



## EFFECT OF SUPPLEMENTAL ZINC AND COPPER ON PERFORMANCE OF GROWING RABBITS

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**ABSTRACT:** Forty-two New Zealand White male rabbits with average body weight 546.74g were randomly assigned to 7 groups (6 animals in each) in a completely randomized design to study the effect of dietary zinc supplementation through inorganic (ZnO) or organic (Zinc EDTA) sources in combinations with copper (CuSO<sub>4</sub>) on growth performance. Rabbits of the first group (T1) were given basal diet without any supplementations (control group), while the other 6 groups were given basal diet containing zinc and copper as follows: group 2 (T2) received basal diet + 250 mg Cu/kg diet from CuSO<sub>4</sub>, group 3 (T3) received basal diet + 500 mg Cu/kg diet, group 4 (T4) received basal diet +20 mg Zn from Zinc EDTA + 250 mg Cu/kg diet, group 5 (T5) received basal diet + 20 mg Zn from Zinc EDTA + 500 mg Cu/kg diet, group 6 (T6) received basal diet +20 mg Zn from ZnO + 250 mg Cu/kg diet and group 7 (T7) received basal diet + 20 mg Zn from ZnO + 500 mg Cu/kg diet, respectively. Live body weight, daily body gain, daily feed intake and feed conversion ratio were significantly increased by feeding rabbits on diets supplemented with 250 or 500 mg Cu/ kg diet. More enhancements were recorded in rabbits fed with 20 mg zinc as ZnO and 250 mg copper (T6). Total protein concentration in blood serum was significantly increased in rabbits fed 20 mg Zn from Zn EDTA + 500 mg Cu/kg diet (T5). Also the same treatment increased creatinine (CREAT) concentration in blood serum. While, Cu supplementations at 250 (T2) or 500 (T3) mg/kg feed increased urea concentration. All supplementation treatments significantly increased pre-slaughter weight comparing to un-supplemented control rabbits. The highest pre-slaughter weight was found in rabbits fed with diet containing 250 mg Cu/kg diet (T2) or with 20 mg Zn from ZnO + 250 mg Cu/kg diet (T6). Weights of carcass, liver and kidney and dressing (%) as well as weights of head and hind part did not significantly affected with the tested supplementations. Economically final margin was increased in all rabbits fed supplemented feed. The highest income from gain and the highest final margin were recorded in rabbit groups fed diet supplemented with 250 mg Cu/kg diet (T2) or 20 mg Zn from ZnO + 250 mg Cu/kg diet (T6).

**Key words:** Rabbits, zinc, copper, growth performance, blood analysis, carcass components, economic efficiency.

### INTRODUCTION

The livestock sector globally is highly dynamic. In developing countries, it is evolving in response to rapidly increasing demand for livestock products. In developed countries, demand for livestock products is stagnating, while many production systems are increasing their efficiency and environmental sustainability. Historical changes in the demand for livestock

products have been largely driven by human population growth, income growth and urbanization and the production response in different livestock systems has been associated with science and technology as well as increases in animal numbers (Thornton, 2010).

Life on earth has evolved within a complex mixture of organic and inorganic compounds. While organic molecules such as amino acids, carbohydrates and nucleotides form the

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backbone of proteins, these fundamental components of macromolecules are enzymatically synthesized and ultimately degraded. Inorganic elements, such as copper and zinc, once solubilized from the earth's crust, are neither created nor destroyed and therefore their homeostatic regulation is under strict control. In the fascinating field of metals in biology, by virtue of direct interactions with amino acid side-chains within polypeptide chains, metals play unique and critical roles in biology, promoting structures and chemistries that would not otherwise be available to proteins alone (Festa and Thiel, 2011).

Trace elements, though required in minute quantities are essential for maintaining health and immunity. They are involved in growth, production and reproduction. Trace elements act as cofactors of enzymes which are important to the immunity of animal (Aksu *et al.*, 2012). Superoxide dismutase, glutathione reductase, glutathione peroxidase, thioredoxin reductase, ceruloplasmin and catalase are important enzymes that have trace elements as cofactors. These enzymes act as antioxidants and prevent oxidative stress by neutralizing oxidants produced under different stresses. Besides, trace elements contribute to general health of animal thereby enhancing disease resistance. Trace elements are important for proper functioning of a number of enzymes and proteins which are involved in many physiological, biochemical and metabolic processes that contribute to growth and production (Yatoo *et al.*, 2013). Overall, trace elements improve immune competence and productive performance (Terpilowska and Siwicki, 2011).

