

Effect of dietary citric acid with garlic (*Allium sativum*) powder on growth performance, carcass traits and production efficiency of broiler

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Abstract

The study was for assessment of effect of citric acid with garlic powder in various combinations on growth, nutrient digestibility, production efficiency and carcass traits of broiler birds. Two-hundred forty one-day old broiler chicks were distributed into 6 treatments as T-1 (control, rations without AGP or citric acid or garlic powder), T-2 (rations with AGP i.e. BMD @ 0.05g/kg), T-3 (rations with 0.5% citric acid and 0.4% garlic powder), T-4 (rations with 0.4% citric acid and 0.3% garlic powder), T-5 (rations with 0.3% citric acid and 0.2% garlic powder) and T-6 (rations with 0.2% citric acid and 0.1% garlic powder). Feeding trial was conducted for 6 weeks adopting standard managemental protocols under deep litter system. Metabolic trial for 3 days and carcass studies on four birds from each group were carried out starting at 42nd day. Results revealed significant effect of feeding citric acid with garlic powder on feed consumption from 3rd week onwards, and significant improvement of body weight gain in 1st, 4th and 5th weeks with increasing trends in the 2nd, 3rd and 6th weeks. Improvements in nutrient digestibility and carcass traits were recorded for dietary supplementation of citric acid with garlic powder. FCR was significantly better in T-3, followed by T-2 and T-4. At 6th week, EPEI was significantly highest in T-3 than other treatments. Based on the findings, dietary inclusion of 0.5% citric acid with 0.4% garlic powder was recommended to broiler birds as alternative to AGP and for improvement of growth, nutrient digestibility and production efficiency.

Keywords: Citric acid; garlic powder; growth; digestibility; production efficiency; broilers.

Introduction

The Indian poultry sector is one of the fastest-growing segments of the Agricultural sector in India which is expanding at a compound annual growth rate of 8.9%. India ranks 3rd in egg production and 5th largest poultry meat producer globally (APEDA, 2021). India's poultry industry not only plays a crucial role in food and nutritional security, but also livelihood to people who are associated directly or indirectly with this sector.

Despite its rapid growth, the poultry industry suffered many setbacks due to high feed costs, emergence of new or re-emerging existing diseases. Optimum feed efficiency is the top priority for a profitable poultry enterprise as feed cost accounts for 65-70% of total expenditure. To improve nutrient utilization and feed efficiency, many feed additives and supplements are used in broiler ration (Gobezie, 2022; Yonatan *et al.*, 2023). Antibiotic growth promoter is one such common additive which is incorporated to improve feed efficiency of broiler birds. The antibiotic growth promoters are known to control gastrointestinal infection and modify intestinal microbiome in favourable way (Singh *et al.*, 2013; Torok *et al.*, 2011) and thereby improving productivity for increased feed conversion, growth rate and disease prevention. However, after the European Union ban of antibiotic use in animal feeds since 1st January, 2006 (Catala-Gregori *et al.*, 2008) for risk of antimicrobial resistance and antibiotic residues, there have been gradual removal of antibiotics as therapeutic and prophylactic in food animals. But this has negatively affected broiler production for increased incidence of bacterial infection (Solis-Cruz *et al.*, 2019) and public health problems associated with food-borne pathogens. Thus, these issues have forced broiler producers to find suitable alternatives with similar benefits to antibiotics.

Amongst different alternatives, organic acids and phytochemicals like garlic, turmeric etc. have gained increasing interest as alternatives to AGPs for their cost-effectiveness and potential health modulating roles. Organic acids enhance feed digestibility, lower gastric pH, chelate cations, and act as substrate for intermediate metabolism. Citric acid, amongst organic acids, is the most potential as a growth stimulant as it enhances phytate hydrolysis by acting as a powerful calcium chelator and proton donor (Shah *et al.*, 2018). Amongst the phytochemicals, garlic (*Allium sativum*) is gaining momentum in recent years as alternative to AGPs in broiler production (Asghar *et al.*, 2023) which is known for its anti-atherosclerotic, antibacterial, immune-modulating, hypolipidemic, antithrombotic, antihypertensive, and antidiabetic properties since long (Mansoub, 2011). As a natural feed additive, it has been demonstrated to improve broiler performance and reduce mortality (Makwana *et al.*, 2015; Karangiya *et al.*, 2016, Puvaca *et al.*, 2019).

