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EVALUATING THE USE OF CITRIC ACID AS AN ECO-FRIENDLY SUPPLEMENT IN BROILER DIETS

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ABSTRACT

Due to the adverse effects of using antibiotics in poultry feed, the European Union has authorized the use of organic acids as alternative feed additives. This study aimed to determine the effect of supplementation with an organic acid (citric acid) for a period of 35 days on body weight, feed efficiency, carcass yield, and immune status of broilers. Two hundred and forty unsexed one-day-old Indian River (IR) broiler chicks were randomly split into four groups; each group contained 60 chicks, with three replicates of 20 chicks under the same management conditions. The basal starter, grower, and finisher diets were supplemented with 0% (control), 0.15%, 0.30%, and 0.45% citric acid. Growth performance, carcass characteristics, and feed conversion ratio were recorded. European productivity and the performance index (PI) were also computed. Data were analyzed statistically using one-way ANOVA followed by Duncan's Multiple Range Test to identify significant differences among treatments ($P < 0.05$). The results showed that, compared to other treatments, chicks fed diets supplemented with 0.15% and 0.30% citric acid had the lowest feed consumption, highest body weight, and best feed conversion ratio ($P < 0.05$). Compared to the control diet, citric acid supplementation significantly ($P < 0.05$) enhanced the performance index (PI). Additionally, citric acid supplementation had a significant ($P < 0.05$) positive impact on dressing percentage, giblets, and certain immunological organ weights at 35 days of age compared to the control group. It can be concluded that adding 0.15% citric acid to Indian River chicks' diets positively affects productivity.

Key words: Organic acids, Citric acid, performance, carcass traits, broiler chicks.

INTRODUCTION

Poultry meat is a source of protein, minerals and vitamins for humans with a low content of saturated fatty acids **(Vlaicu *et al.*, 2022)**. It not only contributes to the gross domestic product (GDP) but is also a significant source for humans.

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The increase in poultry industry demand due to higher population growth led to the use of in-feed antibiotics (IFAs) as growth promoters at sub-therapeutic levels. Although additives feed antibiotics, promote the growth of broiler chickens, and contribute to the development of antibiotic resistance, they are harmful to the customer's health. As a result, according to **Abd El-Ghany (2024)**, the European Union outlawed antibiotics as growth promoters in animal feed in 2006 (EC Regulation No. 1831/2003). Using herbal growth promoters in the poultry sector can increase profits by improving feed efficiency and the health status of the poultry **(Alagawany *et.al.* 2021)**. These plant-derived additives, furthermore, known as phytogenic feed additives, are used in poultry nutrition to improve growth performance **(Alagawany *et al.*, 2019)**. It is used to promote poultry growth rate and is made up of various spices, herbs, and essential oils **(Abo Ghanima *et al.*, 2020; Alagawany *et al.*, 2021; Khafaga *et al.*, 2019)**.

Nonetheless, studies showed that organic acids have a positive impact on nutritional digestion and absorption in broiler chickens, intestinal brush limits topical effects, and mucosal immunity **Mirza and Mukhtar (2016)**. Organic acids also enhanced and increased pepsin proteolysis secretion, release of the hormone's cholecystokinin and gastrin, which control how well proteins are absorbed and digested.

Suiryanrayna and Ramana (2015) reported that weak acids with a carboxylic acid group (R-COOH) that function as intermediaries in the breakdown of fats, amino acids, and carbohydrates, as well as organic acids, are utilized in poultry feed for their antimicrobial properties and nutritional value. So, organic acids are chosen as a promising feed additive in poultry production to improve digestion and nutrient absorption rates, modulate intestinal microbiota, preserve the cellular integrity of the gut barrier, and enhance production performance **(Melaku *et al.* 2021)**. Citric acid (CA) is the most often utilized organic acid in chicken feed.

