EFFECT OF DIETARY CITRIC, ACETIC ACIDS OR THEIR MIXTURE ON BROILER CHICKS PERFORMANCE, CARCASS CHARACTERISTICS AND SOME INTESTINAL HISTOMORPHOLOGICAL PARAMETERS

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SUMMARY

A total number of 120, 1d old unsexed chicks were randomly distributed and divided equally into 4 dietary treatment groups with 3 replicates each. All broiler chickens were kept under similar managerial conditions. Basal starter and finisher diets were supplemented with two types of organic acids as follows: T1: basal diet (control, without supplementation), T2: basal diet + 2% citric acid (CA), T3: basal diet + 1% acetic acid (AC) and T4: basal diet + 1% citric acid + 0.5% acetic acid. Two corn-soybean based basal diets were formulated to be fed during starter (1 to 21 d, 22.13% CP and 3088 Kcal ME/kg diet) and finisher (22 to 42 d, 19.82% CP and 3154 Kcal ME/kg diet) periods. Growth performance parameters, feed conversion ratio, some carcass characteristics and some lymphoid organs were estimated. Some blood parameters (total protein, albumin, total cholesterol, creatinine, ALT and AST) and histomorphological samples and parameters were determined at 42 day. Also, European productive and economic efficiency were calculated. Results indicated that; chicks fed diets supplemented with a mixture of citric acid (1%) and acetic acid (0.5%) had significantly (P ≤ 0.05) the highest values of body weight, body weight gain and the best feed conversion ratio, while recorded the lowest feed intake compared to the other treatments. Moreover, using mixture of supplementation significantly (P ≤ 0.05) improved performance index (PI) in comparison with the control treatment. A significant (P ≤ 0.05) beneficial effect of citric acid and acetic acid or their mixture as feed supplementation were found concerning dressing, giblets and some immune organs percentages at 42d of age compared to the control group. Mixture of citric acid and acetic acid supplementation significantly (P ≤ 0.05) increased some serum biochemical constituents (total protein, albumin, globulin and liver enzyme; ALT), while, total lipids and cholesterol concentrations were significantly (P ≤ 0.05) decreased. Histomorphological sections of the small intestine revealed villi height and villi widths were significantly (P ≤ 0.05) increased with the supplementation of organic acid alone or in their mixture compared to the control group. Also, the mixture of 1% CA + 0.5% AC supplementation had beneficial effects on economical efficiency. In conclusion, there are some beneficial effects of using a mixture of citric acid and acetic acid (1% citric acid + 0.5% acetic acid) in the diets of chicks on productive performance, carcass traits, with no harm effect on health under experimental conditions.

Keywords: Citric acid, acetic acid, carcass traits, serum biochemical constituents, histomorphological parameters and broiler chicks.

INTRODUCTION

A modernistic challenge in the poultry production is to exploit the use of specific dietary supplements to boost the intrinsic potential of poultry for better growth. The nutritional and health status of birds are largely influenced by their gut health, which affects digestion, absorption, and metabolism of nutrients, as well as disease resistance and immunity (Yegani and Korver, 2008).

High levels of production and efficient feed conversion are critical to modern poultry industry, which could be achieved by using specific feed additives. Some of the commonly used feed additives are organic acids, probiotics, prebiotics, medicinal extract and exogenous enzymes. These feed additives were used as antimicrobial, antioxidants, emulsifiers, binders and pH control agents in the poultry diet (Rehman et al., 2016; Jasim and Fehan, 2017; Attia et al., 2018 and Adhikari et al., 2020).
Organic acid treatments composed of individual acids or blends of several acids to perform antimicrobial activities similar to those of antibiotics (Wang et al., 2009). The European Union allowed the use of organic acids and their salts in poultry production because these are generally considered safe (Adil et al., 2010). Organic acids are weak acids, which modulate the intestinal pH. When these compounds are used correctly a long with good nutritional, management and biosecurity measures, they could be a powerful tool in maintaining the health of the gastrointestinal tract (GIT) in poultry thus improving the performance (Sabour et al., 2019 and Adhikari et al., 2020). Organic acids had higher globulin concentration and better immune response and reduced serum cholesterol and total lipid (Youssef et al., 2017; Ali et al., 2019 and Mirderikvandi et al., 2019).

Citric acid (CA) is the most common organic acid used in poultry diets. It acts as a growth promoter through acidifying the gastrointestinal (GI) content. CA is an organic acid that has been recently employed to improve feed utilization and its influence seems to depend on the diet composition (Mohammadi and Khosravinia 2015 and AL-Harthi and Attia, 2016). In addition, citric acid was found to change the gut pH and increase the activity of some enzymes that need acidic conditions, such as pepsin and phytase, therefore enhancing the utilization of protein and some minerals (Wickramasinghe et al., 2014), increasing the digestibility of protein and fibre (Atapattu and Nelligaswatta, 2005), improving live weight gain, feed conversion efficiency and absorption of minerals (Sharifuzzaman et al., 2020). Citric acid also decreased pH of ceecal digesta (Jozefiak and Rutkowski, 2005), crop and gizzard (Andrys et al., 2003) and intestine (Dehghani and Jahanian, 2012 and Attia et al., 2018) in broiler chicks. It reduced microbial load and result in better immune response in broilers (Wickramasinghe et al., 2014).

Acetic acid is among greater attention for poultry industry (Kral et al., 2011 and Mohammadi et al., 2018). It is generally believed that use of acetic acid in broiler diets may inhibit pathogens like salmonella in both raw material and feed (Choct, 2001). The lower PH created can protect the animal from infection especially at their younger ages (Mohammadi et al., 2018). Acetic acid at a wide dose range from 0.5 to 5% has been implemented in diets for broiler chickens which mainly reduced growth of many pathogenic or non-pathogenic intestinal bacteria, therefore, reduced the risk of intestinal colonization and infectious processes, ultimately decrease inflammatory processes at intestinal mucosa, a phenomenon which in turn, increase villus highet and function of secretion, digestion and absorpition of nutrients by the mucosa (Pelicano et al., 2005). Acetic acid (AC) supplementation in diet improves growth performance (Seifi et al., 2015 and Abdel Razek et al., 2016), quicken intestinal tissue, resulting in changes in villus width, height and area of the duodenum, jejunum and ileum, which all are the promising factors for the better intestinal health and nutrient digestion and absorpition (Kum et al., 2010; Mohammadagheni et al., 2016 and Saleem et al., 2016). Citric acid (CA) and acetic acid (AC) have been used in diets due to their positive effect on bird's health and growth (Islam et al., 2008).

Therefor, the objective of the present study was to investigate the effects of dietary supplementation of some organic acids such as citric, acetic or the mixture citric and acetic at the levels of 2, 1, or 1 and 0.5%, as respectivily on growth performance, carcass characteristics, intestinal histomorphology, some serum blood parameters and economic efficiency in broiler chicks.