Copper and zinc are antagonists, and the balance between them is an example of biological dualism. This does that, and that does this, and they often fight with each other. Both minerals play important roles in the body. Balancing copper (Cu) and zinc (Zn), though vitally important, may not be as easy as expected. Copper is an essential constituent of the growing number of cuproenzymes and copper metalloprotein with functions as diverse as electron transfer (Cobine *et al.*, 2006 ; Festa and Thiel, 2011), pigmentation (Sendovski *et al.*, 2011; Xu *et al.*, 2013) and oxidation

resistance (Wang *et al.*, 2013; Ladomersky and Petris, 2015).

Ayyat and Marai (2000) reported that supplementing rabbits with 100, 200 or 300 Zn mg/kg diet significantly increased live weight gains, but had no effect on feed intake, feed conversion ratio compared to control animals or those fed 400 Zn mg/kg diet. Adequate zinc positively affects feed utilization through participating in the metabolism of carbohydrates, lipids, and proteins (McDonald, 2000).

So, the present work was conducted to study the combined effect of dietary zinc and copper supplementation on growth performance, feed efficiency and carcass composition of male rabbits.

## MATERIALS AND METHODS

Such experiment was carried out in Animal Production Department, Faculty of Agriculture, Zagazig University, Egypt, during the period from November to January (duration of the experimental period of 8 weeks) to study the effect of dietary zinc supplementation through inorganic (ZnO) or organic (Zinc EDTA) sources in combination with copper (CuSO<sub>4</sub>) on growth performance of male New Zealand White rabbits (NZW).

Forty-two New Zealand White male rabbits with average body weight of 546.74g were randomly assigned to 7 groups (6 animals in each) in a completely randomized design. Rabbits of the first group (T1) were given basal diet without any supplementations (control group), while the other 6 groups were given basal diet containing zinc and/ or copper as follows: group 2 (T2) received basal diet + 250 mg Cu/kg diet from CuSO<sub>4</sub>, group 3 (T3) received basal diet + 500 mg Cu/kg diet, group 4 (T4) received basal diet +20 mg Zn from Zinc EDTA + 250 mg Cu/kg diet, group 5 (T5) received basal diet + 20 mg Zn from Zinc EDTA + 500 mg Cu/kg diet, group 6 (T6) received basal diet +20 mg Zn from ZnO + 250 mg Cu/kg diet and group 7 (T7) received basal diet + 20 mg Zn from ZnO + 500 mg Cu/kg diet, respectively.

Basal diet was as pellets contained 17% yellow corn, 35% clover hay, 10% barley, 13% soybean meal, 21% wheat bran, 3.0% molasses, 0.20% sodium chloride, 0.40% vitamins and minerals and 0.40% limestone. These components were reflected as 88% organic matter, 17.3% crude protein, 13.42% crude fiber, 2.89% ether extract, 54.39% nitrogen free extract and 12% ash. Additionally, Oxide zinc was used as a source of mineral Zn while EDTA Zinc ( $C_{10}H_{12}N_2Na_2Zn.2H_2O$ ) was used for organic zinc supplementations. Copper sulfate was used as a source for Copper.

All animals were kept under similar managerial and hygienic conditions, during the experimental period. The rabbits were raised in cages provided with feeders and automatic nipple drinkers. The building was naturally ventilated and provided with electric fans. Feed consumption was recorded during the experimental period and feed conversion was calculated. Animal body weight (g) was measured at the beginning of the experiment, at 4<sup>th</sup> week and at the end of the trial. Also, daily body weight gain and feed conversion ratio (Feed intake / body weight gain) were calculated at 4<sup>th</sup> and 8<sup>th</sup> week.

At the end of the experimental period, three rabbits were chosen randomly from each group and sacrificed. After complete bleeding, pelt, viscera and tail were removed and the carcass and some carcass components (fore, intermediate and hind parts, liver and head), were weighed. Blood samples of rabbits were collected during slaughter. Serum samples were obtained by centrifugation of blood at 3000 rpm for 20 minutes and kept at -20°C for analyses. Serum total proteins, albumin, creatinine, Urea-N and transaminase enzymes were determined using commercial kits.

