

## TESTING TWO LEVELS OF LACTIC AND CITRIC ACIDS AS GROWTH PROMOTERS IN RABBITS DIETS

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### SUMMARY

A total of 150 weaned V-Line rabbits aged five weeks were used in this study. Rabbits were randomly distributed into five equal groups of three replications 10 rabbits each at similar average of initial weight ( $594.68 \pm 18.22$ g). All rabbits housed in galvanized wire cages within well-ventilated pen under similar hygienic and husbandry conditions. The 1<sup>st</sup> group consumed the basal diet in the absence of organic acids (control, T1). The 2<sup>nd</sup> and 3<sup>rd</sup> groups consumed control diet supplemented with 0.5 and 0.25% lactic acid, respectively, the 4<sup>th</sup> and 5<sup>th</sup> groups consumed control diet supplemented with 0.5 and 0.25% citric acid, respectively. Feeding rabbits on a diet containing lactic acid at either 0.25 or 0.5% led to a significant improvement in all final growth traits, superior those received diet supplemented with citric acid and control group. Regarding carcass traits, the feeding on diets containing organic acids did not show any significant differences for the carcass characteristics. Regarding blood parameters there were no significant effects of the dietary treatments on the different blood and hematology measures, except for total lymphocytes and blood urea, which increased significantly in favor of rabbits fed lactic acid 0.5%. Economically, rabbits fed on supplemented diets with lactic acid at two levels 0.5% and 0.25% had higher economic efficiency and relative economic efficiency compared to control and groups fed on citric acid at two levels.

**Keywords:** Growing rabbits, lactic acid, citric acid, growth performance, carcass traits and blood constituents.

### INTRODUCTION

Nowadays, there is an increased public awareness about the risk of developing cross-resistance of pathogens to antibiotics (Hunter *et al.*, 2010). For more than 30 years organic acids, such as lactic acid, have been used to limit the growth of bacteria and moulds in feedstuffs and consequently preserve hygienic quality. It has been proven that the use of organic acids such as lactic, citric, formic, and fumaric and their salts in nutrition has enhancing effects on health and productive performance. Organic acid supplementation in animal diets leads to improve feed conversion rates, increase gain, reduce the incidence of diarrhea, feed costs and time to market, subsequently, it enhance economic return (Freitag, 2007 and Liu *et al.*, 2018).

Using of organic acids as an alternative to antibiotics, had an effects on mucosal immunity, microflora population and growth performance in rabbits (Falcao *et al.*, 2007, Kishawy *et al.*, 2018 and Tag-El-Din, 2020 ).

In developing countries, rabbit production significantly contributes in improving meat supply (Ebeid *et al.*, 2013). Although there is an increasing interest in projects of breeding rabbits in Egypt, the success of the rabbit projects enterprises were stood against by many constraints and difficulties. Currently the most common causes of morbidity in growing rabbits are digestive disorders that resulting in dramatic mortality rate during fattening rabbitries (Rosell *et al.*, 2009). The activity of the digestive enzymes in pancreatic tissue is low after five days post-weaning due to interaction without factors which may increase the risk of developing post-weaning diarrhea (Hedemann and Jensen, 2004).

Organic acids maintain cellular integrity of the gut lining and improve the digestive process by maintaining normal gut flora (Sultan *et al.*, 2015). The supplementation of organic acids on diets can lower gastric pH thereby accelerates the conversion of pepsinogen to pepsin and improve the absorption rate of proteins, amino acids, and minerals. This may contribute not only to improve performance, but also reducing nitrogen and phosphorus excretion with decreasing environmental pollution (Nguyen and Kim, 2020). Organic acids have many additional

effects beyond antibiotics effects, include decrease the pH of digestive tract, increase of pancreatic secretion, alimentary effects on the gastrointestinal mucosa (Dibner and Buttin, 2002), and improve the color and the firmness of meat subsequently increasing carcass quality

Citric acids exert anti-microbial activity in rabbits and improve nutrients utilization and consequently rabbit performance (Uddin *et al.*, 2014). Also, Ahmad *et al.* (2018) classified citric acid as a growth promoter, antioxidant, acidifier, bacterial inhibitor and antitoxin. Furthermore, it diminishes gut pH level and reduce harmful microbiota thus modify the bacterial profile in gut and enhancing the animal health. In addition, citric acid increase live weight gain, feed conversion ratio and availability of nutrients (Tag-El-Din, 2020). To clarify the role of organic acids as growth promoters for newly weaned rabbits, this study was conducted.