Numerous studies have already been undertaken to determine the effective inclusion levels of citric acid and garlic powder in broiler feed. However, works on combined dietary supplementation of citric acid with garlic powder in broilers are not available. Their combined supplementation in broilers may amplify their individual benefits for synergistic effects and could be a comprehensive approach for optimizing performance without relying on antibiotics and a step forward in achieving sustainable broiler farming. Therefore, the present study was undertaken with the aim to exploit the synergistic effects of dietary supplementation of citric acid with garlic (*Allium sativum*) powder on growth performance, carcass traits and production efficiency of broilers.

Materials and methods

Location of the study

The study was conducted during November to December, 2024 in the nutritional experimental shed of the Department of Animal Nutrition, College of Veterinary Sciences & Animal Husbandry, Central Agricultural University (Imphal), Selesih, Aizawl, Mizoram. The study was approved by IAEC via letter no. CVSC/CAU/IAEC/23-24/P-2 dated 21.10.2024.

Design of experiment

Two hundred and forty (240) one-day-old broiler chicks (Venn Cobb 400) were procured from authorized retailer and homogeneously divided into six treatments (T-1, T-2, T-3, T-4, T-5 and T-6) of 40 chicks in each by following completely randomized block design. Birds of each group were further divided into 4 homogenous replicates of 10 chicks in each replicate. The treatments were assigned as T-1 (control, without any supplementation), T-2 (ration supplemented with antibiotic growth promoter (bacitracin methylene di-salicylate) @ 0.05g/kg), T-3 (ration supplemented with 0.5% citric acid and 0.4% garlic powder), T-4 (ration supplemented with 0.4% citric acid and 0.3% garlic powder), T-5 (ration supplemented with 0.3% citric acid and 0.2% garlic powder) and T-6 (ration supplemented with 0.2% citric acid and 0.1% garlic powder). The feeding trial was conducted for 6 weeks.

Formulation of experimental rations

Balanced pre-starter, starter and finisher rations were formulated following BIS (2007) standards (Table 1). For preparation of garlic powder, raw garlic (*Allium sativum*) was procured from local farmers or markets of Aizawl city, Mizoram. Any dirt or foreign materials adhering to them were removed, cloves were separated manually, they were thinly cut into slices (0.2-0.3 cm thick) and then dried in hot air oven at 50-60^o C for 2-3 days. They were ground into powder using a grinder, and was then placed in airtight containers until utilization.

Table 1. Ingredient composition (%) of the broiler pre- starter, starter and finisher rations

