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Effect of Dietary Citric Acid Powder on Growth Performance and Carcass Characteristics of Broiler Chickens

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Abstract	Article History
This study evaluated the effects of dietary citric acid powder supplementation on the growth performance and carcass characteristics of broiler chickens under the environmental conditions of Kabul, Afghanistan. A total of 48 one-day-old broiler chicks were randomly assigned to four dietary treatments using a Completely Randomized Design (CRD). The treatments included a control group without citric acid and three experimental groups supplemented with 0.25%, 0.50%, and 0.75% of citric acid powder administered through drinking water. Each treatment had three replicates with four chicks per replicate, and the experiment lasted 35 days. We measured growth performance parameters, including body weight, body weight gain, average daily gain (ADG), feed intake, feed conversion ratio (FCR), and feed conversion efficiency, weekly. We also evaluated carcass traits, including carcass, breast, thigh, liver, heart, and gizzard weights, at the end of the experiment. Data were analyzed using analysis of variance (ANOVA) and the Least Significant Difference (LSD) test. The results showed that dietary citric acid supplementation significantly improved growth performance compared with the control group. Broiler chickens receiving 0.75% citric acid showed the highest final body weight (2591.93 g), total body weight gain (2461.10 g), and average daily gain (70.32 g/day) ($P < 0.01$). Feed conversion ratio was also improved, with the lowest FCR (1.33) observed in the 0.75% citric acid group. Furthermore, citric acid supplementation significantly ($P < 0.05$) increased carcass yield and organ weights. In conclusion, 0.75% citric acid supplementation improved growth performance, feed efficiency, and carcass characteristics in broiler chickens. Keywords: Broiler chickens, citric acid, growth performance, carcass characteristics, feed conversion ratio.	Published: September 30, 2026 Accepted: August 05, 2026 Revised: June 16, 2026 Received: May 17, 2026

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Introduction

The broiler poultry industry is considered one of the most important sectors for animal protein production worldwide and plays a vital role in ensuring food security, particularly in developing countries. Rapid growth, efficient feed conversion, and desirable carcass quality are key indicators of success in broiler production. In the past, antibiotics were widely used as growth promoters in broiler diets; however, growing concerns about antimicrobial resistance

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and drug residues in animal products have led to restrictions or complete bans in many countries (Rahman et al., 2021).

Over recent decades, antibiotics have been extensively incorporated into broiler diets as growth-promoting agents to enhance gut health, reduce microbial load, and improve growth performance and production efficiency. Nevertheless, the continuous and indiscriminate use of antibiotics has resulted in the emergence of antimicrobial resistance, posing serious threats to public health and leading to the presence of drug residues in animal-derived products. These concerns have prompted regulatory restrictions and bans in numerous countries, thereby highlighting the urgent need for safe, natural, and sustainable alternatives to antibiotic growth promoters (Rahman et al., 2021; Zhu et al., 2020; Afridi et al., 2020).

In this context, organic acids have emerged as effective non-antibiotic alternatives in poultry nutrition. Citric acid, a weak organic acid, has attracted considerable attention for its antimicrobial properties, ability to regulate gastrointestinal pH, and capacity to enhance nutrient digestibility. By lowering the pH of intestinal contents, citric acid inhibits the proliferation of pathogenic bacteria such as *Salmonella* and *Escherichia coli* while creating favorable conditions for the growth of beneficial microorganisms (Qaid et al., 2021).

Recent studies have shown that dietary citric acid supplementation can improve body weight gain, increase effective feed intake, and improve feed conversion ratio in broiler chickens. These benefits are primarily attributed to improved intestinal morphology, increased villus height, and enhanced digestive enzyme activity, ultimately leading to more efficient nutrient absorption (Toghyani et al., 2011; Iqbal et al., 2020). Moreover, citric acid has been reported to increase the bioavailability of essential minerals such as calcium and phosphorus, thereby positively influencing bone development and muscle tissue growth (Qaid et al., 2021).

