extract with Sulphur containing compounds like thiosulfinates have improved performance with better body weight, feed efficiency, better gut health and carcass characteristics in broilers and can be a potential alternative for antibiotics (Onibi *et al*., 2009) [22].

Peinado *et al*. (2012) [25] conducted experiment on effects of dietary supplementation of garlic derived product propyl propane thiosulfinate (PTSO) in broilers supplemented at 45 and 90 mg/kg diet and revealed significantly higher ($P \leq 0.01$) body weight and better feed conversion ratio in thiosulfinates fed groups compared to control group. Whereas, thiosulfinates fed groups showed no significant ($P > 0.05$) effect on feed intake at any dose compared to control group.

Cinnamon (*Cinnamomum verum*) belongs to the genus *Cinnamomum* and family *Lauraceae*. Cinnamon consists of a variety of resinous bioactive compounds including cinnamaldehyde, cinnamate, cinnamic acid and other numerous essential oils. Cinnamon and their bioactive compounds have mechanism of actions based on the alteration of the intestinal microbiota, increased enzyme secretion, improved immune response and better histomorphological maintenance of the GIT (Brugalli, 2003) [4]. Better intestinal health and high digestibility of nutrients in broilers are extremely important in order to attain higher body weight and better FCR (Roberts *et al*., 2015) [29]. Cinnamon added in diet of broilers at various levels has positive impact on the performance in terms of body weight gain, feed intake, feed conversion ratio and blood profile (Chowlu *et al*., 2018) [7].

Pathak *et al*. (2017) [24] conducted an experiment on replacing antibiotic growth promoter (AGP) with a combination of cinnamaldehyde and calcium formate in broilers. Here, enramycin (AGP) fed at 125 mg/kg feed fed in T_2, combination of cinnamaldehyde and calcium formate fed at 500 mg/kg feed in T_3 and calcium formate alone fed at 500 mg/kg diet in T_4, respectively. Results showed that, body weight gain, FCR and survivability rates were significantly ($P \leq 0.05$) improved in cinnamaldehyde and calcium formate combination compared with enramycin, calcium formate and control groups. Saied *et al*. (2022) [31] studied the supplementation of dietary cinnamon oil in broilers at 0, 500, 1000 and 1500 mg/kg in T_1, T_2, T_3 and T_4, respectively. Results indicated that broilers fed with cinnamon oil had significantly ($P \leq 0.05$) higher body weight, weight gain and feed conversion ratio than the control group.

Henna plants are rich in bioactive compounds called naphthoquinones also called lawsone reported to exhibit both antifungal and antibacterial activity (Gull *et al*., 2013). Kiavandani *et al*. (2021) [16] evaluated *Lawsonia inermis* (henna) in broiler which T_1 supplemented basal diet, T_2 fed with flavophospholipol, T_3, T_4 and T_5 supplemented henna at 0.15%, 0.20% and 0.25%, respectively. Result showed henna fed groups had significantly ($P \leq 0.05$) higher body weight than broilers fed the control diet and flavophospholipol. Whereas, no significant ($P > 0.05$) effect was seen in feed conversion ratio, feed intake and mortality rate in all treatment groups the increase in the body weight could be due to the increase of the *lactobacillus* species count caused by the addition the henna on the diets.

In broilers, data on effect of supplementing garlic, cinnamon and henna are available whereas the effect of extracts of these herbs like natural thiosulfinate, cinnamaldehyde and naphthoquinones and combination (TCN) are not available, hence the present study was undertaken with the objective to study the effect of supplementing combination of natural thiosulfinate, cinnamaldehyde and naphthoquinones on growth performance in broilers.

Materials and Methods

Design of Experiment: A total of two hundred, day-old commercial broiler chicks of uniform body weight were procured from the Venkateshwara hatcheries private limited, Bengaluru. The chicks were wing banded, weighed and allocated randomly to four experimental groups each consisting of five replicates of ten chicks each. The chicks on 7th day were vaccinated with ND with B_1 strain followed by booster dose on 21st day through ocular or nasal route. On 14th day chicks were vaccinated against IBD intermediate vaccine followed by booster dose on 28th day through ocular route.

