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Comparative Appraisal of Relative Economic Efficiency of Spirulina, Cinnamon oil and Citric Acid Dietary Supplementations and Their Effect on Growth Performance and Carcass Traits in Broiler chicken

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Abstract

The aim of this research was to test the hypothesis of an improved growth, feed utilization efficiency, and economic efficiency (EE) of broiler chickens reared on different diets supplemented with spirulina (SPA), cinnamon oil (CO) and citric acid (CA). Total of 128 broiler chicken were divided randomly in to 4 group 32 chicks for each, with 4 replicants (8 bird/replicant). Group1 (control) fed diet without any additives. Group2 fed control diet + spirulina (2g /kg feed). Group3 fed control diet + cinnamon oil (1ml /kg feed). Group4 fed control diet + citric acid (5g /kg feed). The result indicated that SPA, CO, and CA has a significant effect at ($p<0.05$) on growth performance parameters (feed intake (FI), weight gain (WG) and feed conversion ratio (FCR)). SPA recorded the highest FI while CA recorded the lowest value. It was noticed that SPA and CA do better than CO in live weight and weight gain. The best FCR was in CA group (1.61). SPA and CA has considerable effect at ($P<0.05$) on dressing percent while, CO had no significant effect. CO and CA had a significant impact at ($P<0.05$) on thymus relative weight. From The Economic point of view CA and SPA in the select doses had improved economic measures and relative economic efficiency (REE) indicating high return and net profit, benefit cost ratio, profitability percent, net profit margin. In contrast CO had no distinct effect on these parameters in the selected dose. Bearing in mind that citric acid had a preference in improving economic efficiency over spirulina. SPA, CO and CA may be used as feed additives for broiler chicken to enhance growth performance, Economically CA and SPA in the selected doses is better to increase return and profitability. Citric acid has the advantage in terms of its presence in the market and its low price compared to spirulina.

KEYWORDS
Broiler, Cinnamon oil, Citric acid, Spirulina, Relative economic efficiency, Growth performance.

INTRODUCTION

In recent years, there has been a surge in demand for meat, particularly poultry meat. Poultry became the most popular meat in the world in 2020 after achieving a global production level of 137 million tons. Thus, the chicken sector has a considerable positive impact on human nutrition, animal protein consumption, and global food security (Rashid *et al*., 2020). The future expansion of the poultry business is hampered by several issues, including poultry immunity, health, and productivity. Major obstacles to the current state of the sector and its strategic future will continue to be consumer confidence, product quality and safety, and product types. The risks to public health from eating food with significant antibiotic residues will also continue to be a major problem (Hafez and Attia., 2020). Antibiotic resistance is on the rise and is spreading rapidly, which is extremely concerning. A considerable number of new types of antibiotics have not been developed in recent years, and nearly all the types that are now in use are losing effectiveness against pathogenic bacteria. The consumption of poultry products is among the largest in the world, but many nations use a lot of critical antibiotics in poultry production, endangering the safety of such products and raising the chances of the emergence and spread of bacterial resistance in poultry environments (Agyare *et al*., 2018). Researchers have been forced to come out with unusual and secure antibiotic growth promoter (AGP) replacements as several nations have banned their use as feed additives in chicken nutrition. It has been researched to use probiotics, prebiotics, enzymes, organic acids, herbs, immune stimulants, and essential oils (EO) as natural feed additives in poultry farming (Abd El-Hack *et al*., 2020).

Spirulina is a multicellular, filamentous cyanobacterium that has become quite well-known in the food, healthcare, and aquaculture industries. It contains a lot of macro- and micronutrients, proteins, lipids, vital amino acids, vitamins, minerals, and antioxidants. Spirulina is regarded as a complete food supplement to alleviate malnutritional inadequacies in poor nations (Soni *et al*., 2017). Spirulina dietary supplements can have a positive impact on the gut microbial community, serum biochemical indicators, and chicken development performance. It also has polyphenolic components with antimicrobial properties (El-Shall *et al*., 2023). Several studies have investigated that spirulina supplementation in poultry feed had improved growth performance and meat quality (Altmann and Rosenau, 2022).