**MATERIALS AND METHODS**

The present study was conducted in a private farm in Menouf, Menoufia Governorate, Egypt, throughout the experimental period from May to June 2018 to study the effect of dietary supplementation of some organic acids (citric or acetic acids and their mixture) on growth performance, carcass characteristics, some histomorphological measurements, some serum biochemical parameters and economic efficiency of broiler chicks.

**Experimental diets:**

Two corn-soybean based basal diets were formulated to be fed during starter (1 to 21 d) and finisher (22 to 42d) periods. The broiler diets were formulated to be approximately isocaloric and isonitrogenous and meet or exceed the nutritional requirements according to National Research Council’s nutrient (NRC, 1994) and used to formulate the basal diet (Table 1). The basal corn – soybean meal starter diet contained approximately, 22.13% CP and 3088.38 Kcal ME/kg diet and 19.82% CP and 3154 Kcal/kg in finisher diet and both were offered in mash form. Proximate chemical analysis of the basal diets fed was performed according to AOAC (2011). Basal starter and finisher diets were supplemented with two types
of organic acids,(OA)* as: citric acid, (CA) and acetic acid, (AC) as follows:

- **T1**: basal diet (control, without any supplementation).
- **T2**: basal diet + 2% citric acid.
- **T3**: basal diet + 1% acetic acid.
- **T4**: basal diet +1% citric acid + 0.5% acetic acid. Mixing of experimental diets was done weekly.

**Chicks assay procedures:**

On the day of hatch, one hundred and twenty, mixed sex Arbor Acres chicks were used in this experiment. Chicks were wing banded, weighed and randomly allotted to four treatment groups, 3 replicates of 10 chicks each nearly similar in initial body weight (45g). Groups were reared in pens with litter (wheat straw) from 1 day old up to 42 days of age.

Throughout the experimental period (42d), chicks were given feed and water ad libitum. The management of broiler chickens was consistent with the guidelines (Arbor Acres Broiler Commercial Management Guide; http://en. aviagen.com/assets/Tech_Center/AA_Broiler/AA-Broiler-Handbook2014i-EN.pdf). A 23 h of light and 1 h of darkness lighting schedule was maintained for the duration of the experiment. The initial temperature was 33 °C at the first day of age and decreased approximately 2 °C/ week until 24 °C, 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. All proper husbandry practices were followed.

**The following parameters were measured:**

**Body weight (BW)** an individual body weight was recorded while, **body weight gain (BWG) and average daily gain (ADG)** were calculated from the first day of the experiment and by weekly throughout the experimental periods.

**Feed intake and feed conversion ratio:** Total feed intake / dietary treatment group / day was recorded and expressed as feed (g) / bird / day. Feed conversion ratio was expressed as feed (g) / body weight gain (g).

**Performance index (PI), mortality ratio (MO) and livability (Liv), %:**

Performance index was calculated according to North (1984) as follows:

\[
PI = \frac{\text{Live body weight gain (Kg)}}{\text{feed conversion ratio}} \times 100.
\]

Mortality was recorded during the experimental periods, mortality % was calculated by subtracting the number of live birds at the end of the experiment from the total number of birds at the beginning of the experiment. The product was multiplied by 100 to obtain the percentage mortality % as follow: MO,% = (No. of birds at the beginning of a given period – No. of birds at the end of the same period) × 100 / No. of birds at the beginning of a given period. Livability (Liv, %) = No. of birds at the end of the experiment period × 100 / No. of birds at the beginning of the experiment.

**Slaughter and carcass information:**

At the end of 42 days of age, three birds from each dietary treatment were weighed and slaughtered, after feed withdrawal for 12 hours to determine carcass traits: eviscerated carcass (without head, neck and legs) and total giblets (liver, gizzard and heart) weights were expressed relative to live body weight.

The bursa of fabricius, spleen and thymus (all lobes from left side of the neck) were cut and weighed to the nearest milligram. Data obtained was used for the calculation of dressing percentage as follows:

\[
\text{Dressing percentage (\%)} = \frac{\text{carcass weight}}{\text{live weight of bird}} \times 100.
\]

**Serum samples and biochemistry parameters:**

Blood samples were taken at slaughter time from each bird, individual blood samples were collected into tubes without heparin and serum was separated by centrifugation at 3500 rpm for 15 minutes and frozen at –20°C until analysis. Serum total protein (TP), albumin (A), total lipids (TL), cholesterol (Chol.), creatinine and glucose were determined using commercial kits. The globulin (G) value was obtained by subtracting the values of albumin from the corresponding values of total protein. Also, albumin/ globulin (A / G ratio) values were obtained by dividing the values of albumin on the values of globulins according to Coles, (1974). Also, liver function enzymes including aspartate amino transaminase (AST) and alanine amino transaminase (ALT) were calorimetrically estimated according to Reitman and Frankel (1956).

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*Organic acids, citric acid (CA) and Acetic acid, AC were supplied from Egyptian Company for Laboratory Services, Cairo, Egypt and Acetic acid, AC powder was obtained from AVITASA (ESP43100164) I C. Europa s/n pol Constanti (Tarragona) Spain and sale only from EVPCO group, Egypt veterinary pharmaceuticals company for animal and poultry feeding line only, Alexandria, Egypt.
Table (1): Composition and chemical analysis of the experimental diets fed during starting (1–21) and finisher periods (22–42) days of age.

| Ingredient                        | Starter diet | Finisher diet |
|-----------------------------------|--------------|---------------|
| Ground yellow corn (8.5%)         | 50.85        | 57.64         |
| Soybean meal (44%)                | 40.47        | 33.92         |
| Vegetable oil                     | 5.39         | 5.23          |
| Limestone ground                  | 2.10         | 2.04          |
| Di-calcium phosphate              | 0.39         | 0.35          |
| Vitamins and minerals mixture¹    | 0.30         | 0.30          |
| DL-Methionine²                    | 0.20         | 0.22          |
| Salt (sodium chloride)            | 0.30         | 0.30          |
| Total                             | 100          | 100           |
| Calculated values³:              |              |               |
| Crude protein, %                  | 22.13        | 19.82         |
| ME, kcal/kg diet                  | 3088         | 3154          |
| C/P ratio                         | 140          | 159           |
| Lysine, %                         | 1.29         | 1.11          |
| Methionine, %                     | 0.57         | 0.54          |
| Calcium, %                        | 1.02         | 0.97          |
| Available phosphorus, %           | 0.44         | 0.42          |
| Determined values:                |              |               |
| Dry matter, %                     | 89.40        | 88.49         |
| Crude protein, %                  | 22.09        | 19.80         |
| Ether extract, %                  | 4.56         | 6.01          |
| Crude fiber, %                    | 3.64         | 3.58          |
| Ash, %                            | 6.01         | 6.14          |

¹Vitamin and Mineral mixture at 0.30% of the diet supplies the following per kilogram of the diet: Vitamin A 12,000 IU, vitamin D₃ 3,000 IU, vitamin E 40 mg, vitamin K₃ 3 mg, vitamin B₁ 2mg, vitamin B₂ 6 mg, vitamin B₆ 5 mg, vitamin B₁₂ 0.02 mg, niacin 45 mg, biotin 0.075 mg, folic acid 2 mg, pantothenic acid 12 mg, manganese 100 mg, zinc 600 mg, iron 30 mg, copper 10 mg, iodine 1 mg, selenium 0.2 mg, cobalt 0.1 mg.