The increasing acidity of the gastrointestinal (GI) promotes development. Furthermore, CA enhances nutrient absorption, the solubility of feed elements, and digestion, and alters intestinal pH **(Haq *et al*. 2017).**

The purpose of this study is to assess the impact of citric acid supplementation on the growth performance and several carcass characteristics of broiler chicks.

MATERIALS AND METHODS

The current study was carried out at in private farm (El-Horria company, El-Sadat city, Menofia governorate, Egypt, in corporate with the Poultry Production Department, Faculty of Agriculture, Ain Shams University, Shoubra El-Kheima, Qalyubia governorate, Egypt. All chemical analyses were done in the laboratories of the Poultry Production Department, Faculty of Agriculture, Ain Shams University. The duration of the experimental period was from January to March 2024 to study the effect of dietary supplementation of citric acids on growth performance, and carcass characteristics of broiler chicks.

Experimental design

A total of 240 unsexed, one–day–old Indian River (IR) broiler chicks were used in this experiment. Chicks were randomly divided into experiments comprised of control and three treatments; each treatment contained three replicates of twenty chicks. The chicks were reared in litter pens (wheat strap) from 1 to 35 days of age. The management of broiler chickens was consistent with the guidelines (Arbor Acres Broiler Commercial Management Guide).

The initial temperature was 33ºC on the first day of age and decreased by approximately 2ºC/week until 24ºC, which was maintained at this temperature till the end of the experiment. Temperature, humidity, light, and ventilation were the same for all treatments. Vaccination was performed according to breeder standards and was the same for all experimental treatments.

Experimental diets

Three corn-soybean-based basal diets were formulated to be fed during (starter 1-14 days, grower 14-28 days, finisher 28-35 days of age). The broiler diets were formulated to be isocaloric and isonitrogenous meeting, the nutrition requirements according to Indian River Broiler Nutrition Specifications.

The experimental diets and their calculated chemical analysis, which are presented in Tables 1,2,**3**

Table (1): Composition and calculated analysis of diets (starter)

INGREDIENTS %	CONTROL	T1	T2	T3
Yellow Corn	56.00	56.00	56.00	56.00
Soybean Meal (46%)	32.33	32.33	32.33	32.33
Corn Gluten Meal	5.00	5.00	5.00	5.00
Soybean Oil	1.45	1.45	1.45	1.45
Wheat Bran	0.76	0.61	0.46	0.31
Calcium Carbonate (Limestone)	1.33	1.33	1.33	1.33
Mono Calcium Phosphate	1.66	1.66	1.66	1.66
HCL- Lysine	0.32	0.32	0.32	0.32
D-L Methionine	0.33	0.33	0.33	0.33
Threonine	0.13	0.13	0.13	0.13
Tryptophan	0.10	0.10	0.10	0.10
Salt (NaCl)	0.30	0.30	0.30	0.30
Premix	0.30	0.30	0.30	0.30
Citric acid	0.00	0.15	0.30	0.45
Total	100.00	100.00	100.00	100.00
Calculated chemical analysis**				
Metabolizable energy (kg/kcal)	3000.02	3000.02	3000.02	3000.02
Crude protein (%)	23.00	23.00	23.00	23.00
Crude fibres (%)	2.77	2.77	2.77	2.77
Calcium (%)	0.96	0.96	0.96	0.96
Phosphor (%)	0.48	0.48	0.48	0.48
Lysine (%)	1.44	1.44	1.44	1.44
Methionine (%)	0.70	0.70	0.70	0.70
Methionine + Cysteine (%)	1.08	1.08	1.08	1.08
Threonine (%)	0.97	0.97	0.97	0.97
Tryptophan (%)	0.23	0.23	0.23	0.23
Price/ton (LE)***	24612.3	24612.3	24612.3	24612.3

***Each 3 kg of premix containing: 15000000 I.U. Vit, A, 3000000** I.U vit. D 50g. Vit E, 3000mg vit. K3. 3000 mg vit. B1, 8000 mg. vit B2, 4000 mg. vit B6, 20mg. Vit. B12, 15000 mg pantothenic acid, 60000 mg. niacin, 1500 mg. folic acid, 200mg. Biotin, 200000 mg VIT C, 700 gm. choline chloride, 80 gm. Mn, 80 gm. zinc, 60 gm. iron, 10 gm. CU, 1 gm. Iodine, and 0.2 gm millennium, where $CaCo_3$ was taken as a carrier up to 3kg, the inclusion rate was 3 kg premix/ton feed. ** Calculated analysis of the experimental diets was done according to (NRC, 1994). *** Cost in 2024.