Plants produce bioactive, non-nutritive substances called phytochemicals, which are often found in trace amounts (Sharifi-Rad *et al*., 2021). Phytogenic feed additives as essential oils also used as alternative to antibiotic growth premotor (AGP), Cinnamon essential oils are intriguing due to their antioxidant, anti-mi-

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crobial, anti-inflammatory, antifungal, and hypercholesteremic properties, as well as their capacity to activate digestive enzymes in the gut (Ali *et al*., 2021). the main components that present in cinnamon oil are cinnamaldehyde and eugenol (Hamidpour *et al*., 2015). Broiler chicken's digestive system is improved by cinnamaldehyde, which is regarded as a digestion-stimulating substance. For instance, cinnamaldehyde stimulated salivary gland production, which boosted the activity of pancreatic and intestinal enzymes and ultimately enhanced the digestion of broiler (Chowdhury *et al*., 2018). Many studies have proven that cinnamon oil has an effective role in improving the growth of broiler chickens, improving the nutritional conversion rate, in addition to stimulating the immune response (Abd El-Hack *et al*., 2020).

Organic acids often known as acidifiers. The acidifiers have a great impact on heath of Animals' digestive systems. It could be utilized to regulate the intestinal microbial populations in a beneficial way and enhance immune function, acting similarly to antibiotics in food animals to fight pathogenic bacteria (Pearlin *et al*., 2020). Concerning this organic acid that may be used in broiler ration are (propionic acid, formic acid, citric acid, and acetic acid) that could be possible replacements. Their addition to the broiler diet has been demonstrated to increase feed intake, growth, and nutrient digestibility (Gadde *et al*., 2017). Citric acid serves as a natural preservative, but it can also enhance the quality of feed. Although there is evidence that citric acid can boost productivity, this effect is predicted to be substantially greater. Farmers look for poultry feeds that mixed with citric can be kept for a long period without losing their quality. Large-scale feed mixing with citric acid can reduce energy use and production costs and be capable of forecasting the market's highly variable feed material availability (Jamilah and Mursalim, 2020). The key role in antimicrobial activity that its ability in reduction of the guts pH, which prevents growth of bacteria that can't adapted with acidic pH (Hernandez *et al*., 2006). The enhanced feed utilization, the decreased pathogenic microbial load, and the provision of a favorable environment for the growth-promoting bacteria could all contribute to the organic acids' improved growth-promoting effects (Baghban-Kanani *et al*., 2019). According to previous literature about spirulina, cinnamon oil and citric acid, and their effective role in improving the growth of broiler chickens and maintaining the general health of the bird. This study aimed to investigate if these materials have economic benefits additionally to improving the growth or not through study of some productive and economic variables.

MATERIALS AND METHODS

Ethical approval

The experimental work was carried out at the Faculty of Veterinary Medicine, Alexandria university, Egypt with approval of the institutional animal care and use committee (IACUC) Alexandria university (permit 12/9/2022 with serial 139).

Experimental design

Total of 128 broiler chicks (cobb 500) were purchased from new hope company with initial body weight (IBW) 44.59 g. were divided randomly in to 4 groups each group contain 32 chicks with 4 replicant, 8chicks for each. Chicks reared separately in floor pens with wood shaving floor for 6 weeks. Feed and water were supplied free access. Environmental conditions (temperature, humidity, ventilation, and lighting) were maintained all over the Experimental period. Group 1 (control) fed on a basal diet without any additives. Groups 2, 3 and 4 were fed on basal diet with 2g of spirulina (SPA) /kg feed, 1ml cinnamon oil (CO) /kg feed and 5g citric (CA) acid /kg feed respectively. All the experiments groups were fed formulate mash diet. Starter, grower ration was introduced for 4 weeks with crude protein 22.2% and 2950 ME Kcal/kg diet, finisher diet was introduced after the 4th week until the end of experiment with 19.21% crude protein and 3050 ME Kcal/kg.

Table 1. Basal composition of the diet (%) and chemical composition.