Economic evaluation was calculated according to Ayyat (1991) using the following equation, final margin (Profit) = Income from body gain weight - feed cost. Other overhead costs were assumed constant. Price of one kg of basal diet was 3 LE (Egyptian pound 0.057 US\$) and price of selling of one kg live body weight of rabbits was 27 LE. Additionally, price of one kg of feed supplemented with 250 mg Cu was 3.175 LE, price of one kg of feed supplemented with 500 mg Cu was 3.351 LE, price of one kg of feed

supplemented with 20 mg Zn from Zn EDTA and 250 mg Cu was 3.195 LE, price of one kg of feed supplemented with 20 mg Zn from Zn EDTA and 500 mg Cu was 3.371 LE, price of one kg of feed supplemented with 20 mg Zn from ZnO and 250 mg Cu was 3.178 LE and price of one kg of feed supplemented with 20 mg Zn from ZnO and 500 mg Cu was 3.354 LE.

Data of the trial was statistically analyzed using one-way ANOVA analysis of SPSS Program (Version 20). Resulted data of growth performance, blood components and pre-slaughter live body weight were analyzed using analysis of variance, according to the following model:

$Y_{ik} = \mu + T_i + e_{ik}$ , Where:  $Y_{ik}$  = an observation,  $\mu$  is the overall mean,  $T$  is the fixed effect treatments ( $i = 1 \dots 7$ ), and  $e_{ik}$  is random error. The data of slaughter traits were statistically analyzed by analysis of covariance according to the following Model 2:  $Y_{ij} = \mu + T_i + b(X-x) + e_{ij}$ , where,  $Y_{ijk}$ ,  $\mu$ ,  $T_i$ , and  $e_{ij}$  were as defined in the Model 1,  $b$  = partial linear regression coefficients of  $Y_{ij}$  on slaughter weight,  $X$  = value of slaughter weight and  $x$  = overall average of slaughter weight. Significant differences between treatments were tested with Duncan's multiple range test (Duncan, 1955).

## RESULTS AND DISCUSSION

### Growth and Feed Performance

Live body weight (at 4 and 8 weeks) and daily body gain were affected significantly ( $P < 0.001$ ) by the experimental treatments (Table 1). Feeding rabbits on diets supplemented with 250 or 500 mg copper/kg diet, significantly increased final body weight and daily gain as compared to control group. Final body weight increased by 35.97 and 31.08% in rabbits fed diet supplemented with 250 or 500 mg copper, respectively, when compared with the control group. The same figures for the total daily gain (0-8 weeks of the experimental period) were 47.80 and 42.85%, respectively. On the other hand, rabbits fed diet supplemented with 20 mg zinc as zinc oxide and supplemented with 250 mg copper recorded higher final body weight and growth rate (39.83 and 51.49%, respectively) than the control group. Rabbit group fed diets

**Table 1. Live body weight and gain of New Zealand White male rabbits as affected by zinc and copper supplementation (Mean ± SE)**

Item	Live body weight (g) at			Daily gain (g/day) at		
	0 W	4 W	8 W	0-4 W	4-8 W	0-8 W
T1	530.67±14.95	1290.33±16.23 <sup>e</sup>	2031.33±50.09 <sup>f</sup>	27.13±0.71 <sup>d</sup>	26.47±1.55 <sup>f</sup>	26.80±0.83 <sup>e</sup>
T2	544.17±23.07	1554.83±18.77 <sup>bc</sup>	2762.00±58.28 <sup>ab</sup>	36.10±0.82 <sup>b</sup>	43.12±2.18 <sup>a</sup>	39.61±1.18 <sup>a</sup>
T3	519.17±21.96	1615.00±24.33 <sup>ab</sup>	2662.67±66.72 <sup>bc</sup>	39.14±1.36 <sup>ab</sup>	37.42±1.71 <sup>bcd</sup>	38.28±1.31 <sup>ab</sup>
T4	541.83±23.42	1582.33±21.41 <sup>b</sup>	2665.17±45.29 <sup>bc</sup>	37.16±0.88 <sup>ab</sup>	38.67±2.00 <sup>abc</sup>	37.92±0.60 <sup>ab</sup>
T5	555.83±18.03	1612.83±19.66 <sup>ab</sup>	2411.83±45.94 <sup>de</sup>	37.75±0.92 <sup>ab</sup>	28.54±1.32 <sup>ef</sup>	33.14±1.01 <sup>cd</sup>
T6	567.00±29.02	1668.17±33.14 <sup>a</sup>	2840.33±56.27 <sup>a</sup>	39.33±1.36 <sup>a</sup>	41.86±2.37 <sup>ab</sup>	40.60±0.73 <sup>a</sup>
T7	566.50±18.16	1620.50±19.33 <sup>ab</sup>	2556.00±38.57 <sup>cd</sup>	37.64±0.33 <sup>ab</sup>	33.41±1.48 <sup>cde</sup>	35.53±0.70 <sup>bc</sup>
<b>Significance</b>	NS	***	***	***	***	***

NS = Not significance and \*\*\* = P<0.001.

