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Growth Performance, Serum Biochemical, Economic Evaluation and IL6 Gene Expression in Growing Rabbits Fed Diets Supplemented with Zinc Nanoparticles

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Abstract

Zinc nanoparticles showed a great potential as mineral feed supplements in animals than the conventional sources. However, this potential has not been applied in rabbit nutrition. Therefore, this study was designed to evaluate the effects of dietary nano-zinc oxide on the growth performance, serum biochemical, economic parameters and gene expression of interleukin-6 in growing rabbits. A total of 120 male, five-week-old New Zealand White (NZW) rabbits were randomly distributed into four equal groups. The control group (Z_0) was fed on a basal diet with zinc free premix; the other three experimental groups received the basal diet supplemented with 60 mg zinc oxide/kg diet (Z_1), 60 mg nano-zinc oxide/kg diet (Z_2) and 30 mg nano-zinc oxide/kg diet (Z_3), respectively. The results revealed that rabbits in the groups Z_2 and Z_3 had higher body weight, daily weight gain, daily feed intake, serum total protein, globulin, IgG and SOD when compared with those of groups Z_0 and Z_1 (P<0.001). In addition, growth hormone level was higher in Z_3 group than in the other groups, whereas no significant differences were recorded among the treated groups in respect to serum TSH concentration (P>0.05). Hepatic and serum zinc contents were high in Z_2 and Z_3 groups, but the copper contents were decreased. Rabbits of group Z_3 yielded the highest gross margin with the lowest expenses to produce 1 kg of live weight compared with the others. The production of IL6 in spleen was increased in Z_3 group than that in the other groups. Thus, it can be concluded that nano-zinc oxide at a concentration of 30 mg/kg diet may be used instead of the traditional zinc sources in rabbit diets.

Keywords: Nano-ZnO, Performance, Serum indices, Hepatic zinc, *IL6*, Costs

Introduction

Recently, commercial rabbit production acquired increasing interest due to their high prolificacy and rapid growth rate which is comparable to that of broiler chicken [1]. Rabbits can utilize up to 30% crude fiber as against 10% by most poultry species and convert 20% of the protein they eat into edible meat [2]. Rabbit meat constitutes a vital source of protein for human because of its high quality and low fat and cholesterol [3]. With the rise of rabbit production, the need for animal supplements has become a necessary part of their daily diet.

Trace minerals are essential for many metabolic processes and physiological functions of animals [4]. Zinc is an indispensable component of several enzymes (>300) that participate in the synthesis and degradation of proteins, lipids, carbohydrates and nucleic acids [5] and also involved in the metabolism of other micronutrients [6]. In addition, it is necessary component of superoxide dismutase (SOD) enzyme, which has a vital role in the antioxidant defense system [7]. Zinc plays an important role in polynucleotide transcription and thus in the genetic expression process. Zinc also has a vital role in the immune system and affects several aspects of humoral and cellular immunity [8]. Zinc can affect thymulin secretion from thymus gland, which stimulates production of T-cell. Thus, zinc deficiency resulted in thymus malfunctioning, which

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severely affects normal immune function [9]. Moreover, zinc is involved in the production of tumor necrotic factor-α and cytokines such as interleukin (*IL1 and IL6*) [10]. IL6, is a pro-inflammatory cytokine and a member of the cytokine family that involved not only in the immune system activation but also in the regenerative processes, metabolism regulation, maintenance of bone homeostasis and in several neural functions [11]. The important role of zinc leads to its continuous dietary supplementation in animal feed because an unfortified animal diet is poor in zinc to meet the daily requirement. The most widely used zinc compound in animal feed is zinc oxide.

Recently, zinc oxides in the form of nanostructure have attracted considerable interest in many areas of animal husbandry [12]. The term ″nanostructure″ refers to various metal particles of a size smaller than 100 nm. Owing to their nanoscale size, they can pass easily through the intestinal mucosa during absorption [13]. In addition, the surface area of nanoparticles is high, which enhances the digestion [14] leading to reduction in the quantity of metal required in supplements, this in turn reduces the cost of feeding. So, these nanoparticles are expected to be effective in small doses, offer better bioavailability and have stable interaction with other components when fed as an alternative to the traditional sources. Feeding nano-zinc oxide to livestock enhanced growth, reproduction and immunity. There are several studies that have investigated the effect of traditional zinc oxide on the growth performance and immune response of rabbits [15-18], while the reports related to the consumption of nano-ZnO as an alternate source to meet the zinc requirement are very scarce. Therefore, this study was designed to study the effects of dietary nano-ZnO on growth performance, serum biochemical, economic parameters and gene expression of *IL6* in New Zealand White rabbits.