Ingredients	Starter grower	Finisher
Ground corn, yellow	59	66.7
Soya bean oil meal (46%)	33.9	25.7
Vegetable oil	0.9	1.3
Corn gluten meal	2.2	2.5
Monocal Phos	1.3	1.2
Limestone	1.6	1.5
Lysine	0.2	0.25
DL-Methionine	0.2	0.15
Minerals mix	0.15	0.15
Vitamins mix	0.15	0.15
Anti-coccidial	0.05	0.05
Anti-clostridial	0.05	0.05
Anti-mycotoxins	0.1	0.1
NACL	0.2	0.2
Chemical analysis %		
Crude protein	22.2	19.21
ME Kcal/kg diet	2950	3050
Crude Fiber	5.4	4.51
Moisture	11.5	11.7
Lipids	3.6	4.2
Ash	5.2	6.9
NFE	52.1	53.48
Calorie/protein ratio	132.88	158.77

Mineral mix each kg contain 120, 000 mg Manganese. 110, 000 mg zinc. 40, 000 mg Iron. 16, 000 mg Copper. 1, 250 mg Iodine. 300 mg Selenium. 150mg cobalt. Vitamin mix each kg contains Vit A 13, 000, 000 IU. Vit D3 6, 000, 00 IU. Vit E 80, 000 mg Vit K3 4000 mg. vit B1 5000 mg. Vit B2 9000 mg. Pantothenic acid 20, 000 mg. Vit B6 5000 mg. Vit B12 35, 000 mg. Niacin 70, 000 mg. Biotin 250, 000 mg. folic acid 2000 mg. BHT 3000 mg. ME Kcal/kg diet Calculated according to Lodhi *et al*. (1976) as Kcal/kg diet. NFE= Nitrogen free extract (calculated by difference "100- (moisture% + CP% + EE% + CF% + ash%)". Calorie/protein ratio = ME Kcal/CP%

Variables and data

Broilers' weight (g), body weight gain (BWG), feed intake (FI), and feed conversion rate (FCR) was calculated at 7, 14, 21, 28, 35 and 42 days of age. At the end of the experiment (42 days of age), Five chicks from each group were randomly selected and weighed to acquire live body weight (LBW). Chicks were slaughtered and de feathered. Dressing percentage was measured (carcass weight / live weight)*100, and internal organs were individually weighted as a percentage of live body weight (LBW).

Economic evaluation

Calculation of the total feed intake /chick (g), Total feed cost/ chick (LE), Price/kg feed (LE), chick cost (LE), Fixed cost/chick (LE), Feed Additive cost (LE), Total cost/chick (LE), Price of kg broiler meat at end of the trial (LE), Total revenue /chick (LE), Net profit margin (NP/TR)*100, Benefit cost ratio (BCR)= TR/TC, profitability percent (p.p.) or Economic efficiency (EE) = (NP/TC)*100, Relative economic efficiency= (EE of tested group / EE of control group)*100, Partial efficiency of feed additives were calculated according to Hassan and El-Ktany (2020) (Additive cost/TC)*100, (Additive cost /TVC)*100.

Table 2. Chemical analysis of spirulina used in the treatment on dry matter basis.

Parameters	%
Moisture (%)	11.2
Crude protein (%)	55.3
Lipids (%)	5.6
Crude Fiber (%)	4.9
Ash (%)	9.8
NFE (%)	13.2
ME Kcal/kg diet	3240

Statistical analysis

Microsoft excel was used to organize row data, then ANOVA of SPSS/PC+ version25 X_{ij}=M+T_i+E_{ij} where, X_{ij}=observations, M=treatment average, Ti=effect of treatment, E_{ij}=error, for analysis of all calculated and recorded variables. Differences among treatments means were tested by Duncan's multiple range technique at 5% probability.