Table (2): Composition and calculated analysis of diets (grower)

INGREDIENTS %	CONTROL	T1	T2	T3
Yellow Corn	59.00	59.00	59.00	59.00
Soybean Meal (46%)	30.00	30.00	30.00	30.00
Corn Gluten Meal	4.11	4.11	4.11	4.11
Soybean Oil	2.54	2.54	2.54	2.54
Wheat Bran	0.38	0.23	0.08	0.08
Calcium Carbonate (Limestone)	1.21	1.21	1.21	1.21
Mono Calcium Phosphate	1.47	1.47	1.47	1.47
HCL- Lysine	0.23	0.23	0.23	0.23
D-L Methionine	0.28	0.28	0.28	0.28
Threonine	0.09	0.09	0.09	0.09
Tryptophan	0.09	0.09	0.09	0.09
Salt (NaCl)	0.30	0.30	0.30	0.30
Premix	0.30	0.30	0.30	0.15
Citric acid	0.00	0.15	0.30	0.45
Total	100.00	100.00	100.00	100.00
Calculated chemical analysis**				
Metabolizable energy (kg/kcal)	3100.00	3100.00	3100.00	3100.00
Crude protein (%)	21.50	21.50	21.50	21.50
Crude fibres (%)	2.68	2.68	2.68	2.68
Calcium (%)	0.87	0.87	0.87	0.87
Phosphor (%)	0.44	0.44	0.44	0.44
Lysine (%)	1.29	1.29	1.29	1.29
Methionine (%)	0.63	0.63	0.63	0.63
Methionine + Cysteine (%)	0.99	0.99	0.99	0.99
Threonine (%)	0.88	0.88	0.88	0.88
Tryptophan (%)	0.21	0.21	0.21	0.21
Price/ton (LE)***	24212.87	24212.87	24212.87	24212.87

***Each 3 kg of premix containing: 15000000 I.U. Vit, A, 3000000** I.U vit. D 50g. Vit E, 3000mg vit. K3. 3000 mg vit. B1, 8000 mg. vit B2, 4000 mg. vit B6, 20mg. Vit. B12, 15000 mg pantothenic acid, 60000 mg. niacin, 1500 mg. folic acid, 200mg. Biotin, 200000 mg VIT C, 700 gm. choline chloride, 80 gm. Mn, 80 gm. zinc, 60 gm. iron, 10 gm. CU, 1 gm. Iodine, and 0.2 gm millennium, where $CaCo_3$ was taken as a carrier up to 3kg, the inclusion rate was 3 kg premix/ton feed. ** Calculated analysis of the experimental diets was done according to (NRC, 1994). *** Cost in 2024.