## MATERIALS AND METHODS

### Experimental Animals and Diets:

A total of 150 weaned V- Line rabbits aged five weeks were used in this study. Rabbits were randomly distributed into five equal groups of three replications 10 rabbits each (5 males and 5 females) at similar average of initial live weight. All rabbits housed in galvanized wire cages within well-ventilated pen under similar hygienic and husbandry conditions. Every cage contained a metal feeder and a stainless steel nipple for drinking. Diet and water were offered *ad libitum* all the time. The 1<sup>st</sup> group consumed the basal diet in the absence of organic acids (control, T1). The 2<sup>nd</sup> and 3<sup>rd</sup> groups consumed control diet supplemented with 0.5 and 0.25% citric acid, respectively the 4<sup>th</sup> and 5<sup>th</sup> groups consumed control diet supplemented with 0.5 and 0.25% lactic acid, respectively. The experiment was conducted in the summer during the months of May and June from the fifth week to the tenth week of life, diets composition and chemical analysis are shown in Table (1).

**Table (1): Ingredients and calculated chemical analysis of the control diet.**

Ingredients	%
Clover hay	30.0
Wheat bran	32.0
Barley grain	19.0
Soybean meal 44%	14.0
Molasses	3.00
Limestone	1.30
Premix*	0.30
Sodium chloride	0.30
Anti- coccidia	0.10
Total	100.0
Calculated analysis**	
Crude protein %	17.75
DE kcal/kg diet	2555
C/P ratio	144.54
Ether extract %	2.29
Crude fiber %	12.8
Calcium %	1.21
Phosphorus %	0.73
Methionine %	0.30
Methionine + Cysteine %	0.65
Lysine %	1.04
Arginine %	1.44

\* Each 3 kg of the premix (vitamins and minerals mixture) contains: vit. A 6000000 IU. Vit. D3 900000 IU, Vit. E 40000 mg, Vit. K<sub>3</sub> 2000 mg, Vit. B<sub>1</sub> 2000 mg, Vit. B<sub>2</sub> 4000 mg, Vit. B<sub>6</sub> 2000 mg, Vit. B<sub>12</sub> 10 mg, Biotin 50 mg, Pantothenic acid 10000 mg, Nicotinic acid 50000 mg, Folic acid 3000 mg, Choline chloride 250000 mg, Mn 8500 mg, Zn 50000 mg, Fe 50000 mg, Cu 5000 mg, I 200 mg, Se 100 mg, and Co 100 mg. \*\* Calculated according to NRC (1977).

### **Growth Performance:**

Live body weight of rabbits was individually recorded at the beginning of the experiment (BW<sub>0</sub>) and weekly thereafter till 10 weeks of age from 5 to 10 weeks of age (BW<sub>1</sub>, BW<sub>2</sub>, BW<sub>3</sub>, BW<sub>4</sub>, BW<sub>5</sub>, respectively). Body weight gain during the whole period was calculated per each rabbit by subtracting the BW<sub>0</sub> from the BW<sub>5</sub>. Growth rate (GR) was calculated per rabbit during the whole period according to the following equation (Brody, 1945). Where: BW<sub>0</sub> is body weight at the beginning of the experiment and BW<sub>5</sub> is live body weight at the end of the experiment.

$$GR = \frac{(BW_5 - BW_0)}{0.5 (BW_0 + BW_5)} \times 100$$

### **Feed Traits:**

Feed intake (FI) was recorded every week for each replicate. Average FI was obtained by dividing the total FI by the number of rabbits in this replicate. Feed conversion ratio (FCR) was calculated per each rabbit according to the following equation:

$$FCR = \frac{FI, g / rabbit}{Live\ body\ weight\ gain, g / rabbit}$$

### **Carcass Traits:**

At the end of the experimental period, eight rabbits (4♂ + 4♀) from each of the five groups were selected around average treatment weight to study the carcass traits. Rabbits were fasted for approximately 16 hours, individually weighed (to record the pre-slaughter weight) and thereafter slaughtered by severing the neck with a sharp knife according to the Islamic Religion and instantly the head was separated, peeled and weighed. Skinning off was carried out by removing the skin including the tail and feet. Then, the carcass was eviscerated down and all entrails were removed. The liver, kidneys, heart and spleen were also removed and the rest of the body was weighed to determine the dressed weight. All weights were taken to the nearest gram. The flesh of each carcass was partitioned (front, middle and rear), weighed and separated from the bones, re-weighed, minced and stored for chemical analysis.