RESULTS

Growth indicators (FI, LBW, BWG and FCR) were significantly differed at p<0.05 with different dietary treatments (spirulina, cinnamon oil, and citric acid) as shown in Table 3. Generally, spirulina group showed the highest level of overall FI (4429.17 g/chick). In addition, the citric acid group recorded the lowest value of total FI (4289.05 g/bird). Furthermore, cinnamon oil significantly decreased whole feed consumption compared to control group (4381.71, 4361.64 g/bird) for control group and cinnamon oil group, respectively. Initial body weight (IBW) of control group and different feed additives groups (SPA, CO, and CA) was the same with no significant differences (Table 4). There was a significant improvement (P< 0.05) in final body weight (FBW) in all treated groups. SPA, CO, and CA recorded the highest FBWs values (2720.41, 2644.25 and 2713.97 g/chicks) respectively. Control group reported the lowest value (2446.41 g/chick). SPA, CO and CA reported the highest BWG values (2675.85, 2599.47 and 2669.38 g/chick), respectively. Control group recorded the lowest value of BWG (2401.82 g/chick). The finding revealed that dietary treatments had significantly enhanced cumulative FCR at (P<0.05) When comparing their values (1.66, 1.68, and 1.61 for SPA, CO, and CA, respectively), to the control group that got the highest value of cumulative FCR. (1.82)

Live body weight, carcass weight and dressing percent (Table 4) were significantly differed at P<0.05. SPA, CO, CA recorded the highest value compared to control group. SPA and CA recorded the highest dressing percent (64.81, 64.06%) while CO had no significant effect on dressing percent. Relative weight of internal organ and immune organs (spleen and thymus) didn't significantly vary except liver weight, proventriculus and thymus. even though abdominal fat didn't significantly differ. SPA, CO, CA recorded the highest value of liver percentage (2.22, 2.15 and 2.20%) in comparison to control group (2.00%), while (CO and CA) recorded the highest value of thymus percentage (0.30, 0.29 %) compared to control and SPA (0.17, 0.21%).

Chicks and managemental costs (Table 5) were the same in all experimental groups. While other economic measures were significantly affected by the addition of various feed additives. Feed costs recorded the highest value (71.48 LE) in SPA group, CA group recorded the lowest value (69.3 LE). Additive cost of CO was the Greatest Cost (5.23 LE) while CA addition recorded the minimal cost (2.56 LE), concerning to TVC and TC indicated that CO exhibited the highest values (85.63, 86.35 LE) respectively. The least TVC and TC was in control group (80.59, 81.31 LE). SPA and CA recorded the highest total revenue (TR) and net profit (NP) values (101.60, 101.36 LE) and (16.81, 18.93 LE), control group was the lowest TR value (91.46 LE). CO addition had no significant effect on NP in comparison to control group (10.15, 12.43 LE), respectively. Economic efficiency (EE) indicators were signifi-

Table 3. Effect of different dietary treatments on growth indicators of broilers chicks.

Traits	Control	Spirulina	Cinnamon oil	Citric acid
FI (g)	4381.71±0.609 ^{b}	4429.17±0.649 ^{a}	4361.64±0.522^{c}	4289.05±0.786 ^{d}
IBW(g)	44.59±0.540*	44.56±0.641*	44.78±0.523*	44.59±0.483*
FBW(g)	2446.41±17.92 ^{b}	2720.41±16.73 ^{a}	2644.25±33.68^{a}	2713.97±19.38 ^{a}
BWG (g)	2401.82±17.62 ^{b}	2675.85±16.88 ^{a}	2599.47±33.85 ^{a}	2669.38±19.44 ^{a}
FCR	1.82±0.04 ^{a}	1.66±0.01 ^{b}	1.68±0.02 ^{b}	1.61±0.01 ^{b}

Data are presented as Mean±S.E., Means within the same row bearing different superscripts are significantly different at (P<0.05). *Non-significant at (p<0.05).

Table 4. Effect of different dietary treatment on carcass traits and relative weight of internal and some immune organs.