Table (3): Composition and calculated analysis of diets (finishe)r

INGREDIENTS %	CONTROL	T1	T2	T3
Yellow Corn	63.00	63.00	63.00	63.00
Soybean Meal (46%)	24.58	24.58	24.58	24.58
Corn Gluten Meal	5.00	5.00	5.00	5.00
Soybean Oil	3.25	3.25	3.25	3.25
Wheat Bran	0.41	0.26	0.11	0.11
Calcium Carbonate (Limestone)	1.11	1.11	1.11	1.11
Mono Calcium Phosphate	1.37	1.37	1.37	1.37
HCL- Lysine	0.27	0.27	0.27	0.27
D-L Methionine	0.26	0.26	0.26	0.26
Threonine	0.09	0.09	0.09	0.09
Tryptophan	0.08	0.08	0.08	0.08
Salt (NaCl)	0.30	0.30	0.30	0.15
Premix	0.30	0.30	0.30	0.30
Citric acid	0.00	0.15	0.30	0.45
Total	100.00	100.00	100.00	100.00
Calculated chemical analysis**				
Metabolizable energy (kg/kcal)	3200.00	3200.00	3200.00	3200.00
Crude protein (%)	20.00	20.00	20.00	20.00
Crude fibres (%)	2.55	2.55	2.55	2.55
Calcium (%)	0.79	0.79	0.79	0.79
Phosphor (%)	0.41	0.41	0.41	0.41
Lysine (%)	1.19	1.19	1.19	1.19
Methionine (%)	0.60	0.60	0.60	0.60
Methionine + Cysteine (%)	0.94	0.94	0.94	0.94
Threonine (%)	0.81	0.81	0.81	0.81
Tryptophan (%)	0.19	0.19	0.19	0.19
Price/ton (LE)***	23686.54	23686.54	23686.54	23686.54

*Each 3 kg of premix contains: 15000000 I.U. Vit, A, 3000000 I.U vit. D 50g. Vit E, 3000mg vit. K3. 3000 mg vit. B1, 8000 mg. vit B2, 4000 mg. vit B6, 20mg. Vit. B12, 15000 mg pantothenic acid, 60000 mg. niacin, 1500 mg. folic acid, 200mg. Biotin, 200000 mg VIT C, 700 gm. choline chloride, 80 gm. Mn, 80 gm. zinc, 60 gm. iron, 10 gm. CU, 1 gm. Iodine, and 0.2 gm millennium, where $CaCo_3$ was taken as a carrier up to 3kg, the inclusion rate was 3 kg premix/ton feed. ** Calculated analysis of the experimental diets was done according to (NRC, 1994). *** Cost in 2024.

Basal starter, grower, and finisher diets were supplemented with three levels of citric acid (0.15, 0.30, and 0.45%) to formulate four experimental diets.

The experimental design was prepared as follows.

Control:	**Basal diets.**
Treatment 1:	Control diet plus 0.15% CA (starter, grower, and finisher diet).
Treatment 2: (T2)	Control diet plus 0.30% CA (starter, grower, and finisher diet).
Treatment 3: (T3)	Control diet plus 0.45% CA (starter, grower, and finisher diet).

Experimental birds and management

Water and pellet feed was provided ad-lib. Fresh water was accessible all the time by automatic nipple drinkers. Body weights were recorded at the of each period (14, 28 and 35 days) for each replicate and average body weight gain was calculated for each replicate and treatment group. Feed intake was obtained in grams and the feed conversion ratio was calculated as gram feed/gram gain. The experimental diets (starter, grower, and finisher) were supplemented with four citric acid levels: 0(control), 0.15, 0.30 and 0.45%. At the end of the experiment, 4 chicks per treatment were weighed and slaughtered after feed withdrawal for 12 hours to determine carcass characteristics.

Measurements and Procedures:

<u>Performance Index (PI)</u>

performance index was calculated according to **North (1981).**

(Final Body Weight [kg]/FCR) *100

<u>European productive efficiency factor (EPEF)</u>

(Final body weight [kg] * survival rate %) / (FCR * rearing periods [days]) *100

Carcass characteristics

Four birds from each treatment were chosen at random, weighed, and slaughtered when they reached 35 days old. Following complete bleeding and feather removal, the carcass, gizzard, heart, liver, gut length, and abdominal fat were weighed and expressed as a percentage of body weight.

Statistical analysis

Data were statistically analyzed using the General Linear Model procedure of Analysis (**SAS, 2001).** Duncan's multiple range test **(Duncan, 1995)** was used to evaluate differences within means of treatments, while the level of significance was typically set at a minimum ($P \leq 0.05$).