Material and Methods

Experimental design, animals, diets, and husbandry

A total of 120 male, five-week-old New Zealand white (NZW) rabbits with average body weight of 585.1±8.13 g were randomly distributed into four equal dietary treatment groups. Each diet was given to ten cages consisting of three animals each. Zinc oxide 99.99% (ZnO powder; contains 80.32% Zn, commercial product from Sigma Company, Egypt) as inorganic form of Zn, and nano-zinc oxide 97% (nZnO powder; contains 77.92% Zn, commercial product from Sigma Company, Egypt) as nano-form of Zn were used for feed supplementation. The size of zinc oxide nanoparticles was <50 nm according to the manufacturer Company. The dietary treatment groups included: control group (Z_0), fed on basal diet with Zn free premix (The zinc content in the un-supplemented diet was 22.1 mg/kg due to the natural mineral content of feedstuffs); Z_1 group, fed on basal diet with 60 mg ZnO/kg diet; Z_2 group, fed on basal diet with 60 mg nZnO/kg diet; and Z_3 group, fed on basal diet with 30 mg nZnO/kg diet. The feeding trial lasted for 6 weeks. Rabbits were housed in galvanized wire cages (35x40x50 cm highxwidthxlength), with an automatic system of nipple drinkers. The basal diet was formulated to meet the nutrient requirements (except Zn) according to NRC [19] recommendations for rabbits (Table 1) and was used for baseline value feedstuffs for zinc determination. The animals were provided with ad libitum feed and water. All the experimental rabbits were kept under the same environmental, managerial and hygienic conditions. The average room temperature was maintained at 22±1.5°C throughout the experiment and all animals were housed in the same artificially lightened room with a day-night cycle of 14 h light and 10 h dark.

Table 1: Ingredients and chemical composition of the basal diet fed to the rabbits according to NRC

Items	Amount (*%*)
Ingredients	
Yellow corn	22.0
Soybean meal	15.0
Wheat bran	25.0
Berseem hay	30.2
Wheat straw	3.0
Molasses	3.0
Salt	0.3
Premix*	0.3
Limestone	1.1
DL-Methionine	0.1
Analyzed composition (%)	
Crude protein	16.1
Dry matter	89.0
Organic matter	92.4
Ether extract	2.2
Crude fiber	14.3
Crude ash	7.6
Nitrogen-free extract	59.8
Neutral detergent fiber	30.9
Acid detergent fiber	14.3
Metabolize energy, MJ/kg	10.9

* Supplied per kg of diet: Vitamin A, 6000 IU; Vitamin D3, 1200 IU; Vitamin E, 26 IU; Vitamin K3, 1 mg; Vitamin B1, 1 mg; Vitamin B2, 3 mg; Vitamin B6, 1.5 mg; Pantothenic acid, 10 mg; Vitamin B12, 3.5 µg; Niacin, 30 mg; Folic acid, 1.25 mg; Biotin, 16 µg; Fe, 50 mg; Mn, 20 mg; Cu, 6 mg; I, 0.3 mg; Se, 0.03 mg; Choline chloride, 500 mg.

Growth performance

Body weight (BW) was measured at the beginning of the experiment (5^{th}), 8^{th}, and 11^{th} week of age, daily feed intake (DFI), daily weight gain (DWG), and feed conversion ratio (FCR) were then calculated as per the period and cumulatively. Feed conversion was calculated as g feed/g gain [20]. The animals died during the study were weighed, and all feed losses in each cage were collected and weighed in order to maintain the feed intake and FCR accuracy.

Sample collection

At the end of the experimental period, individual blood samples were taken from marginal ear vein of ten representative rabbits from each group into a vacutainer tube without coagulant. The vacutainer tubes were maintained in a slanted position for 3 h at room temperature and centrifuged at 3000 rpm for 15 min at 4°C to separate the serum, which was then harvested and stored at -20°C until analysis. The animals were then euthanized and liver and spleen samples were collected. Two segments of spleen (1cm) were collected immediately after euthanized, gently flushed with phosphate-buffered saline (PBS) and stored in -80°C freezer after steeped in liquid nitrogen until RNA extraction. Also, liver samples were frozen at -80°C for the estimation of zinc and copper contents.