Traits	Control	Spirulina	Cinnamon oil	Citric acid
LBW (g)	2294±84.84 ^{b}	2518±37.07 ^{a}	2479±62.30 ^{a}	2668±52.19 ^{a}
Carcass weight (g)	1430±71.12 ^{c}	1632±37.57 ^{a}	1531±41.87 ^{b}	1709±36.96 ^{a}
Dressing percent (%)	62.34±1.05 ^{b}	64.81±0.96 ^{a}	61.76±0.44 ^{b}	64.06±0.61 ^{a}
Liver (%)	2.00±0.07 ^{b}	2.22±0.10 ^{a}	2.15±0.08 ^{a}	2.20±0.08 ^{a}
Heart (%)	0.48±0.05*	0.53±0.03*	0.53±0.03*	0.49±.02*
Proventriculus (%)	0.44±0.03 ^{a}	0.48±0.02 ^{a}	0.42±0.01 ^{b}	0.41±0.01 ^{b}
Gizzard (%)	1.93±0.12 *	1.95±0.02*	1.90±0.07*	1.82±0.08*
Abdominal fat (%)	1.22±0.20 *	0.98±0.13*	0.86±0.11*	1.00±0.13*
Spleen (%)	0.15±0.01 *	0.13±0.01*	0.14±0.01*	0.13±0.01*
Thymus (%)	0.17±0.02 ^{b}	0.21±0.01 ^{b}	0.30±0.03 ^{a}	0.29±0.01 ^{a}

Data are presented as Mean±S.E., Means within the same row bearing different superscripts are significantly different at (P<0.05). *Non-significant at (p<0.05).

Table 5. Effect of different dietary treatments on Economic efficiency measure.

Parameters	Control	Spirulina	Cinnamon oil	Citric acid
Chick cost (LE)	7	7	7	7
Feed cost (LE)	70.74±0.22^{b}	71.48±0.26 ^{a}	70.55±0.18 ^{b}	69.3±0.20 ^{c}
Additive cost (LE)	0 .00 d	2.74±0.08 ^{b}	5.23±0.05 ^{a}	2.56±0.05 ^{c}
Management cost (LE)	2.85	2.85	2.85	2.85
TVC (LE)	80.59±0.22 ^{d}	84.07±0.29 ^{b}	85.63±0.19 ^{a}	81.71±0.20 ^{c}
TC (LE)	81.31±0.22 ^{d}	84.79±0.29 ^{b}	86.35±0.19 ^{a}	82.43±0.20 ^{c}
TR (LE)	91.46±0.66 ^{c}	101.60±0.62 ^{a}	98.78±1.25 ^{b}	101.36±0.72 ^{a}
NP (LE)	10.15±0.56 ^{b}	16.81±0.62 ^{a}	12.43±1.28 ^{b}	18.93±0.72 ^{a}
BCR (TR/TC) (Ratio)	1.12±0.01 ^{c}	1.20±0.01 ^{b}	1.14±0.01 ^{c}	1.23±0.01 ^{a}
P.P. (NP/TC) %	12.48±0.76 ^{c}	19.83±0.76 ^{b}	14.39±1.49 ^{c}	22.96±0.88 ^{a}
Net profit margin (%)	11.10±0.60 ^{c}	16.55±0.50 ^{b}	12.58±1.04 ^{c}	18.68±0.54 ^{a}
Add cost / TC (%)	0.00 ^{c}	3.23±0.09 ^{b}	6.07±0.05 ^{a}	3.11±0.06 ^{b}
Add cost /TVC (%)	0.00 ^{c}	3.26±0.09 ^{b}	6.11±0.05 ^{a}	3.13±0.06 ^{b}
REE (%)	100	158.89	115.3	183.97

Data are presented as Mean±S.E., Means within the same row bearing different superscripts are significantly different at (P<0.05).

cantly affected by using different supplementations. CA recorded the highest value of benefit cost ratio (BCR), profitability percent (PP) and Net profit margin (1.23, 22.96% and18.68 %). in addition, SPA has a positive effect on these indicators as follow (1.20, 19.83% and 16.55%) while CO addition had no significant effect. CO addition recorded the highest additive cost (%) as a percent of TVC and TC respectively value (6.11, 6.07 %) while CA recorded the lowest percent (3.13 and 3.11%). The best relative economic efficiency value (REE) was in CA and SPA (183.97 and 158.89), respectively. which means that CA improved economic efficiency by 83.97% compared to control group and SPA improved economic efficiency by 58.89%.