In addition to growth performance, carcass characteristics represent an important economic criterion in broiler production. Improvements in gut health and feed utilization efficiency have been associated with increased carcass yield, enhanced breast meat proportion, and reduced undesirable fat deposition. Natural feed additives, including organic acids such as citric acid, may therefore play a significant role in improving carcass quality and increasing the overall economic value of the final product (Yang et al., 2018; Kabir et al., 2004).

Several studies have evaluated the effects of citric acid supplementation in broiler chickens using different inclusion levels in either feed or drinking water. Boling et al. (2000) reported that dietary citric acid improved nutrient utilization and growth performance, although the magnitude of response depended on the supplementation level. Similarly, Atapattu and Nelligaswatta (2005) observed improvements in growth performance and nutrient utilization when citric acid was included in broiler diets at moderate levels. Hassanabadi et al. (2007) demonstrated that increasing citric acid supplementation positively affected carcass characteristics and growth performance, whereas excessive inclusion did not consistently produce additional benefits. Haque et al. (2010) further reported improvements in body weight gain and feed conversion ratio in broilers receiving citric acid supplementation. More recently, Yang et al. (2018) highlighted that organic acids can improve digestive function, intestinal health, and nutrient absorption, thereby enhancing growth performance. However, responses to citric acid supplementation have varied across studies because of differences in inclusion

level, method of administration (feed versus drinking water), diet composition, bird genotype, and environmental conditions. Most previous studies were conducted under commercial production systems outside Afghanistan, and information regarding the use of citric acid in broiler drinking water under local Afghan conditions remains scarce. Therefore, a clear knowledge gap remains regarding the optimal citric acid supplementation level for broiler chickens reared under the environmental and management conditions of Kabul, Afghanistan. Based on inclusion rates commonly reported in previous studies and to evaluate a practical dose-response relationship, the present study selected three supplementation levels (0.25%, 0.50%, and 0.75% citric acid powder) for comparison with an supplemented control group. The study addressed the following research questions: (1) Does citric acid supplementation improve body weight gain and average daily gain in broiler chickens? (2) Does citric acid supplementation influence carcass yield and carcass component weights?

Methods and Materials

Study Area

This experiment was conducted at the research and experimental poultry farm of the Faculty of Agriculture, Kabul University. The farm was maintained under standard scientific conditions for broiler production, including appropriate environmental management, ventilation, lighting, and general husbandry practices throughout the experimental period.

Experimental Birds and Management

A total of 48 one-day-old mixed broiler chicks were purchased from the Asia Zone Agricultural, Livestock, and Poultry Services Company and transferred to the experimental farm. During the first week, chicks were reared under a brooder to help them adapt to the experimental environment and diets. Before chick placement, the poultry house was thoroughly disinfected with formalin and lime to ensure a disease-free environment.

Ambient temperature and relative humidity were monitored and controlled according to the birds' requirements throughout the experiment. Broiler chicks were randomly allocated to experimental groups. The trial commenced on 15th of Saur (May) and lasted for 35 days.

A standard vaccination program against major viral diseases was followed. Newcastle disease vaccine (NDV) was administered on day 6, infectious bronchitis vaccine (IBV) on day 12, and infectious bursal disease vaccine (IBD) on day 18. Vaccines were applied as eye drops and in drinking water, as recommended.

Experimental Design and Dietary Treatments

At the start of the experiment, chicks were individually weighed, wing-tagged, and randomly assigned to four dietary groups: G1 (0%), G2 (0.25%), G3 (0.50%), and G4 (0.75%) citric acid supplementation, following a completely randomized design. Each group had three replicates, with four chicks per replicate, for a total of 12 chicks per treatment group. Birds were allocated to treatments on the seventh day of the experiment.

Immediately after weighing and allocation, chicks were provided with lukewarm water and maize meal using tray feeders. Feed allocation was adjusted according to the number of birds

and age within each treatment group. Powdered citric acid at predetermined inclusion levels was administered via drinking water and was available to the birds throughout the experimental period.

Environmental Monitoring

Ambient temperature and relative humidity were recorded daily at approximately 08:00 a.m. and 02:00 p.m. We documented minimum and maximum temperature and humidity values daily at 08:00 a.m., and calculated weekly averages accordingly. Recorded environmental conditions were as follows:

- Week 1: 35 °C and 30% relative humidity
- Week 2: 33 °C and 38% relative humidity
- Week 3: 30 °C and 45% relative humidity
- Week 4: 28 °C and 50% relative humidity
- Week 5: 25 °C and 60% relative humidity

We provided adequate ventilation and lighting continuously throughout the experimental period.