Procurement of feed ingredients and herbal extract feed supplements: Feed ingredients required for the formulation of the experimental diet were procured from the known sources. The herbal extract feed supplements used in the trial were a combination of natural thiosulfinate, cinnamaldehyde and naphthoquinones (Promogen) procured from Quadragen Vet Health Private Limited, Bengaluru. The herbal extract feed supplements were extracted by accelerated natural biotransformation (ANBiot) technology contained thiosulfinates -70%, cinnamaldehydes -15% and naphthoquinones -15%, respectively. The extraction and analysis of herbal extract feed supplements combination was carried out at Chemlife Innovations Private Limited, Bengaluru.

Description of experimental design and diets: The broiler chicks were randomly assigned to one of the four dietary treatments: T_1 (control group) - basal diet without growth promoters, T_2 - basal diet with antibiotic growth promoter (Zinc bacitracin) incorporated at 250 mg/kg in broiler diet, T_3 - basal diet added with herbal extracts combination of natural thiosulfinate, cinnamaldehyde and naphthoquinones (TCN) at 250 mg/kg in broiler diet and T_4 - basal diet added with herbal extracts combination of natural thiosulfinate, cinnamaldehyde and naphthoquinones at 500 mg/kg in broiler diet.

Groups	Description of the treatment	No. of replicates	birds per replica	Total
T_1	Basal diet without growth promoter	05	10	50
T_2	Basal diet added with antibiotic growth promoter (AGP) supplemented at 250 mg/kg broiler diet	05	10	50
T_3	Basal diet added with herbal extracts combination TCN at 250 mg/kg broiler diet	05	10	50
T_4	Basal diet added with herbal extracts combination of natural TCN at 500 mg/kg broiler diet	05	10	50
Total				200

Formulation of experimental diet: A standard pre-starter, starter and finisher rations of experimental diets were formulated as per BIS (2007) [3] specifications and the basal diet was prepared which served as control group

Ingredients	Pre-starter (1 - 7 days)	Starter (8 - 21 days)	Finisher (22 - 42 days)
Yellow maize	53.10	56.00	59.50
Soya bean meal	40.50	36.70	32.50
Vegetable oil	2.50	3.45	4.30
Dicalcium phosphate	1.50	1.50	1.50
Common salt	0.35	0.30	0.30
Mineral mixture*	1.30	1.30	1.30
Vitamin premix	0.20	0.20	0.15
B complex	0.10	0.10	0.10
Trace minerals	0.05	0.05	0.05
DL-Methionine	0.30	0.30	0.30
Toxin binder	0.10	0.10	0.10
Total	100.0	100.0	100.0
Nutrient composition			
ME (Kcal/kg) [a]	3023.00	3091.00	3163.00
Crude protein (%) [b]	22.45	21.52	19.76
Calcium (%) [a]	1.01	1.01	1.01
Phosphorous (%) [a]	0.47	0.47	0.47
Lysine (%) [a]	1.21	1.24	1.09
Methionine (%) [a]	0.55	0.50	0.53

* Mineral mixture: Each 100 g contains Magnesium oxide - 1.48 g, Ferrous sulphate - 6.0 g, copper sulphate - 0.05 g, Manganese Sulphate - 0.04 g, Potassium Iodide - 0.001 g, Potassium Chloride - 17.09 g and Sodium selenite - 0.001 g.

Growth parameters: During the course of experiment the data on growth performance parameters *viz*., body weight, feed consumption, feed conversion ratio and survivability were collected as follows.

Weekly cumulative body weight: Body weight of individual birds was recorded at weekly intervals to study the growth rate. The weighing of the birds was done in the early hours of the day before feeding. Cumulative body weight at weekly intervals and at the end of the trial was recorded.

