Al-Qadisiyah Journal of Veterinary Medicine Sciences
(P-ISSN 1818-5746/ E-ISSN 2313-4429)
www.qu.edu.iq/journalvm

Productive performance traits of broilers chickens fed diet supplemented with organic and inorganic zinc

Sura Bakir Al-Mossawy ✉ **Zahira A. Al-Zuhairi** ✉
Department Of Veterinary Public Health, College of Veterinary Medicine, University of Al-Qadisiyah, Al-Diwaniyah, Iraq

Abstract

The health of the body might impair broiler performance; thus, mineral supplementation is necessary to avoid diseases caused by dietary mineral deficiencies. This study aimed to evaluate the effect of both organic and inorganic zinc and compare them to the control group regarding their effect on the productive response of broiler chickens. The experiment lasted six weeks, from 26 /9/2022 to 7 /11/ 2022 and was conducted in a private farm in Hilla city. A total of 300 one-day-old (Ross308) fattening chicks were weighed upon arrival and randomly grouped into three equal groups, each one hundred chicks/group: the first group, the control (C), included birds fed the basic diet without any supplementation; the second group the first treatment (T1) included feeding birds on the basic diet with organic zinc compounds (zinc acetate) 250 mg/kg diet; and the third group the second treatment (T2) included feeding birds on the basic diet with inorganic zinc compounds (zinc oxide) 250 mg /kg diet. Feed and water were supplied *ad libitum* till the end of the study. The feeding period was divided into a starter and a finisher period. Compared to the control, the growth performance of broiler chickens fed organic zinc or inorganic zinc differed significantly (P≤0.05) in terms of feed intake, body weight, feed conversion ratio, and body weight gain. Adding organic and inorganic zinc to a broiler chicken's basic diet can improve broiler production performance.

Keywords: performance, broiler, supplemented, organic zinc, inorganic zinc

Introduction:

Intensive poultry production and high stocking density are boost supply networks (1). Poultry farming uses numerous feedstuff to provide protein and nutritional security worldwide (2). Poultry meat and eggs account for 35% of world meat output, up 167% in 30 years (3). Compared to low-impact backyard methods, industrial livestock agriculture produces 98% of the world's poultry (4). Trace minerals are essential for broiler breeder productivity, egg quality, and offspring (5), and supplementation requires accurate bioavailability values. High gastrointestinal mineral levels create nutrient-mineral interactions (6). Mineral excretion is costly and dangerous (7). Trace minerals are metalloenzyme cofactors important for digestive, physiological, and biosynthetic activities. Zn, Mn, and Cu deficits may affect breeder performance, embryo development, and egg production, reducing fertility, hatchability, eggshell, and bone strength (8). Poultry diets include organic and inorganic trace minerals for growth, health, and reproduction (7). To reduce mineral absorption, weight growth, and excretion in broilers, replacing inorganic trace minerals with organic or nano sources (7). Due to raw material variability, broiler premixes include zinc, manganese, and copper to optimize performance and safety (9). Organically bound Zn is more bioavailable than inorganic versions; Poultry mineral administration involves sulfates, oxides, and carbonates. Organic trace elements are chelate minerals and chemicals to enhance nutrition, environment, carcass, and meat quality (10). Organically complex trace minerals stabilize animal upper gastrointestinal tracts, reducing losses, inclusion rates, and excretion (11). Dietary antagonists cause inorganic trace mineral loss; animal diets include two to ten times the required quantity. Studies show amino acid or peptide transport routes absorb organically bound T.M.s better (12). Zinc, copper, and manganese increase broiler performance, footpad injuries, and inflammation. Minerals boost production, growth, and disease resistance (12). Animal growth requires zinc, reproduction, eggshell quality, immunity, and reproduction (13). Zinc affects birds' metabolic, physiological, and digestive functions (14). Enzyme components are essential to organs, tissues, and fluids (15). Three hundred enzyme cofactors for reproduction, protein, lipid, and carbohydrate metabolism. (15) appetite control, growth, and glandular development. Hormone secretion, including growth and insulin, requires it (16) for protein synthesis and wound healing, activating antioxidant status, and vital free radical scavenger in the defense system (17). Zinc generates glutathione peroxidase, an antioxidant; Zn binds to antagonistic components, limiting trace element uptake and stability (18). Enzymes like alkaline phosphatase and carbonic anhydrase need Zn ions for bone tissue ossification and mineralization. Chicken skin, keratin, and collagen need zinc, and Zn supplementation boosts antioxidant status, immunity, and reproduction. (19). Zn deficiency can cause pathological changes, reduced growth and immunity, and free radical generations, that is harmful to animals (20). Organic zinc has increased bioavailability but is too expensive for animal diets. Animals should employ organic Zn sources like gluconate and MHA-Zn owing to their stability and absorption. (21). In chicken production, digestible organic zinc replaces inorganic zinc. Organic Zn enhances broiler chicken growth (22) and improves immunity and antioxidant defense (23). Organic Zn decreases oxidative stress and increases processing yield, enhancing broiler performance and