The statistical model used for analyzing the data was as follows:

Yij = μ + Ti + eij

Where: Yij = observation of the parameter measured. μ = overall mean. Ti = the effect of treatment. eij = random error effect.

RESULTS

Effect of dietary treatments on the productive performance of broiler chicks

Data presented in Table 4 show the effect of dietary treatments on body weight, body weight gain, feed consumption, feed conversion ratio, and mortality rate of broiler chicks.

Live Body Weight g (LBW) and Body Weight Gain g (BWG)

According to the results, there were insignificant differences in the initial live body weight of the chicks at one day of age among all experimental treatments; the corresponding values ranged between 40.67 and 41.17 g. There were significant differences between birds in each treatment. There was significant difference in chicks fed T1 diets which gave heavier live body weight (2283.33g) compared with control group (2134.50g) at 35 days of age while the other groups (T2 and T3) values were (2224.17 and 2122.67g), respectively.

The result of body weight gain (BWG) showed that T1 diets gave a significant higher LBWG (2242.42g) compared with control (2093.50g) at 35 days of age while the other dietary treatments (T2 and T3) values were (2183.25 and 2081.92g), respectively.

Feed Consumption g (FC)

Table 4 shows insignificant differences in average feed consumption (g) during the starter period (1:14 days) between all treatments, but there were differences ($P < 0.05$) during the grower (14–28 day) and finisher (28–35 day) period, as well as for the whole experimental period (1–35 day). During the whole experiment period, broilers fed on a diet containing citric acid supplementation consumed more feed than the control birds. The increase in feed intake could have resulted from increased diet palatability or from stimulating the activity of digestive enzymes upon the inclusion of citric acid.

Feed conversion ratio g/bird (FCR)

The results of the feed conversion ratio are shown in Table 4. No significant differences were observed in the 1–14 days (starter) and 14–28 days (grower) periods. However, there were significant differences during the finisher period (28–35 days) and in the overall trial (1–35 days). Feed conversion ratio values during the overall period were 1.64, 1.56, 1.66 and 1.83 in Control, T1, T2 and T3, respectively. It seems that chicks fed a diet supplemented with 0.15% citric acid recorded the best feed conversion ratio. This enhancement may be related to increased nutrient digestibility and improved cercal condition resulting from the presence of citric acid.

Mortality rate

No mortality rate was recorded throughout the experimental period (1–35 days in the different experiments and this is evidence that citric acid had no adverse effect on the health of the birds.

According to the results in Table 4. It seems that we can include citric acid up to 0.45**%** in broiler diets without any negative impact on the performance of the broilers.

The lack of mortality in all treatments suggests that citric acid supplementation to 0.45% is safe to be included in the diet for broiler chicks and does not cause any adverse effects under the conditions of this study. This endorses its potential as an environmentally friendly feed additive in place of antibiotics in full compliance with the regulatory guidelines and the preference of consumers for poultry meat produced without antibiotics.

Table (4): Effect of dietary treatments on productive performance of broiler chicks.

ITEMS	TREATMENT				SEM	SIG
	Control	T1	T2	T3		
Live body weight (g)						
1 day	41.00	40.92	40.92	40.75	0.12	0.931
14 days	491.58^{ab}	510.92^{a}	517.08^{a}	471.75^{b}	6.52	0.024
28 days	1496.33^{ab}	1563.42^{a}	1516.50^{ab}	1426.67^{b}	19.40	0.060
35 days	2134.50^{b}	2283.33^{a}	2224.17^{ab}	2122.67^{b}	24.69	0.031
body weight gain (g)						
1:14 days	450.58^{ab}	470.00^{a}	476.17^{a}	431.00^{b}	6.53	0.026
14:28 days	1004.75^{ab}	1052.50^{a}	999.42^{ab}	954.92^{b}	15.12	0.142
28:35 days	638.17	719.92	707.67	696.00	21.36	0.605
0:35 days	2093.50^{b}	2242.42^{a}	2183.25^{ab}	2081.92^{b}	24.67	0.030
Feed consumption (g)						
1:14 days	581.70	611.17	579.30	592.13	10.80	0.774
14:28 days	1963.38^{a}	1687.38^{b}	1871.73^{ab}	1911.70^{a}	39.57	0.039
28:35 days	892.92^{c}	1195.87^{ab}	1175.50^{b}	1311.50^{a}	49.15	0.000
0:35 days	3438.00^{c}	3494.42^{c}	3626.53^{a}	3815.33^{a}	45.98	0.000
Feed conversion ratio (g feed / g gain)						
1:14 days	1.30	1.30	1.22	1.37	0.02	0.318
14:28 days	1.30	1.37	1.31	1.31	0.01	0.267
28:35 days	1.41^{b}	1.67^{ab}	1.66^{ab}	1.90^{a}	0.07	0.035
0:35 days	1.64^{b}	1.56^{c}	1.66^{b}	1.83^{a}	0.03	0.000