Ingredients	T-1			T-2			T-3			T-4			T-5			T-6		
	PS	S	F	PS	S	F	PS	S	F	PS	S	F	PS	S	F	PS	S	F
Maize	49.5	52	58.45	50	53	58.75	49.5	52.5	58.75	50	52.5	58.75	50	52.5	59.55	50.2	52.7	58.7
Rice polish	5	5	3.75	4	4.5	3.75	4	4.6	3.35	5	4.8	3.55	5	5	3.05	5	5	3.5
Soyabean meal	37.6	34.85	30	37.6	34.40	29.2	38.05	34.30	29.2	37.05	34.30	29.2	37.25	34.30	29.1	37.25	34.55	29.7
Vegetable oil	3.6	4.4	5	3.5	4.4	5	3.5	4.5	5	3.75	4.5	5	3.75	4.5	5	3.75	4.3	5
Dicalcium phosphate	0.5	0.7	0.5	0.75	0.5	0.5	0.5	0.5	0.5	0.75	0.5	0.5	0.75	0.5	0.5	0.75	0.5	0.5
Limestone powder	1.75	1	0.4	1.5	0.65	0.4	1.5	0.65	0.4	0.7	0.65	0.4	0.7	0.65	0.4	0.7	0.65	0.4
L-Lysine	0.25	0.25	0.1	0.25	0.25	0.1	0.25	0.25	0.1	0.25	0.25	0.1	0.25	0.25	0.1	0.25	0.25	0.1
DL-Methionine	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Coccidiostat*	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Toxin binder**	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Vitamin & Trace mineral mixture#	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02
Antioxidant***	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Iodized salt	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Citric Acid	0	0	0	0	0	0	0.5	0.5	0.5	0.4	0.4	0.4	0.3	0.3	0.3	0.2	0.2	0.2
Garlic	0	0	0	0	0	0	0.4	0.4	0.4	0.3	0.3	0.3	0.2	0.2	0.2	0.1	0.1	0.1
BMD	0	0	0	0.5	0.5	0.5	0	0	0	0	0	0	0	0	0	0	0	0

PS-Pre-starter, S-Starter, F-Finisher, * Amproforte, ** Toximar, *** Vimeral
Per kg contains Vitamin A:700,000 IU, Vitamin D3: 70,000 IU, Vitamin E: 250 mg, Calcium: 25.5%, Phosphorous: 12.5%, Sulfur: 0.72%, Zinc: 9600 mg, Magnesium: 6000 mg, Manganese: 1500 mg, Copper: 1200 mg, Iodine: 325 mg, Cobalt: 150 mg, Potassium: 100 mg, Sodium: 5.9 mg.

Feeding and management of broiler birds

The experimental birds were raised under deep litter system of management. The broiler chicks were kept in a well-ventilated battery brooder for the first 7 days, and from the 8th day onwards, they were kept in a deep litter house where sawdust and rice husk (1:1 w/w) were used as litter materials. Plastic wire nets and wooden bars were utilized for the separation of different pens. Feed and clean drinking water were provided *Ad libitum*. Continuous light was provided to the birds and proper ventilation was maintained during the study. Vaccination and deworming were done following standard protocol.

Recording of data and analysis of samples

The daily feed consumption was calculated from the difference between the amount of feed offered and the residue left in 24 hours. Body weight of the birds was recorded at weekly interval. A metabolic trial was conducted after 42 days of trial randomly selecting four birds from each treatment. After 2 days adaptation, the daily feed provided and residue left was recorded for three days. Amount of faeces voided was recorded every 24 hours. A sufficient amount of faeces was stored for 3 days, mixed together and representative sample was used to quantify dry matter and other proximate principles.

The proximate analysis of the feed and faeces samples were done following method of AOAC (2000). The calcium and phosphorous contents were estimated following methods of Talapatra *et al.* (1940).

Studies of carcass traits

At the end of feeding trial, twenty-four bird i.e., one bird from each replicate was selected for carcass characteristics study. 12 hours of fasting before slaughter was maintained during which only clean and fresh drinking water was provided. The weight of the live birds was measured prior to slaughter. Slaughtering and bleeding of the birds were done in the animal slaughterhouse of the Department of Livestock Products Technology,

College of Veterinary and Animal Sciences and A.H., Selesih, Aizawl, Mizoram. The birds were bled, plucked, scaled, singed, and eviscerated. Weight of the eviscerated organ along with the weight of wholesale cuts and edible offal such as breast, back, drumstick, neck, wing, liver, heart, gizzard, and abdominal fat was recorded.

Dressing percentage was calculated by the following formula:

$$\text{Dressing percentage (\%)} = \frac{\text{Carcass weight}}{\text{Live weight}} \times 100$$

Production efficiency of broiler birds

The Production efficiency of birds was assessed by calculating feed conversion ratio (FCR) and European productive and economic efficiency index (EPEI) as per formula given by Soltan and Kusainova (2012).