DISCUSSION

Spirulina increased feed intake than control group (Table 1), this result is in harmony with Fathi *et al.* (2018) and Khan *et al.* (2020) as indicated that Spirulina at various levels greatly increased the amount of feed consumed. This may be due to spirulina increase the palatability of feed as it is a good taste, rich in mineral, vitamins, and B-carotene (Abd El-Hady *et al.*, 2022) and it may be totally substitute of vitamin and mineral premix (Islam *et al.*, 2021). In addition, the obtained result with Abou–Ashour *et al.* (2021) who reported that dietary treatments of citric acid and acetic acid even alone or their mixture had significantly decreased feed intake than control group (95.67, 91.45 g/bird/day) from 1-42 day for control group and 2% citric acid respectively. Elbaz *et al.* (2021) also revealed that citric acid (0.5g/kg feed) treated group had lower level of feed consumed than control group (80.13, 79.38 g/bird/day) for control and critic acid group respectively. While the results were contradictory with Archana *et al.* (2019) who indicated that there was no significant effect for citric acid as feed additive on feed intake of broiler. The reduction of feed intake in citric acid treated group may be due to bitter taste of acidifiers that reduce palatability (Pearlin *et al.*, 2020). Moreover, the result is in line with Saied *et al.* (2022) who reported that feed intake was significantly lower in cinnamon oil group (1000 mg/kg feed) compared to control group that didn't receive any additional cinnamon oil with feed intake (92.48 g/day/bird) for control group and (90.69 g/day/bird) for cinnamon oil group from 1-42 day. The decreasing in feed intake may be because cinnamon oil enhances absorption of nutrients. Krauze *et al.* (2021) showed that administering a phytobiotic that contains cinnamon oil and citric acid improves the metabolic coefficient and nutrient availability from feed.

Outcomes of our finding demonstrated that SPA, CO, and CA had improved growth performance of broiler chicken (LBW, BWG and FCR). Dietary supplements' growth-promoting effects may be related to their effects on gut flora through preserving microbiota homeostasis, palatability, digestibility, and nutrients absorption and utilization. (Sabour *et al.*, 2019; Abd El-Hack *et al.*, 2020 and Altmann and Rosenau, 2022). Result from this study showed that CA improved LBW with 267.56 g/chick more than control and SPA also improved LBW with 274 g/chick more than control. These findings match with Ismita *et al.* (2022) as they reported that 0.5% CA and SP 1% enhanced the growth parameters as LBW values were 1256, 1475, 1539 g/chick for control, 1% SPA and 0.5% CA respectively also reported that this supplement improved FCR, for control (1.91), SPA (1.70), CA (1.67). Fik *et al.* (2021) and Katoch *et al.* (2023) reported that broiler LBW, BWG and FCR improved considerably at P<0.05 when their diet supplemented with 0.5% CA opposed to control group. Comparing the results of the 0.5% CA-fed group to the prebiotic, antibiotic, and control groups, the 0.5% CA-fed group exhibited the greatest LBW, BWG and the best FCR (Asgar *et al.*, 2013). In contrast Islam *et al.* (2020) narrated that using CA as feed additives didn't affect weight gain. Broilers treated with organic acids may have a higher weight gain and an enhanced FCR because of their reduced feed intake and improved nutrient utilization. (Hernandez *et al.*, 2006). Organic acid can acidify the diet which allows better digestion of proteins and minerals (Adil *et al.*, 2010) as result of reduction of the digesta pH and increase secretion of pancreatic enzymes (Dibner and Buttin, 2002), which in turn improve digestion and absorption. Spirulina improved growth performance characteristics (LW, WG and FCR) which is in line with Ansari *et al.* (2018) and Khan *et al.* (2020) as they revealed that 2g/kg feed of SPA as additives recorded the highest value for LW, and WG, and better FCR compared to other level of spirulina (1, 1.5 g/kg feed) and control group. Hassan *et al.* (2022) reported that SPA supplement had enhanced live weight, weight gain and FCR. In addition, Jamil *et al.* (2015) reported that using different levels of SPA (2g, 4g and gm) had a positive effect on body weight and FCR. Billah *et al.* (2022) concluded that for better performance and health status of broilers, spirulina would be supplemented separately or at the same time in feed and water. Moreover, this finding is not harmony with Sugiharto *et al.* (2018) who indicated that SPA supplement didn't affect growth performance. The benefits of spirulina in growth promotion due to SPA has tremendous amount of carotenoid and protein ranging from 55 to 56% which contain all essential amino acids for growth requirements (Velten *et al.*, 2018). SPA supplementation in the feed may probably increase lactobacillus colonization that improve vitamin absorption (Mariey *et al.*, 2012)

