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EFFECT OF CHELATED ORGANIC ZINC SUPPLEMENTATION ON PRODUCTIVE PERFORMANCE AND SOME PHYSIOLOGICAL RESPONSES OF GROWING RABBITS.

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ABSTRACT

This study investigated the effects of adding 150, 300, and 450 mg/kg of chelated organic zinc amino acids (CH-ZnAA) to rabbits' diets on some physiological and productive performance. Forty weaned V-line rabbits were assigned to four equal groups, nominated as T1 (Control, fed basal diet without any supplementation), T2 (fed basal diet plus 150 mg/kg diet), T3 (fed basal diet plus 300 mg/kg diet), and T4 (fed basal diet plus 450 mg/kg diet), respectively. The results showed that diets supplemented with 150, 300, and 450 mg CH-ZnAA/kg diet increased the average body weight (ABW) and average weight gain (AWG) as well as, final body weight (FBW) and total body weight gain (TBWG) of experimental animals as compared to control group. In the same line, an improvement was recorded in digestibility of crude protein (CP), ether extract (EE), crude fiber (CF), and nitrogen-free extract (NFE) with CH-ZnAA. Moreover, it was found that the rising inclusion of CH-ZnAA from 150 up to 450 mg/kg in the rabbits' diets improved slaughter weight (SW), hot carcass weight (HCW), and HCW + total edible (HCWE). Total erythrocyte counts (RBCs), hemoglobin (Hb, g/dl), and Hematocrit (Hct%) were increased when different levels of CH-ZnAA were supplemented to rabbit diets; however, supplementation did not effect on the WBCs, platelets, or erythrocytic indices. These supplementations also improved total protein (TP), albumin (ALB), globulin (Glob), and glucose concentrations. No significant differences were noticed in liver enzymes [aspartate aminotransferase (AST) and alanine aminotransferase (ALT)], kidney functions (creatinine and urea) concentrations, and Thyroid hormones (triiodothyronine and thyroxin) among the studied treatments. Supplemented CH-ZnAA to the rabbits' diet up to 450 mg/kg improved serum levels of the antioxidants superoxide dismutase (SOD), glutathione S-transferase (GST), and decreased malondialdehyde (MDA) concentrations. The net revenue (NR) was improved by 11.11, 21.95, and 30.82 %, respectively when feeding diets T2, T3, and T4 *vs* T1 (control). In conclusion, CH-ZnAA improved the productivity of V-line rabbits, it is secure and might be advised for use.

Keywords: : Zinc, rabbits, growth, digestibility, carcass, and blood characteristics.

INTRODUCTION

Each decade, the demand for animal-derived food increases. This reflects the increases in the human population and general knowledge of the importance of animal protein consumption. Egypt, with a population of over 100 million persons, faced a lack of animal protein, which affected the majority of Egypt's population. Moreover, consumers tend to look for a higher-quality protein source at a lower cost. In this way, Rabbits are now recognized as an excellent source of protein at a reasonable price for humans and may play a principal role in alleviating meat shortages in developing countries.

Rabbits have received a lot of attention among livestock and becoming increasingly essential in meat production around the world (Biagini et al., 2016, El-Ratel, 2017 and El-Moghazy et al., 2019), because of their rapid growth rate, high fertility, and one of the highest feed conversion ratios and a small land area required. Moreover, rabbit meat has a low-fat content with few saturated fatty acids and a low cholesterol content, making it a beneficial and healthy food product. It also contains high levels of protein (20-21%), essential amino acids, and easily digestible protein (Dalle Zotte, 2002 and Naser et al., 2017). Rabbits are a good choice for large-scale livestock production in the future (Morshdy et al., 2022). However, with all these advantages, the productivity of rabbit meat is limited and still lower.

A wide range of dietary additives were used to enhance the growth performance of rabbits in order to boost the production of rabbit meat (Hassan et al., 2017). One of these additives was trace minerals. Trace minerals in animal’s diet are associated with improved immune systems, reproductive success, and growth rates. (Suttle, 2010).

Zinc (Zn) as a trace element supports several biological functions, such as healthy development of the bones, body's defenses, control of hunger, and the activity of numerous enzymes involved in body metabolism, such as protein, energy, and carbohydrate (Salim et al. 2011and El-Hack *et al.*, 2017) and immunological defense (Liu *et al.*, 2011 and Yan *et al.*, 2017). Moreover, Zn is important in the antioxidant defense system since it is an essential part of superoxide dismutase (Powell, 2000). Furthermore, utilizing trace elements, such as zinc, helps with a variety of physiological and metabolic processes, thereby reducing the detrimental effects of heat stress in rabbits (Abdel-Wareth et al., 2022).

There are many forms of zinc such as inorganic zinc, organic zinc, and chelated organic zinc. Nevertheless, due to high Zn secretion in feces and the danger of environmental contamination from using inorganic Zn, animal nutritionists are currently lowering the permissible dosage of inorganic Zn in diets and replacing it with organic zinc or chelated organic Zn. Chelated zinc offers better results than conventional Zn sources and can be used at lower concentrations (Hassan et al., 2021). Chelated minerals are molecules in which a metal is coordinately bound to an organic ligand; however, many organic minerals are not chelates or are not even coordinately bound (Vieira, 2008). Chelation is a type of chemical reaction that connects organic molecules to minerals at two or more locations to form rings. The mineral is surrounded by the molecule, which protects it from any negative interactions (Jacob et al., 2022). Using new technology, such as advanced chelate compounds, it is now possible to design and create effective structures to be used in a variety of scientific fields, such as agriculture, medicine, animal husbandry, and poultry (Hafizi et al., 2015 and Fakharzadeh et al., 2020).

Recommendations of Zn addition in the rabbits' diet were variable, which was 50 mg/kg (NRC, 1977). The European Food Safety Authority (EFSA) reported that rabbit diets would contain 150 mg Zn/kg. (EFSA., 2019). However, a few researchers have noted varying doses of zinc that affected performance in rabbits. El-Moghazy et al., (2019) reported 100 mg Zn/kg as organic zinc methionine (Zn-Me), 50 mg/kg as Zn proteinate (Kuckova et al., 2021), 20 up to 40 mg/kg as zinc oxide nanoparticles (Abdel-Wareth et al., 2022). These variable reports may refer to various zinc sources and levels of bioavailability. According to Selim et al. (2014) and Kishawy et al. (2020), the various sources and levels of Zn used as supplements have an impact on the bioavailability of zinc.

The purpose of this study was to gather basic information about the effectiveness and safety of supplementing different levels of chelated organic zinc amino acids (CH-ZnAA) to rabbit feeds by examining how it affects growth performance, blood hematological, biochemical parameters, antioxidant status, and economics feature in weaned growing rabbits.

MATERIALS AND METHODS

2.1. Animals, Diet Formulations, and experimental design.

The current study was conducted at the Animal and Poultry Production research farm, Faculty of Agriculture, Minia University.