Means in the same column with different letters differ significantly (P<0.05).

T1 control group, T2 received 250 mg Cu/kg diet, T3 received 500 mg Cu/kg diet, T4 received 20 mg Zn from Zinc EDTA + 250 mg Cu/kg diet, T5 received 20 mg Zn from Zinc EDTA + 500 mg Cu/kg diet, T6 received 20 mg Zn from ZnO + 250 mg Cu/kg diet and T7 received 20 mg Zn from ZnO + 500 mg Cu/kg diet.

supplemented with 20 mg zinc as zinc oxide and supplemented with 250 mg copper recorded higher growth rate than the other experimental groups, then followed by group fed diet supplemented with 250 mg Cu/kg diet, then group fed diet supplemented with 500 mg Cu/kg diet and this fed diet supplemented with 20 mg Zn from Zinc EDTA and 250 mg Cu/kg diet. **Adu and Egbunike (2009)** reported that copper supplemented rabbits had a positive improvement in final live weight. The synergistic effect of Zn and Cu supplementation was predicted because of their vital roles.

The mechanism by which high levels of copper and zinc improve growth rate in rabbits is still unclear. Both have some antibacterial properties (**Dupont et al., 1994**), which may explain the growth-promoting effect, but there is a lack of scientific evidence to understand the exact mode of action. The improvement in growth performance when the diet is supplemented with high levels of dietary copper is similar in magnitude to that achieved when in-feed antimicrobials are fed to nursery animals. Even though copper has antibacterial properties, growth rate is stimulated in an additive manner when both antimicrobials and high levels of

copper are added to nursery animal diets (**Cromwell, 2001**). Thus, it appears that the growth-promoting properties of high dietary levels of copper are in addition to its antimicrobial effect.

Daily feed intake follows the same trend as in final body weight. Since, daily feed intake was significantly (P<0.001) increased in rabbit groups treated with Zn and Cu (Table 2). Rabbits group fed diets supplemented with 20 mg Zn from ZnO and 500 mg Cu/kg diet recorded higher feed intake, then followed by the rabbit group fed diet supplemented with 20 mg Zn from Zinc EDTA and 500 mg Cu/kg diet, then group fed diet supplemented with 20 mg Zn from ZnO and 250 mg Cu/kg diet. Also, Cu supplementations at 250 or 500 mg/kg diet enhanced daily feed intake comparing to control group, with no significant differences between the two Cu tested levels. While, **Ayyat and Marai (2000)** and **Selim et al. (2012)** found no effect on feed intake of rabbits fed diets supplemented with Zn.

Feed conversion ratio was significantly (P<0.001) improved in rabbit groups treated with Zn and Cu (Table 2). In general, tested supplementations reduced ratio of daily feed

**Table 2. Feed intake and conversion of New Zealand White male rabbits as affected by zinc and copper supplementation (Mean±SE)**

Item	Daily feed intake (g) at			Feed conversion (g food/g gain) at		
	0-4 W	4-8 W	0-8 Wz	0-4 W	4-8 W	0-8 W
T1	89.74±0.52 <sup>d</sup>	117.89±2.43 <sup>c</sup>	103.82±1.28 <sup>d</sup>	3.32±0.08 <sup>a</sup>	4.54±0.30 <sup>a</sup>	3.90±0.14 <sup>a</sup>
T2	99.14±1.94 <sup>bcd</sup>	129.16±1.89 <sup>ab</sup>	114.15±1.61 <sup>bc</sup>	2.75±0.07 <sup>cde</sup>	3.04±0.16 <sup>d</sup>	2.89±0.08 <sup>e</sup>
T3	106.46±5.22 <sup>abc</sup>	122.08±2.84 <sup>bc</sup>	114.27±3.19 <sup>bc</sup>	2.72±0.08 <sup>d</sup>	3.29±0.14 <sup>cd</sup>	2.99±0.07 <sup>de</sup>
T4	97.49±2.40 <sup>bcd</sup>	124.87±2.16 <sup>bc</sup>	111.18±1.76 <sup>c</sup>	2.63±0.10 <sup>e</sup>	3.27±0.18 <sup>cd</sup>	2.93±0.05 <sup>e</sup>
T5	114.13±2.85 <sup>a</sup>	126.68±2.75 <sup>b</sup>	120.41±0.90 <sup>ab</sup>	3.04±0.11 <sup>abcd</sup>	4.47±0.14 <sup>a</sup>	3.65±0.11 <sup>ab</sup>
T6	108.69±6.36 <sup>ab</sup>	124.77±0.94 <sup>bc</sup>	116.74±3.44 <sup>bc</sup>	2.80±0.23 <sup>cde</sup>	3.03±0.17 <sup>d</sup>	2.88±0.08 <sup>e</sup>
T7	117.18±3.85 <sup>a</sup>	135.38±3.08 <sup>a</sup>	126.28±3.28 <sup>a</sup>	3.12±0.11 <sup>abc</sup>	4.10±0.25 <sup>ab</sup>	3.57±0.14 <sup>b</sup>
Significance	***	***	***	**	***	***