²DL-Methionine: 98% feed grade (98 % Methionine).

³Calculate according to NRC (1994).

Histomorphological samples and parameter:

For the histological study of intestinal villi, at 42 days age, samples of duodenum, jejunum and ileum were obtained from the slaughtered birds. The specimens was 2 cm of the middle portions of the duodenum, jejunum and ileum were excised and fixed in 4% buffered formalin (Bancroft et al., 1996). Segments referred to the midpoint of the duodenum (from gizzard to pancreo-biliary duct), jejunum (the midpoint between the entry of the common bile duct and the Meckel’s diverticulum) and ileum (from the Meckel’s diverticulum to ileocecal junction). Particular segments were gently flushed and rinsed with 0.9% physiological saline and then fixed in 4% neutral-buffered formalin solution for histological study.

Samples of the small intestine were transferred from formaldehyde after dehydration through passing tissue by sequences of alcohol solutions and then were cleared by xylene and embedded in paraffin. These fragments were opened longitudinally on styrofoam plates and washed with saline. The samples were fixed with Bouin’s solution for 24 h for histological analysis, according to Uni et al. (1999). The fragments cuts of 5 µm thick and stained with Hematoxylin and Eosin (H &E).

Morphometric data from villus height and crypt depth were obtained from images captured by photomicroscope (Olympus). The tissue sections were taken for measuring the villus height, villus width and crypt depth. Morphometric measurements were performed on the selected 9 villi from each sample. The height of intestinal villi was measured from the tip to the base of villi at the opening crypt, and the villus width was measured at its midpoint (Geyra et al., 2001). The intestinal crypt depth was measured from the base of the villi to submucosa, and the muscular thickness from the submucosa to the external layer of the intestine (Ebrahim et al., 2017).
Economical efficiency, relative economical efficiency and European productive efficiency, (%):  
The economic efficiency was calculated from the input – output analysis (Heady and Jensen, 1954) assuming that other head costs were constant, as follows: \[ \text{Economical efficiency} = \left( \frac{\text{price of kg weight gain-feed cost/kg gain}}{\text{feed cost/kg gain × 100}} \right) \times \text{marketing age, days} \] under the experimental conditions and European productive efficiency was calculated as: \[ \text{EPE, %} = \left( \frac{\text{Mean body weight (Kg) × livability % ×100}}{\text{feed conversion ratio × marketing age, days}} \right) \] cited by Soltan and Kusainova, (2012).

Statistical Analyses:  
The experiment was conducted using a completely randomized design using SPSS (2011) program and the difference among treatment means were determined using Duncan’s multiple range test (Duncan, 1955). Percentages were transformed to the corresponding arcsine values before performing statical analysis (Snedecor and Cochran, 1982) the following statical model was applied:

\[ Y_{ij} = \mu + \alpha_i + E_{ij} \]

Where:
- \( Y_{ij} \) = Observed traits,
- \( \mu \) = Overall mean,
- \( \alpha_i \) = Effect of treatment (I = 1, 2, 3 and 4) and
- \( E_{ij} \) = Experimental random error.

RESULTS AND DISCUSSION

Effect of dietary citric acid (CA), acetic acid (AC) or their mixture on broiler performance:

Body weight, weight gain and daily gain:

The effect of dietary citric acid (2% CA), acetic acid (1%AC) or their mixture (1% CA + 0.5% AC) supplementation on body weight (BW) , body weight gain (BWG) and average daily gain (ADG) of growing broiler chickens up to 42 days of age are shown in Table (2). The data showed a significant (P ≤ 0.05) increased in body weight for birds fed dietaries 2% CA (T\(_2\)) and 1% acetic acid (T\(_3\)) or their mixture of organic acids (T\(_4\), 1% CA + 0.5% AC) being 1232.23, 1220.06 and 1262.50 g, respectively compared to 1218.45 g in the control group. As for BWG and ADG (Tables 2), chicks fed basal diets without supplementation had significantly lower (P ≤ 0.05) body weight gain (751.74 g) and ADG (53.79 g) during the period from 28 to 42 days of age. Broiler chicks fed 2% CA, 1% AC supplementation have the heighest BWG being (795.11 and 775.36 g) and ADG values were 56.79 g and 55.50 g for T\(_2\) and T\(_3\), respectively during the period from 28 to 42 days of age, body weight gain and average daily gain were significantly increased (P ≤ 0.05) with the mixture of citric acid and acetic acid supplementation being; 812.63 and 58.07 g, respectively for T\(_4\) compared to other treatment and control group.

In general, birds fed dietary the mixture of 1% CA + 0.5%AC (T\(_4\)) or chicks fed dieary 1% AC (T\(_3\)) followed by those fed 2% CA supplementation (T\(_2\)) had the greatest BW, BWG and ADG, being (2075.13, 1995.42 and 2027.34 g) for BW at 42 days of age; 2029.97, 1982.53 and 1948.15 g in BWG and for ADG; were 50.02, 47.36 and 46.28 g, respectively during the period from 1 – 42 days of age compared to 1970.19 for BW at 42 days of age, 1924.98 and 46.13 g for BWG and ADG, respectively for the control group during the period from 1 to 42 of age.

The improvement in BW, BWG and ADG of broilers fed diet contain of citric acid, acetic acid or thire mixture may be due to the following reasons a) acetic acid acts on pepsinogen and convert it to pepsin and increased the activity of pepsin and improves protein digestibility in broiler chicks (Ulaawi et al., 2017), b) the antimicrobial property and low pH of organic acid inhibits the pathogenic intestinal bacteria and decreases the level of toxic bacterial products. So, energy and protein digestibility were improved (Adil et al., 2011 and Sultan et al., 2015), c) organic acids improve the protein digestibility by decreasing endogenous nitrogen losses and production of ammonia as well as other growth depressing metabolites (Dibner and Buttib 2002), d) intestinal cell proliferation and hence more available nutrients for absorption (Samanata et al., 2010), and the acidic condition increases the nutrients availability for better performance (Boling et al., 2001). Acetic acid has more effects on performance of broiler, addition of acetic acid to mash diet may lead to increase in palatability and improve mixing ration items.
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(Mohammadaghieni et al., 2016). These results were agreement with the results reported by Khan and Iqbal (2016) and Yousef et al. (2017), who recorded that an improvement in BW and BWG for birds fed diets supplemented with organic acids meantime the growing period, which was due to the effect of keeping the beneficial bacteria population, improving nutrient digestion and may be impact the safety of microbial cell membrane or prohibit the nutrient transport and energy metabolism causing the bactericidal effect (Ricke, 2003). Many investigators reported that single or mixture of organic acid (CA and AC) can improve performance of chicks and had a significant effect of mean BW, WG and ADG on broiler chicks (Sabour et al., 2019; Adhikari et al., 2020; Sharifuzzaman et al., 2020 and Stamilla et al. 2020). On the other hand, Kopecky et al. (2012) and Flamand et al. (2014) showed that organic acid (citric and acetic acids) addition to the corn-soybean diet did not affect chick body weight, body weight gain and average daily gain.