In the present study cinnamon oil (1 ml) enhanced growth parameters, these finding is agreed with Ciftci *et al*. (2009) and Saied *et al*. (2022) as they indicated that 1000 ppm and 1 ml of cinnamon oil had significant effect on LBW and FCR compared to control group. Isabel and Santos (2009) concluded that cinnamon oil improved FCR and percentage of breast weight. While Symeon *et al*. (2014) reported that 1ml cinnamon oil didn't affect growth performance. To enhance immunity, metabolism, health, growth performance, carcass characteristics, and meat quality, bioactive components of CO as cinnamaldehyde and phenolic compounds, among others, have been added to poultry feed. These components have strong anti-inflammatory anti-microbial and antioxidant effects (Zhu *et al*., 2020). FCR, BWG, and the general health performance of broilers are all improved by better feed use. The two widely known mechanisms of this component that play a key role in enhancing feed utilization and preventing growth-depressing disorders that involve metabolism and digestion are the stabilization of the gut microbiota environment and the promotion of digestive enzyme release (Lee *et al*., 2003 and O'Bryan *et al*., 2015).

The finding presenting in Table 4 concluded that SPA improved dressing percent at $P<0.05$ with no significant effect on relative weights of gizzard, heart, spleen, and abdominal fat, the result agrees with Abdel-Moneim *et al*. (2021) who indicated that administration of spirulina increased dressing percentage, while having no appreciable impact on the gizzard, heart, spleen, and abdominal fat relative weight. in addition, Moustafa *et al*. (2021) concluded that SPA supplementation improved dressing percent and was effective in reducing the effects of heat stress on the final average daily growth, body weight, and feed conversion ratio. Moreover Islam *et al*. (2021) narrated that feed containing 0.15% vitamin and mineral premix+0.15% spirulina) improved dressing percent (63.12 %) compared to control group (62.05). while the finding disagreed with Ismita *et al*. (2022) who observed that spirulina and citric acid didn't affect effect dressing percent of broiler. SPA improved dressing percent due to its high-quality protein; meat is better quality, and more protein is accumulated in muscle instead of fat (Jung *et al*., 2019).

In this study, citric acid improved dressing percent, which is in line with Sharifuzzaman *et al*. (2020) as reported that using of citric acid with different levels (0.5%, 0.75% and 1%) in low protein and low energy diet had positive effect on dressing percent. Tanzin *et al*. (2015) and Abou–Ashour *et al*. (2021) concluded that 0.5% and 2% CA supplementation was significantly affect dressing present at $P<0.05$, in comparison to the control group without any significant effect on relative weight of internal organs. Abou–Ashour *et al*. (2021) also indicated that even though spleen relative weight was not affected by 2% CA, relative weight of thymus had been significantly affected by addition of CA. This is in line with our findings. Organic acids may be beneficial to improve immunity of broiler due to their capacity to decrease the number of hazardous bacteria (Scicutella *et al*., 2021). Mild to moderate lymphoid hyperplasia showed an improvement in the immune response because the thymus is a lymphoid organ that is responsible for avian immunity (Attia *et al*., 2018).

The finding revealed that CO supplementation has no significant effect on dressing percent and relative weights of internal and immune organs except thymus had been significantly affected. The result is in harmony with Symeon *et al*. (2014); Chowlu *et al*. (2019) and Saied *et al*. (2022) who reported that supplementation of cinnamon didn't affect dressing percent and relative weight of organs. In addition, Gomathi *et al*. (2018) reported that carcass characteristics including abdominal fat, eviscerated, gizzard, heart, and giblet weights as a percentage of live body weight were not changed by the supplementation of cinnamon oil at levels of 250 or 500 mg/kg and coated sodium butyrate at 0.09% or 0.18% in broiler diet Hussein *et al*. (2023) concluded that CO had positive effect on thymus relative weight. Moreover, Krauze *et al*. (2021) stated that phytobiotic preparation containing CO and CA had positive impact on metabolism, immunological and antioxidant systems, small intestine microbiota, and morphometry.