Tissue and serum biochemical

According to AOAC [21] methodology (No. 2.109), tissue samples (0.5g) from liver were dehydrated at 100°C for 8 h, dry-ashed at 550°C overnight, then exposed to 10 mL 3 N-HCL under a heating plate and heated until the solution became clear. The samples were then allowed to cool and filtered through Whatman 42 filter paper. The extract was diluted using deionized water to the required volume, and then Zn and Cu contents were measured by flame atomic absorption spectrophotometry (Perkin-Elmer, Atomic Analyst 300, USA). To determine serum Zn and Cu, 4 mL of nitric acid (65%; Sigma, Steinhein, Germany) and perchloric acid (70%; Sigma, St Louis, MO,

USA) mixture (ratio 3:2) was added to a 1 mL serum sample. The solution was then heated at 300°C until it became clear. The following procedure was the same as that of the liver analysis.

Serum concentrations of total protein, albumin, immunoglobulin G (IgG), and superoxide dismutase (SOD) were determined using a commercially available diagnostic kit (Spinreact Co., Santa Coloma, Spain). Growth hormone (GH) and thyroxin-stimulating hormone (TSH) were estimated in serum using specific rabbit ELISA kits of MyBiosource Co. following the recommended procedures.

Table 2: Effect of dietary nano-zinc oxide supplementation on growth performance of New Zealand White rabbits

Parameters	Experimental treats				[4]SEM	*P*-value
	Control (Z_0)	[1]Z_1	[2]Z_2	[3]Z_3		
Live body weight (g)						
5 weeks of age	568.30	589.00	594.30	588.62	5.29	0.321
8 weeks of age	1185.11^{b}	1195.32^{b}	1281.51^{a}	1259.16^{a}	7.88	<0.001
11 weeks of age	1889.13^{b}	1941.30^{b}	2047.44^{a}	2030.11^{a}	9.86	<0.001
Daily weight gain (g)						
5-8 wk	29.37^{b}	28.87^{b}	32.72^{a}	31.92^{a}	0.21	<0.001
8-11 wk	33.52^{c}	35.52^{b}	36.47^{ab}	36.71^{a}	0.19	<0.001
5-11wk	31.45^{b}	32.20^{b}	34.60^{a}	34.32^{a}	0.16	<0.001
Daily feed intake (g)						
5-8 wk	83.61^{c}	84.51^{bc}	89.89^{a}	88.21^{ab}	0.68	0.001
8-11 wk	118.19^{b}	121.57^{b}	129.61^{a}	126.75^{a}	0.93	<0.001
5-11 wk	100.90^{b}	103.04^{b}	109.75^{a}	107.48^{a}	0.73	<0.001
Feed conversion rate						
5-8 wk	2.84	2.92	2.74	2.76	0.04	0.090
8-11 wk	3.52	3.42	3.55	3.45	0.02	0.185
5-11 wk	3.21	3.20	3.17	3.13	0.02	0.127
Mortality %	3.33	3.33	0.00	0.00	0.13	0.038

[1]Z= 60 mg ZnO/kg diet; [2]Z= 60 mg nZnO/kg diet; [3]Z= 30 mg nZnO/kg diet; [4]SEM= Standard error of the mean
[a-c]Means bearing different superscripts within the same row are significantly different (P<0.05).

Economic analysis of supplemented diets

The economic viability of the studied supplement was calculated in terms of total expenses incurred and total revenue received as per the prevailing market price of ingredients and rabbit live body weight at the time of experiment. This was done as mentioned below:

Total expenses were calculated by considering feeding cost as well as the expense of experimental rabbits, labor, veterinary services and other miscellaneous expenditure.

Feed cost/kg weight gain = feed conversion × cost of one kg diet [22].

Total revenue = rabbit live body weight × price per kg.

Gross margin = total revenue – total expenses.

Benefit-cost ratio (BCR) = gross margin / total expenses [23].