Feeding Program and Citric Acid Supplementation

The control group and three experimental groups (four treatment groups) received 0%, 0.25%, 0.50%, and 0.75% citric acid supplementation, as per the experimental design. During the first three hours after placement, sugar was dissolved in drinking water and provided to the chicks. Maize meal was fed during the first, second, and third days. Thereafter, experimental diets were offered daily in the morning. Starter feed was provided from day 1 to day 21, followed by finisher feed until the end of the experiment.

Citric acid powder was administered daily at specified inclusion levels by dissolving it in the drinking water. Poultry drinkers were cleaned daily to maintain hygiene and ensure uniform intake of the treated water.

Table 1: Chemical Composition of the Experimental Diets Fed to Broiler Chicks

Nutrient Composition	Starter Diet(1-21 d)	Finisher Diet(22-35 d)
Crude protein (%)	22.00	20.00
Metabolizable energy (kcal/kg)	2900	2880
Calcium (%)	0.90	0.80
Phosphorus (%)	0.62	0.59
Ash (%)	6.32	5.15
Moisture (%)	12 ± 1	12 ± 1

Nutrient composition values were obtained from the manufacturer's feed specification label.

Experimental Design

The experiment used a Completely Randomized Design (CRD). In this study, broiler chicks were allocated to four dietary treatments: one control group and three experimental groups receiving different inclusion levels of citric acid powder administered through drinking water.

Observations and Data Recording

Various parameters were measured to evaluate the effects of citric acid powder supplementation in drinking water on broiler chickens. The evaluated parameters are described as follows:

Body Weight Gain and Carcass Characteristics

We weighed broiler chicks in all experimental groups individually each morning throughout the experimental period. Based on these records, we calculated daily average weight gain and weekly body weight gain for each treatment over the experimental period.

Slaughter Record and Carcass Evaluation

At the end of the experiment, one broiler chick from each replicate was randomly selected for carcass evaluation. Initially, the live body weight of each selected bird was recorded, after which the birds were slaughtered following standard procedures.

We separated and weighed different carcass components, including the breast, thigh, gizzard, liver, and heart. All birds were weighed in the morning to ensure the digestive tract contents were emptied before slaughter.

To assess the effect of citric acid supplementation on carcass traits, the selected birds from each treatment were slaughtered for comparative evaluation. After slaughter, the carcass weight was recorded following the removal of the head and neck.

The liver was carefully cleaned and weighed, and its weight was expressed as a percentage of live body weight. The heart was gently removed from the thoracic cavity, and the surrounding pericardial membrane and blood clots were removed before weighing. Heart weight was also expressed as a percentage of live body weight.

The gizzard was opened using a knife, and feed residues, external fat, and the inner lining were removed before weighing. Gizzard weight was expressed as a percentage of live body weight.

Thigh weight was determined after separating the thigh portion from the carcass and expressed as a percentage of live body weight. The breast muscle was carefully separated after removing the contents of the thoracic cavity, weighed, and expressed as a percentage of live body weight.

Statistical Analysis

Data were analyzed using a one-way analysis of variance (ANOVA) under a Completely Randomized Design (CRD) in Statistica 9. The statistical model used was:

$$Y_{ij} = \mu + T_i + e_{ij}$$

Where Y_{ij} is the observed value, μ is the overall mean, T_i is the effect of the i th treatment, and e_{ij} is the random experimental error. When treatment effects were significant ($P < 0.05$), means were separated using the Least Significant Difference (LSD) test.

Findings

Table 2 presents the mean effect of the different treatment groups on the body weight gain of broiler chicks. The results shown in Table 2 indicate that, based on the Least Significant Difference (LSD) test, the body weight gain of broiler chicks in Group 4 was significantly higher than that observed in Groups 3, 2, and the control group (Group 1).