NS = Not significance, \*\* P<0.01 and \*\*\* = P<0.001.

Means in the same column with different letters differ significantly (P<0.05).

T1 control group, T2 received 250 mg Cu/kg diet, T 3 received 500 mg Cu/kg diet, T4 received 20 mg Zn from Zinc EDTA + 250 mg Cu/kg diet, T5 received 20 mg Zn from Zinc EDTA + 500 mg Cu/kg diet, T6 received 20 mg Zn from ZnO + 250 mg Cu/kg diet and T7 received 20 mg Zn from ZnO + 500 mg Cu/kg diet.

intake related to daily weight gain. Rabbits fed diet supplemented with 20 mg Zn from ZnO and 250 mg Cu/kg diet recorded the best feed conversion. Feed conversion improved to 26.15, 25.90, 24.87, 23.33, 8.46 and 6.41%, respectively in rabbit groups fed diet supplemented with 20 mg Zn from ZnO and 250 mg Cu/kg diet (T6), rabbits fed diet supplemented with 250 mg Cu/kg diet (T2), rabbits fed diet supplemented with 20 mg Zn from Zinc EDTA and 250 mg Cu/kg diet (T4), rabbits fed diet supplemented with 500 mg Cu/kg diet (T3), rabbits fed diet supplemented with 20 mg Zn from ZnO and 500 mg Cu/kg diet (T7) and rabbits fed diet supplemented with 20 mg Zn from Zinc EDTA and 500 mg Cu/kg diet (T5). **Selim et al. (2012)** reported improvements in feed conversion ratio in rabbits fed Zn supplemented diet at levels of 50, 100 or 200 mg/kg diet.

The immune modulator and antimicrobial properties of Zn and Cu have been extensively studied. Both Zn and Cu are claimed to provide protection against infectious diseases *in vivo*, and to regulate innate immune response (**Stafford et al., 2013**). However, it is known that the redistribution of Zn in the organism following an inflammatory stimulus follow a

specific strategy; while plasma Zn decreases, liver, thymus, and bone marrow accumulate Zn (**Cousins and Leinart, 1988**). Among the well-known functions of Zn and Cu, their role in the defense against free radical has been extensively studied. It has been shown above that reduced serum levels of Zn with advancing aging might also occur, independently of a decrease in serum albumin, by dislocation of Zn from the serum albumin pool and its subsequent delivery in the free or labile form into other compartments. Interestingly, a different role for cellular function of Zn in the free or labile form than in the Zn-Alb ones has been observed. Indeed, the quota of free or labile Zn seems to be mostly involved in the oxidative stress response (**Maret, 2006 ; Putics et al., 2008**) by modulating the mechanisms of resistance to apoptosis (**Thambiayya et al., 2012**), immune function (**Haase and Rink, 2014**), as well as in the production of specific antioxidant proteins (**Liuzzi et al., 2005**).

### Blood Analyses

Results of Table 3 revealed that comparing to control group, all tested diet supplementations had no significant effect on concentrations of albumin and cholesterol and activity of ALT