Forty males growing V-Line rabbits of 6 weeks old. Rabbits were randomly divided into four equal treatment groups (10 rabbits/treatment; 5 replicates, 2 rabbits/each). The basal diet is formulated to provide appropriate nutritional levels for growing V-Line rabbits as recommended by the National Research Council, (NRC, 1977). The formulation and chemical composition of the basal diet are shown in Table (1). Three supplemental dietary treatment groups were formulated to contain the basal diet incorporated with chelated organic zinc amino acid (CH-ZnAA) at 150, 300, and 450 mg /kg diet for T2, T3, and T4, respectively as shown in Table (2). The CH-ZnAA used in this experiment (containing 17% Zinc, 19% Lysine, and 19% Glutamic acid) was a 1:1 compound of zinc lysine and zinc glutamic acid (Availa ® Zn 170) supplied by Zinpro Corporation (Edina, MN, USA).

All rabbits were housed in an open house. Rabbits were allocated in cages with a slatted floor of iron. The cage's measurements were (45 × 45 × 38cm) in length, width, and highest, respectively. Feed and water were given to the rabbits *ad libitum* during the experimental period.

1.2. Growth performance:

Every two weeks throughout the experiment, which lasted from 6 to 16 weeks of age, average body weight (ABW) and average feed intake (AFI) of each replicate were measured. Using the average daily gain (ADG) and average daily feed intake (ADFI) of rabbits, the feed conversion ratio (FCR) was calculated.

2.3. Digestion trial and analysis of basal diet and feces:

At the end of the experiment, feces were collected and taken for chemical analysis. According to A.O.A.C. (2006), proximate analysis was done on the samples of feces and experimental diets. Using acid-insoluble ash (ALA) as an internal marker, (Van Keulen and Young, 1977) determined the total digestibility of DM, OM, CP, EE, CF, NDF, ADF, ADL, hemicellulose, and NFE. cellular walls (Neutral detergent fiber (NDF), acid detergent fiber (ADF), and acid detergent lignin (ADL)) were determined according to (Van Soest et al., 1991). The nutritional values of the experimental rations were computed as total digestible nutrients (TDN) and digestible crude protein (DCP).

2.4.Evaluations of carcass characteristics:

At the end of the experimental period, three rabbits were randomly chosen from each treatment. All rabbits were individually weighed and slaughtered after approximately 12 hours of fasting, when complete bleeding was achieved, slaughter weight was recorded. The slaughtered rabbits removed the fur and cleaned from all entails, and the hot carcass had its weight measured and noted, including the head. The edible portions (liver, lung, heart, spleen, and kidneys) were weighed and recorded individually.

2.5. Blood samples:

At 16 weeks of age, blood samples were collected from three rabbits from each treated group, and two blood samples were immediately collected from each rabbit during the slaughter. The first sample was collected in the heparinized tube (2.25µ heparin / 5 ml blood) for the hematological blood parameters. The second sample was collected in the non-heparinized tube and centrifuged for 10 minutes at 5000 R.P.M to separate serum which was stored at (-20°C) for some biochemical parameters.

2.6. Hematological blood parameters:

Total erythrocyte counts (RBCs) ($10^6/mm^3$), Total leucocytes count (WBCs) ($10^3/mm^3$), platelet count (PLT)

($\times 10^3/mm^3$), Whole blood hemoglobin concentration (Hb) (gm/100ml%), Hematocrit (Hct) or (packed cell volume) (PCV %), erythrocytic indices (mean corpuscular volume (MCV) (fl.), mean corpuscular hemoglobin (MCH) (pg.), and mean corpuscular hemoglobin concentration (MCHC) (g/dl)) were performed using a veterinary hematology analyzer (Vet Scan HM5 Hematology System Abaxis Europe, UK).

2.7. Serum biochemical parameters:

serum total protein (TP, g/dl), Glucose (mg/dl), albumin (ALB, g/dl), Triglycerides (TG, mg/dl), total cholesterol (TC, mg/dl), liver functions (aspartate aminotransferase (AST, U/l), alanine aminotransferase (ALT, U/l)), kidney functions (creatinine (mg/dl), urea (mg/dl)), antioxidant parameters (superoxide dismutase (SOD, IU), glutathione S-transferase (GST, mg/dl), and malondialdehyde (MDA, nmol/ml)) were determined by using reagent kits purchased from a bio diagnostic chemical company (Egypt) according to the manufacturers' instructions. Serum globulin (GLOB, g/dl) was obtained by calculating the difference between TP and ALB. Thyroid hormones (triiodothyronine (T3), and Thyroxine levels (ng/ml)) concentration in serum was determined according to the method of (Sterling and Lazarus, 1977), and (McComb *et al.*, 1979) respectively. Serum CH-ZnAA components concentration (Zn (µ/dl), glutamic acid (U/ml), and lysine (U/ml)) was determined according to (Wedekind *et al.*, 1992), (Lund, 1990) and (Kusakabe et al., 1980) respectively.

2.8. Economic efficiency:

The cost-effectiveness of dietary treatments was calculated based on prices in Egyptian pounds (L.E.) for 2021. For each experimental diet, the economic evaluation is shown in (Table, 11).

2.9. Statistical Analysis:

The data was presented as mean SE. One-way ANOVA was used for statistical analysis. The differences between the four experimental groups were tested using the general linear model (GLM). According to SAS Institute (2020), statistical significance was defined as a p-value of less than 0.05. The significance levels between means were examined using (Dancan, 1955). The following equation was used to calculate the statistical analysis:

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

Where: Yij = Experiment observation. µ = The overall mean. Ti = The effect of dietary treatment.

I = T1, …. T4. Eij = The experimental error.

RESULTS

3.1. Effect of chelated organic zinc amino acid (CH-ZnAA) on growth performance of V- line rabbits.

3.1.1. Average body weight.

Results are shown in Table (3) displays the effect of chelated organic zinc amino acid on the average body weight (ABW) of V-line rabbits. The results were significantly affected at all ages for rabbits that received diets containing 300 and 450 mg/kg CH-ZnAA compared to the control diet. Rabbits fed ration supplemented with 150 mg/kg CH-ZnAA had significantly (P < 0.01) higher weight at 12 and 14 weeks. and slightly heavier weight at weeks 8 and 10 in comparison with the control diet, (Table, 3). The final body weight of treatment groups (T2, T3 and T4) were highly significant ($P<0.001$) than the control group (T1) by 5.04, 9.8, and 12.31% respectively. In terms of ABW, there was no discernible difference between the T3 and T4 groups.

3.1.2. Body weight gain (BWG):

The body weight gain (BWG) of the V-line rabbits is presented in Table (4). The outcomes showed that there were substantial increases in body weight gain at all ages except 10-12 and 12-14 weeks for rabbits fed diets supplemented with CH-ZnAA at 300 (T3) and 450 (T4) mg/kg in comparison with rabbits fed the unsupplemented diet. In addition, results cleared that TBWG, and average daily gain (ADG) were highly significantly ($P<0.01$) increased by 7.82, 15.29, and 19.52%, respectively for treated groups (T2, T3, and T4) *vs.* the control group. The T3 and T4 treatments did not significantly ($P>0.05$) differ in BWG or ADG.