Increasing dietary citric acid supplementation significantly improved final body weight and body weight gain. Birds receiving 0.75% citric acid achieved the highest final body weight and differed significantly ($P < 0.05$) from the other treatments, whereas no significant difference was observed between the 0.25% and 0.50% supplementation levels.

Table 2. Comparison of the mean effect of different treatment groups on body weight gain of broiler chicks based on the LSD test

Groups	Mean body weight gain (g)
G4	2591.9a
G3	2246.3b
G2	2232.4b
G1 (Control)	2174.2c

Table 3 presents the mean weekly effect of different treatment groups on body weight gain of the broiler chicks during the experimental period. Body weight increased progressively in all treatment groups throughout the experimental period.

Table 3. Effect of different treatment groups on the mean weekly body weight (g) of broiler chicks during the experimental period

Days	G1	G2	G3	G4
0–7	338.24 ± 13.68	332.05 ± 8.12	339.18 ± 11.67	319.40 ± 6.73
8–14	655.54 ± 28.83	629.13 ± 29.59	642.30 ± 15.51	642.37 ± 10.28
15–21	1081.97 ± 19.39	1088.00 ± 22.64	1111.35 ± 22.45	1063.03 ± 27.36
22–28	1672.30 ± 81.08	1669.06 ± 29.39	1687.63 ± 32.33	1701.21 ± 25.98
29–35	2174.25 ± 110.33 ^c	2232.42 ± 54.97 ^b	2246.25 ± 13.48 ^b	2591.93 ± 67.85 ^a
Total	5922.48	5950.65	6026.70	6317.92
Mean weekly weight	1184.50 ± 50.67 ^c	1190.13 ± 28.95 ^b	1205.34 ± 19.09 ^b	1263.59 ± 27.64 ^a

Note: Values are presented as mean ± standard error. Means within the same row bearing different superscript letters (a, b, c) are significantly different (LSD test, $p < 0.05$).

However, broilers supplemented with 0.75% citric acid exhibited superior growth performance during the later stages of production and achieved the highest final body weight at 35 days of age. Significant differences ($P < 0.05$) were observed among treatments during the final week, with birds receiving 0.75% citric acid outperforming the control and lower supplementation groups. No significant differences were detected between the 0.25% and 0.50% citric acid treatments.

Table 4 presents the changes in initial and final body weights (g) of broiler chicks among the different experimental groups. As shown in Table 4, the fourth group supplemented with 0.75% citric acid showed greater effectiveness in body weight gain than the control group (G1). Next, the third group receiving 0.50% citric acid and the second group receiving 0.25% citric acid also showed higher weight gain than the control group. Overall, dietary supplementation with citric acid resulted in a dose-dependent improvement in body weight gain of broiler chicks.

Table 4. *Changes in Initial and Final Body Weights of Broiler Chicks in Different Experimental Groups (g)*

Groups	Initial body weight (g)	Final body weight (g)	Body weight gain (g)	Standard deviation (SD)
G1 (Control)	136.87	2174.25 ^c	2037.38 ^c	96.79
G2 (0.25% CA)	132.13	2232.43 ^b	2100.30 ^b	93.44
G3 (0.50% CA)	132.21	2246.25 ^b	2114.04 ^b	93.49
G4 (0.75% CA)	130.95	2591.93 ^a	2461.98 ^a	92.60

a, b, c: Means within the same column with different superscript letters differ significantly ($P < 0.05$) according to the LSD test.

CA = Citric Acid.

Table 5 presents the mean live body weight and total body weight gain of broiler chicks fed three different levels of citric acid, disaggregated by weekly time intervals throughout the experimental period.