FCR = Feed intake (g)/ Body weight gain (g)

EPEI = Mean body weight (kg) × livability (%) × 100) / FCR × marketing age (days)

Statistical analysis

The data were analyzed by one-way ANOVA using SPSS in a completely randomized design (CRD) as per the procedure described by Snedecor and Cochran (1994). Probability values $P \leq 0.05$ were declared as significant and the values of $0.05 > P \leq 0.10$ were declared as trend. When treatment effect was found to be significant, the differences among the treatment means were identified using Tukey's test.

Results and discussion

Nutritional composition of experimental rations

Composition of the experimental rations (on DM basis) fed to broilers conform to the BIS standards for broilers (Table 2).

Feed consumption

Feed consumption was significantly ($P < 0.01$) increased in treatments supplemented with citric acid and garlic powder (Fig.1). Highest average daily feed intake was recorded in T-4 followed by T-3, T-5, T-6, T-2 and T-1 during the 3rd, 4th, 5th and 6th week of age. Similar trend was noticed for total feed consumption also with significant variation between the groups (Table 3). Significantly more feed consumption in the citric acid with garlic powder supplemented groups might be attributed to their regulating effect on gut microbiota in favorable way enhancing gut health and overall health of the birds. Besides bioactive organosulfur compounds of garlic might enhance nutrient assimilation efficiency and exert antimicrobial effect reducing dysbiosis. Citric acid might also contribute to the acidification of gastrointestinal lumen, fostering an optimal environment for enzymatic activity and potentially mitigating the proliferation and colonization of enteric pathogens. These collective mechanisms might be contributed to improved digestive function and enhanced voluntary feed consumption. Similar significant effect of garlic powder, citric acid and their combined use with other herbs in enhancing feed consumption of broiler birds were also reported by Choudhary *et al.* (2022), Fik *et al.* (2021) and Makwana *et al.* (2019).

Table 2. Nutritional composition (%DM basis) of broiler pre-starter, starter and finisher ration

Attributes	T-1			T-2			T-3			T-4			T-5			T-6		
	PS	S	F															
DM (%)	89.1	88.66	89.00	89.49	88.99	89.15	89.15	88.88	89.31	89.66	88.98	89.12	89.58	88.99	89.29	89.31	88.98	89.30
CP (%)	22.82	21.81	20.07	22.83	21.85	19.87	22.87	21.76	19.94	22.82	21.79	19.85	22.92	21.81	19.75	22.94	21.93	20.06
EE (%)	3.0	3.61	4.46	3.02	3.59	4.61	3.1	3.65	4.70	3.08	3.67	4.71	3.15	3.66	4.70	3.16	3.65	4.75
CF (%)	3.51	3.38	3.15	3.49	3.38	3.12	3.49	3.37	2.96	3.51	3.38	3.12	3.52	3.39	3.10	3.53	3.4	3.14
TA (%)	6.1	6.2	6.30	6.16	6.16	6.39	6.1	6.2	6.35	6.15	6.19	6.33	6.16	6.25	6.36	6.18	6.21	6.38
NFE (%)	63.25	63.53	64.41	63.2	63.52	64.24	63.07	63.36	64.05	63.1	63.24	63.96	62.92	63.35	63.90	62.87	63.19	63.68
Ca (%)	0.95	0.7	0.41	0.91	0.52	0.40	0.85	0.52	0.38	0.61	0.35	0.40	0.61	0.52	0.40	0.61	0.52	0.40
P (%)	0.51	0.53	0.47	0.54	0.49	0.46	0.5	0.49	0.46	0.55	0.49	0.46	0.55	0.5	0.45	0.55	0.5	0.46
ME (kcal/kg)	2990.	3072.	3182.	2974.	3090.	3180.	2962.	3082.	3184.	3016.	3088.	3174.	3021.	3094.	3151.	3028.	3089.	3183.
*Lysine (%)	1.33	1.26	0.99	1.23	1.01	0.88	1.38	1.01	0.97	1.07	1.01	0.88	1.08	1.01	0.87	1.08	1.01	0.89
*Methionine (%)	0.57	0.55	0.52	0.57	0.35	0.32	0.57	0.35	0.36	0.37	0.35	0.32	0.37	0.35	0.32	0.37	0.36	0.32