3.1.3. Feed intake (FI):

Data presented in Table (5) revealed a positive effect of CH-ZnAA supplementation levels on feed intake values. In comparison to the control group, increasing CH-ZNAA levels up to 450 mg/kg diet led to significant ($P<0.05$) increase in feed intake at 8-10 weeks and a highly significant increase ($P<0.01$) at 12-14 and 14-16 weeks. This effect lasted until the end of the experimental period (16 week.). Also, total feed intake and average daily feed intake (ADFI) at 6-16 weeks were considerably greater in treatment groups (T2, T3, T4) compared to the baseline group. The percentage of increments achieved were 2.91, 5.33, and 2.85%, respectively. Differences in feed intake among treatments were not significant through 6-8 and 10-12 weeks old.

3.1.4. Feed conversion ratio:

As shown in Table (6), the feed conversion ratio was significantly ($P< 0.01$) decreased due to feeding T2, T3, and T4 than rabbits fed (T1) the control diet at 6-8 and 8-10 weeks, while no significant difference was found in weeks 10-12, 12-14 and 14-16. From the results presented in Table (6), it can be observed that the average feed conversion (AFC) throughout the experimental period 6-16 weeks of age was considerably ($P< 0.05$) affected between treatments. The lowest value 3.29 g intake/ g body gain was the best for treatment supplemented with 450 mg CH-ZnAA /kg diet (T4).

3.1.5. Digestibility coefficients:

The impacts of nutritional treatments on the nutrient digestibility of growing V-line rabbits are presented in Table (7). The data revealed that supplementing rabbit diets with CH-ZNAA resulted in highly significant ($P< 0.01$) increases in the digestibility of dry matter (DM), organic matter (OM), crude protein (CP), and NFE, as well as significant ($P< 0.05$) improvements in the digestibility of ether extract (EE), crude fiber (CF), NDF, and hemicellulose compared to unsupplemented diets (control).

The nutritional values of T2, T3, and T4 diets increased more favorably than T1 (unsupplemented diet). The increment percentages were 0.78, 2.0, and 3.0% for TDN and 2.43, 3.89, and 4.86% for DCP, respectively. In a similar pattern, rabbits fed T3 and T4 had dramatically (P < 0.01) higher digestibility of DM, OM, CP, and feed nutrient values expressed as TDN and DCP when compared to T2. The digestibility of ADF, ADL, and cellulose did not differ significantly (P>0.05) among the dietary treatments.

3.1.6. Carcass Characteristics.

The averages of various carcass measurements of V-line rabbits fed diets containing 150, 300, and 450g/kg diet CH-ZnAA are displayed in Table (8). The results showed that slaughter weight, hot carcass weight, and hot carcass weight plus total edible organs of rabbits fed supplemented diets were highly significant (P < 0.01) and (P< 0.05) for dressing percentages compared to the control diet. The control group recorded the lowest values, whereas the highest values were found in T4. However, the CH-ZnAA treatment had no appreciable impact on the relative weights of edible organs or the total edible weight.

3.1.7. Blood Hematological Parameters.

Data on blood hematological parameters studied such as RBCs, WBCs, Platelets, Hemoglobin, Hematocrit, and Erythrocytic index as affected by dietary treatments are presented in Table (9). In comparison to the control treatment, CH-ZnAA treatment of rabbits at doses of (300 and 450 mg/kg) increased (P < 0.05) RBC count, Hb concentration, and Hct (%). While supplementing of CH-ZnAA at 150 mg/kg had significant (P<0.05) improvement in RBCs count only and failed to show any improvement in Hb concentration and Hct (%) in comparison with the control group. However, erythrocytic values of MCV, MCH, and MCHC were not significantly affected by CH-ZnAA treatment.

3.1.8. Blood Biochemicals Parameters.

The effects of dietary treatments on some blood biochemical parameters of growing rabbits are presented in Table (10). The data revealed that rising CH-ZnAA supplementation levels in rabbit diets at (T2, T3, and T4) had greatly significant (P<0.01) effect on the concentration of glucose as compared with the control diet (T1). Also, supplementation of CH-ZnAA as 300 mg (T3) or 450 mg (T4) to rabbits' diet led to a significant (P< 0.01) increase in total protein concentration by 4.33 and 14.43 % for rabbits fed T3 and T4 diets, respectively. Also, rabbits fed diet with (450 mg CH-ZnAA /kg diet) had significant (P<0.05) increase in albumin (g/dl) and globulin (g/dl) in comparison with the control treatment. However, there was no significant difference in TP concentrations among rabbits fed diet T2 (150 mg/kg CH-ZnAA) as compared with those fed T3 (300 mg/kg CH-ZnAA) or T1 (control). The outcomes also showed that no discernible difference in ALB and GLB concentrations between the treated groups (T2 and T3) and the control group (T1) was found.

The results revealed that adding CH-ZnAA at levels (150, 300, and 450 mg/kg diet) significantly (P<0.01) decreased triglycerides (mg/dl) and total cholesterol (mg/dl) versus the control diet. No significant difference was found between T2 and T3 in triglycerides (mg/dl) or between T4 and T3 in total cholesterol (mg/dl). Results presented in Table (10) illustrated that liver functions as (AST and ALT), kidney functions as

(Creatinine and Urea), and thyroid hormones as (T_3 and T_4) concentrations were not significantly affected when rabbits fed the tested rations.

Data on some antioxidant enzymes (SOD, GST, and MDA) as affected by dietary treatments are presented in Table (10). Rabbits received diets supplemented with CH-ZnAA appeared to had SOD significantly ($P<0.05$) higher than the control diet, as well as GST concentration was significantly ($P<0.01$) increased, While MDA concentrations were significantly ($P<0.05$) decreased for rabbits received diets supplemented with CH-ZnAA (300 and 450 mg/kg diet) than in rabbits fed T2 (CH-ZnAA 150 mg/kg diet) and the control diet. No significant difference was found between T2 and T1 in GST and MDA concentrations.

Also, rabbits fed T2, T3, and T4 showed significantly ($P<0.05$) higher concentrations of zinc and glutamic acid concentrations in the blood serum than in the control. However, there was no discernible difference in zinc concentration between the treated groups. Also, no significant changes were observed in glutamic acid concentration between (T2 and T3) or (T3 and T4). Supplementation of CH-ZnAA at 350 and 450 mg/kg diet significantly ($P< 0.05$) increased the lysine concentration when compared with T1 (control). The differences between T3 and T4 or between T2 and T3 were not significant.