Table 5. *Effect of citric acid supplementation on live body weight (BW) and body weight gain (BWG) of broiler chickens*

Age (days)	Parameter	Control (G1)	0.25% CA (G2)	0.50% CA (G3)	0.75% CA (G4)
Day 0	BW (g)	136.87 ± 11.9	132.13 ± 6.60	132.21 ± 6.23	130.95 ± 10.48
1–7	BW (g)	338.24 ± 13.7	332.05 ± 8.12	339.18 ± 11.67	319.40 ± 6.73
	BWG (g)	201.37 ± 1.9	199.90 ± 1.6	206.90 ± 5.4	188.50 ± 3.8
8–14	BW (g)	655.54 ± 28.9	629.13 ± 29.59	642.30 ± 15.51	642.37 ± 10.28
	BWG (g)	317.30 ± 15.2	297.08 ± 21.5	303.20 ± 3.9	322.90 ± 3.6
15–21	BW (g)	1081.97 ± 19.4	1088.00 ± 22.64	1111.35 ± 22.50	1063.03 ± 27.36
	BWG (g)	426.43 ± 9.5	458.87 ± 6.95	469.10 ± 6.9	420.70 ± 17.1
22–28	BW (g)	1672.30 ± 81.1	1669.06 ± 29.4	1687.63 ± 32.4	1701.21 ± 25.98
	BWG (g)	590.33 ± 61.7	581.06 ± 6.76	576.30 ± 9.9	638.20 ± 1.4
29–35	BW (g)	2174.25 ± 110.4	2232.42 ± 54.9	2246.25 ± 13.5	2591.93 ± 67.85
	BWG (g)	501.95 ± 29.4	563.36 ± 25.5	558.70 ± 18.9	890.80 ± 41.9
Overall (1–35)	Total Weight Gain (g)	2037.38 ± 117.7	2100.27 ± 62.31	2114.20 ± 45.0	2461.10 ± 67.8
	ADG (g/day)	58.21 ± 3.37	60.00 ± 1.78	60.41 ± 1.28	70.32 ± 1.94

As the experiment progressed, the effects of citric acid intake on body weight gain became more noticeable. Birds receiving 0.75% citric acid showed a strong dose-dependent response, as shown by the highest average daily increase and total body weight gain. The control group, by contrast, showed the poorest growth performance over the trial. These results imply that increased citric acid supplementation improved broiler chickens' growth efficiency and nutrient utilization.

Table 6 below presents the weights of different carcass components of broiler chickens fed citric acid in the experimental groups. Citric acid supplementation significantly influenced

carcass characteristics of broiler chickens. Birds receiving 0.75% citric acid exhibited the highest carcass, breast, thigh, liver, heart, and gizzard weights. Overall, carcass component weights increased with higher citric acid supplementation, suggesting improved nutrient utilization and tissue development. The superior carcass yield in the 0.75% treatment group indicates that citric acid supplementation may enhance meat production and economic returns in broiler production systems.

Table 6. *Weights of different carcass components of broiler chickens fed citric acid in different experimental groups (g)*

Group	Carcass weight (g)	Breast (g)	Thigh (g)	Liver (g)	Heart (g)	Gizzard (g)
G1 (Control)	1734.2 b	614.5 c	393.8 c	48.1 c	11.7 c	56.5 c
G2 (0.25% CA)	1780.9 b	631.3 b	420.3 b	53.8 b	12.6 b	57.2 b
G3 (0.50% CA)	1861.7 ab	634.9 b	431.8 ab	55.3 ab	14.5 ab	59.4 ab
G4 (0.75% CA)	2064.9 a	684.1 a	437.1 a	57.2 a	16.3 a	61.9 a
P-values	0.002	0.001	0.003	0.015	0.008	0.010

Note: Values with different superscript letters within a column indicate statistically significant differences at $P < 0.05$.

Discussion

The present study showed that supplementing broiler drinking water with citric acid improved growth performance, feed efficiency, and carcass characteristics. Birds receiving 0.75% citric acid exhibited the highest final body weight, body weight gain, average daily gain, and carcass yield, indicating that citric acid supplementation can enhance broiler productivity under the environmental conditions of Kabul, Afghanistan.

The improved growth performance in the citric acid-supplemented groups may be attributed to organic acids reducing gastrointestinal pH. A lower intestinal pH suppresses pathogenic microorganisms while promoting a more favorable microbial environment for digestion and nutrient utilization. Consequently, nutrients become more available for growth and tissue development, resulting in improved body weight gain and average daily gain (Haque et al., 2010; Yang et al., 2018; Qaid et al., 2021). The superior performance of birds receiving 0.75% citric acid suggests that this inclusion level provided the most favorable conditions for nutrient utilization in the present study.