Al-Qadisiyah Journal of Veterinary Medicine Sciences
(P-ISSN 1818-5746/ E-ISSN 2313-4429)
www.qu.edu.iq/journalvm

intestinal health (24). Zinc oxide's poor digestion enhances excrement excretion. Due to restricted retention, inorganic trace minerals usage impacts the environment (25). In several studies, broilers were given inorganic zinc (ZnO) addition had the most live body weight compared to control diet-fed chicks (26). Researchers found that adding broiler diets with organic zinc improved growth performance (27). However, most research shows that either organic zinc (28) or inorganic zinc (22) improves broiler growth performance. High supplemental Zn (500 to 1500 mg/kg) also reduced broiler growth. (29) noticed that weight rise, feed intake, and feed efficiency (feed gain) all reacted quadratically to graded levels of added zinc, suggesting that zinc improves broiler growth under optimum management systems. Dietary zinc oxide supplementation improved the baseline intake of feed. In the starting and growth stages, birds ate more inorganic zinc than zinc. Full replacement improved feed conversion efficiency at 1-21 and 1-42 days, whereas partial substitution improved body weight. Zinc replaced inorganic sources and enhanced feed intake (1-42 days) (30). The chicks fed sulfate-enriched diets consumed less feed than those fed other Zn sources (31). As sufficient bioavailable Zn stimulates immunity, it contributes to an improvement of avian health and a reduction in mortality (32). Due to the start diet amount, enzyme-specific metabolism, and supplemental Zn source traits, dietary Zn had different impacts on broiler growth performance (28), and Other dietary ligands, such as phytate, present in the experimental conditions (33).The aim of this study was investigate and compare the effect of inorganic, organic zinc on broiler growth performance.

Materials and Methods

Birds, Ethical approval, and Management

Ethical approval was provided by the Committee of Ethics in Research, College of Veterinary Medicine, University of Al-Qadisiyah. Three hundred one-day-old broilers (unsexed Ross 308). The birds were weighed on arrival and then sorted to three groups of 100/group. The three diet treatment groups comprised the **Control group,** including birds feeding on a basal diet without any supplementation. **First treatment (T1):** including birds providing on basal diet with organic zinc compounds (zinc acetate) 250 mg/kg diet. **The second treatment (T2):** includes birds feeding on a basal diet with inorganic zinc compounds (zinc oxide) 250 mg/kg diet. The experiment was carried out in a private hall from 26 /09/2022 to 7/11/2022. Broiler Chickens were obtained from Al-Anwar Hatchery /Al-Kifl District, Babil Governorate.

Feed and water was provided *ad libitum*. All broiler chickens were fed the starter phase diet (1-21 days) and the finisher phase diet (22- 42 days). The starter and finisher diet of the experiment were prepared according to NRC requirements (34). Table (1).

Table 1: Ingredients and nutrients composition of Starter and finisher diets.

Ingredients/gram	Starter%(1-21 days)	Finisher %(22-42 days)
Corn oil	1.5	2.5
Soybean	33.5	33
Corn	57.5	60
Flour wheat	5	2
Premix	2.5(starter premix 3088)	2.5(finisher premix 3110)
Total	100%	100%
Calculated and determined chemical composition, (g/kg)		
Crude protein CP%	21	20.27
Crude fiber CF%	2.77	2.74
Calcium Ca%	0.961	0.919
AV-phosphorus	0.42	0.371
ME poultry kcal/kg	2800	3100
AV-methionine	0.47	0.42
AV-TSAA	0.74	0.68
AV-threonine	0.63	0.61
AV-Lysine	1.18	0.98
Electrolytes	263	241.12