Eviscerated carcass, front, middle, rear, head, liver, heart, kidneys and spleen% were calculated as a percentage from final BW<sub>5</sub>. Also, dressing percentage from BW<sub>5</sub> was calculated as follows:

$$Dressing\% = \frac{(Eviscerated\ carcass + head + liver + heart + kidneys + spleen, g)}{BW_5} \times 100$$

### **Hematological parameters and plasma biochemicals:**

At the same time of slaughter test, a blood sample from each slaughtered rabbit was collected in heparinized tube. At each collection, 8-10 ml of blood was drained. Blood samples were divided into two parts. The first part was used to determine the hematological parameters, where the second part was centrifuged at 3000 rpm for 15 minutes to separate plasma. Blood plasma was collected and preserved in a deep freezer at (-20°C) until the time of analysis. The biochemical parameters determined in blood plasma were determined colorimetrically by using commercial kits.

Hemoglobin content was determined by using clinical hemoglobinometer according to Singh (1983). Hematocrit (Hct) value was measured by capillary tubes, the opposite end of the tubes were sealed, and then centrifuged for 15 minutes at a speed 3000 rpm according to Bauer (1970). Also mean corpuscular volume (MCV), was calculated. Red blood cells count (RBC's), 10<sup>6</sup>/mm<sup>3</sup> was determined by using hemocytometer according to Bauer (1970). Also, WBCs count, 10<sup>3</sup>/mm<sup>3</sup> and their differentiation: Lymphocytes, segments, staff, eosinophils and basophils were determined according to the methods reported by Schalm *et al.* (1975).

Plasma total protein, g/dl was measured colorimetrically as described by Armstrong and Carr (1964). Albumin, g/dl concentration was determined according to the method of Doumas *et al.* (1977). Globulin concentration was calculated by the difference between total protein and albumin. Albumin: globulin ratio also was calculated. Total cholesterol (mg/dl) was determined according to the method of Carr *et al.* (1993). Urea (mg/dl) concentration was determined as described by Patton and Crouch (1977).

### Economic efficiency (EEf):

Net revenue was calculated by subtraction total feed cost from the price of body weight gain. EEf was estimated individually according to the following formula:

$$EEf = \frac{\text{Price of body gain weight} - \text{feed cost}}{\text{Feed cost}}$$

The other costs were assumed constant. Also relative economic efficiency (REEf %) for each treatments and both of males and females were calculated as a percent from EEf of control group.

### Statistical analysis:

All collected data in this study were analyzed by PROC MIXED (SAS, 2011) to calculate the treatment and sex specific means by the following model:

$$Y_{ijkl} = \mu + a_i + T_j + S_k + (TS)_{jk} + e_{ijkl}$$

where:  $Y_{ijkl}$ : is the observation for a trait  $\mu$ : is the overall mean,  $a_i$ : is the random additive genetic effect of the  $i^{\text{th}}$  animal,  $T$ : the effect of  $j^{\text{th}}$  treatment,  $S$ : the effect of  $k^{\text{th}}$  sex,  $(TS)_{jk}$ : the effect of  $j^{\text{th}}$  treatment with the  $k^{\text{th}}$  sex and  $e_{ijkl}$ : is the random error term. Duncan's multiple range tests was used for the multiple comparisons (Duncan, 1955).

## RESULTS AND DISCUSSION

### Growth performance:

The studied BWs of rabbits as affected by dietary supplementation with organic acids (lactic or citric acids) are presented in Figure (1). Treatment significantly ( $P < 0.01$ ) affected  $BW_2$ ,  $BW_3$ ,  $BW_4$  favoring the supplementation with 0.25% lactic acid followed by the 0.5% lactic acid, control group, 0.25% citric acid and 0.5% citric acid, respectively.

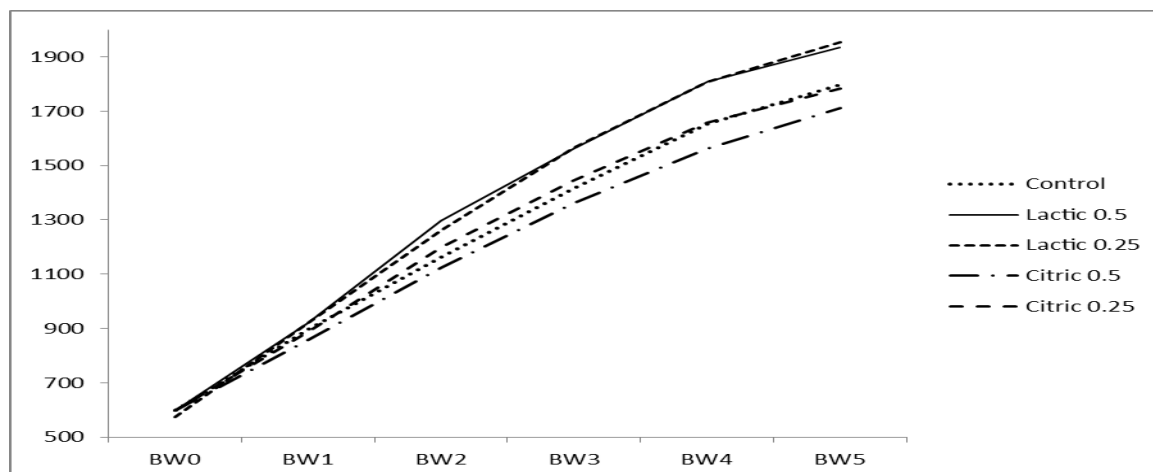


Figure (1): Body weights at different ages by week as affected by dietary organic acids supplementation.