Weekly cumulative feed consumption: Average weekly cumulative feed consumption was recorded for each replication where a measured quantity of feed was daily offered to the experimental bird's replicate- wise. Average weekly cumulative feed consumption was recorded for each replication. Weekly feed consumption was arrived by subtracting the residual feed from the total feed provided during the respective week. The residual feed was added to the succeeding week feed supply to obtain cumulative feed consumption.

Weekly cumulative feed conversion ratio (FCR): The feed conversion ratio (FCR) expressed as the ratio between the quantities of feed consumed (kg) to the body weight (kg) under each treatment of birds was determined.
The FCR was calculated by using the following formulae

$$\text{FCR (weekly)} = \frac{\text{Average feed consumption per bird during the week (Kg)}}{\text{Average weight gain per bird during the week (Kg)}}$$

$$\text{FCR (Cumulative)} = \frac{\text{Average feed consumption/bird at the end of trial (Kg)}}{\text{Average weight of bird at the end of trial (Kg)}}$$

Survivability per cent: Mortality of broilers in respective groups was noted as and when the birds died. Mortality per cent in each treatment during the experiment was recorded. The dead birds were subjected to detailed post-mortem examination to ascertain the cause of death. The survivability per cent was calculated by using the following formula.

$$\text{Survivability per cent} = \frac{\text{Number of birds survived}}{\text{Total number of birds housed at beginning}} \times 100$$

The data pertaining to various parameters of the trial were subjected to statistical analysis by one way analysis of variance (ANOVA) using SPSS 16 statistical software (Snedecor and Cochran, 1994) [32]. The statistical analysis was done at 95% level of significance ($P \leq 0.05$). The significant mean differences among the treatment groups were determined using Tukey's multiple comparison test.

Results and Discussion

Chemical Composition of experimental diets: The detailed chemical composition of the experimental diets used during the trial is presented in Table 1.

Weekly cumulative body weight: The findings of the treatment groups supplemented with the combination of natural thiosulfinate, cinnamaldehyde and naphthoquinones at 250 mg per kg diet (T_3) and 500 mg per kg diet (T_4) in broilers diet revealed significantly ($P \leq 0.05$) improved body weight on cumulative weekly basis at the end of third, fourth, fifth and sixth week compared to control group (T_1) fed with basal diet. Whereas, the cumulative body weights of groups T_3 and T_4 were non-significant ($P > 0.05$) with group supplemented with antibiotic at 250 mg/kg diet (T_2) presented in Table 2.
The results of cumulative body weight of experimental birds were in agreement with Peinado *et al*. (2012) [25] who supplemented garlic derived propyl propane thiosulfinates at 45 and 90 mg/kg in broiler diets revealed significantly ($P \leq 0.01$) higher cumulative body weight compared to control group. Similarly, Salem *et al*. (2017) studied the effect of garlic extract containing allicin in broilers (thiosulfinates) fed at 0 and 40 mg/kg diet and observed significantly ($P \leq 0.05$) increased body weight and he attributed the increased body weight to allicin compound present in garlic. Similarly, Dieumou *et al*. (2011) [10] supplemented garlic extract at 0, 40 and 60 mg/kg in broilers diet and reported significantly ($P \leq 0.05$) improved cumulative body weight and body weight gain. Adibmoradi *et al*. (2006) attributed increased body weight observed in broilers could be due to regenerated physiological structure of the intestinal epithelium by enhancing crypt depth and villus height by thiosulfinates supplementation led to better nutrient absorption because of increased surface area which ultimately supported digestive capacity. Pourali *et al*. (2010) [27] reported that allicin (thiosulfinate) present in garlic promoted the performance of the intestinal flora and enhanced the activity of pancreatic enzymes which lead to better energy utilization and improved growth rate in broilers.
Cumulative body weight of experimental birds were comparable with Chen *et al*. (2008) [6] who conducted a study in broilers fed with cinnamon extract cinnamaldehyde