IL6 Quantitative Real-Time PCR

Total RNA was extracted from the spleen tissue using RNeasy Mini Kit (Qiagen, Germany) following the recommended protocol. The concentration and purity of total RNA were estimated using a GeneQuant spectrophotometer (Pharmacia Biotech, Freiburg, Germany). Total RNA was reverse transcribed into complementary DNA (cDNA) using RevertAid Reverse Transcriptase (Thermo Fisher) in accordance with the manufacturer's instructions. Quantitative RT-PCR was performed using QuantiTect® SYBR® Green PCR kit (Qiagen, Germany),

with glyceraldehyde -3- phosphate dehydrogenase (GAPDH) acting as the internal control gene. The IL6 and GAPDH primer sequences were F:5′-CTA CCG CTT TCC CCA CTT CAG-3′, R:5′-TCC TCA GCT CCT TGA TGG TCTC-3′ and F:5′-TGA CGA CAT CAA GAA GGT GGTG-3′, R:5′-GAA GGT GGA GGA GTG GGT GTC-3′, with product lengths of 135 bp and 120 bp, respectively [24].

The qRT-PCR was performed in a 25-µL reaction mixture containing 12.5 µL of 2× QuantiTect SYBR Green PCR Master Mix (Qiagen, Germany), 0.5 µL of each primer, 5 µL of RNase free water, and 7 µL of the cDNA template. The cycling parameters were as the following: initial denaturation at 95 °C for 5 min, followed by 40 cycles of 15 s at 95°C, 15 s at 60 °C, and 15 s at 72 °C. The melting-curve analysis was performed (from 60 to 95°C, using a 0.5 °C increment in the temperature with 5-s hold at each step) in triplicate.

The amplification curves and Ct values were determined by the Stratagene MX3005P software (Stratagene Technical Services, USA). To estimate the variation in the gene expression of various samples, the Ct value of each sample was compared with that of the control group according to the "ΔΔCt" method outlined by Yuan *et al.* [25].

Statistical Analysis

Data was analyzed using one-way ANOVA procedure of SAS [26] with the cage being considered as an experimental unit, after verifying normality using the Kolmogorov-Smirnov test. The following model was used for data analysis:

$$Yij = \mu + A_i + e_{ij}$$

Where, Y_{ij} is the observed value for a particular character; µ is overall mean, A_i is the effect of the ith treatment, and e_{ij} is random residual error term. The differences among the treatment means were determined using Tukey's multiple comparison tests, where $P<0.05$ was considered significant. Mortality rate was analyzed using chi-square test.

Results

Effects of nZnO on growth performance

The effects of dietary nZnO on the growth performance of NZW rabbits were summarized in Table 2. During the whole experimental period, the rabbits fed on Z_2 and Z_3 had the heaviest live body weight, highest DWG and DFI and the lowest mortality rate in comparison with those fed on control and Z_1 diets ($P<0.001$). However, no statistically significant differences ($P>0.05$) were noted for FCR among the treated groups during the whole growth period.

Table 3: Effect of dietary nano-zinc oxide supplementation on serum parameters, liver and serum trace element content of New Zealand White rabbits

Parameters	Experimental diets				[4]SEM	*P*-value
	Control (Z_0)	[1]Z_1	[2]Z_2	[3]Z_3		
Serum parameters						
Total protein (g/dL)	5.35[c]	5.44[bc]	5.86[ab]	6.15[a]	0.08	<0.001
Albumin (g/dL)	4.45	4.35	4.42	4.29	0.02	0.051
Globulin (g/dL)	0.90[c]	1.09[c]	1.44[b]	1.85[a]	0.07	<0.001
[5]IgG (mg/dL)	1.35[c]	1.53[c]	2.23[b]	3.78[a]	0.16	<0.001
[6]SOD (U/mL)	7.82[c]	9.15[c]	27.32[a]	18.51[b]	1.37	<0.001
[7]GH (ng/mL)	0.16[b]	0.18[b]	0.22[b]	0.37[a]	0.02	<0.001
[8]TSH (µIU/mL)	0.77	0.73	0.72	0.68	0.08	0.873
Zn content (ppm)						
Liver	3.86[c]	4.15[c]	5.06[b]	5.96[a]	0.12	<0.001
Serum	0.59[b]	0.64[b]	0.78[a]	0.81[a]	0.02	<0.001
[9]Cu content (ppm)						
Liver	0.96[a]	0.89[a]	0.48[b]	0.43[b]	0.04	<0.001
Serum	1.02[a]	0.89[a]	0.56[b]	0.54[b]	0.04	<0.001

[1]Z= 60 mg ZnO/kg diet; [2]Z= 60 mg nZnO/kg diet; [3]Z= 30 mg nZnO/kg diet; [4]SEM= standard error of the mean; [5]IgG = immunoglobulin G; [6]SOD = superoxide dismutase; [7]GH = growth hormone; [8]TSH: thyroid stimulating hormone; [9]Cu content (ppm) = copper content (parts per million). [a-c]Means bearing different superscripts within the same row were significantly different (P<0.05).