3.1.9. Economical Feature:

Data presented in Table (11) indicated that supplementation of CH-ZnAA as (150g/kg, T2), (300g/kg, T3) or (450 mg/kg, T4) to rabbits' diet increased the total feed cost/rabbit by 3.36, 6.29 and 4.22 %, respectively compared to those fed T1 (unsupplemented diet) However, the Net revenue (NR) was increased by 11.11, 21.95 and 30.82 %, respectively upon feeding diets T2, T3 and T4 as compared with T1. Also, the Net revenue (NR) increased by 9.76% upon feeding treatment T3 in comparison with T2. In addition, T4 which contains (450 mg CH-ZnAA) had the best and greater NR by 17.75 and 7.82% when compared to T2 and T3, respectively. The highest superiority value above the control treatment was (130.82) when T4 was fed. The superiority values for other treatments were 100, 111.11, and 121.95 for T1, T2, and T3, respectively. Increasing the CH-ZnAA level from 350 to 450 mg of dietary treatments reduced the total feeding cost from 24.64 to 24.16 (L.E.), while increasing the Net revenue from 38.24 to 41.02 (L.E.). The Economic efficiency expressed as (NR/TFC) increased from 1.35 to 1.70 as T1 was compared with T4, which represents a 25.51% improvement.

DISCUSSION

Mineral absorption is an important factor that restricts their application in biological functions in the body. Although microminerals can be absorbed, they may not always be biologically used. Mineral ions from inorganic sources can easily combine with elements in digesta to create insoluble complexes, which hinder mineral absorption. While chelated organic trace elements are in a chemically sluggish state as a result of ligand binding, it is thus protected from unfavorable interactions with digesta components such as phytate (Hassan et al., 2021). Chelated organic zinc is expected to be very effectively absorbed and transported to target tissues because it uses amino acids as carriers to uptake mechanisms and increase bioavailability. This bioavailability is then impacted because of numerous Zn sources used as supplements (Selim et al., 2014 and Kishawy et al., 2020).

In the present study, chelated organic zinc protected by lysine and glutamic acid CH-ZnAA was used. It was applied with a lower amount for enhancing growth performance, ranging from 25.5 to 76.5 mg Zn/kg diet. As a result, it is possible to use organic Zn with a higher bioavailability, which provides better growth performance. Our results found that diets supplemented with 150, 300, and 450 mg CH-ZnAA, which provide 25.50, 51.00, and 76.50 mg Zn/kg increased the ABW and AWG as well as FBW and TBWG in weaned rabbits compared to rabbits fed an unsupplemented diet. Results were in accordance with El-Moghazy et al., (2019) They reported that ABW, AWG, and FBW increased for rabbits fed diets containing 50 and 100 mg Zn/kg as organic zinc methionine (Zn-Me) at 9 and 13 weeks of age in comparison with rabbits fed unsupplemented diets. Furthermore, Zhang et al., (2018) found that supplementing pig diets with 40 and 80 mg Zn/kg as chelated organic zinc with lysine and glutamic acid (ZnAA) resulted in a significant increase in ABW, AWG, and FBW.

The enhancement of growth performance may be explained by increasing feed intake and the rise in the paternal CP digestibility, and nutritive value as DCP and TDN, which had an impact on the physiological functions accompanied by enhancing the growth of their rabbits. In this respect, some reports confirm the findings by demonstrating the beneficial effects of supplemental organic zinc amino acids on rabbit performance. Which were concur with the favorable response to the inclusion of chelated organic zinc that may be due to the high feed intake (Hassan et al., 2021), Improved nutrient digestibility and nutritive values of the diet due to higher Zn bioavailability may lead to better growth in animals (Li et al., 2016). Additionally, dietary zinc is essential for the animal's healthy biological processes, including cell division, DNA synthesis (Prasad., 1991), and growth (Abd El-Hack et al., 2018).

Another possible explanation for the increased growth performance of ABW and AWG is the benefit of chelated organic zine as a growth factor. According to Khan et al. (2014) and El-Moghazy (2019), Zn is thought to be crucial for maintaining the structural integrity of insulin, growth hormone, and growth factor. Recently, Hassan et al., (2021) reported that the inclusion of Zn-Met in rabbits' diet led to a significant increase ($p < 0.001$) in the concentrations of insulin-like growth factor (IGF-1) as compared to the control one.

In the current study, an improvement in feed intake (FI) and feed conversion ratio (FCR) was due to the supplementation of CH-ZnAA levels in growing rabbit diets. The results agree with Hassan et al., (2017). They detected a considerable increase in feed intake when rabbits received various amounts of high-absorption zinc as zinc oxide-nano particles (ZnO-NPs) at 30 and 60 mg/kg as compared with the control group. In addition, Hassan et al., (2021) discovered that rabbits fed a diet added with organic Zn at 50 mg/kg had significantly improve FI and FC than the control group. In contrast, El-Moghazy et al. (2019) found that rabbits given a diet added with organic Zn up to 150 mg/kg did not consume any more feed than the control group. The difference in outcomes may be correlated to the amount of supplementation, sources, the methodology, the strains, the age of the rabbits, and the length of the experiments.

The present study demonstrated an enhancement in the digestibility of CP, EE, CF, and NFE with CH-ZnAA in terms of the impact of zinc levels. These findings are consistent with McDonald (2002)'s assertion that zinc has a positive effect on the absorption and metabolic processes of carbohydrates, lipids, and proteins. Furthermore, organic zinc was discovered to be an important factor in the pancreatic defense against oxidative agents by Saleh et al. (2018), which may enhance digestibility by increasing the excretion of digestive enzymes. Meshreky et al. (2015) found that organic zinc methionine at 100 and 200 mg/kg increased nutrient digestibility in growing rabbits, whereas Chrastinová et al. (2016) found no effect of zinc on nutrient digestibility.

Carcass performance is an important indicator for evaluating meat yield and quality, which is significant for the economic benefits of the rabbits' production industry. The outcomes of this investigation may shed light on the function of active components in CH-ZnAA. Our finding showed that the rising inclusion of CH-ZnAA from 150 up to 450 mg/kg in the rabbit's diets improved SW, HCW, and HCWE. The greatest carcass weights were noted in the group fed the highest dose of CH-ZnAA (450 mg/kg as 76.5 mg Zn/kg diet). The improvement in SW, HCW, and HCWE as a result of using CH-ZnAA may be attributable to the improved FBW, TBWG, better FI, and FCR of rabbits fed CH-ZnAA diets, especially in T4. It was clear that in comparison with the control, T4 was the best as higher feed intake and higher FBW which led to more efficient FCR accompanied by greater TDN and accordingly increase in SW and HCW yield. These findings agree with El-Moghazy et al., (2019). They showed that the addition of 100 mg/kg Zn-Met had improved SW, CW, and dressing percentage, while the addition of various levels of organic Zn-Met up to 150 mg/kg had no impact on the total edible parts. Moreover, rabbits fed Zn-supplemented diets up to 100 mg/kg had higher HCW and dressing percentage than the control group, according to Amer et al. (2016).