PS-Pre-starter, S-Starter, F-Finisher
 *Calculated value
 DM= Dry matter; CP=Crude protein; EE= Ether extract; CF=Crude fibre; TA= Total ash; NFE= Nitrogen free extract; Ca= Calcium; ME= Metabolizable energy; P= Phosphorus

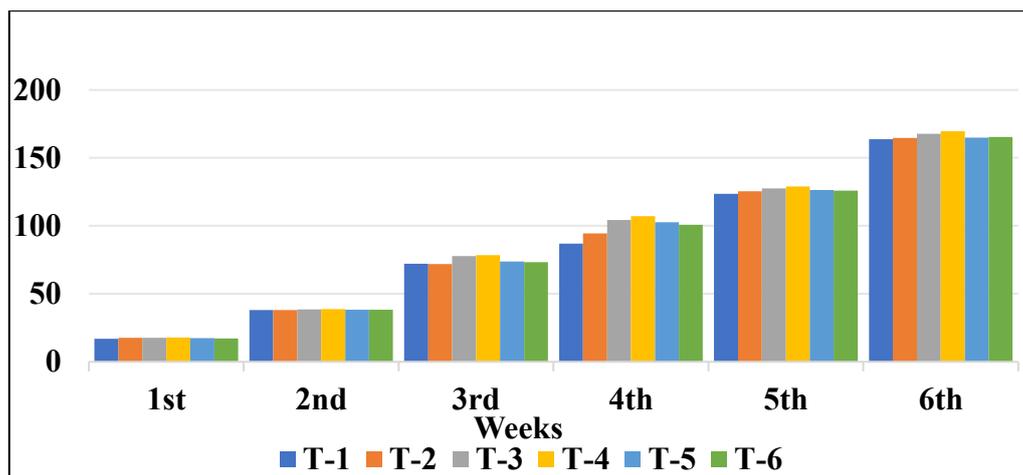


Fig 1. Effect of citric acid and garlic powder supplementation on average daily feed intake (g) of broiler birds.

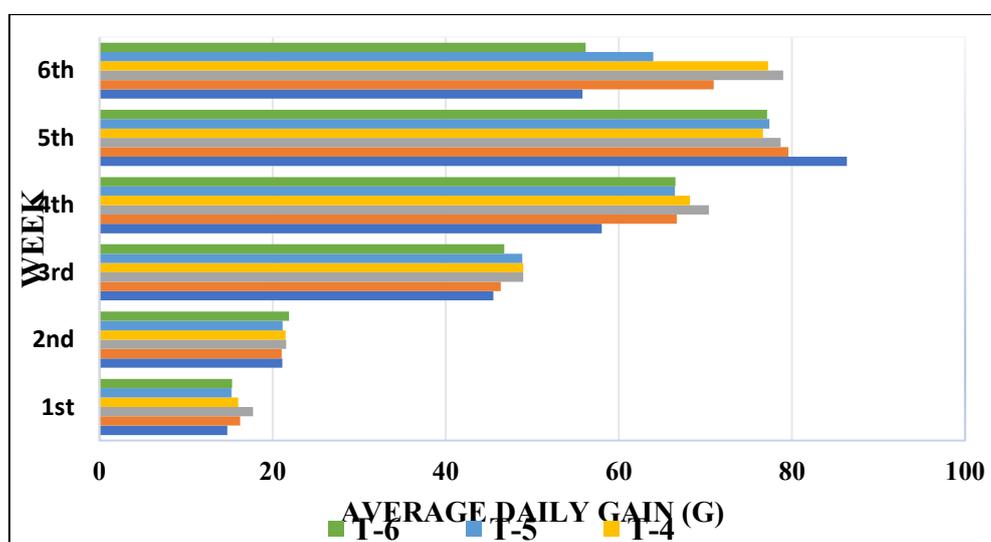


Fig 2. Effect of citric acid and garlic powder supplementation on the average daily gain in body weight of the broiler birds.