Feed intake (FI), feed conversion ratio (FCR) and performance index (PI):

Data describing the effect of dietary organic acid as citric, acetic acids or their mixture on feed intake (FI, g / chick/ day) of broiler chickens during the period from 1 - 42 days of age are presented in Table 3. Broiler chickens fed citric and acetic acid supplemented to the basal diet significantly affect the feed intake of the treated- groups compared to the control group during 1 - 14 days. Also, basal diet contained citric acid and acetic acid (1% CA + 0.5% AC) significantly (P ≤ 0.05) decreased feed intake of ArborAcres chicks during the experimental periods (14 – 28 days of age. Values of FI (g / chick / day) being; 90.17 g compared to other treatments T2 (2% CA), T3 (1% AC) and control group (0, without supplementation) being, 91.14, 93.45 and 95.71, respectively during 14- 28 d. Feed intake (FI) for treatments T2, T3 and T4 were 128.01, 132.08 and 125.33 g), respectively compared to133.16g / chick/day for control group at 28 – 42 days of age. In general, during the entire experimental period from 1- 42 days of age, chicks fed the basal diet with 1% CA + 0.5% AC (T4) had significantly decreased feed intake 90.11g / bird / d in comparison with the control group (95.67) and other experimental groups being, 91.45 and 93.96 g / b / d, respectively during the period from 1 – 42 days of age.

The reduction in feed intake (g / chicks / d) was noticed during the starter and finisher period, this may be due to the decrease in palatability of acidified diets during experimental diets. They had a low tendency to free their H+ ions and thus tended to have a strong taste associated with them which might have decrease the palatability feed and result in reduced feed intake Abdel Fattah et al. (2008); Adil et al. (2010) and Allahdoa et al. (2018). Also, organic acids increase the availability of nutrients from the feed which in turn decrease the feed consumption Pakhira and Samanta (2006) and sultan et al. (2015). These results is harmony with the results of Abdel Razek et al. (2016) who reported that chicks fed diets supplemented citric acid and acetic acid significantly consumed less feed (P ≤ 0.05) compared to control group. It was observed that the lowest (P ≤ 0.05) amount of feed intake was recorded for birds fed diets containing (1.61 and 1.70) of CA and (1.98 and 2.30) of AC. Additionally these results were in line with the finding of Ali et al. (2019); Mirdrikvandi et al. (2019); Omidi et al. (2020) and Stamilla et al. (2020) who reported decreased feed intake with higher level of organic acids such as citric and acetic acids application. On the other hand, the present results disagreed with those observed by Wickramasinghe et al. (2014), Seifi et al. (2015) and Araujo et al. (2018) who reported that adding different levels of citric acid and acetic acid to broilers did not have effect on feed intake. Results in Table 3 presents the effect of dietary different levels of citric acid, acetic acids or their mixture supplementation on feed conversion ratio (FCR) during the experimental periods from 1 to 42 days of age. Data revealed that FCR was significantly improved by the supplementation during the experimental period (1- 42 days of age).

Chicks consuming the basal control diet (T1) had FCR 2.08 during 1 - 42 days of age, but feed conversion ratio was improved gradually with the supplementation of citric acid (2%CA) and acetic acid (1% AC). The best value of FCR was 1.83 for chicks fed diet supplemented with the mixture of citric and acetic acids (1% CA + 0.5% AC) at 1- 42 days of age. The significant improvement in FCR by the addition CA and AC may be due to: a) organic acids as the plays a very important role that acidification increasing gastric proteolysis and protein / amino acid digestibility by enhancing digestive system enzyme activities (Langhout, 2000).

The reason why protein is better used when CA is added to diets is due to the fact that pepsinogen is converted to pepsin, which increases pepsin activity and improves protein digestibility. Moreover, peptides rising from pepsin proteolysis trigger the release of hormones (including gastrin and cholecystokinin) which regulate the digestion and absorption of protein, b) organic acids due to the increasing efficiency of nutrients (Chowdhury et al. 2009), c) the numerical reduction in feed intake and concomitant increase in

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The findings are supported with that of (Mustafa et al. (2014); Sultan et al. 2015; Al- Harthi and Attia (2016) who suggested that the inclusion of organic acids (citric acid and acetic acid) in broiler chicks diet significantly enhanced FCR. Organic acids added to feeds should be protected to avoid their dissociation in the crop and in the intestine (high pH segments), where the bulk of the bacteria population located. The beneficial effect of growth promoter substances on performance is related to a more efficient use of nutrients, which in turn results in an improving FCR. Similar observations were noticed by Rahman et al. (2018); Sabour et al. (2019) and Omidi et al. (2020). However, Araujo et al. (2018) and Elmi et al. (2020) did not observe differences in FCR of broilers fed diets contained acetic acid and citric acid supplementation during 1-35 d and 1-42 days of age.

Results presented in Table (3) indicated that there were significant differences among treatments in performance index (PI) during the different experimental periods 14, 28 and 42 days of age. Performance index recorded 34.05, 29.48, 32.87 and 26.94 ‰ for chicks fed experimental diets (T₄; 1% CA + 0.5% AC), T₃ (1% AC), T₂ (2% CA) and control diets (T₁), respectively at 14 days of age. The highest PI (72.97‰) was recorded in chicks fed the mixture of organic acid (T₄) followed by 68.10, 66.01‰ in groups fed 2% CA (T₂), and 1% AC (T₃), respectively compared to 63.46‰ in the control group at 28 days of age. The best PI was obtained with chickens fed the mixture of 1% citric and 0.5% acetic acids (94.75‰), while the lowest PI value was obtained in control group being 78.81‰. The positive response on PI by organic acid in early life could be attributed to the decreasing pH and increasing the proteolytic enzyme activity and nutrient digestibility along with bacteriostatic and bactericidal action to the pathogenic bacteria (Papatsiros et al. 2013).
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Table (3): Effect of dietary citric acid, acetic acid or their mixture supplementation on average feed intake (FI), feed conversion ratio (FCR) and performance index (PI,%) of broiler chicks during experimental periods (Means ± S.E).

| Parameters                  | Age (days) | T1                          | T2                          | T3                          | T4                          | Sig. |
|-----------------------------|------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|------|
| Feed intake                 | 14-28      | 95.71±0.57                  | 91.14±0.59                  | 93.45±0.79                  | 90.17±0.18                  | *    |
| FI, g/chick/day             | 28-42      | 133.16±0.49                 | 128.01±0.26                 | 132.08±0.22                 | 125.33±0.37                 | *    |
|                             | 1-42       | 95.67±0.47                  | 91.45±0.43                  | 93.96±0.35                  | 90.11±0.56                  | *    |
| Feed conversion ratio       | 14-28      | 1.92±0.01                   | 1.81±0.02                   | 1.86±0.02                   | 1.73±0.01                   | *    |
| (FCR, g feed/ g gain)       | 28-42      | 2.50±0.03                   | 2.25±0.08                   | 2.38±0.08                   | 2.19±0.08                   | *    |
|                             | 1-42       | 2.08±0.18                   | 1.89±0.09                   | 1.99±0.02                   | 1.83±0.02                   | *    |
| Performance index           | 14         | 26.94±2.90                  | 32.87±2.20                  | 29.48±2.43                  | 34.05±2.20                  | *    |
| (PI,%)                      | 28         | 63.46±1.43                  | 68.10±2.73                  | 66.01±1.73                  | 72.97±1.40                  | *    |
|                             | 42         | 78.81±3.21                  | 90.13±2.26                  | 88.84±2.74                  | 94.75±2.33                  | *    |

1 T1: control; basal diet without any supplementation, T2: basal diet + 2% citric acid, T3: basal diet + 1% acetic acid and T4: basal diet + 1% citric acid + 0.5% acetic acid.
2 means ± S.E. of 3 replicates / treatment.
3 a, b, c and etc., means within the same row with each different superscript are significantly different (P ≤ 0.05).