Results of blood hematological and biochemical parameters (Tables, 9 and 10) confirm the picture of enhancement in nutrient digestibilities and carcass weight that was achieved by increasing the CH-ZnAA from 150 to 450 mg/kg on the dietary treatments. The physiological status of rabbits can be accurately predicted by hematological parameters (Khan and Zafar, 2005). A wide variety of conditions and diseases are detected and treated by the field of hematology (Elwan et al., 2020).

According to the description of the reference ranges of normal hematological values for various rabbit species (Moore et al., 2015), all hematological parameters were found to be within the normal range, according to our findings. The hematological parameters (RBCs, Hb%, and Hct%) were increased when different levels of CH-ZnAA were added to rabbit diets; however, supplementation did not affect on the WBCs, platelets, or erythrocytic indices. These results support the findings by El-Moghazy et al., (2019). They reported that adding chelated organic zinc amino acids to rabbits' diets as Zn-Met increased RBCs, Hb%, and Hct%) without affecting erythrocytic indices. It's interesting to note that raising RBC counts and Hct % values in rabbits receiving CH-ZnAA treatment up to 450 mg/kg were assigned to increase Hb concentration. Accordingly, Zn plays a crucial role in the formation of Hb, so greater Zn availability in the organic Zn-supplemented group may have encouraged better Hb synthesis in the treatment group in goats (Chavan et al., 2016). However, Zhang et al., (2018) reported that hematological parameters were not impacted by adding cleated zinc amino acids to pigs' diets. The insignificant differences in WBC's count among the four treatments may indicate that rabbits were healthy and unstressed, while the figures were within the normal range (Moore et al., 2015).

It is a point of interest to see that the bio-chemical outcomes revealed no negative effects on the blood components. Our results found an increase in blood glucose when the dietary CH-ZnAA was raised from 150 to 450 mg/kg and the increment was significant ($P < 0.01$). These results ascertain the improvement obtained in CF, hemicellulose, and NFE digestibilities (Table, 7) and TFI (Table, 5). In general, these results agree with (El-Moghazy et al., 2019). They showed that serum glucose concentration was higher ($p<0.01$) in the diet supplemented with organic zinc methionine. This study cleared those levels of dietary zinc significantly improved TP, ALB, and Glob, which is consistent with earlier reports by Zhang et al. (2018) on pigs and El-Moghazy., (2019) and Hassan et al., (2021) on rabbits. The decrease in total blood cholesterol caused by CH-ZnAA supplementation may be attributed to lowering the amount of cholesterol released into the blood by the liver and controlling the activity of HMG-CoA reductase, a crucial enzyme in the production of cholesterol (Eder et al., 1999). In addition, adding zinc to rabbits' diets had anti-atherogenic effects in hypercholesterolemic rabbits (Ren et al., 2006 and Rashtchizadeh et al., 2008).

No appreciable variations were found in liver enzymes (AST and ALT) and kidney functions (creatinine and urea) concentrations among the studied treatments. This may give a signal that the digestibility and metabolizable processes were working normally without stress and the dietary ingredients were free from any infectious agent. The normal range of AST and ALT activities were recorded previously in rabbits by (Putra et al., 2022). They reported that the normal ranges of AST and ALT activities are 35 to 130 and 45 to 80, respectively and the normal ranges of creatinine and urea activities are 0.5 to

2.5 and 20 to 45, respectively. While the results obtained in this work ranged from 60.10 to 61.87 for AST, from 48.57 to 55.63 for ALT, from 0.79 to 0.90 for creatinine, and from 38.33 to 45.33 for urea. In the same trend, thyroid hormones as T_3 and T_4 concentrations were not affected by treatments, these outcomes agree with (El-Kholy et al., 2021).

Zinc plays a significant role in antioxidant parameters as it is one of the vital parts of the SOD enzyme, which is crucial to the defense mechanism for antioxidants (Powell, 2000). Zine is implicated in the cell's ability to eliminate reactive oxygen species (ROS) and free radicals (Prasad 2008 and Abd El-Hack et al. 2018). Zinc addition had anti-reactive oxygen species (ROS) effects that reduced MDA levels (El-Shobokshy et al., 2023). MDA is an essential marker of lipid peroxidation and the oxidative damage brought on by ROS (El-Far et al. 2020 and Bin-Jumah et al. 2020). Glutathione peroxidase contributes to cellular membrane protection from oxidative damage, which improves rabbit growth under extreme temperatures (Dalle et al., 2018). Zn may play a protective or pro-antioxidant role in biological systems, as well as an antioxidative stress agent (Prasad and Bao., 2019). These may help to explain why the present outcomes were improved when we added CH-ZnAA to the rabbits' diet in amounts up to 450 mg/kg that elevated serum levels of the antioxidants SOD and GST and decreased MDA. El-Moghazy et al., (2019) illustrated that adding Zn-Me up to 100 mg/kg to the diets improved antioxidative properties and immune functions in rabbits. El-Shobokshy et al., (2023) reported that SOD and GSH levels were significantly improved in rabbit fed diets supplemented with high bioavailability zinc (Nano zinc, ZnNPs) group *vs.* unsupplemented group. Meanwhile, MDA was significantly lower in the ZnNPs group compared to the control group. Similar results were reported on broilers (Saleh et al., 2018). Which reported that adding organic-Zn boosted the activity of antioxidant enzymes and reduced lipid peroxidation in heat-stressed poultry. Kamel et al. (2020) also found that adding nano-Zn to rabbits' diets significantly raised GST and SOD activities and lowered MDA levels. According to recent research by Reda et al. (2021), dietary nano-Zn levels significantly ($P < 0.01$) increased serum levels of glutathione peroxidase (GPX) and SOD, but decreased MDA levels.

It is important to find the concentrations of zinc or the amino acids that serve as carriers of zinc in blood serum, which can mirror the absorption and utilization of zinc. A greater amount of Zn is absorbed by the epithelial cells in the small intestine rather than the blood when feeding organic metal chelates, which are composed of Zn chelated with amino acids in coordinate covalent bonds than feeding diets supplemented with inorganic Zn (Behjatian et al., 2021). Additionally, serum zinc levels serve as a gauge for assessing the body's nutritional status (Elleuch et al., 2021). The rise in serum zinc concentration indicates improved zinc absorption (Pattan et al., 2021). This study found that the concentration of zinc in the serum was significantly higher in the treated groups than in the control groups. This indicates that the organic zinc amino acids that were chelated had a higher bioavailability, which is consistent with the findings regarding growth performance. This result is supported by Ren et al., (2020) results, they reported that chelated organic Zn sources like Zn-Met, Zn-proteinate, and Zn-glycinate had a higher bioavailability. These findings are in line with previous studies reported by Hassan et al., (2021) who observed higher zinc concentrations in the liver and serum of rabbits fed diets supplemented with nano-zinc and organic zinc. In addition, Zhang et al., (2018) informed that pigs in the unsupplemented group had lower serum zinc levels than those who received supplements of 20, 40, 80, and 120 mg/kg of chelated organic zinc with lysine and glutamic acid (ZnAA).