Growth performance and production efficiency

Weekly body weight changes showed an increasing trend in the citric acid with garlic powder supplemented groups. Significantly ($P < 0.05$) higher body weight gain was recorded in T-3 than other treatments in 1st week. Again, significantly ($P < 0.01$) higher body weight at 42nd day of age was recorded in T-3 (2258.20 ± 7.81 g), followed by T-4 (2204.30 ± 7.98 g) and T-2 (2149.70 ± 5.64 g), T-5 (2096.60 ± 7.54 g) and T-6 (2030.80 ± 3.06 g), while the lowest gain was in T-1 (1938.10 ± 6.94 g) (Table 3). The results indicated a positive effect of citric acid with garlic powder supplementation on growth of broiler birds which might be for their synergistic effects on digestion, nutrient absorption and gut health influencing increased body weight gain. Citric acid could lower pH of gastrointestinal tract inhibiting pathogenic bacteria and creating favorable environment for beneficial microbes. This might enhance enzymatic activity and improve nutrient digestibility. Garlic has antimicrobial, antioxidant, and immunomodulatory properties and supports gut health by reducing harmful microbial load and inflammation. Makwana *et al.* (2019) also recorded significantly ($p < 0.01$) improved body weight gain in broilers for supplementation of garlic powder. Fik *et al.* (2021) reported that supplementation of various doses of citric acid (0.25-3%) increased body weight of broiler chickens. Similarly, improvement in body weight gain for citric acid and garlic powder supplementation was also reported by Nezhadet *et al.* (2007), Makofane *et al.* (2022), Hayat *et al.* (2022) and Ajayi *et al.* (2024).

The production efficiency of broilers under different dietary treatments was evaluated by calculating the feed conversion efficiency (FCR) and European Productive and Economic Efficiency Index (EPEI) at the end of the feeding trial. The FCR calculated at 42nd day of age was significantly ($P < 0.01$) better in T-3 followed by T-2, T-4, T-5, T-6 and T-1 (Table 3). The improvement might be for significant effects of citric acid and garlic powder on the growth performance of broiler birds which might be contributed by better absorption and utilization of dietary nutrients for improved intestinal morphology, optimal gut microbial status and immune status of the broiler

Table 3. Effect of supplementation of citric acid with garlic powder on growth and production efficiency of broiler birds.

Attribute	T-1	T-2	T-3	T-4	T-5	T-6	SEM/p-value
Day-one BW (g)	44.45 ±0.28	43.34 ±0.75	43.86 ±0.82	44.38 ±0.76	45.09 ±0.48	44.20 ±0.28	0.24/0.48
42 nd day BW (g)	2013.07 ^a ±6.94	2149.70 ^{bcd} ±5.64	2258.20 ^d ±7.81	2204.30 ^{cd} ±7.98	2096.60 ^{bc} ±7.54	2030.80 ^{ab} ±3.06	27.08/<0.01 **
BW gain (g)	1968.61 ^a ±45.05	2106.31 ^{abc±} 52.36	2214.30 ^c ±33.87	2159.96 ^{bc±2} 5.55	2051.51 ^{ab±4} 6.26	1986.63 ^a ±52.54	24.29/<0.01 **
Total feed intake (kg)	3.50 ^a ±0.002	3.58 ^b ±0.001	3.73 ^c ±0.001	3.79 ^d ±0.002	3.67 ^e ±0.002	3.65 ^f ±0.003	0.02/<0.01
FCR	1.85 ^a ±0.04	1.70 ^b ±0.04	1.69 ^b ±0.02	1.75 ^{ab} ±0.02	1.79 ^{ab} ±0.04	1.84 ^a ±0.50	0.19/0.02*
EPEI	163.89 ^a ±5.40	221.38 ^{ab} ±22.67	253.78 ^b ±14.54	239.66 ^{ab} ±25.13	195.08 ^{ab} ±32.42	166.59 ^a ±35.44	11.47/0.04*