at 150, 250 and 350 mg/kg in broilers diet, revealed significantly ($P \leq 0.05$) increased cumulative body weight and weekly weight gain. Similarly, Karadas *et al*. (2014) [15] also reported feeding a combination of cinnamaldehyde, carvacrol, and *capsicum oleoresin* at 100 mg per kg diet to broilers showed significantly ($P \leq 0.05$) improved cumulative body weight. The higher body weight in cinnamaldehyde supplemented group could be due to the active compound cinnamaldehyde present in cinnamon which acts as a digestibility enhancer balancing the gut microbial ecosystem and stimulating the secretion of endogenous digestive enzymes leading to improved growth performance in poultry (Lovkova *et al*., 2001) [19].

Adedeji *et al.* (2019) [1] who studied the effect of *Lawsonia inermis* (henna) on broilers fed at 10, 20, 30 and 40 g/kg diets and reported significantly ($P \leq 0.05$) improved weekly cumulative body weight while their highest performance was observed in 30 and 40 g/kg fed groups. Denil *et al*. (2003) [9] attributed increased body weight in broilers supplemented with *Lawsonia inermis* was due to better nutrient utilization by increased *Lactobacillus* species count. Similar results on improved body weight were reported by Mohamed *et al*. (2016) [21]; Pathak *et al*. (2017) [24]; Kiavandani *et al*. (2021) [16] and Saied *et al*. (2022) [31].

On the contrary, no significant ($P > 0.05$) effect on weekly cumulative body weight was reported by Petrolli *et al*. (2012) [26] with supplementation of garlic extract at 150 mg/kg and cinnamon extract at 100 mg/kg in broiler diets. Similarly, Lee *et al*. (2003) [18] who observed cinnamaldehyde in broilers diet supplemented at 100 ppm had no significant ($P > 0.05$) effect on body weight throughout experiment.

Cumulative feed consumption: The findings of the groups supplemented with the combination of natural thiosulfinate, cinnamaldehyde and naphthoquinones at 250 mg per kg diet (T_3) and 500 mg per kg diet (T_4) in broiler diets revealed no significant ($P > 0.05$) effect on cumulative feed consumption on weekly basis compared to T_1 and T_2 groups presented in Table 3.

A study conducted by Peinado *et al*. (2012) [25] on effect of garlic derived propyl propane thiosulfinates on broilers supplemented at 45 and 90 mg/ kg in diets had no significant ($P > 0.05$) effect on cumulative feed intake. Similarly, the non-significant ($P > 0.05$) difference in feed consumption was reported by Ciftci *et al*. (2009) [8] supplemented cinnamon oil at 500 and 1000 ppm (contains 60-75% of cinnamaldehyde) in broiler diets.

Similarly, Kiavandani *et al*. (2021) [16] supplemented henna at 0.15%, 0.20% and 0.25% broiler diets and revealed no significant ($P > 0.05$) effect on feed intake. Varmaghany *et al*. (2015) [33] reported that non-significant difference in feed consumption among the various garlic and their extract supplemented treatment groups attributed to the varied level of inclusion of garlic and their extracts. Similar results on non- significant difference in feed consumption were reported by Petrolli *et al*. (2012) [26]; Karadas *et al*. (2014) [15] and Brzoska *et al*. (2015) [5].

On contrary to the results noticed in this study, the improved feed consumption was noticed by Mohamed *et al*. (2016) [21] who supplemented allicin at 0, 25, 50, 75 and 100 mg/kg broilers diet and revealed significantly ($P \leq 0.05$) higher feed consumption. Similarly, Jamroz *et al*. (2003) [14] reported significantly ($P \leq 0.05$) increased feed consumption in broilers supplemented with 150 and 300 ppm of plant extract (XT) containing capsaicin, carvacrol and cinnamaldehyde. Similar results were reported by Dieumou *et al*. (2011) [10] and Adedeji *et al*. (2019) [1].