Effects of nZnO on serum biochemical parameters

The results showed no obvious difference in albumin and TSH concentrations among the treated groups (P>0.05, Table 3). The values of serum total protein, globulin and IgG were significantly elevated in Z_2 and Z_3 groups when compared with the control and Z_1 groups (P<0.001). The growth hormone level in Z_3 group was higher than that of other treated groups (P<0.001). The activity of SOD enzyme was significantly improved in Z_2 and Z_3 groups when compared with the control and Z_1 groups, and the highest values appeared in Z_2 group (P<0.001).

The Contents of Zn and Cu in liver tissue and serum

The results revealed that Zn contents in the liver and serum were boosted significantly (P<0.001) in Z_2 and Z_3 groups when compared with the control and Z_1 groups (Table 3). The hepatic zinc content of Z_3 group was significantly higher than in Z_2 group. Meanwhile, hepatic and serum Cu contents showed remarkable decreases (P<0.001) in Z_2 and Z_3 groups when compared with the control and Z_1 groups.

Economic efficiency of the fortified diet

As shown in Table 4, the feed cost per kg gain in Z_2 group was greater than that in control group (P<0.05). The rabbits fed on Z_3 diet showed the lowest expenses to produce 1 kg of live weight and the highest revenue compared to those fed on control and Z_1 diets. Interestingly, the gross margin and benefit cost ratio (indicators of efficiency) were the highest in Z_3 group when compared with the other groups (P<0.01).

The Expression of IL6 in spleen tissue

The relative changes in mRNA transcript levels for *IL6* were presented in Figure 1. The results clearly demonstrated that the mRNA expression of *IL6* significantly improved in the spleen of the rabbits fed on Z_3 followed by Z_2 when compared with the control group. There was statistically insignificant increase in *IL6* expression in Z_1 group when compared with the controls.

Table 4: Effect of dietary nano-zinc oxide supplementation on economic parameters of New Zealand White rabbits

Parameters	Experimental diets				[4]SEM	*P*-value
	Control (Z_0)	[1]Z_1	[2]Z_2	[3]Z_3		
Total feed cost/rabbit (LE)	10.94[b]	12.17[ab]	13.67[a]	12.52[ab]	0.96	0.014
Feed cost/kg gain (LE)	8.29[b]	9.00[ab]	9.44[a]	8.73[ab]	0.41	0.021
Total expenses/kg LBW (LE)	21.87[a]	21.96[a]	21.12[ab]	20.16[b]	0.28	0.002
Total revenue/ rabbit (LE)	59.62[b]	61.29[b]	64.65[a]	64.12[a]	1.04	0.004
Gross margin/Kg LBW (LE)	9.70[b]	9.61[b]	10.05[b]	11.41[a]	0.15	0.014
Benefit cost ratio (BCR)	0.44[b]	0.44[b]	0.48[b]	0.57[a]	0.01	0.003

[1]Z= 60 mg ZnO/kg diet; [2]Z= 60 mg nZnO/kg diet; [3]Z= 30 mg nZnO/kg diet; [4]SEM= standard error of the mean
[a,b]Means bearing different superscripts within the same row are significantly different (P<0.05).

Discussion

Zinc nanoparticles showed a great potential as mineral feed supplements in animals than the conventional sources. In the current study, the supplementation of rabbit diets with nZnO at 30, 60 mg/kg increased body weight, DWG and DFI when compared to the control and ZnO diets, suggesting a better absorption and higher bioavailability of nano-zinc, which is consistent with the previous studies [27-29].