Mortality, Livability and European productive efficiency:

Experimental results presented in Table 4 showed the effect of dietary citric and acetic acids or their mixture supplementation on mortality, livability and European productive efficiency at 42 days of age. Mortality % was obtained between 3 and 13%. The lower value of mortality percentage (3.33) was in T4 and the higher mortality percentage was obtained in T1: control (13.33). Moreover, livability % was significantly improved (96.67%) in chicks fed diet supplemented with the mixture of 1% CA+ 0.5% AC followed by chicks fed 1% AC and those fed 2% CA, being 93.33 and 90.00%, respectively compared to 86.67% in the control group. The same trend was noticed at European productive efficiency which recorded 218.61, 192.38, 186.31 and 162.62 for chicks fed T4, T3, T2 and T1, respectively at 42 days of age (Table 4). In summary, the better livability % and European productive efficiency (EPE) in organic acid (CA+ AC) addition in broiler diets may be due to the effect of organic acid in controlling pathogenic bacteria or maintaining the health of the GIT (Flamand et al. 2014).

Allahdoa et al. (2018); Adhikari et al. (2020) and Stamilla et al. (2020) observed that overall mortality was lower in organic acid supplementation compared to control groups. Generally the positive impact of dietary organic acids as citric acid (CA), acetic acid (AC) or their mixture on growth performance may be attributed to: a) A reduction of the pH values in the feed and digestive tract, serving as a barrier against pathogenic microorganisms which are sensitive to low pH values. b) The direct antimicrobial effect. Our results are disagree with the results of (Flamand et al., 2014 and seifi et al., 2015) who reported that there were no significant differences in mortality rate by adding levels of organic acids (0.5, 1, 1.5 and 2%) than control group during 22-42 d. in broiler chickens.

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Effect of dietary citric acid and acetic acid supplementation on carcass characteristics and some immune responses parameters of broiler chicks:

Experimental results of the effect of adding CA, AC or their mixture supplementation to broiler chick diet on carcass characteristics and immune organs parameters at 42 days of age are shown in Tables 5 and 6. At 42 days of age addition of AC and CA mixture to broiler chicks significantly increased pre-slaughter and carcass weight (2243.76 and 1733.70g) for T4 (1% CA + 0.5% AC) in comparison with (2115.40 and 1593.40) T2 (2% CA) and (1992.10 and 1517.70g) in T3 (1% AC) compared to (1944.50 and 1428.00g) in T1, control treatment, respectively. Weight and percentages of liver, gizzard were significantly affected by dietary levels of organic acids, 2% CA, 1% AC and their mixture at 42 days of age. The increased dressing yield on dietary organic acids might be due to increasing live weight (Mohammed 2016). The mixture addition of 1% citric acid with 0.5% acetic acid resulted in decreasing the level of abdominal fat percentage (Mohammed 2016). The mixture addition of 1% citric acid with 0.5% acetic acid resulted in decreasing the level of abdominal fat percentage.

Table (5): Effect of dietary citric acid, acetic acid or their mixture supplementation on carcass characteristics of broiler chicks at 42 days of age (Means ± S.E.).

| Item                        | Dietary treatments¹ | T1               | T2               | T3               | T4               |
|-----------------------------|---------------------|------------------|------------------|------------------|------------------|
| Number of birds at the end of the experiment | 30                  | 30               | 30               | 30               |
| Final body weight, (Kg)     | 1.97                | 2.02             | 1.99             | 2.08             |
| Mortality percentage, (%)   | 13.33               | 10               | 6.67             | 3.33             |
| Livability percentage, (%)  | 86.67               | 90.00            | 93.33            | 96.67            |
| European productive efficiency, (EPE, %)² | 162.62             | 192.38           | 186.31           | 218.61           |

¹T1: control; basal diet without any supplementation, T2: basal diet + 2% citric acid, T3: basal diet + 1% acetic acid and T4: basal diet + 1% citric acid + 0.5% acetic acid
²EPE, % = (Mean body weight, Kg. × livability % × 100) / feed conversion × marketing age, days, cited by Soltan and Kusainova, 2012.

The present results indicated that organic acids used for 42d maintained sufficient undissociated acid molecules, which appeared to produce bacteriostatic or bactericidal effect leading to better carcass yield.
and lower abdominal fat than diets without organic acids. The reduction in abdominal fat might be supplemented dietary acidification in broiler diets and has a role in lipid metabolism (Leeson et al., 2005). Also, the results are coincides with Yousef et al. (2017) who indicated that chicks fed diet supplemented with CA or AC had significantly increased carcass yields. Also, Sharifuzzaman et al. (2020) reported that the highest dressing percentage (69%) was noticed where 0.75% citric acid was added to diet. While, Lakshmi and Sunder (2013) who observed that abdominal fat percent was lower in broiler fed 1 and 2% citric acid up to 42 days of age. On contrary, Rehman et al. (2016), Saleem et al. (2016), Ali et al. (2019) and Sabour et al. (2019) observed that there was no significant differences in dressing percentage by having diets supplemented with citric and/or acetic acid.

Data presented in Table (6) showed the effect of dietary 2% CA, 1% AC or their mixture on some immune organs of relative weights and percentage (thymus, spleen and bursa of fabricus) at the end of experiment (42 days of age broiler chicks). Data exhibited the relative weights and percent of thymus and bursa increased by addition of single citric or acetic acids or their mixture. The highest values were reported for (1% CA + 0.5% AC, T4), being (3.99g % and 0.23%) of thymus % and (3.34g and 0.19%) for bursa %, respectively at 42 d in comparison with other treatments. While, percentages of spleen did not significantly differ between all treatments. The improvement in immunity might be due to the inhibitory effects of these OA on gut pathogens. In addition, OA supplementation caused hyper-thyroidism and peripheral conversion of T4 – T3 which indicate that these birds had better immune competence and bursa growth (Abdel Fattah et al., 2008). The major constituents of the avian immune system are the lymphoid organs as bursa, spleen and thymus had mild to moderate hyperplasia of their lymphoid follicles which indicate that the immune response was increased (Attia et al. 2018).