Feed conversion ratio: The findings of the groups supplemented with the combination of natural thiosulfinate, cinnamaldehyde and naphthoquinones at 250 mg per kg diet (T_3) and 500 mg per kg diet (T_4) in broiler diets revealed significantly ($P \leq 0.05$) better feed conversion ratio on weekly cumulative basis at the end of second, third, fourth, fifth and sixth week compared to control group. However, FCR remained non-significant ($P > 0.05$) with antibiotic fed group (T_2) presented in Table 4.

Reports of Peinado *et al*. (2012) [25] who conducted a study on effect of garlic derived propyl propane thiosulfinates on broilers supplemented at 45 and 90 mg/kg in diets revealed significantly ($P \leq 0.05$) better feed conversion ratio. Similarly, Zweil *et al*. (2016) studied on effect of allicin on broilers fed at 100, 200 and 300 mg/kg diets revealed significantly ($P \leq 0.05$) improved feed conversion ratio. The improved FCR could be attributed to garlic extract which increases the intestinal villus height, villus area, cell area and cell mitosis in the intestine leading to increased nutrient utilization and better feed efficiency (Incharoen *et al*., 2010) [12].

Effects of cinnamaldehyde supplementation studied by Jamroz and Kamel (2002) [13] with a dose of 1000 ppm in diet and reported significantly ($P \leq 0.05$) superior FCR in birds. The improvement of FCR was due to the active materials cinnamaldehyde found in cinnamon which increases efficiency in the utilization of feed by improving the immune system, regulating the gut micro flora, endogenous digestive enzymes secretion and eliciting antioxidant and antibacterial properties (Saeed *et al*., 2018) [30].

Further, Adedeji *et al*. (2019) [1] who reported *Lawsonia inermis* (henna) leaf meal supplemented at 0, 10, 20, 30 and 40 g/kg diets in broilers had significantly ($P \leq 0.05$) better FCR. However, supplementing higher level at 40 g/kg henna leaf meal showed superior FCR compared to other groups. Similar results on better FCR were reported by Saied *et al*. (2022) [31].On the contrary, non-significant ($P > 0.05$) improvement in feed conversion ratio was reported by Rahimi *et al*. (2011) [28] with supplementation of garlic extract at 0.1% in broiler diets and Petrolli *et al*. (2012) [26] with supplementation of both garlic extract at 150 mg/kg and cinnamon extract at 100 mg/kg diet in broilers diet. Similarly non-significant results on FCR were reported by Kiavandani *et al*. (2021) [16].

Survivability per cent: The survivability per cent for T_1, T_2, T_3 and T_4 was 96.43 ± 0.24, 98.14 ± 0.20, 96.57 ± 0.24 and 98.21 ± 0.20 respectively. The findings of the groups supplemented with the combination of natural thiosulfinate, cinnamaldehyde and naphthoquinones at 250 mg per kg diet (T_3) and 500 mg per kg diet (T_4) in broiler diets revealed no significant ($P > 0.05$) effect on survivability per cent compared to T_1 and T_2 groups.

The survivability per cent of experimental birds were in accordance with studies conducted by Elmowalid *et al*. (2019) [11] who reported dietary garlic supplemented at 0,1 and 2% in broilers had no significant ($P > 0.05$) effect on survivability per cent. Similarly, Ciftci *et al*. (2009) [8]

reported the effects of supplementing cinnamon oil in broilers at 500 and 1000 ppm (contains 60- 75% of cinnamaldehyde) diets had no significant ($P > 0.05$) effect on survivability percentage in all treatment groups. The mortality rate among the experimental birds was not affected which could be due to antimicrobial, antioxidant and antifungal properties of bioactive compounds thiosulfinates, cinnamaldehyde and naphthoquinones. Similar findings on survivability were reported by Symeon *et al*. (2014); Brzoska *et al*. (2015) [5] and Kiavandani *et al*. (2021) [16].