In fact, the first and main objective of any rabbit holder is how much he will gain from his project. From the economic point of view increasing the dietary CH-ZnAA levels up 150, 300, and 450 mg/kg led to an increase in net revenue (L.E) by 11.11% for T2 and 21.95% for T3. The feeding cost increased by 4.22% while the net revenue (L.E) increased by 30.82% for feeding diets containing CH-ZnAA 450mg/kg diet.

CONCLUSION

It was clear from the present study, that supplementation with 150, 300, and 450 mg Zn/kg as CH-ZnAA improved nutrient digestibility, growth performance, carcass characterization, and some blood parameters as compared to the control group, and the fourth treatment supplementation with 450 mg Zn/kg was the best among treatments.

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Table (1): The composition and chemical analysis of the basal diet used for growing V-Line rabbits.

Ingredients	%	Chemical analysis	%
Ground corn	26	Dry matter %	91.46
Soybean meal	11	Organic matter %	91.61
Wheat bran	40	ME (kcal/kg)[2]	2700
Berseem Hay	20	Crude protein%	16.41
Limestone	2	Crude fiber%	12.33
Sodium chloride	0.5	Ether extract %	2.94
Vitamin-mineral premix[1]	0.5	NDF%	22.85
Total	100	ADF%	17.19
		ADL%	2.87
		Hemicellulose%	20.65
		Cellulose%	14.33
		Nitrogen-free extract %	59.93
		Ash %	8.39
		Zinc (mg/kg)[3]	50.86
		Lysine (g/kg)[4]	8.1
		Glutamic acid (g/kg)[4]	30.8

1. Each one kg of vitamins and minerals mixture contains 12000 IU of vitamin A acetate; 2000 IU of vitamin D3; 10 mg of vitamin E acetate; 2000 mg of vitamin K3; 100 mg of vitamin B1; 4000 mg vitamin B2; 1500 mg vitamin B6; 10 mg vitamin B12; 10 mg Pantothenic acid; 20 mg Nicotinic acid; 1000 mg Folic acid; 50 mg Biotin; 500 mg Chorine; 10 mg Copper; 1000 mg Iodine; 300 mg Iron; 55 mg Manganese; 55mg Zinc, and 100 mg selenium.
2. Metabolisable energy (ME) value was calculated according to its concentrations in each feed component (NRC, 1977).
3. Zn concentration in the feed of rabbits was measured according to the method of (A.O.A.C. methods, 2012).
4. Lysine and Glutamic acid were calculated according to (INRA-CIRAD-AFZ., 2018).

Table (2) Calculations of zinc concentration (mg/kg) in diets used for growing V-line rabbits.

Items	T1	T2	T3	T4
CH-ZnAA provided [1]				
CH-ZNAA dose (mg/kg)	0	150	300	**450**
Zn (mg/kg)	0	25.50	51.00	**76.50**
Lysine (g/kg)	0	0.029	0.057	**0.086**
Glutamic acid (g/kg)	0	0.029	0.057	**0.086**
Total [2]				
Zn (mg/kg)	**50.86**	**76.36**	**101.86**	**127.36**
Lysine (g/kg)	8.13	8.16	8.19	8.22
Glutamic acid (g/kg)	30.80	30.83	30.86	30.89

2. Each one kg Availa ® Zn 170 (CH-ZNAA) (containing 17% Zinc, 19% Lysine and 19% Glutamic acid).
3. Total = Zn, lysine, and glutamic acid in basal diet + their component in CH-ZnAA provided.

Table (3). Effect of chelated organic zinc amino acid (CH-ZNAA) on average body weight of V-line rabbits at different ages (wks.) postweaning.

Age/wks.	Average body weight (g) Treatments[1] T1	T2	T3	T4	SE±	Sig
Initial BW 6	**696.00**	**695.00**	**693.00**	**688.00**	6.80	**NS**
8	967.00^{b}	991.00^{ab}	997.00^{ab}	1007.50^{a}	12.18	*
10	1224.50^{b}	1258.50^{b}	1321.00^{a}	1346.00^{a}	14.95	**
12	1489.00^{c}	1557.50^{b}	1622.50^{a}	1649.50^{a}	18.19	**
14	1750.50^{c}	1825.50^{b}	1902.00^{a}	1937.50^{a}	25.72	**
Final BW 16	**1994.50^{c}**	**2095.00^{b}**	**2190.00^{a}**	**2240.00^{a}**	31.13	**

* Significant (P<0.05), ** significant (P<0.01)

[a, b, and c] Means within a row with different superscripts differ significantly at $P < 0.05$.

Table (4). Effect of chelated organic zinc amino acid (CH-ZNAA) on BWG and ADG of V-line rabbits at different age intervals.

Body weight gain (BWG, g)						
Age/wks.	**Treatments**				**SE±**	**Sig**
	T1	**T2**	**T3**	**T4**		
6-8	271.00^{b}	296.00^{ab}	304.00^{a}	319.50^{a}	9.31	**
8-10	257.50^{b}	267.50^{b}	324.00^{a}	338.50^{a}	9.53	**
10-12	264.50	299.00	301.50	303.50	13.12	**NS**
12-14	261.50	268.00	279.50	288.00	16.07	**NS**
14-16	244.00^{b}	269.50^{ab}	288.00^{ab}	302.50^{a}	15.77	*
Total BWG 6-16	**1298.50^{c}**	**1400.00^{b}**	**1497.00^{a}**	**1552.00^{a}**	29.52	**
ADG 6-16	**18.55^{c}**	**20.00^{b}**	**21.39^{a}**	**22.17^{a}**	0.421	**

* Significant (P<0.05), ** Significant (P<0.01)

a, b, and c Means within a row with different superscripts differ significantly at $P < 0.05$.

Table (5). Effect of chelated organic zinc amino acid (CH-ZnAA) on feed intake (g) of V-line rabbits at different age intervals postweaning.

Feed intake (g / Rabbit)						
Age/wks.	**Treatments**				**SE±**	**Sig**
	T1	**T2**	**T3**	**T4**		
6-8	855.40	837.20	830.20	826.00	13.30	**NS**
8-10	914.20^{c}	939.40^{ab}	959.00^{a}	950.60^{a}	8.88	*
10-12	953.40	1008.00	1023.40	985.60	26.00	**NS**
12-14	1052.80^{c}	1104.60^{ab}	1124.20^{a}	1090.60^{b}	10.55	**
14-16	1187.20^{c}	1218.00^{bc}	1290.80^{a}	1251.60^{ab}	16.13	**
TFI[1] 6-16	**4963.0^{c}**	**5107.2^{b}**	**5227.6^{a}**	**5104.4^{b}**	36.73	**
ADFI[2] 6-16	**70.90^{c}**	**72.96^{b}**	**74.68^{a}**	**72.92^{b}**	0.524	**

1. TFI = total feed intake. 2. ADFI = Average daily feed intake. * Significant (P<0.05), ** Significant (P<0.01)

a, b, and c Means within a row with different superscripts differ significantly at $P < 0.05$.