The relative increase in weight organs of bursa, spleen and two primary lymphoid organs were concidered as an indication of immunological advances. The establishment of immune response associated with dietary acidification could be on account for their inhibitory effects against the pathogenic microorganisms throughout the GI tract providing scope for improved nutrient absorption. The higher immunity due to organic acids can also be attributed to higher nutrient efficiency, which might have triggered immunogenic cells to record higher immune response (Ram Rao et al., 2004). The results of the peresnt experiment reported herein were also in agreement with those of Mohammadi and Khosravinia (2015) and Attila et al. (2018) who noted that the use of organic acid leads to an increase in the number of contributing cells in immune and then increase the bursa of fabricius weight. However, the results of Saleem et al. (2016) and Allahdoa et al. (2018) disagree with of the peresnt study

Table (6): Effect of dietary citric acid, acitic acid or their mixture supplementation on immune organs of broiler chicks at 42 days of age (Means ± S. E.).

| Item                | Dietary treatment1 | Sig. |
|---------------------|--------------------|------|
|                     | T1 | T2 | T3 | T4 |               |
| Thymus weight, g.   | 2.17±0.06 | 3.03±0.15 | 2.92±0.12 | 3.99±0.17 | *             |
| Thymus, %           | 0.15±0.005 | 0.19±0.02 | 0.19±0.01 | 0.23±0.01 | *             |
| Spleen weight, g.   | 1.15±0.13 | 1.59±0.06 | 1.36±0.12 | 2.08±0.16 | *             |
| Spleen, %           | 0.08±0.01 | 0.10±0.004 | 0.09±0.01 | 0.12±0.01 | NS            |
| Bursa, g.           | 2.04±0.15 | 2.75±0.15 | 2.92±0.12 | 3.34±0.15 | *             |
| Bursa, %            | 0.14±0.01 | 0.17±0.01 | 0.19±0.01 | 0.19±0.01 | *             |

1 T1: control; basal diet without any supplementation, T2: basal diet + 2% citric acid, T3: basal diet + 1% acetic acid and T4: basal diet + 1% citric acid + 0.5% acetic acid
2 means ± S. E. of 3 replicates / treatment.
3a, b, c and ...etc. means within the same row with each different superscript are significantly different (P ≤ 0.05).
NS: Non Significant.

Effect of dietary citric acid and acetic acid supplementation on some serum biochemical parameters of broiler chicks:

Data concerning the effect of citric and acetic acids or their mixture as a diet supplementation on blood serum constituents at 42 days are shown in Table 7. The mixture of citric acid and acetic acid (1%CA + 0.5% AC; T4) significantly (P ≤ 0.05) improved total protein, albumin, globulin and A/G ratio compared to the control group. Globulin is a source of antibody production, so its level in the serum is a good indicator of immune responses and consequently better disease resistance (Griminger and Scances 1986). Also, Ghazalah et al. (2011) noticed a higher level of globulin in serum blood concentration which used
as an indicator for measuring immunity response by addition of organic acids, suggesting that the improvement in bird immunity could be related to the inhibitory effects of organic acids on gut system pathogens and enhancing the density of the lymphocytes in the lymphoid organs, enhancing the nonspecific immunity (Haque et al., 2010). In this study, the concentration of serum blood creatinine was not significantly (P ≤ 0.05) different between all dietary supplemented treatments compared to T₁ (unsupplemented) during 42 days of age. Also, the concentration of blood glucose was significantly (P ≤ 0.05) differences by organic acid (CA and AC or their mixture) during 42 days of age. The present results showed that broiler chicks fed diets containing CA and AC or their mixture had significantly lower serum total lipids and cholesterol. Meanwhile, broiler chicks fed diet containing a mixture of CA + AC showed the lowest total lipids (TL) and total cholesterol (TCH); being 430.27 and 133.11 mg / dl for T₁, (1% CA+ 0.5%AC), respectively, when compared to the control treatment (550.39 and 159.13 mg / dl) for TL and TCH, respectively.

The decrease in blood lipid profile may be due to the beneficial role of organic acids in decreasing the microbial intracellular pH. Thus, inhibits the action of important microbial enzymes and forces the bacterial cell to use energy to release the acid protons, lead into an intracellular accumulation of acid anions (Young and Foegeding, 1993). Organic acid treatments insignificantly influenced each of ALT and AST compared to the control treatment at 42 days of age, chicks fed diet supplemented with 2% CA (T₂), 1% AC (T₃) and 1% CA + 0.5%AC (T₄) had the lowest value of ALT (14.78, 14.81 and 14.35), respectively in comparison with control treatment (15.14), while AST enzyme was insignificantly influenced by dietary treatments (P > 0.05) at 42 days of age (Table 7). This result is harmony with those of Capcarova et al. (2014); Rahman et al. (2018) and Ali et al. (2019) who report that total protein, globulin and A / G ratio were (P ≤ 0.05) higher in birds fed diets supplemented with single citric and acetic acids or their mixture supplementation in broiler diets.

Where, Abdel Razek et al. (2016) and Mirderikvandi et al. (2019) reported that total cholesterol was significantly (P < 0.05) decreased in citric acid supplementation of broiler chickens at 5 weeks of age. Other studies noticed negative effects on total protein, globulin, glucose, albumin and A / G ratio in corn-based diets supplemented with organic acids of Mohammadi and Khosravinia (2015) and Mirderikvandi et al. (2019). Generally, serum biochemical constituents reflect the health, nutrition, climate and management conditions which the animals are submitted (Minafara et al., 2010). The levels of biochemical parameters in the blood can be used as an indicator of the productive performance of the birds and of metabolic disease (Rotava et al., 2008). Measurements of AST and ALT activities are indicators of liver damage in broiler chicks and its therefore available tool for determination of a safe inclusion rate for feed additives.

### Table (7): Effect of dietary citric acid, acetic acid or their mixture supplementation on some blood serum constituents of broiler chicks at 42 days of age (Means ± S.E.).

| Item                          | Dietary treatment¹ | T1                  | T2                  | T3                  | T₄                  | Sig.        |
|-------------------------------|--------------------|---------------------|---------------------|---------------------|---------------------|-------------|
| Total protein, g / dl.         |                    | 4.38±0.006          | 4.43±0.011          | 4.51±0.006          | 4.56±0.006          | *           |
| Albumen (A), g / dl.           |                    | 2.40±0.006          | 2.47±0.006          | 2.52±0.012          | 2.58±0.012          | *           |
| Globulon (G), g / dl.          |                    | 1.94±0.006          | 1.96±0.006          | 1.99±0.006          | 1.98±0.006          | *           |
| A / G ratio                   |                    | 1.24±0.005          | 1.26±0.001          | 1.27±0.003          | 1.30±0.002          | *           |
| Creatinine, mg / dl.           |                    | 1.43±0.006          | 1.42±0.006          | 1.40±0.001          | 1.42±0.001          | NS          |
| Total lipids, mg / dl.         |                    | 550.39±0.57         | 448.13±0.02         | 435.88±0.58         | 430.27±0.58         | *           |
| Total cholesterol, mg / dl.    |                    | 159.13±0.58         | 149.00±0.57         | 137.18±0.33         | 133.11±0.01         | *           |
| Glucose, mg / dl.              |                    | 234.07±0.02         | 231.66±0.57         | 232.91±0.38         | 227.11±0.59         | *           |
| ALT, U / L.                    |                    | 15.14±0.059         | 14.78±0.058         | 14.81±0.059         | 14.35±0.058         | *           |
| AST, U / L.                    |                    | 42.12±0.59          | 42.03±0.57          | 42.14±0.57          | 42.03±0.57          | NS          |