From the results shown in Table (2), it is clearly evident that all the final measures of growth, body weight, weight gain, growth rate, feed intake and feed conversion ratio showed significant differences, as the group fed on lactic acid was better than the control and citric acid. With regard to lactic acid, rabbits fed at the lower level (0.25%) were better than the higher level (0.5%) for  $BW_5$ , BW gain and GR recorded 1954.75g, 1380.25g and 1.09, respectively, while, rabbits fed the diet containing 0.5% lactic acid had higher value of FI and the best FCR.

**Table (2): Growth performance of V-line rabbit fed organic acids ( $X \pm SE$ ).**

Item	BW <sub>0</sub>	BW <sub>5</sub>	BW gain	GR	FI	FCR
Treatment effect	NS	***	***	*	***	***
Control	600.36±24.08	1795.85±41.77 <sup>b</sup>	1195.49±33.87 <sup>b</sup>	1.00±0.02 <sup>bc</sup>	3444.94±8.88 <sup>a</sup>	2.90±0.08 <sup>b</sup>
Lactic acid 0.5%	599.90±25.12	1934.06±43.58 <sup>a</sup>	1334.17±35.35 <sup>a</sup>	1.06±0.03 <sup>ab</sup>	3203.98±9.26 <sup>d</sup>	2.42±0.08 <sup>a</sup>
Lactic acid 0.25%	574.50±26.52	1954.75±46.01 <sup>a</sup>	1380.25±37.31 <sup>a</sup>	1.09±0.03 <sup>a</sup>	3380.79±9.78 <sup>b</sup>	2.50±0.08 <sup>a</sup>
Citric acid 0.5%	598.93±24.08	1710.09±41.77 <sup>b</sup>	1111.16±33.87 <sup>b</sup>	0.97±0.02 <sup>c</sup>	3320.07±8.88 <sup>c</sup>	3.01±0.08 <sup>b</sup>
Citric acid 0.25%	597.80±25.88	1783.04±44.90 <sup>b</sup>	1185.24±36.41 <sup>b</sup>	1.00±0.03 <sup>bc</sup>	3440.02±9.54 <sup>a</sup>	2.95±0.08 <sup>b</sup>
Sex effect	NS	NS	NS	NS	NS	NS
Females	586.18±16.84	1823.90±29.21	1237.72±23.69	1.03±0.02	3358.16±6.21	2.78±0.05
Males	602.41±14.92	1847.21±25.88	1244.80±20.99	1.02±0.02	3357.76±5.50	2.73±0.05
Treatment x sex	NS	NS	NS	NS	NS	NS

Means having different superscripts within each effect within the same column are significantly differed at specified probability, SE: stander error, BW<sub>0</sub> and BW<sub>5</sub>: initial and final body weights, respectively, GR: growth rate, FI: feed intake, FCR: feed conversion ratio during the whole period, NS, insignificant, \*, \*\*\*: significant at  $P \leq 0.05$  and  $P \leq 0.001$ , respectively.

The positive effect of lactic acid may be due to the fact that it represents an active environment for the growth of lactic acid bacteria, which affect digestion, absorption and pathogens inhibition (Vieco-Saiz *et al.*, 2019). Pathogens inhibition by lactic acid bacteria probiotics include: inhibitory compounds production, adhesion prevention of the pathogens, competition for nutrients, modulation immune system of the host, improvement of the digestibility, feed conversion ratio and reduction the bioavailability of toxins. Moreover, lactic acid participated in vitamins D and K absorption and the formation of soluble salts of calcium and iron (Majewska *et al.*, 2009).

Byrd *et al.* (2001) suggested that incorporation of 0.5% organic acids (lactic acid, acetic acid or formic acid) in the drinking water during pre-transport feed withdrawal may reduce *Campylobacter* and *Salmonella* contamination of crops and carcasses at processing. Also, they suggested that the supplementation of lactic acid in the drinking water decreases the crop pH and may be provided as a temporary source of carbon for beneficial bacteria that normally present in the crop. There were no significant differences between males and females in all growth parameters.