Table (6). Effect of chelated organic zinc amino acid (CH-ZnAA) on feed conversion ratio of V-line rabbits at different age intervals postweaning.

Feed Conversion Ratio						
Age/wks.	**Treatments**				**SE±**	**Sig**
	T1	**T2**	**T3**	**T4**		
6-8	3.16^{a}	2.83^{b}	2.73^{b}	2.59^{b}	0.105	**
8-10	3.55^{a}	3.51^{a}	2.96^{b}	2.81^{b}	0.153	**
10-12	3.60	3.37	3.39	3.25	0.199	NS
12-14	4.03	4.12	4.02	3.79	0.263	NS
14-16	4.87	4.52	4.48	4.14	0.297	NS
AFC[1] 6-16	$\mathbf{3.82^{a}}$	$\mathbf{3.65^{ab}}$	$\mathbf{3.49^{bc}}$	$\mathbf{3.29^{c}}$	0.103	*

1. AFC = Average feed conversion = (Feed intake g / Body weight gain g).

* Significant (P<0.05), ** Significant (P<0.01). [a, b, and c] Means within a row with different superscripts differ significantly at $P < 0.05$.

Table (7). Effect of chelated organic zinc amino acid (CH-ZnAA) on the nutrient digestibility coefficients and nutritive values of the experimental rations.

	Digestibility coefficients (%)					
Items	**T1**	**T2**	**T3**	**T4**	**SE±**	**Sig**
DM	68.12^{d}	68.83^{c}	69.62^{b}	70.26^{a}	0.112	**
OM	71.18^{d}	71.71^{c}	72.53^{b}	73.23^{a}	0.116	**
CP	75.20^{c}	77.08^{b}	78.16^{a}	78.86^{a}	0.294	**
EE	76.01^{b}	76.82^{b}	78.72^{a}	79.74^{a}	0.504	*
CF	53.21^{c}	54.11^{bc}	54.62^{ab}	55.35^{a}	0.314	*
NDF	41.28^{c}	43.16^{b}	44.29^{ab}	45.64^{a}	0.494	*
ADF	34.88	35.14	35.38	36.37	0.684	NS
ADL	12.05	12.21	13.17	13.46	0.709	NS
Hemicellulose	46.60^{b}	49.83^{ab}	51.71^{a}	53.36^{a}	1.11	*
Cellulose	39.45	39.72	39.82	40.95	0.80	NS
NFE	73.53^{c}	73.60^{c}	74.37^{b}	75.05^{a}	0.183	**
TDN	$\mathbf{67.98^{d}}$	$\mathbf{68.51^{c}}$	$\mathbf{69.34^{b}}$	$\mathbf{70.02^{a}}$	**0.110**	**
DCP	12.35^{c}	12.65^{b}	12.83^{a}	12.95^{a}	0.0490	**

* Significant (P<0.05), ** Significant (P<0.01)

[a, b, c, and d] Means within a row with different superscripts differ significantly at $P < 0.05$.

Table (8). Effect of chelated organic zinc amino acid (CH-ZnAA) on Carcass characteristics of V-line rabbits.

Items	Treatments				SE±	Sig
	T1	**T2**	**T3**	**T4**		
Carcass characteristics						
Slaughter weight (SW, g)	1946.00^{d}	2026.50^{c}	2152.50^{b}	2201.50^{a}	14.10	**
Hot carcass weight (HCW, g)	1113.48^{c}	1254.75^{b}	1305.50^{a}	1381.12^{a}	23.73	**
(HCW, g) + Total edible (HCWE, g)	1193.2^{c}	1285.4^{b}	1388.2^{a}	1464.0^{a}	21.92	**
Dressing %						
HCW/ SW	57.22^{b}	59.50^{ab}	60.65^{ab}	62.73^{a}	1.07	*
HCWE/SW	61.36^{b}	63.49^{ab}	64.55^{ab}	66.56^{a}	0.96	*
Edible Organs weight, (g)						
Liver	54.95	52.50	54.25	53.66	2.68	NS
Kidney	10.15	10.85	11.90	12.04	0.45	NS
Heart	5.18	5.36	5.50	5.71	0.22	NS
Lung	9.45	10.92	11.06	11.48	0.56	NS
Spleen	1.29	1.26	1.55	1.58	0.15	NS
Total	79.73	79.63	82.71	82.88	3.16	NS

* Significant (P<0.05), ** Significant (P<0.01)

[a, b, c and d] Means within a row with different superscripts differ significantly at $P < 0.05$.

Table (9). Effect of chelated organic zinc amino acid (CH-ZnAA) on blood hematological parameters of V-line rabbits.

Items	Treatments				SE±	Sig
	T1	**T2**	**T3**	**T4**		
Hematological Parameters						
Red blood cells ($10^6/mm^3$)	5.35^{b}	5.73^{a}	5.85^{a}	5.89^{a}	0.12	*
WBCs ($10^3/mm^3$)	6.97	6.80	6.73	6.40	0.23	NS
Platelets (x $10^3/mm^3$)	205.7	187.6	195.7	203.1	16.54	NS
Hemoglobin (g/dl)	10.70^{b}	11.27^{ab}	11.70^{a}	11.93^{a}	0.25	*
Hematocrit (%)	30.50^{b}	32.20^{ab}	33.40^{a}	34.00^{a}	0.83	*
Erythrocytic indices[1]						
MCV (fl.)	57.05	56.17	57.08	57.66	0.67	NS
MCH (pg.)	20.01	19.66	20.00	20.24	0.17	NS
MCHC (g/dL)	35.10	35.00	35.03	35.11	0.35	NS

1. Erythrocytic indices: MCV= Mean corpuscular volume (fl.) MCH= Mean corpuscular Hemoglobin (pg.). MCHC= Mean corpuscular Hemoglobin concentration (g/dL). * Significant (P<0.05), ** Significant (P<0.01)
   [a and b] Means within a row with different superscripts differ significantly at $P < 0.05$.

Table (10). Effect of chelated organic zinc amino acid (CH-ZnAA) on blood biochemical parameters of V-line rabbits.