¹T₁: control; basal diet without any supplementation, T₂: basal diet + 2% citric acid, T₃: basal diet + 1%
²Means ± S. E. of 3 replicates / treatment.
³Acetic acid and T₄: basal diet + 1% citric acid + 0.5% acetic acid
⁴Means ± S. E. of 3 replicates / treatment.
⁵a, b, c and ....etc. means within the same row with each different superscript are significantly different (P ≤ 0.05).
⁶NS: Non Significant.
parameters of broiler chicks:

The average villus height, width, crypt depth, muscular thickness and villi height: crypt depth of duodenum, jejunum and ileum of broiler chickens measurements at 42 days of age are presented in Tables (8, 9 and 10) and illustrated in Figures (1, 2 and 3). Data showed significant increase (P ≤ 0.05) in villi height of duodenum, jejunum and ileum with the addition of citric and acetic acids mixture (1% CA + 0.5% AC, T4); being 2173.99, 1453.94 and 970.07 µm as comparison with the other treatments (1741.36, 1339.26 and 1028.18 µm, T3), (1783.06, 1101.42 and 784.07 µm, T2) and in the control (T1) group were 1485.17, 1079.76 and 718.09 µm, respectively. The increase in villus height of the different segments of the small intestine epithelium play key roles in the digestion, absorption and assimilation of nutrients (Wang and Peng, 2008). Organic acidifiers especially acetic acid reduce the growth of many pathogenic or non-pathogenic intestinal bacteria, therefore, reduce intestinal colonization and reduce infectious processes, ultimately decrease inflammatory processes at the intestinal muscosa, which increase villus height, function of secretion, digestion and absorption of nutrients can be appropriately performed by the muscosa (Loddi et al., 2004). Also, Pelicano et al. (2011) reported that increased villus heights in duodenum and jejunum with most of the organic acids reduces the growth of many pathogenic or non-pathogenic intestinal bacteria, decreasing the intestinal colonization and infectious processes, ultimately decreasing the inflammatory reactions at the intestinal muscosa, which increases the villus height, the functions of secretion, digestion and absorption of nutrients by the muscosa.

Table (8): Effect of dietary citric acid, acetic acid or their mixture supplementation on the intestinal morphology (duodenum) of broiler chicks at 42 days of age (Means ± S.E.).

| Histological parameter | Dietary treatment | Sig. |
|------------------------|------------------|------|
|                        | T1               | T2   | T3   | T4   |      |
| Villi height, µm.      | 1485.17 ± 13.58  | 1741.36 ± 55.37 | 1783.06 ± 41.49 | 2173.99 ± 4.12 |      |
| Villi width, µm.       | 156.32 ± 10.55   | 241.09 ± 9.31   | 198.85 ± 5.68   | 313.10 ± 15.83 |      |
| Crypt depth, µm.       | 140.85 ± 4.55    | 266.37 ± 21.42  | 195.87 ± 5.07   | 261.94 ± 13.44 |      |
| Muscular thickness, µm.| 220.44 ± 3.06    | 327.94 ± 13.85  | 264.37 ± 4.12   | 293.84 ± 12.68 |      |
| Villi height / Crypt depth | 9.69 ± 0.58    | 7.29 ± 0.44    | 9.03 ± 0.44    | 7.04 ± 0.39    |      |

1 T1: control; basal diet without any supplementation; T2: basal diet + 2% citric acid, T3: basal diet + 1% acetic acid and T4: basal diet + 1% citric acid + 0.5% acetic acid.
2 a, b, c and … etc: means within the same row with each different superscript are significantly different (P ≤ 0.05).

Villi intestine width values being: 313.10, 217.74 and 213.87 µm for T4 of duodenum, jejunum and ileum compared to other treatments which were (241.09, 207.94 and 177.52 µm, T2) and (198.85, 183.67 and 169.44 µm, T3), and for control group were (156.32, 143.02 and 132.15 µm), respectively. Also, crypt depth and muscular thickness of duodenum, jejunum and ileum of broiler chicks measured at 42 days of age and presented in Tables 8, 9 and 10 and illustrated in Figures (1, 2 and 3). Muscularis thickness were increased in all segments of small intestine by the addition of citric acid, acetic acid or their mixture compared to the control group. The villus crypt considered as the villus factory, deeper crypts indicate fast tissue turn over to permit renewal of the villus as needed in response to normal sloughing or inflammation from pathogens or their toxins and high demands for tissue (Yason et al., 1987).

Increases in the VH and VH to CD ratio directly correlated with increased epithelial cell turnover and longer villi are associated with activated cell mitosis (Awad et al., 2009). These results agreed with those of Rehman et al. (2016); Allahdoa et al. (2018); Sabour et al. (2019) and Stamilla et al.(2020) who showed that supplementation of dietary organic acid had significantly effects in small intestine histology. On the other hands, Mohammadaghieni et al. (2016) and Attia et al. (2018) found no significant effects of dietary organic acids on muscular thickness of small intestine of broiler chicks.

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Table (9): Effect of dietary citric acid, acetic acid or their mixture supplementation on the intestinal Morphology (Jejunum) of broiler chicks at 42 days of age (Means ± S.E.).

| Histological parameter | Dietary treatment | Sig. |
|------------------------|-------------------|------|
|                        | T1                | T2   | T3          | T4          |
| Villi height, µm.      | 1079.76±15.57     | 1339.26±8.93 | 1101.42±20.71 | 1453.94±35.25 | * |
| Villi width, µm.       | 143.02±6.47       | 207.94±9.67  | 183.67±11.52 | 217.74±5.16  | * |
| Crypt depth, µm.       | 175.69±4.75       | 193.36±7.67  | 188.15±1.24  | 240.26±11.46 | * |
| Muscular thickness, µm.| 255.34±10.65      | 237.65±11.91 | 282.48±4.31 | 238.08±3.25  | * |
| Villi height / Crypt depth | 7.66±0.41       | 6.51±0.32  | 6.11±0.38  | 6.71±0.26  | * |

1 T1: control; basal diet without any supplementation; T2: basal diet + 2% citric acid, T3: basal diet + 1% acetic acid and T4; basal diet + 1% citric acid + 0.5% acetic acid.
2 Means ± S. E. of 3 replicates / treatment.