#### **Carcass characteristics:**

The effects of treatment and sex on the carcass characteristics are shown in Tables (3 and 4), it was clear that there is no significant effect of the different treatments on the carcass measures shown, and the only differences are numerical differences ( $P > 0.05$ ) in favor of rabbits fed on citric acid at two levels (0.25 and 0.50%).

**Table (3): Least square means  $\pm$  SE for some carcass characteristics% as affected by dietary treatments and sex.**

Item	Dressing	Eviscerated carcass	Front	Middle	Rear	Total Giblets
Treatment effect	NS	NS	NS	NS	NS	NS
Control	56.54±5.67	46.56±4.54	8.43±0.93	20.89±1.90	17.24 ±1.71	4.05 ±0.29
Lactic acid 0.5%	53.34±3.52	42.86±3.35	7.77±0.68	18.97±1.96	16.12 ±0.70	4.58 ±0.47
Lactic acid 0.25%	57.99±1.27	47.01±1.29	7.96±0.17	21.95±1.03	17.10 ±0.43	4.81 ±0.49
Citric acid 0.5%	58.92±3.40	47.18±2.66	8.93±0.39	20.76±1.47	17.49 ±0.80	5.26 ±0.48
Citric acid 0.25%	63.30±4.61	51.36±4.11	9.33±0.77	21.95±1.65	18.39 ±1.68	5.54 ±0.01
Sex effect	NS	NS	NS	NS	NS	NS
Females	58.46±2.81	47.20±2.03	8.42±0.44	21.40±1.11	17.38 ±0.62	5.13±0.26
Males	57.58±2.28	46.79±2.29	8.54±0.43	21.08±1.13	17.16 ±0.77	4.56±0.37
Treatment x sex	NS	NS	NS	NS	NS	NS

NS = insignificant.

**Table (4): Least square means  $\pm$  SE for other carcass characteristics% as affected by dietary treatments and sex.**

Item	Head	Heart	Liver	Spleen	Kidney
Treatment effect	NS	NS	NS	NS	NS
Control	5.91 $\pm$ 0.56	0.23 $\pm$ 0.03	3.07 $\pm$ 0.64	0.15 $\pm$ 0.06	0.59 $\pm$ 0.01
Lactic acid 0.5%	5.47 $\pm$ 0.06	0.18 $\pm$ 0.01	3.60 $\pm$ 0.31	0.14 $\pm$ 0.01	0.66 $\pm$ 0.04
Lactic acid 0.25%	6.08 $\pm$ 0.37	0.21 $\pm$ 0.02	3.79 $\pm$ 0.38	0.14 $\pm$ 0.06	0.67 $\pm$ 0.05
Citric acid 0.5%	6.32 $\pm$ 0.14	0.23 $\pm$ 0.04	4.05 $\pm$ 0.31	0.22 $\pm$ 0.02	0.76 $\pm$ 0.11
Citric acid 0.25%	6.36 $\pm$ 0.49	0.23 $\pm$ 0.02	4.38 $\pm$ 0.02	0.17 $\pm$ 0.02	0.73 $\pm$ 0.05
Sex effect	NS	NS	NS	NS	NS
Females	6.01 $\pm$ 0.19	0.24 $\pm$ 0.02	3.99 $\pm$ 0.21	0.19 $\pm$ 0.02	0.72 $\pm$ 0.04
Males	6.04 $\pm$ 0.29	0.21 $\pm$ 0.01	3.57 $\pm$ 0.32	0.13 $\pm$ 0.02	0.65 $\pm$ 0.03
Treatment x sex	NS	NS	NS	NS	NS

NS=insignificant.

With regard to the effect of gender on the measures shown in the Tables (3 and 4), gender had no significant effect on the carcass characteristics. These insignificant results agreed with those of Nguyen and Kim (2020) who reported that increasing addition of the blend of organic acids and medium-chain fatty acids did not affect pH, the color of breast muscle, cooking loss, breast meat yield, and organ weight percent. Similarly, Dorra *et al.* (2013) and Sherif (2018), reported that the supplementation of organic acids in growing diets had no significant effects on carcass traits of the rabbits. Carcass characteristics of rabbits did not affected by dietary inclusion with organic acids such as 0.5% acetic or lactic acids (Radwan and Abdel-Khalek, 2007) and 0.5% of acetic, citric or formic acids (Amaefule *et al.*, 2011). Similar to the present results, Viliene *et al.* (2017) found that neither carcass yield nor their parts were significantly affected by adding organic acids or its salts on the diets for growing rabbits.