As shown in our results, significant variation was noticed in the serum protein, globulin and IgG levels and obtained consistently higher values in 30 mg nZnO group compared with other treatments. While, no significant differences were detected among treated groups in serum albumin levels. These results were in agreement with the previous report that nZnO supplementation of weanling piglet diets increased γ–globulin and IgG levels compared to piglets fed on ZnO [30]. Borah *et al.* [31] reported that serum albumin level in growing pig was not affected by different supplemented level of zinc, while serum total protein revealed a significantly higher trend in Zn-supplemented (500 ppm) animals compared with control ones. However, other studies showed that the concentrations of TP, globulin and IgG in serum of weaning piglets were not affected by capsulated or modified ZnO [32,33].

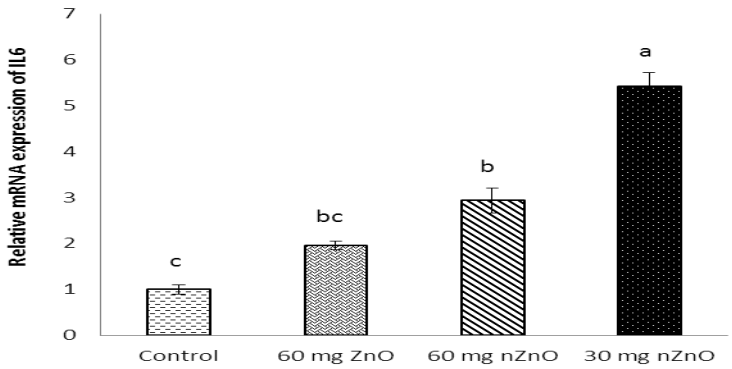

Figure 1: Effect of dietary nano-zinc oxide on the relative expression of *interleukin-6* in the spleen of rabbits. Each bar carrying different letters was significantly different (P<0.05) (mean ± SE, n = 3).

Dietary zinc supplementation can modulate SOD activity in piglets [34] and rabbits [35]. In addition, Zhao *et al.* [29] found that the concentration of Cu-Zn-SOD was significantly increased in serum of broilers after feeding 60 or 100 mg/kg nZnO compared with ZnO group. In our study, nZnO at applied levels (30 and 60 mg/kg) were associated with significantly increased in SOD concentration in serum and the highest values appeared in 60 mg nZnO group. This observation confirmed the role of zinc in antioxidant defense system.

The significant effect of nZnO at 30 mg/kg on serum growth hormone demonstrated in our study was in agreement with the result of Li *et al.* [30] who reported that serum growth hormone level of piglets was elevated in the nano-Zn group than in the other groups. Meanwhile, no significant differences were found among treated groups in respect to serum TSH concentration, which is consistent with the previous report [36]. In contrast, Baweja *et al.* [37] demonstrated that the levels of TSH were elevated after 8-weeks of zinc supplementation in female Westar rats.

The effect of nano-zinc oxide supplementation on tissues and serum mineral contents has not been clearly elucidated yet, so further researches are required. nZnO supplementation did not affect minerals blood profiles of Angora goat kids [38]. On contrary, our results revealed that nZnO supplementation significantly increased hepatic and serum zinc concentrations, which partly supported better absorption of nZnO and subsequently the positive relationship between nZnO supplementation and growth performance of rabbits. This difference could be due to the species-specific differences or the differences in diet contents and nZnO levels.

In contrast to zinc concentrations, hepatic and serum copper concentrations were reduced significantly after nZnO supplementation, which was in line with the findings of Marques *et al.* [39] and confirmed the competitive biological interaction between zinc and copper during absorption [40-43]. The mechanism(s) by which Zn antagonizes Cu is not well comprehended, although it has been assumed that these antagonisms are due to their similar chemical and physical properties. They compete for uptake sites in the intestinal mucosa and are controlled by the same metallothionein protein [42]. However, our finding seemed to be inconsistent with the results of Zaboli *et al.* [38] who found that Cu concentrations in serum and liver were unaffected by supplemental nano-zinc oxide.

When it comes to deciding which mineral supplements should be used in livestock feeding, two criteria need to be considered: biological efficacy and cost effectiveness. In this context, our results demonstrated that rabbits fed on nZnO at 30 mg/kg yielded the highest gross margin and lowest expenses to produce 1 kg of live weight when compared with the other treatments. Similarly, Zhao et al. [29] indicated that 20 mg/kg of nZnO was the favorable concentration in broiler feeds in respect to the growth performance and feed cost. This indicated that nano-Zinc oxide at a dose lower than the recommended one can be efficiently used and economic alternative in livestock feeding.