Table (10): Effect of dietary citric acid, acetic acid or their mixture supplementation on the intestinal morphology (Ileum) of broiler chicks at 42 days of age (Means ± S.E.).

| Histological parameter | Dietary treatment | Sig. |
|------------------------|-------------------|------|
|                        | T1                | T2   | T3          | T4          |
| Villi height, µm.      | 718.09±5.56       | 1028.18±50.40 | 784.07±22.80 | 970.07±11.46 | * |
| Villi width, µm.       | 132.15±4.86       | 177.52±12.81 | 169.44±12.26 | 213.87±15.56 | * |
| Crypt depth, µm.       | 126.43±9.17       | 170.56±8.50  | 142.29±9.70  | 208.66±12.54 | * |
| Muscular thickness, µm.| 214.25±2.73       | 261.10±11.31 | 249.57±1.56 | 287.03±8.45  | * |
| Villi height / Crypt depth | 5.47±0.21       | 5.95±0.50  | 4.79±0.46  | 4.70±0.36  | * |

1 T1: control; basal diet without any supplementation; T2: basal diet + 2% citric acid, T3: basal diet + 1% acetic acid and T4; basal diet + 1% citric acid + 0.5% acetic acid.
2 Means ± S. E. of 3 replicates / treatment.

1a, b, c and ...etc: means within the same row with each different superscript are significantly different (P ≤ 0.05).
Figure (1): Photomicrographs of intestinal villi from the duodenum of broiler chicks on 42 days of age in T1, control, basal Diet without supplementation; T2; basal diet +2% citric acid; T3; basal diet+ 1% acetic acid and T4; basal diet+1% cetic + 0.5% acetic acids.

Figure (2): Photomicrographs of intestinal villi from the jujunum of broiler chicks on 42 days of age in T1, control, basal diet without supplementation; T2; basal diet +2% citric acid; T3; basal diet+ 1% acetic acid and T4; basal diet+ 1% cetic+ 0.5% acetic acids.

Figure (3): Photomicrographs of intestinal villi from the ileum of broiler chicks on 42 days of age in T1, control, basal diet without supplementation; T2; basal diet +2% citric acid; T3; basal diet+ 1% acetic acid and T4; basal diet+ 1% cetic + 0.5% acetic acids.
Effect of dietary citric acid and acetic acid or their mixture supplementation on economic efficiency of broiler chickens:

Data pertaining to dietary citric, acetic acids or their mixture supplementation on the relative economical efficiency (REE) are presented in Table (11). In comparison with the control treatment (100%), the supplementation of citric and acetic mixture improved REE by 20.72% for T4 which was supplemented with (1% CA + 0.5% AC). This may be due to better feed conversion obtained in chicks received the experimental diets. The low values of economical efficiency were obtained for chicks fed diet supplemented with 1% AC (T3) and 2% CA (T2), respectively compared to T4 (1% CA + 0.5% AC) but higher than the control group. This may be due to the increase in the price of acetic acid in the markets. Abdel Fattah et al. (2008) observed that the economic and relative economic efficiency were increased by using citric and acetic acids at (1.5 and 3%) levels. Ghazalah et al. (2011) found that 0.25% AC and 3% CA supplementation gave the best value of European economic efficiency compared to the control group at 42 days of age. On the other hand, Mirderikvandi et al. (2019) showed that acidified diet (20 mg acetic acid / kg diet) significantly reduced economic efficiency of birds by about 16.77%. Also, Omidi et al. (2020) indicated that acetic acid supplementation to diet decreased economic efficiency by 40 units compared to control birds during 14 to 42 days of age.

Table (11): Effect of dietary citric acid, acetic acid or their mixture supplementation on economic efficiency of broiler chicks during experimental period.

| Item                        | T1    | T2    | T3    | T4    |
|-----------------------------|-------|-------|-------|-------|
| Initial body weight, g.     | 45.21 | 45.17 | 45.24 | 45.17 |
| Final body weight, kg.      | 1.97  | 2.02  | 1.99  | 2.08  |
| Body weight gain, kg.       | 1.92  | 1.97  | 1.94  | 2.03  |
| Total revenue\(^2\), L.E.  | 61.44 | 63.04 | 62.08 | 64.96 |
| Feed intake, kg.            | 4.02  | 3.84  | 3.95  | 3.78  |
| Price of one kg feed, L.E.  | 7.25  | 7.30  | 7.36  | 7.34  |
| Feed cost, L.E.             | 29.15 | 28.03 | 29.07 | 27.75 |
| Net revenue\(^3\), L.E.    | 32.29 | 35.01 | 33.01 | 37.21 |
| Economical efficiency\(^4\), % | 1.11  | 1.25  | 1.14  | 1.34  |
| Relative economical efficiency, % | 100   | 112.61| 102.70| 120.72|

\(^1\) T1; control; basal diet without any supplementation; T2; basal diet + 2% citric acid, T3; basal diet + 1% acetic acid and T4; basal diet + 1% citric acid + 0.5% acetic acid.

\(^2\) Total revenue = live body weight gain × marketing price (32 L.E. according to prices in June, 2018).

\(^3\) Net revenue = Total revenue – Feed cost.

\(^4\) Economical efficiency = Net revenue / Feed cost.

CONCLUSION

In general, based on the obtained experimental results reported herein and from the nutritional and economical point of view, there are some beneficial effects of using mixture of citric acid and acetic acid (1% citric acid + 0.5% acetic acid) to broiler (Arbor Acres) diets showed the best productive performance, carcass characteristics, some serum components, some histological parameters and better economic efficiency without any adverse effects on health under our local environmental conditions.

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تأثير إضافة حامضي الستريك، الخليك أو مخلوطهما في علاقات كاككيت التسمين على أداء النمو، صفات الذبيحة وبعض القياسات الهيستولوجية للامعاء

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استخدمت هذه الدراسة عدد 120 كاككيت تسمين أربر أكريس Arbor Acres على أعمار مختلفة. قسمت الكاككيت إلى 4 معاملات غذائية - كل منها قسمت إلى 3 مكررات. تم إضافة الأحماض العضوية (حامض الستريك، حمض الخليك) إلى الماء. المعاملة أولا: الماء الطازج، المعاملة الثانية: 1% حمض الستريك، المعاملة الثالثة: 1% حمض الخليك، المعاملة الرابعة: مخلوط الستريك (1% حمض الستريك + 0.5% حمض الخليك).

تم إضافة الأحماض إلى علاقات البادئ ونهايتي فضلاً عن إضافة الزيت النباتي (22.13% بروتين، 30.88% طاقة ممثلة/ كجم علائق، 23.21% بروتين، 31.54% طاقة ممثلة/ كجم علائق).

تم تدريج الطيور تحت نفس الظروف، وذلك عن عمر 42 يوم، وتم تقدير بعض القياسات الهيستولوجية للأمعاء. وقامت القياسات الهيستولوجية بت릅 معنوية في معدلات النمو وزيادة وزن الجسم، وتحسنت صفات الذبيحة وبعض أعضاء جهاز المناعة، كذلك انخفض مستوى الدهون الكلية والكوليسترول في الدم. وظلت الكفاءة الاقتصادية دون تأثير سلبي على الصحة العامة تحت ظروف التجربة.

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