Table 1: Chemical composition of experimental diets compounded for different phases of trial in broilers.

Constituents%	Pre-starter diets				Starter diets				Finisher diets			
	T_1	T_2	T_3	T_4	T_1	T_2	T_3	T_4	T_1	T_2	T_3	T_4
Dry matter	89.76	90.13	89.75	91.83	89.64	91.29	90.88	91.77	89.67	89.87	89.60	89.81
Crude protein	22.45	22.31	22.18	22.38	21.52	21.42	21.35	21.28	19.76	20.1	19.95	20.26
Ether extract	6.18	6.24	6.31	6.01	7.31	7.26	7.06	7.15	7.79	7.30	7.80	8.23
Total Ash	6.32	6.38	6.71	6.65	6.85	7.11	7.37	7.18	7.25	7.43	7.16	7.39
Crude fiber	5.45	5.29	5.88	5.42	6.09	5.17	5.35	5.21	5.13	5.06	5.17	5.04
NFE	59.60	59.78	58.92	59.54	58.23	59.04	58.87	59.18	59.03	59.16	58.88	58.45
ME* (kcal/kg)	3023	3018	3013	3015	3091	3078	3067	3081	3163	3158	3145	3159

*Estimated value

Table 2: Effect of supplementing combination of natural thiosulfinate, cinnamaldehyde and naphthoquinones at 250 and 500 mg/kg diet on weekly cumulative body weight (g/week/bird) (Mean ± SE) in commercial broilers.

Group	Particulars	Body weight (g/bird/week)					
		1st Week	2nd Week	3rd Week	4th Week	5th Week	6th Week
T_1	Control group	160.62 ± 2.99	360.52 ± 5.93	678.12 ^{b} ± 13.18	1169.36 ^{b} ± 24.16	1710.44 ^{b} ± 38.17	2307.31 ^{b} ± 41.55
T_2	Antibiotics (250mg/kg diet)	162.33 ± 2.35	366.67 ± 6.19	719.46 ^{ab} ± 12.86	1227.89 ^{ab} ± 16.73	1815.02 ^{a} ± 19.36	2404.31 ^{a} ± 26.60
T_3	Herbal extracts TCN combination (250 mg/kg diet)	163.72 ± 2.71	369.94 ± 6.88	727.08 ^{a} ± 10.64	1245.48 ^{a} ± 18.55	1823.96 ^{a} ± 20.60	2433.13 ^{a} ± 33.62
T_4	Herbal extracts TCN combination (500 mg/kg diet)	166.34 ± 2.24	378.09 ± 5.93	749.72 ^{a} ± 10.76	1281.50 ^{a} ± 16.22	1839.00 ^{a} ± 23.71	2450.60 ^{a} ± 33.19

$^{a\,b}$ Means in the same column with no common superscript differ significantly ($P \leq 0.05$)

Table 3: Effect of supplementing combination of natural thiosulfinate, cinnamaldehyde and naphthoquinones at 250 and 500 mg/kg diet on weekly cumulative feed consumption (g/bird/week) (Mean ± SE) in commercial broilers.

Group	Particulars	Feed Consumption (g/bird/week)					
		1st Week	2nd Week	3rd Week	4th Week	5th Week	6th Week
T_1	Control group	146.65 ± 1.70	559.50 ± 5.77	1197.98 ± 21.86	2095.74 ± 23.79	3146.65 ± 19.06	4371.65 ± 5.68
T_2	Antibiotics (250 mg/kg diet)	141.53 ± 7.21	564.05 ± 7.50	1199.21 ± 11.57	2090.45 ± 17.30	3126.89 ± 20.65	4311.43 ± 20.41
T_3	Herbal extracts TCN combination (250 mg/kg diet)	137.52 ± 3.89	544.99 ± 5.23	1209.19 ± 8.02	2111.88 ± 31.14	3165.97 ± 33.80	4385.06 ± 32.15
T_4	Herbal extracts TCN combination (500 mg/kg diet)	141.07 ± 4.20	539.29 ± 9.40	1202.19 ± 13.54	2107.84 ± 25.78	3113.52 ± 28.90	4318.97 ± 30.14

Table 4: Effect of supplementing combination of natural thiosulfinate, cinnamaldehyde and naphthoquinones at 250 and 500 mg/kg diet on weekly cumulative feed conversion ratio (Mean ± SE) in commercial broilers.