**Table 3. Blood analysis of growing rabbits as affected by zinc and copper supplementation (Mean ± SE)**

Item	Total protein	Albumin	Cholesterol	ALT	AST	Urea	Creatinine
T1	6.01±0.12 <sup>b</sup>	3.770±0.17	91.04±4.78	51.62±6.20	48.07±4.71	18.89±0.85 <sup>c</sup>	0.475±0.03 <sup>b</sup>
T2	6.600±0.09 <sup>ab</sup>	4.075±0.12	99.67±2.45	47.58±13.99	44.92±9.23	28.59±0.82 <sup>ab</sup>	0.530±0.03 <sup>ab</sup>
T3	6.640±.18 <sup>ab</sup>	4.340±0.04	137.79±19.32	33.36±2.28	29.32±1.99	30.43±2.14 <sup>a</sup>	0.470±0.01 <sup>b</sup>
T4	7.050±0.10 <sup>ab</sup>	3.370±0.14	88.22±5.22	23.10±3.30	30.23±2.83	21.29±1.73 <sup>ab</sup> <sub>c</sub>	0.456±0.04 <sup>b</sup>
T5	7.315±0.13 <sup>a</sup>	3.996±0.09	112.31±4.61	36.10±0.83	36.69±2.61	17.31±1.30 <sup>c</sup>	0.660±0.02 <sup>a</sup>
T6	6.560±0.32 <sup>ab</sup>	3.606±0.35	118.58±9.73	47.06±1.70	38.89±0.64	19.76±1.74 <sup>bc</sup>	0.666±0.03 <sup>a</sup>
T7	6.380±0.28 <sup>ab</sup>	4.256±0.15	123.78±9.39	31.07±2.93	25.50±2.60	25.14±1.6 <sup>abc</sup>	0.570±0.03 <sup>ab</sup>
<b>Significance</b>	<b>**</b>	<b>NS</b>	<b>NS</b>	<b>NS</b>	<b>NS</b>	<b>***</b>	<b>***</b>

NS = Not significance, \*\* P<0.01 and \*\*\* = P<0.001.

Means in the same column with different letters differ significantly (P<0.05).

T1 control group, T2 received 250 mg Cu/kg diet, T 3 received 500 mg Cu/kg diet, T4 received 20 mg Zn from Zinc EDTA + 250 mg Cu/kg diet, T5 received 20 mg Zn from Zinc EDTA + 500 mg Cu/kg diet, T6 received 20 mg Zn from ZnO + 250 mg Cu/kg diet and T7 received 20 mg Zn from ZnO + 500 mg Cu/kg diet.

(alanine aminotransferase) and AST (aspartate aminotransferase), while concentrations of total protein, urea and creatinine were significantly affected. Total protein concentration significantly (P<0.01) increased in blood of rabbits group fed 20 mg Zn from Zn EDTA + 500 mg Cu/kg diet (T5), other supplementation treatments did not significantly differ comparing to control. Significant (P<0.001) increases were noticed respecting urea concentration in rabbits fed Cu supplemented feed at 250 (T2) or 500 (T3) mg/kg. also, creatinine concentration was significantly (P<0.001) increased in rabbits fed 20 ppm Zn from Zinc EDTA + 500 mg Cu/kg diet (T5) or 20 ppm Zn from Zinc ZnO + 250 mg Cu/kg diet (T6) comparing to control.

### Carcass Components

Rabbits fed the tested supplementation diet treatments exhibited significant (P<0.05) increases in pre-slaughter weight (Table 4) as compared to control group. The highest increases in this regard were recorded under the effect of T2 (250 mg Cu/kg diet) and T6 (20 mg Zn from ZnO + 250 mg Cu/kg diet) compared to other supplementation treatments. As mentioned

above, these treatments also recorded the highest increases in daily body weight gain and final live body weight at the end of the experimental feeding period (Table 1) and also favored feed conversion ratio (Table 2).

Weights of carcass, liver and kidney and weights of head and hind part (Tables 4 and 5) were not significantly affected with the tested supplementation treatments. However, **Selim *et al.* (2012)** reported that dressing (%) was not significantly affected with Zn supplementation at levels of 50, 100 or 200 mg kg<sup>-1</sup> diet, but liver and kidney weights (as % of live weight) were increased with Zn supplementation at levels of 50, 100 or 200 mg/kg diet compared to rabbits fed with no Zn supplementation or those fed with high level of 400 mg/kg diet.

### Economic Efficiency

Feed cost and income from gain per rabbit as well as final margin were increased in all rabbits fed supplemented feed (Table 6). The highest income from gain was recorded in rabbit groups affected with T2 and T6 comparing to other supplementation treatments, and this in turn reflected as the highest final margin.