#### Blood parameters:

Tables (5 and 6) showed the effect of feeding the grower rabbits on lactic acid, citric acid at two levels and gender, as it was evident that there were no significant effects of the dietary treatments on the different blood and hematology measures, except for total lymphocytes (TLC) and blood urea, which increased significantly in favor of rabbits fed lactic acid 0.5%. With regard to the effect of sex on blood parameters, no significant difference was found between males and females. The present results agree with the findings of Dorra *et al.* (2013) and Sherif (2018) who reported that dietary organic acids did not significantly influence the blood parameters of rabbits. The present results are also in harmony with those reported by Radwan and Abdel-Khalek (2007) who found that the dietary supplementation with 0.5% acetic or lactic acids did not affect plasma biochemicals such as total protein, albumin, globulin and total lipids of rabbit blood.

**Table (5): Least square means  $\pm$  SE for some blood characteristics as affected by dietary treatments and sex.**

Item	HGb (g/dL)	HCT (%)	RBCs, $10^6/\text{mm}^3$	MCV. $\mu\text{m}^3$	TLC, cmm	Lymp, %	Seg%
Treatment effect	NS	NS	NS	NS	*	NS	NS
Control	13.20 $\pm$ 0.52	43.60 $\pm$ 2.14	3.08 $\pm$ 0.11	141.50 $\pm$ 2.02	137.00 $\pm$ 3.46 <sup>c</sup>	54.50 $\pm$ 0.87	42.00 $\pm$ 0.01
Lactic acid 0.5%	14.50 $\pm$ 0.17	48.50 $\pm$ 0.52	3.33 $\pm$ 0.01	145.50 $\pm$ 1.44	161.55 $\pm$ 1.07 <sup>a</sup>	55.50 $\pm$ 0.87	42.50 $\pm$ 0.87
Lactic acid 0.25%	14.55 $\pm$ 0.03	48.65 $\pm$ 0.09	3.51 $\pm$ 0.02	138.50 $\pm$ 0.87	151.95 $\pm$ 1.93 <sup>b</sup>	55.50 $\pm$ 2.60	42.00 $\pm$ 2.31
Citric acid 0.5%	14.05 $\pm$ 0.09	47.15 $\pm$ 0.26	3.25 $\pm$ 0.06	145.00 $\pm$ 1.73	151.45 $\pm$ 1.65 <sup>b</sup>	50.50 $\pm$ 0.87	48.50 $\pm$ 0.88
Citric acid 0.25%	14.40 $\pm$ 0.12	48.20 $\pm$ 0.35	3.46 $\pm$ 0.06	139.50 $\pm$ 0.29	157.70 $\pm$ 0.17 <sup>ab</sup>	58.50 $\pm$ 0.29	40.00 $\pm$ 0.01
Sex effect	NS	NS	NS	NS	NS	NS	NS
Females	13.90 $\pm$ 0.27	46.30 $\pm$ 1.08	3.29 $\pm$ 0.07	140.60 $\pm$ 0.58	151.26 $\pm$ 3.73	55.40 $\pm$ 1.02	42.20 $\pm$ 1.04
Males	14.38 $\pm$ 0.11	48.14 $\pm$ 0.33	3.36 $\pm$ 0.05	143.40 $\pm$ 1.53	152.60 $\pm$ 2.02	54.40 $\pm$ 0.26	43.80 $\pm$ 1.24
Treatment x sex	NS	NS	NS	NS	NS	NS	NS

Means having different superscripts within each item in the same column are significantly different at  $P \leq 0.05$ , SE: standard error, HGb: hemoglobin, Hct: hematocrit, RBCs: red blood cells, MCV: mean corpuscular volume, TLC: total leucocytes, Lymp: Lymphocytes, Seg: segments, NS=insignificant and \*: significant at  $P \leq 0.05$ .