The finding in Table 5 revealed that CA decreased the feed cost as it decreased amount of FI compared to control group Contrasting to SPA that increased the feed cost as result of its increasing of FI, while CO didn't significantly affect feed cost. The total production cost was the lowest in the control group due to the additive cost of the different supplemented materials in the other experimental groups. SPA, CA and CO increased the total return due to their improvement of final weight (Mohammed *et al*., 2021). Regarding to collective efficiency measure (BCR, P.P. and net profit margin) and relative economic efficiency both SPA and CA has improved all the efficiency parameters and net profit, in addition CA had the superior over SPA in improving the economic efficiency while CO addition didn't have a significant impact on collective efficiency measures as it represent the most expensive additive.

Our finding is in accordance with Fathi *et al*. (2018) and Khan *et al*. (2020) as they concluded that SPA had increased feed cost, total return, net profit, and improved economic efficiency. Ismita *et al*. (2022) reported that using of 0.5% CA and 1% spirulina has positive impact on growth performance and economics with preference application of CA as spirulina is slightly more expensive because it is not as widely accessible as CA in local market. Furthermore Hassan *et al*. (2022) indicated that using 0.25% *Spirulina platensis* is more economic and better REE as higher amount of spirulina the higher production cost. Fathi *et al*. (2018) narrated that 0.7 g/kg diet is better from economic point of view. Furthermore, Abbass *et al*. (2020) revealed that using different levels of spirulina (1%, 2% and 3%) improved economic efficiency compared to the control group.

CA outcomes are consistent with Abou–Ashour *et al*. (2021) as narrated that CA addition in feed had decreased feed cost, increased total return and REE. On the other hand, Archana *et al*. (2019) stated that citric acid supplementation increased the total cost, while decreased feed cost per kg live BW and increased return and net profit per kg live BW. Tanzin *et al*. (2015) mentioned that 0.5% CA recorded high net profit /bird in comparison to the control group and 0.2% herbal feed additive (keqinling) or combination between (0.5 % CA + 0.2% K). Sharifuzzaman *et al*. (2020) indicated that using of 0.5% CA in low energy and low protein diet increased TC, return, NP/bird compared to control group. Katoch *et al*. (2023) concluded that 0.5% citric acid is cost effective in reducing cost when supplemented to moderately low calcium and phosphorus diet.

The obtained result revealed that CO has no significant effect on economic measures, this is harmony with Hussein *et al*. (2023) who concluded that addition of CO separately in feed didn't significantly affect feed cost and in relative economic efficiency in comparison to when mixed with other essential oils (clove, peppermint oil). Also, the selected dose may be high as the pure essential oils are high in price. Chowlu *et al*. (2019) indicated that addition of high level of cinnamon increased the production cost which in turn affected profitability. The same result was reported by Gaikwad *et al*. (2019) that addition of cinnamon by 3% compared to other levels 1% and 2% of cinnamon and ginger (1%, 2% and 3%) increased the total production cost per bird, also indicated that with increased cinnamon percent the net profit per bird and benefit cost ratio were decreased. The more purity and increase cinnamaldehyde content and good quality, the high price of the oil (Ravindran *et al*., 2003 and Haddi *et al*., 2017).

CONCLUSION

Spirulina, cinnamon, and citric acid may be used in broiler feed as effective feed additives for improving growth performance, while, from the economic point of view citric acid and spirulina are more economic than cinnamon oil in the selected doses. Citric acid has a superior effect in the economic efficiency as its low price even applicable by high dose and availability while the economic effect of spirulina is dependent on its dose. Further study is required to illustrate the economic effect of cinnamon oil in another doses.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interests regarding the publication of this paper.

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