A, b, and c mean in the same raw with different superscripts are significantly ($p > 0.05$) different, SEM: Control: basal diets, T1: diet with 0.15% CA, T2: diet with 0.30% CA and T3: diet with 0.45% CA.

Performance index (PI) and European production efficiency factor (EPEF)

According to the findings in Table 5, there was no difference in EPEF across the treatments, but there was a significant difference in PI over the duration of the entire period (0–35 days) between the dietary treatments.

The highest PI and EPEF were obtained in groups receiving diets supplemented with 0.15% (T1) and 0.30% (T2) citric acid in comparison with the control group.

More specifically, PI was within the range of 115.85-146.66, and EPEF was in the range of 463.00 - 485.06. The highest PI (146.66) and EPEF (485.06) were recorded in T2 group, while the lowest were in T3 group citric acid) with PI and EPEF values of 115.85. Better PI and

EPEF of T1 and T2 could be due to the beneficial effects of CA as a nutrient digestibility, gut health, and growth performance enhancer.

Table (5): Effect of dietary treatments on performance index and European productive efficiency factor of broiler chicks.

ITEMS	**TREATMENT**				**SEM**	**SIG**
	Control	T1	T2	T3		
Performance index (PI)						
0:35 days	١٣٠.٠٤^{b}	133.94^{ab}	146.66^{a}	115.85^{c}	3.74	0.005
European Productive Efficiency Factor (EPEF)						
0:35 days	470.48	477.98	485.06	463.00	4.82	0.456

A, b, and c mean in the same raw with different superscripts are significantly ($p > 0.05$) different, SEM: Control: basal diets, T1: diet with 0.15% CA, T2: diet with 0.30% CA and T3: diet with 0.45% CA.

Impact of nutritional treatments on broiler chick carcass parameters

Table 6 summarizes the average values of carcass characteristics (edible and inedible parts percentage). There were no significant differences between treatments in different parameters except edible parts percentage (liver, gizzard, and heart) and inedible parts percentage (spleen and abdominal fat).

<u>Carcass yield</u>

The mean values for carcass traits Table 6. demonstrated that dietary citric acid supplementation had a significant effect on some traits in the mean study. They improved carcass yield and edible and inedible parts weights. Birds supplemented with 0.15% citric acid (T1) presented the highest significant carcass yield percentage (76.21%) compared with control group (73.78%) and the other treatment groups were 75.36% and 71.98% in T2 and T3, respectively. The increasing effect on carcass yield might be due to improved nutrient digestibility and absorption by citric acid.

<u>Liver Weight</u>

The relative liver weight was markedly reduced in correlation with the increasing amounts of citric acid supplied. The greatest percentage of liver (2.43%) was in control group followed by (2.00%) in T3 group. The reduced liver size may be due to improved metabolic efficacy or decreased liver stress, despite there were no significant differences in the relative weight of the gizzard and heart between all experimental groups, gizzard weights (1.67%) of the control group were a little higher than those of the other groups, and the highest heart percentage was observed in the T1 group (0.52%). The absence of differences may still represent a subtle influence of citric acid on the development of digestive organs.