**Table (6): Least square means  $\pm$  SE for other blood characteristics as affected by dietary treatments and sex.**

Item	Staff, %	Eosinophils, %	Basophils, %	Total Protein (g/dl)	Albumin g/dl	Cholesterol mg/dl	Urea mg/dl
Treatment effect	NS	NS	NS	NS	NS	NS	*
Control	2.50 $\pm$ 0.29	1.00 $\pm$ 0.58	0.00 $\pm$ 0.00	6.15 $\pm$ 0.14	3.65 $\pm$ 0.32	279.50 $\pm$ 8.95	34.00 $\pm$ 1.15 <sup>b</sup>
Lactic acid 0.5%	2.00 $\pm$ 0.01	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00	6.25 $\pm$ 0.09	3.55 $\pm$ 0.26	256.50 $\pm$ 28.00	37.50 $\pm$ 0.86 <sup>a</sup>
Lactic 0.25%	2.50 $\pm$ 0.29	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00	5.85 $\pm$ 0.26	3.80 $\pm$ 0.06	250.00 $\pm$ 23.09	31.50 $\pm$ 0.86 <sup>c</sup>
Citric acid 0.5%	1.00 $\pm$ 0.01	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00	6.75 $\pm$ 0.03	3.65 $\pm$ 0.09	297.00 $\pm$ 1.72	29.50 $\pm$ 0.29 <sup>c</sup>
Citric acid 0.25%	1.50 $\pm$ 0.29	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00	6.65 $\pm$ 0.14	3.20 $\pm$ 0.12	237.50 $\pm$ 21.65	34.50 $\pm$ 0.29 <sup>b</sup>
Sex effect	NS	NS	NS	NS	NS	NS	NS
Females	2.00 $\pm$ 0.21	0.40 $\pm$ 0.27	0.00 $\pm$ 0.00	6.20 $\pm$ 0.18	3.80 $\pm$ 0.10	252.40 $\pm$ 13.77	32.60 $\pm$ 0.83
Males	1.80 $\pm$ 0.25	0.00 $\pm$ 0.00	0.00 $\pm$ 0.00	6.46 $\pm$ 0.06	3.34 $\pm$ 0.11	275.80 $\pm$ 11.43	34.20 $\pm$ 1.10
Treatment x sex	NS	NS	NS	NS	NS	NS	NS

Means having different superscripts within each item in the same column are significantly different at  $P \leq 0.05$ , SE: standard error, NS=insignificant and \*:significant at  $P \leq 0.05$ .

### Economic Efficiency (EEf)

Table (7) illustrated the effect of dietary treatments and sex on EEf of rabbit at 70 days of age. Based on the obtained results, rabbits fed on supplemented diets with lactic acid at two levels (0.5 % and 0.25%), the results showed less feed cost, higher net returns based on feed cost, higher economic efficiency and relative economic efficiency compared to control and groups fed on citric acid at two levels, and the differences were highly significant ( $P \leq 0.001$ ). These results agreed with those of Tag-El-Din, (2020) who showed no significant effect of citric acid on economic efficiency. Regardless of treatment, sex had no significant effects on all economic efficiency parameters.

**Table (7): Least square means  $\pm$ SD for economic efficiency (EEf) at the end of experiment as affected by dietary treatments and sex.**

Item	Total LBWG	Total FI	Price LBWG	Feed Cost	Net Revenue	EEf	REEf ♦
Treatment effect	***	**	***	***	***	***	***
Control	1195.49 $\pm$ 33.87 <sup>b</sup>	3444.94 $\pm$ 8.88 <sup>a</sup>	45.43 $\pm$ 1.29 <sup>b</sup>	19.98 $\pm$ 0.05 <sup>a</sup>	25.45 $\pm$ 1.27 <sup>b</sup>	1.27 $\pm$ 0.06 <sup>b</sup>	99.96 $\pm$ 5.00 <sup>b</sup>
Lactic acid 0.5%	1334.17 $\pm$ 35.35 <sup>a</sup>	3203.98 $\pm$ 9.26 <sup>d</sup>	50.70 $\pm$ 1.34 <sup>a</sup>	18.77 $\pm$ 0.05 <sup>d</sup>	31.92 $\pm$ 1.32 <sup>a</sup>	1.70 $\pm$ 0.07 <sup>a</sup>	133.32 $\pm$ 5.22 <sup>a</sup>
Lactic 0.25%	1380.25 $\pm$ 37.31 <sup>a</sup>	3380.79 $\pm$ 9.78 <sup>b</sup>	52.45 $\pm$ 1.42 <sup>a</sup>	19.71 $\pm$ 0.06 <sup>b</sup>	32.74 $\pm$ 1.40 <sup>a</sup>	1.66 $\pm$ 0.07 <sup>a</sup>	130.12 $\pm$ 5.51 <sup>a</sup>
Citric acid 0.5%	1111.16 $\pm$ 33.87 <sup>b</sup>	3320.07 $\pm$ 8.88 <sup>c</sup>	42.22 $\pm$ 1.29 <sup>b</sup>	19.32 $\pm$ 0.05 <sup>c</sup>	22.90 $\pm$ 1.27 <sup>b</sup>	1.19 $\pm$ 0.06 <sup>b</sup>	92.86 $\pm$ 5.00 <sup>b</sup>
Citric acid 0.25%	1185.24 $\pm$ 36.41 <sup>b</sup>	3440.02 $\pm$ 9.54 <sup>a</sup>	45.04 $\pm$ 1.38 <sup>b</sup>	19.98 $\pm$ 0.06 <sup>a</sup>	25.05 $\pm$ 1.36 <sup>b</sup>	1.25 $\pm$ 0.07 <sup>b</sup>	98.22 $\pm$ 5.37 <sup>b</sup>
Sex effect	NS	NS	NS	NS	NS	NS	NS
Females	1237.72 $\pm$ 23.69	3358.16 $\pm$ 6.21	47.03 $\pm$ 0.90	19.55 $\pm$ 0.04	27.48 $\pm$ 0.89	1.41 $\pm$ 0.04	110.28 $\pm$ 3.50
Males	1244.80 $\pm$ 20.99	3357.76 $\pm$ 5.50	47.30 $\pm$ 0.80	19.55 $\pm$ 0.03	27.75 $\pm$ 0.79	1.42 $\pm$ 0.04	111.43 $\pm$ 3.10
Treatment x sex	NS	NS	NS	NS	NS	NS	NS