**Table 4. Actual pre-slaughter live weight and adjusted carcass, liver and kidney weight of growing rabbits as affected by zinc and copper supplementation (Mean ± SE)**

Item	Pre-slaughter weight (g)	Carcass weight (g)	Dressing (%)	Liver weight (g)	Kidney weight (g)
T1	2131.0±26.3 <sup>c</sup>	1735.88±238.6	59.51±2.40	81.19±23.24	18.74±5.23
T2	2873.3±17.6 <sup>a</sup>	1814.76±104.58	69.59±0.43	79.37±10.19	20.43±2.29
T3	2778.0±49.6 <sup>b</sup>	1773.05±70.40	67.47±0.28	72.93±6.86	22.79±1.54
T4	2754.3±31.1 <sup>b</sup>	1794.14±63.36	68.02±2.33	67.82±6.17	20.52±1.39
T5	2508.3±16.4 <sup>d</sup>	1790.91±83.71	65.97±1.92	63.18±8.15	19.10±1.83
T6	2956.7±33.8 <sup>a</sup>	1779.99±137.97	68.92±1.08	69.22±13.44	18.48±3.02
T7	2638.7±19.9 <sup>c</sup>	1739.26±50.16	65.15±2.83	76.01±4.89	18.79±1.10
<b>Significance</b>	*	NS	NS	NS	NS
<b>LW- Significance</b>	-----	NS	NS	NS	NS

LW- Significance = Regression on pre-slaughter weight.

\* P<0.05 and NS = Not significant.

Means in the same column within each classification with different letters differ significantly (P<0.05).

T1 control group, T2 received 250 mg Cu/kg diet, T 3 received 500 mg Cu/kg diet, T4 received 20 mg Zn from Zinc EDTA + 250 mg Cu/kg diet, T5 received 20 mg Zn from Zinc EDTA + 500 mg Cu/kg diet, T6 received 20 mg Zn from ZnO + 250 mg Cu/kg diet and T7 received 20 mg Zn from ZnO + 500 mg Cu/kg diet.

**Table 5. Adjusted carcass components of growing rabbits as affected by zinc and copper supplementation (Mean ± SE)**

Item	Head weight (g)	Fore part weight (g)	Intermediate weight (g)	Hind part weight (g)
T1	108.27±13.27	497.26±75.31	509.63±81.23	296.01±93.65
T2	141.49±5.82	445.56±33.01	424.45±35.60	349.41±41.05
T3	137.88±3.91	473.26±22.22	475.94±23.97	316.80±27.63
T4	130.82±3.52	459.30±19.99	423.34±21.57	352.97±24.87
T5	128.90±4.66	524.83±26.42	508.19±28.50	306.48±32.86
T6	139.39±7.67	396.59±43.54	358.21±46.97	333.12±54.15
T7	129.59±2.79	490.86±15.83	461.24±17.08	332.22±19.69
<b>Significance</b>	NS	*	*	NS
<b>LW- Significance</b>	NS	NS	NS	NS

LW- Significance = Regression on pre-slaughter weight.

\* P<0.05 and NS = Not significant.

Means in the same column within each classification with different letters differ significantly (P<0.05).

T1 control group, T2 received 250 mg Cu/kg diet, T 3 received 500 mg Cu/kg diet, T4 received 20 mg Zn from Zinc EDTA + 250 mg Cu/kg diet, T5 received 20 mg Zn from Zinc EDTA + 500 mg Cu/kg diet, T6 received 20 mg Zn from ZnO + 250 mg Cu/kg diet and T7 received 20 mg Zn from ZnO + 500 mg Cu/kg diet.

**Table 6. Profit analysis of growing rabbits as affected by zinc and copper supplementation**

Item	Feed cost (LE/rabbit)	Return from gain (LE/ rabbit)	Margin (LE/ rabbit)
T1	17.441	54.837	37.396
T2	20.295	74.574	54.279
T3	21.443	71.874	50.431
T4	19.892	71.955	52.063
T5	22.730	65.097	42.367
T6	20.773	76.68	55.907
T7	23.715	69.012	45.297

T1 control group, T2 received 250 mg Cu/kg diet, T 3 received 500 mg Cu/kg diet, T4 received 20 mg Zn from Zinc EDTA + 250 mg Cu/kg diet, T5 received 20 mg Zn from Zinc EDTA + 500 mg Cu/kg diet, T6 received 20 mg Zn from ZnO + 250 mg Cu/kg diet and T7 received 20 mg Zn from ZnO + 500 mg Cu/kg diet.