Our results revealed a significant relationship between the production of *IL6* in spleen and feeding of zinc supplemented diet, especially nZnO at 30 mg/kg, which showed the highest expression status compared with the other treatments. Such amelioration can be ascribed to the activation effect of zinc on signaling pathways that react with the signal transduction of Toll-like receptors in monocytes and thereby stimulate the secretion of pro-inflammatory cytokines [44]. In parallel with our result, a study conducted by Sundaresan et *al.* [45] also reported that the expression of *IL6* in the ovary and oviduct of hens was upregulated significantly during zinc-induced molting. Chai *et al.* [46] stated that the supplementation of piglet diets with high levels of zinc resulted in higher TGEV-specific antibody response and upregulation of cytokine expression. However, Hu *et al.* [47,48] reported that mRNA levels of IL-6, *IFN-γ* and *TNF-α* decreased with elevating levels of dietary zinc (2250 mg Zn/kg) in jejunum of pigs.

Conclusion

The administration of zinc nanoparticles to growing rabbits as an alternative to conventional zinc sources could elicit favorable influences on growth performance, serum parameters and splenic expression of *IL6*. From the economic point of view 30 mg/kg of zinc nanoparticles is the optimum concentration.

Conflict of interest

The authors declare that they have no conflict of interest.

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الملخص العربي

أداء النمو، مؤشرات مصل الدم ، التقييم الإقتصادي والتعبير الجيني للإنترلوكين ٦ في الأرانب الناميه المغذاه علي عليقه مضاف إليها النانو زنك أوكسيد

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أظهرت جسيمات النانو زنك إمكانيه كبيرة كمكملات غذائية معدنية في الحيوانات عن المصادر التقليدية. ومع ذلك، لم يتم تطبيق هذه الإمكانية في تغذية الأرانب. لذلك أجريت هذه الدراسه لفحص تأثير النانو أكسيد زنك علي أداء النمو، مؤشرات مصل الدم، القيمة الأقتصادية والتعبير الجيني للإنترلوكين ٦ في الأرانب الناميه. تم إستخدام ١٢٠ أرنب نيوزيلندي عمر خمس أسابيع حيث قسمت عشوائيا الي أربع مجموعات متساوية. تم تغذية المجموعة الضابطة علي العليقة الأساسية بدون زنك. بينما غذيت الثلاث مجموعات التجريبية الأخري علي العليقة الأساسية مضافا إليها ٦٠ مليجرام أكسيد زنك /كجم عليقه، ٦٠ مليجرام نانو أكسيد زنك /كجم عليقة و٣٠مليجرام نانو أكسيد زنك /كجم عليقة علي التوالي. أظهرت النتائج ان الأرانب المغذاة علي نانو أكسيد زنك (٣٠و ٦٠ مليجرام/كجم عليقة) كانت الأعلي في وزن الجسم، معدل إكتساب الوزن وإستهلاك العلف وأعلي تركيزات في البروتين، الجلوبيولين، الأمينو جلوبين G وSOD في مصل الدم مقارنة مع تلك المغذاه علي زنك أكسيد والعليقه الضابطه. بالإضافة إلي ذلك كان مستوي هرمون النمو أعلي في مجموعة ٣٠مليجرام نانو زنك أكسيد عن المجموعات الأخري. بينما لم يتم إكتشاف أي فروق معنويه بين المجموعات المعالجه فيما يتعلق بتركيزTSH هرمون في مصل الدم. أوضح محتوي الزنك في الكبد ومصل الدم زيادة معنويه في مجموعات النانو زنك أكسيد (٣٠ و ٦٠ مليجرام/كجم عليقة) في حين إنخفض محتوي النحاس. الأرانب التي غذيت علي ٣٠ مليجرام/كجم عليقة أظهرت أعلي هامش ربح وأدني نفقات لإنتاج ١ كجم من الوزن الحي مقارنة مع تلك التي غذيت علي العلائق الأخري. لقد تم زيادة إنتاج الإنترلوكين ٦ في الطحال في مجموعة ٣٠ مليجرام نانو أكسيد زنك عن المجموعات الأخري. لذلك يمكن إستنتاج ان النانو زنك أكسيد عند تركيز ٣٠مليجرام/كجم عليقه هو بديل فعال لمصادر الزنك التقليدية في علائق الأرانب.