Means having different superscripts within each item in the same column are significantly different. \* = significant at  $P \leq 0.05$ , \*\* = significant at  $P \leq 0.01$  and \*\*\* = significant at  $P \leq 0.001$ . LBWG: live body weight gain, FI: feed intake, EEf: economic efficiency, REEf: relative economic efficiency.

♦: noted to economic efficiency of the dietary treatments and sex groups relative to control economic efficiency.

There is no mortality recorded during the whole experimental period these findings agreed with Papatsiros *et al.*, (2011) who showed that Post-weaning piglets fed organic acids-supplemented diets exhibited lower contents of pathogenic bacteria and less incidence of diarrhea and mortality rate. Statistically, treatment x sex interaction had no significant effects ( $P > 0.05$ ) on growth traits, carcass characteristics, blood parameters and economic efficiency.

## CONCLUSION

Both levels of lactic acid can be used in the diets of growing rabbits as safe growth stimulants and immunity. Moreover, the level 0.25% of lactic acid surpassed numerically 0.50% lactic acid in the diets of growing rabbits and significantly improved all growth performance and feed traits compared to the other treatments, bearing in mind that both lactic and citric acids did not affect the characteristics of the blood or carcass. The addition of organic acids in the diets of growing rabbits has a great effect on the growth characteristics and feeding efficiency, but it needs further study and scrutiny, especially with regard to the percentage of addition, the consumed nutrients and the breeding season. Economically, rabbits fed on supplemented diets with lactic acid at two levels 0.5% and 0.25% had higher economic efficiency and relative economic efficiency compared to control and groups fed on citric acid at two levels.

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## اختبار مستويين من حمضي اللاكتيك والستريك كمحفزات نمو في علائق الأرناب

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استخدم في هذه الدراسة عدد 150 أرناب مفطوم من سلالة V-Line عمر خمسة أسابيع وزعت الأرناب عشوائياً على خمس مجموعات متساوية تتكون من ثلاثة مكررات 10 أرناب (5 ذكور و 5 إناث) لكل مكرر بمتوسط وزن اولي مماثل ( $18.22 \pm 594.68$  جم). تم تسكين جميع الأرناب في أقفاص من السلك المجلفن داخل حظائر جيدة التهوية في ظل ظروف صحية وتربية مماثلة. المجموعة الأولى تناولت عليقه قاعديه بدون إضافة أحماض عضوية (مجموعة الكنترول). اشتملت المجموعتان الثانية والثالثة على عليقة كنترول مضاف اليها 0.5 و 0.25% حمض اللاكتيك، على التوالي، اشتملت المجموعتان الرابعة والخامسة على 0.5 و 0.25% حامض الستريك على التوالي. أدت تغذية الأرناب على علائق تحتوي على حمض اللاكتيك سواء 0.25% أو 0.5% إلى تحسن كبير في جميع مقاييس النمو النهائية متفوقة على حامض الستريك ومجموعة الكنترول. فيما يتعلق بصفات الذبيحة لم تظهر التغذية على العلائق المحتوية على أحماض عضوية أي فروق معنوية لخصائص الذبيحة و فيما يتعلق بمقاييس الدم لم يكن هناك تأثير معنوي للمعاملات الغذائية على قياسات الدم المختلفة باستثناء الخلايا الليمفاوية الكليه واليوريا في الدم والتي زادت معنوياً لصالح الأرناب التي تغذت على حمض اللاكتيك بنسبة 0.5%. من الناحية الاقتصادية وكفاءة اقتصادية نسبية أعلى من الكنترول والمجموعات التي غذيت على حمض اللاكتيك بالمستويين 0.5% و 0.25% ذات كفاءة اقتصادية وكفاءة اقتصادية نسبية أعلى من الكنترول والمجموعات التي غذيت على حمض الستريك بمستويين.