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## تأثير إضافة الزنك والنحاس على أداء الأرناب النامية

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قسم عدد ٤٢ من ذكور الأرناب النيوزلاندى الأبيض (عمر ٣٥ يوم ومتوسط وزن الأرناب ٥٤٦,٧٤ جم) عشوائياً إلى ٧ مجاميع (٦ حيوانات بكل مجموعة) في تصميم عشوائى تام لدراسة تأثير إضافة الزنك فى الغذاء من مصدر معدنى (ZnO) أو عضوى (Zn EDTA) فى توليفات مع النحاس (CuSO<sub>4</sub>) على أداء النمو، أعطيت المجموعة الأولى (T<sub>1</sub>) عليقة أساسية بدون أى إضافات (مجموعة مقارنة) بينما المجاميع الست الأخرى أعطيت عليقة أساسية تحتوى على الزنك والنحاس كالتالى: المجموعة الثانية (T<sub>2</sub>) أعطيت عليقة أساسية/كجم عليقة + ٢٥٠ جزء فى المليون نحاس/كجم عليقة، المجموعة الثالثة (T<sub>3</sub>) أعطيت عليقة أساسية + ٥٠٠ جزء فى المليون نحاس/كجم عليقة، المجموعة الرابعة (T<sub>4</sub>) أعطيت عليقة أساسية + ٢٠ جزء فى المليون زنك من Zn EDTA + ٢٥٠ جزء فى المليون نحاس/كجم عليقة، المجموعة الخامسة (T<sub>5</sub>) أعطيت عليقة أساسية + ٢٠ جزء فى المليون زنك من Zn EDTA + ٥٠٠ جزء فى المليون نحاس/كجم عليقة، المجموعة السادسة (T<sub>6</sub>) أعطيت عليقة أساسية + ٢٠ جزء فى المليون زنك من ZnO + ٢٥٠ جزء فى المليون نحاس/كجم عليقة، المجموعة السابعة (T<sub>7</sub>) أعطيت عليقة أساسية + ٢٠ جزء فى المليون زنك من ZnO + ٥٠٠ جزء فى المليون نحاس/كجم عليقة، زاد معنويًا كل من وزن الجسم الحى، الزيادة اليومية فى وزن الجسم، التغذية اليومية، وكفاءة التحويل الغذائى بتغذية الأرناب على عليقة مضاف لها ٢٥٠ أو ٥٠٠ مجم نحاس/كجم عليقة، سُجلت زيادات إضافية فى الأرناب المغذاه بـ ٢٠ مجم زنك كأكسيد زنك + ٢٥٠ مجم نحاس (T<sub>6</sub>)، زاد معنويًا تركيز البروتين الكلى فى سيرم الدم فى الأرناب المغذاه بـ ٢٠ مجم زنك من Zn EDTA + ٥٠٠ مجم نحاس/كجم عليقة (T<sub>5</sub>)، أيضاً أدت نفس المعاملة لزيادة تركيز الكرياتينين فى سيرم الدم، بينما أدت إضافة النحاس بتركيز ٢٥٠ أو ٥٠٠ مجم/كجم عليقة إلى زيادة تركيز اليوريا، أدت تغذية الأرناب على عليقة مضاف لها ٢٥٠ أو ٥٠٠ ملجم نحاس /كجم علف إلى زيادة معنوية فى الوزن الحى و معدل الزيادة اليومية فى الوزن و معدل استهلاك العلف اليومي و كفاءه تحويل الغذاء، سُجل تحسن إضافي عند تغذية الأرناب على عليقة مضاف لها ٢٠ ملجم زنك من أكسيد الذنك و ٢٥٠ ملجم نحاس/كجم علف (T<sub>6</sub>)، أدت كل معاملات الإضافة إلى زيادة معنوية فى وزن الأرناب قبل الذبح مقارنةً بالأرناب فى مجموعة المقارنة، وُجد أعلى وزن للأرناب قبل الذبح فى الأرناب المغذاه على عليقة مضاف لها ٢٥٠ ملجم نحاس/كجم علف (T<sub>2</sub>) أو على عليقة مضاف لها ٢٠ ملجم زنك من أكسيد الزنك + ٢٥٠ ملجم نحاس/كجم عليقة (T<sub>6</sub>)، لم تتأثر معنويًا أوزان كل من الذبائح والكبد والكليتين و نسبة التصافي ووزن الرأس والجزء الخلفي من الذبيحة بمعاملات الإضافة المختبرة، اقتصاديًا، زاد هامش الربح فى الأرناب المغذاه على كل معاملات الإضافة، سُجل أعلى عائد من الوزن وأعلى هامش ربح فى مجموعات الأرناب المغذاه على عليقة مضاف لها ٢٥٠ ملجم نحاس /كجم عليقة (T<sub>2</sub>) أو مضاف لها ٢٠ ملجم زنك من أكسيد الذنك + ٢٥٠ ملجم نحاس/كجم عليقة (T<sub>6</sub>).

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