Blood Biochemicals Parameters						
Items	**Treatments**				**SE±**	**Sig**
	T1	**T2**	**T3**	**T4**		
Glucose (mg/dl)	104.00^{b}	131.00^{a}	141.67^{a}	142.67^{a}	5.89	**
Total proteins (g/dl)	6.93^{c}	7.17^{bc}	7.23^{b}	7.93^{a}	0.09	**
Albumin (ALB) (g/dl)	4.07^{b}	4.27^{b}	4.30^{ab}	4.70^{a}	0.13	*
Globulin (Glob) (g/dl)	2.87^{b}	2.90^{b}	2.93^{b}	3.23^{a}	0.05	*
Triglycerides (mg/dl)	127.33^{a}	116.98^{b}	115.17^{b}	95.00^{c}	2.37	**
Total cholesterol (mg/dl)	165.17^{a}	157.83^{b}	153.33^{c}	146.50^{c}	1.79	**
Liver Functions:						
AST[1] (U/l)	60.10	58.83	57.80	61.87	2.18	NS
ALT[2] (U/l)	48.57	52.17	52.90	55.63	2.69	NS
Kidney Functions:						
Creatinine (mg/dl)	0.90	0.88	0.80	0.79	0.030	NS
Urea (mg/dl)	44.67	45.33	42.00	38.33	3.75	NS
Thyroid hormones:						
T_3 (ng/ml)	88.00	90.67	93.00	82.00	8.11	NS
T_4 (ng/ml)	5.43	5.97	5.17	7.00	0.74	NS
Antioxidant parameters:						
SOD (IU)	4.12^{c}	5.02^{b}	5.32^{ab}	5.83^{a}	0.17	*
GST[3] (mg/dl)	105.67^{b}	112.00^{b}	121.33^{a}	125.00^{a}	2.37	**
MDA[4] (nmol/ml)	0.18^{a}	0.17^{a}	0.14^{b}	0.13^{b}	0.008	*
Serum CH-ZnAA components						
concentrations						
Zn (µg/dl)	73.67^{b}	87.67^{a}	90.67^{a}	95.67^{a}	3.57	*
Glutamic acid (U/ml)	202.00^{c}	260.67^{b}	278.00^{ab}	291.33^{a}	7.45	**
Lysine(U/ml)	145.67^{c}	155.67^{bc}	193.33^{ab}	213.00^{a}	13.81	*

1. AST = aspartate aminotransferase (U/l),
2. 2. ALT= alanine aminotransferase (U/l)
3. 3. GST= Glutathione-S-transferase (Units/ml)
4. 4. MDA= Malondialdehyde Concentration (Mg/dl).

* Significant (P<0.05), ** Significant (P<0.01)

[a, b, and c] Means within a row with different superscripts differ significantly at $P < 0.05$.

Table (11): Economical Feature of tested rations fed to V-line Rabbits:

Economical Feature				
Items	**Treatments**			
	T1	**T2**	**T3**	**T4**
Total feed intake/rabbit (kg)	4.96	5.11	5.23	5.10
Price of Kg feed (L.E) [1]	4.67	4.69	4.71	4.73
Total feed cost (TFC)/rabbit (L.E)	23.18	23.96	24.64	24.16
Market price (MP)/Kg live weight (L.E)	42	42	42	42
Total body weight gain (TBWG, Kg)	1.299	1.400	1.497	1.552
Selling price (SP)[2]	54.54	58.80	62.87	65.18
Net revenue (NR, L.E)[3]	31.36	34.84	38.24	41.02
Economic efficiency (EE)[4]	1.35	1.45	1.55	1.70
Relative economic efficiency (REE)[5]	100.00	107.48	114.74	125.51
% Superiority[6]	100.00	111.11	121.95	130.82

1- The price of each feed ingredient (L.E) on one kilogram basis is soybean meal (9.0), wheat bran (4.0), corn (6.0), Berseem hay (2.0), Limestone (0.40), sodium chloride (2.5) and Premix (20). The price of one kg CH-ZnAA was 140 L.E, and the price of one kg body weight (BW) was 42 L.E at the time of the experiment.
2- Selling price = MP× TBWG
3- NR = SP- TFC
4- EE= NR/TFC
5- REE (according to EE)
6- % Superiority (according to NR).

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الملخص العربي

تأثير إضافة الزنك العضوي المخلبي علي الأداء الإنتاجي و بعض الاستجابات الفسيولوجية في الأرانب النامية

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تم إجراء هذه الدراسة بهدف دراسة تأثير إضافة الزنك العضوي المخلبي المحمل على الأحماض الأمينية في عليقة الأرانب بمعدلات 150، 300، 450 مللجم/كجم عليقة علي الأداء الإنتاجي والفسيولوجي. حيث تم توزيع عدد 40 أرنباً من سلالة V-line على أربع مجموعات متساوية ، وكانت المجموعة الاولي (المجموعة الضابطة بدون أي إضافات) و الثانية (تغذت علي المجموعة الضابطة بلاضافة الي 150 مللجم/ كجم) و الثالثة (تغذت علي المجموعة الضابطة بلاضافة الي 300 مللجم/كجم) و الرابعة(تغذت علي المجموعة الضابطة بلاضافة الي 450 مللجم) . واستمرت الدراسة لمدة 10 أسابيع.

أظهرت النتائج أن المجموعات المعاملة بالإضافة (150، 300، 450 مللجم زنك عضوي مخلبي محمل على الليسين والجلوتاميك أسيد/كجم عليقة) أدت إلى :-

- زيادة متوسط وزن الجسم ومتوسط الزيادة في وزن الجسم بالمقارنة مع المجموعة الكنترول.
- تحسنت معاملات هضم البروتين الخام والمستخلص الإثيري والألياف الخام والكربوهيدرات الذائبة تحت تأثير إضافة مستويات مختلفة من الزنك العضوي المخلبي.
- زيادة الوزن عند الذبح ووزن الذبيحة مباشرة ووزن الذبيحة والأعضاء المأكولة.
- تحسن عدد كرات الدم الحمراء و% للهيموجلوبين و% لحجم كرات الدم الحمراء.

ومع ذلك لم يكن هناك أثر للإضافة علي عدد كرات الدم البيضاء والصفائح الدموية أو مؤشرات خلايا الدم الحمراء.

كما حسنت أيضاً الإضافة بمختلف المستويات كلاً من (البروتين الكلي والألبيومين والجلوبيولين والجلوكوز). ولكن لاتوجد فروق معنوية بين المعاملات في كلاً من :-

- إنزيمات الكبد (الألنين ترانساميناز ALT والاسبرتات ترانساميناز AST).
- وظائف الكلى (الكرياتينين واليوريا).
- هرمونات الغدة الدرقية (الثيرونين ثلاثي اليود والثيروكسين).

تحسنت النتائج عند الاضافة (450 مللجم/كجم) المجموعة الرابعة كانت هناك إختلافات معنوية بين المعاملات في كلاً من الجلوتاثيون(GST) وسوبراوكسيد ديسميوتاز(SOD) والمالوندالدهيد (MDA).

كما ارتفع صافي الربح بنسبة 11.11 و21.95 و30.82% لكلاً من المجموعة الثانية والثالثة والرابعة على التوالي مقارنة بالمجموعة الضابطة.

وفي الختام، اوضحت الدراسة ان اضافة الزنك العضوي المخلبي المحمل على الأحماض الأمينية ادي الي تحسين إنتاجية الأرانب V-line، وهي آمنة و يوصى باستخدامها حتي مستوي 450 مللجم /كم.