Means bearing different superscripts (a, b, c, d) in a row differ significantly [* means (P<0.05), ** means (P<0.01)].

birds. Better FCR for supplementation of citric acid at 3 % level was reported by Shuvo and Rahman (2023). Similarly, Makofane *et al.* (2022) observed improved feed conversion efficiency for feeding citric acid at 0.3, 0.5 or 0.7% level in broiler. The European Productive and Economic Efficiency Index (EPEI) is used to standardize and compare performance of broiler flocks based on feed conversion efficiency, mortality, and daily weight gain. It is an assessment of economic viability of broiler production. In the present study, EPEI was significantly (P<0.05) better in T-3 supplemented with 0.5% citric acid and 0.4% garlic powder followed by T-4 and T-2. The lowest EPEI was calculated for T-1. As supplementation of citric acid with garlic powder resulted significantly better body weight gain and feed conversion ratio without causing any mortality, it might contribute to better EPEI score in broilers.

Effects on nutrient digestibility

The apparent nutrient digestibility was found to be numerically higher in citric acid with garlic powder supplemented treatments without any significant difference (P>0.05). This might be the indication of improved utilization of dietary nutrients by broilers supplemented with citric acid with garlic powder. As reported, the enhanced nutrient utilization might possibly due to increased digestive enzyme activity and better gut health. Ghazalah *et al.* (2011) also reported significantly increased phosphorus, CP, EE, CF and NFE utilization in broilers supplemented with citric acid at 1.0% and 2.0% level. Haq *et al.* (2017) found that 2% citric acid in broiler feed enhanced the absorption of DM, CP and neutral detergent fibre. Both garlic (*Allium sativum*) and citric acid could positively influence nutrient digestibility for natural phytochemicals and antimicrobial effect modulating gut microbiota improving gut health and enzymatic activity. It might also be for optimizing the activity of digestive enzymes by Citric acid for its gastrointestinal pH lowering effect.

Effect on carcass traits of broilers

Numerically higher values for carcass traits were observed, especially in breast and thigh weights in groups supplementing with citric acid and garlic powder, but without any significant difference (P>0.05), indicating improvement in meat yield due to better growth feed utilization. Similar observations were also reported by Islam *et al.* (2010) who found that citric acid positively influenced dressing percentage, but the impact was statistically non-significant. Ismail *et al.* (2021) who conducted a study on Cobb broiler chicks and found that that inclusion of garlic powder or phenyl acetic acid in the diet enhanced the relative liver weight. Similar positive effect of citric acid on carcass traits was also reported by Fik *et al.* (2021). Saki *et al.* (2012) evaluated the effects of antibiotics, organic acids, and herbal supplements on broiler chicks and observed that citric acid significantly enhanced the proportion of liver and gizzard. Sultan *et al.* (2015) also reported that supplementation of organic acid blend (80 g citric acid, 52 g lactic acid, 10 g CuSO₄, and 92 g phosphoric acid per litre) significantly increased carcass outputs.

Conclusion

Based on findings of the study, dietary supplementation of 0.5% citric acid with 0.4% garlic powder was recommended in the rations of broiler birds as alternative to antibiotic growth promoter i.e. BMD and for better growth, nutrient digestibility and production efficiency.

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Conflict of interest

Authors do not have any conflict of interest.

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