<u>Weight Percentage of Immune Organs</u>

There were no effects observed for the relative weights of the bursa and spleen (Table 6). The greatest bursa relative weight was observed in the T3 group (0.25%) while the lowest was in T2 (0.12%). Such discrepancies could be accounted for by the weight of the body or the stress level, as stress can significantly decrease the size of the lymphatic organ. Spleen weights of groups T1 and T3 (0.15%) were higher than those of the controls and T2 groups (0.12%), indicating immune modulation by the citric acid, in any case.

<u>Abdominal fat</u>

Results in Table 6 showed that dietary treatments significantly affected the abdominal fat weight percentage. The highest value was found in the control group (1.28 %), and the lowest percentage of abdominal fat weight T3 (0.68%) compared to other dietary treatments (T1 and T2) whose values were 1.05%.

Table (6): Effect of dietary treatments on carcass characteristics of broiler chicks.

ITEMS	**TREATMENT**				**SEM**	**SIG**
Control T1 T2 T3						
Carcass %	73.78^{b}	76.21^{c}	75.36^{c}	71.98^{a}	0.53	0.001
Liver %	2.43^{b}	2.24^{ab}	2.22^{ab}	2.00^{a}	0.06	0.089
Heart %	0.51	0.52	0.43	0.48	0.02	0.540
Spleen %	0.12	0.15	0.12	0.15	0.01	0.388
Bursa %	0.20	0.24	0.12	0.25	0.02	0.000
Gizzard %	1.67	1.51	1.50	1.58	0.04	0.574
Abdominal fats %	1.28^{b}	1.05^{ab}	1.05^{ab}	0.68^{a}	0.09	0.068
Bursa length cm	6.00^{a}	6.67^{ab}	6.67^{ab}	7.67^{b}	0.25	0.106
A, b, and c mean in the same raw with different superscripts are significantly (p> 0.05) different, SEM: Control: basal diets, T1: diet with 0.15% CA, T2: diet with 0.30% CA and T3: diet with 0.45% CA.						

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DISCUSSION

The highest results in the body's weight gain (BWG) were recorded at the lowest level of citric acid compared with the fed control at 35 days of age, were significant, and other dietary treatments. **Hassan, R. I.*et al.* (2016); Chowdhury *et al.* (2009); Abdel-Fattah *et al.* (2008); Asgar *et al.* (2013); Moghadam *et al.* (2006); Paras *et al.* (2022); Islam *et al.* (2008); and Ahmed M. Fikry *et al.* (2021),** on the other hand, these results **disagreed with Abd-Elsamee *et al.* (2020); Nezhad *et al.* (2007); Khooshechin *et al.*, (2015) and Haque *et al.* (2010).**

During the whole experiment period, broilers fed on a diet containing citric acid supplementation consumed more feed than the control birds. The increase in feed intake could have resulted from increased diet palatability or from stimulating the activity of digestive enzymes upon the inclusion of citric acid. Results like this study were reported by **Islam *et al.* (2012), Asgar *et al.* (2013), and Nourmohammadi & Khosravinia (2015).** In other studies, however **(Abd-Elsamee *et al.*, 2020; Islam *et al.*, 2008; Hassan, R. I.*et al.* (2016); Haque *et al.*, 2010),** such effects have not been reported.

It seems that chicks fed a diet supplemented with 0.15% citric acid recorded the best feed efficiency. This enhancement may be related to increased nutrient digestibility and improved cercal condition resulting from the presence of citric acid. **Asgar *et al.* (2013), Islam *et al.* (2008), Afsharmanesh *et al.* (2005), Nourmohammadi** and **Khosravinia (2015), Fikry et al. (2021),** and **Islam *et al.* (2012).** Conversely**, Chowdhury *et al.* (2009)** did not describe favorable effects of citric acid on FCR. The higher FCR in the 0.15% citric acid group indicates better utilization of feed, which may be due to an increase in the activity of digestive enzymes by enhancing the gut morphology, leading to better nutrient absorption as reported by **Asgar *et al.* (2013).** The worst FCR at higher citric acid concentrations (0.30% and 0.45%) could be due to negative effects on the balance of gut microflora or on mucosal irritation and subsequent impairment of nutrient absorption.