Another important finding was the improvement in feed conversion ratio (FCR) with increasing levels of citric acid supplementation. The 0.75% citric acid group showed the lowest FCR, indicating more efficient conversion of feed into body mass. Improved FCR may be associated with enhanced digestibility of dietary protein and energy, increased digestive enzyme activity, and better intestinal morphology. Organic acids have been reported to increase villus height and improve nutrient absorption, thereby reducing feed wastage and improving feed utilization efficiency (Adil et al., 2011; Yang et al., 2018; Melaku et al., 2021).

The positive effects of citric acid supplementation were also reflected in carcass characteristics. Birds receiving 0.75% citric acid produced significantly heavier carcasses and higher weights of breast, thigh, liver, heart, and gizzard compared with the control group. These improvements

may reflect enhanced protein deposition and more efficient nutrient partitioning toward muscle growth. Increased carcass yield is economically important because it directly influences meat production and market value in broiler enterprises. Atapattu and Nelligaswatta (2005), Kabir et al. (2004), and Hassanabadi et al. (2007) reported similar improvements in carcass traits following organic acid supplementation.

The present findings generally agree with previous reports indicating beneficial effects of citric acid on broiler performance (Boling et al., 2000; Haque et al., 2010; Wickramasinghe et al., 2014). However, make direct comparisons among studies with caution because responses to citric acid supplementation may vary by inclusion level, method of administration, diet composition, bird age, management practices, and environmental conditions. In the current study, citric acid was administered through drinking water under local Afghan production conditions, which may partly explain differences from studies conducted in other regions or using dietary inclusion in feed. Islam (2012) and Yang et al. (2018) have also reported similar variability in responses to organic acid supplementation.

From a practical perspective, the results suggest that citric acid supplementation may serve as a useful non-antibiotic growth-promoting strategy in broiler production. Given growing concerns about antibiotic resistance and restrictions on antibiotic growth promoters, citric acid may offer a safe, sustainable alternative for improving growth performance and carcass quality. Organic acids have been widely recognized as promising alternatives to antibiotic growth promoters because of their antimicrobial activity and positive effects on gut health and nutrient utilization (Dibner & Buttin, 2002; Yang et al., 2018). Under the conditions of the present study, supplementation with 0.75% citric acid produced the most favorable biological response and may therefore be recommended for broiler production.

Nevertheless, the study used a relatively small number of birds and a single set of environmental conditions. Future research should evaluate larger populations, different broiler strains, and additional levels of citric acid supplementation to determine the optimum inclusion rate and further clarify the mechanisms by which citric acid influences growth performance and carcass development.

Conclusion

Broiler chicks in all supplemented treatment groups recorded higher body weight and greater weight gain compared with those in the control group fed the commercial diet. These findings indicate that including citric acid in broiler diets improved body weight and weight gain performance. The fourth group, supplemented with 0.75% citric acid, showed the highest body weight and weight gain, with statistically significant differences during the fourth and fifth weeks of the experiment ($P < 0.01$). This demonstrates citric acid's effectiveness in improving broiler growth performance.

Carcass characteristics also differed among the supplemented groups receiving three different levels of citric acid and the control group. The average carcass weight was lowest in the control and second groups, whereas the highest carcass weights were recorded in the fourth and third groups. Furthermore, the average weights of all carcass parts in the fourth group (0.75% citric acid supplementation) were higher than those observed in the control, second, and third groups.

Author Contribution

- Abdul Khaliq Sahes: Conceptualized the study, designed the research framework, conducted the investigation, and prepared the original draft of the manuscript.
- Abdul Ghafoor Muradi: Supervised the research process, provided methodological and technical guidance, and contributed to reviewing and revising the manuscript.
- Abdul Jamil Ghanizada: Assisted in data analysis and interpretation of results, and contributed to critical revision of the manuscript.
- Noor Ahmad Nsatoh: Participated in data collection, literature review, and supported the research activities.
- Faizurahman Rahmani: Contributed to data collection, analysis support, and manuscript editing.
- All authors: Reviewed and approved the final version of the manuscript.

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