Group	Particulars	CUMULATIVE FCR					
		1st Week	2nd Week	3rd Week	4th Week	5th Week	6th Week
T_1	Control group	0.915 ± 0.025	1.552 ^{a} ± 0.031	1.767 ^{a} ± 0.035	1.792 ^{a} ± 0.027	1.840 ^{a} ± 0.019	1.895 ^{a} ± 0.017
T_2	Antibiotics (250 mg/kg diet)	0.872 ± 0.039	1.538 ^{ab} ± 0.008	1.668 ^{ab} ± 0.030	1.702 ^{ab} ± 0.022	1.723 ^{b} ± 0.010	1.793 ^{b} ± 0.013
T_3	Herbal extracts TCN combination (250 mg/kg diet)	0.840 ± 0.027	1.473 ^{ab} ± 0.014	1.664 ^{ab} ± 0.025	1.696 ^{ab} ± 0.032	1.736 ^{b} ± 0.025	1.802 ^{b} ± 0.019
T_4	Herbal extracts TCN combination (500 mg/kg diet)	0.848 ± 0.023	1.429 ^{b} ± 0.042	1.604 ^{b} ± 0.028	1.645 ^{b} ± 0.027	1.693 ^{b} ± 0.023	1.762 ^{b} ± 0.016

$^{a,\,b}$ Means in the same column with no common superscript differ significantly ($P \leq 0.05$)

Summary and Conclusion

In the present experiment, supplementing herbal extracts combination of natural thiosulfinate, cinnamaldehyde and naphthoquinones at 250 mg/kg (T_3) and 500 mg/kg (T_4) diet revealed significantly ($P \leq 0.05$) increased cumulative body weight compared to control group (T_1), whereas cumulative body weight was non-significant with antibiotic supplemented group (T_2). While higher body weight was observed in group supplemented with combination of herbal extracts at 500 mg/kg diet (T_4) than group supplemented with 250 mg/kg (T_3).

The herbal extract combination of natural thiosulfinate, cinnamaldehyde and naphthoquinones at 250 mg/kg (T_3) and 500 mg/kg (T_4) in broilers diet revealed non- significant ($P > 0.05$) difference in cumulative feed consumption (g) compared to T_1 and T_2 groups. The combination of natural thiosulfinate, cinnamaldehyde and naphthoquinones at 250 mg/kg (T_3) and 500 mg/kg (T_4) diet revealed significantly ($P \leq 0.05$) better cumulative feed conversion ratio values when compared to control group (T_1) whereas non-significant with antibiotic supplemented group (T_2). While better FCR was observed in group supplemented with combination of

herbal extracts at 500 mg/kg diet (T_4) than group supplemented with 250 mg/kg (T_3).

Feeding combination of natural thiosulfinate, cinnamaldehyde and naphthoquinones (TCN) at 250 mg/kg (T_3) and 500 mg/kg (T_4) as supplement in broilers diet revealed non-significant ($P > 0.05$) difference in survivability per cent when compared to T_1 and T_2 groups.

Supplementing combination of natural thiosulfinate, cinnamaldehyde and naphthoquinones at 250 and 500 mg/kg broiler diets had beneficial effect on cumulative body weight and feed conversion ratio which could be due to therapeutic properties of bioactive compounds thiosulfinate, cinnamaldehyde and naphthoquinones present in garlic, cinnamon and henna extract.

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