Regarding the previous report of **Hassan *et al.* (2016)**, the reduction of these parameters, PI, and EPEF, in the T3 group could indicate citric acid excess supplementation has a limiting effect on, or even inhibits, inefficient use.

Demonstrated that dietary citric acid supplementation had a significant effect on some traits. Improved carcass yield and edible and inedible parts weights. **Hassan *et al.* (2016),** who submitted a report improving carcass yield due to the use of organic acids.

The reduced liver size may be due to improved metabolic efficacy or decreased liver stress, as shown by **Hassan *et al.* (2016)** and **Fikry *et al* (2021)**.

CONCLUSION AND RECOMMENDATIONS

The study demonstrates that supplementing Indian River Broiler chicken diets with 0.15% citric acid significantly enhances growth performance, and carcass traits. These findings underscore the potential benefits of citric acid as a feed additive in poultry production efficiency in the context of our local environment without having any negative health impacts.

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تقييم استخدام حمض الستريك كمكمل صديق للبيئة فى علائق الدواجن

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المستخلص

نظرًا للآثار السلبية لاستخدام المضادات الحيوية في علف الدواجن، سمح الاتحاد الأوروبي باستخدام الأحماض العضوية كمضافات غذائية بديلة. هدفت هذه الدراسة إلى تحديد تأثير إضافة حمض عضوي (حمض الستريك) لمدة ٣٥ يومًا على وزن الجسم، كفاءة استهلاك العلف، مردود الذبيحة، والحالة المناعية لدجاج إنتاج اللحم. تم تقسيم ٢٤٠ كتكوتًا غير مجنس من سلالة Indian River بعمر يوم واحد عشوائيًا إلى أربع مجموعات؛ تحتوي كل مجموعة على ٦٠ كتكوتًا مقسمة إلى ثلاث مكررات من ٢٠ كتكوتًا تحت نفس ظروف التربية والإدارة. تمت إضافة حمض الستريك إلى العلائق الأساسية (بادى، نامى، ناهى) بنسبة ٠% (كمجموعة ضابطة)، ٠.١٥%، ٠.٣٠%، و٠.٤٥%. تم تسجيل أداء النمو، صفات الذبيحة، ومعامل تحويل العلف. كما تم حساب مؤشر الإنتاجية الأوروبي ومؤشر الأداء (PI) ثم تحليل البيانات إحصائيًا باستخدام تحليل التباين الأحادي (ANOVA) باختبار Duncan لتحديد الفروق المعنوية بين المعالجات ($P < 0.05$). أظهرت النتائج أن الكتاكيت التي تغذت على علائق مضاف إليها ٠.١٥% و٠.٣٠% من حمض الستريك، مقارنةً بالمعالجات الأخرى، كانت لديها أقل استهلاك للعلف، وأعلى وزن جسم، وأفضل معامل تحويل علف ($P < 0.05$). كما حسّن إضافة حمض الستريك بشكل ملحوظ ($P < 0.05$) مؤشر الأداء (PI) مقارنةً بالعلائق الضابطة. علاوة على ذلك، كان لحمض الستريك تأثير إيجابي معنوي ($P < 0.05$) على نسبة التصافي، الأحشاء، وبعض أوزان الأعضاء عند عمر ٣٥ يومًا مقارنةً بالمجموعة الضاب، .يمكن الاستنتاج أن إضافة حمض الستريك بنسبة ٠.١٥% إلى علائق كتاكيت Indian River لها تأثيرات إيجابية على الإنتاجية.

الكلمات المفتاحية: الأحماض العضوية، حمض الستريك، الأداء، صفات الذبيحة، كتاكيت التسمين.