Each kg of protein concentrate contains 43% crude protein, 2200 kilocalories of represented energy, 8% fat, 3% crude fiber, 6% calcium, 3% phosphorus, 3% lysine, 2% methionine, 2.5% cysteine + methionine, 1.5sodium, 1.7 chlorine, 31000 IU of vitamin A , 3000 IU of vitamin D3, 50 mg vitamin E, 30 mg vitamin K, 75 mg vitamin B1, 120 mg vitamin B2, 400mg pantothenic acid, 60 mg Niacin, 200 mg B6, 15 mg B12, 1500 mg Folic acid, 100 mg Biotein, 5000 mg Vitamin C, 450 mg Iron, 70 mg Copper, 600 mg Zinc, 5 mg Iodine, 1 mg Cobalt, 1 mg Selenium (Provimini Company for the manufacture of feed concentrates / Jordan).

According to the evaluation of the chemical composition of the feed materials included in the composition Diet and chemical composition calculated according to what was stated in NRC.

Al-Qadisiyah Journal of Veterinary Medicine Sciences
(P-ISSN 1818-5746/ E-ISSN 2313-4429)
www.qu.edu.iq/journalvm

The recommended procedure for thoroughly disinfecting the walls, ceiling, and floor is to use clean water and disinfectant. Before entering the chicken enclosure, all windows were opened and ventilation-exhaust air conditioners were activated to eliminate all noxious gases.

The water and feeders were sterilized prior to being sent to the different groups. All experimental groups were provided with sufficient amounts of wood sawdust litter, and lighting and ventilation conditions were thoroughly maintained in accordance with established guidelines.

Performance traits

Live body weights (B.W.) (gm/bird):

The weekly body weight of poultry was determined by counting each chick at one day of age and at the end of each week utilizing a balance. Calculating the ratio of the sum of all chicks' weights to the total number of chicks provided the mean body weight (35).

Body weight gain (gm):

The weight gain was measured at the beginning and end of each week, and the average weekly increase in body weight was calculated for each group (35).

Mean weekly Weight gain = B.W. $^{\text{at the end of the week}}$ – B.W. $^{\text{at the beginning of the week}}$

B.W. = Body weight

Feed Intake (F.I.) (gm/bird):

The daily feed intake was determined by evaluating the amount of feed and substrate that stayed after the daily supplying of feed. In addition, the review included the total number of deceased chicks and the amount of feeding days at the end of the week. The equation supplied, as previously stated (35).

For determining the poultry' intake of food.

Weekly mean feed intake (gm/chick) = WL+D.

W= Quality of feed intake through the week (gm).

L= number of live chicks fed through the week.

D= number of dead chicks × number of their feeding days.

Feed. conversion. ratio. (F.C.R) % :

The Feed Conversion Ratio (FCR) of each group was assessed on a weekly basis until the experiment was completed (35) reported an equation for calculating the feed conversion ratio (FCR).

$$\text{F.C. R} = \frac{\text{mean weekly feed (gm)}}{\text{weekly body weight gain (gm)}}$$

Statistical analysis:

Data was analyzed as one-way ANOVA by using the general linear model (GLM) procedure with SPSS 22.0 software (Corp, 2011). Four treatments means were separated by using a "protected" Duncan`s analysis at level (P < 0.05).

Results

Table (2) shows the effect of supplementation of organic and inorganic Zn on the weekly live body weight (gm/birds) of broiler chickens (Mean ±SE).The results showed a significant increase (P≤0.05) in the **B.W.** in the **first week** in the first treatment (organic Zn), reached (111 ±4.52) compared to the control group and second treatment, where it was (104.5±2.02), and the control group was (109.5±4.8). In the **second week**, the first treatment (organic Zn) also reached the highest levels (140±2.64) compared to the second treatment (inorganic Zn), when it was (134.7±1.25). At the same time, the values in the control group reached (136±5.98). In the **third week**, the values of the first and second treatments were the highest, as they was (270.5±10.1 and 259.7±4.4) respectively, compared to the control group, which amounted to (243±6.05).The values in the **fourth week** of the first and second treatments achieved their highest values in both the (organic Zn) group (680.5±19.1) and (inorganic Zn) group (651.7±9.37), as well as when compared to the control group rising to (621±12.04). The values were measured in the **fifth week** to the control group (1188.7±11.4) and the second treatment (inorganic Zn), which was (1275.2±49.1) compared to the first treatment (organic Zn), which was (1329.7±40.07). The weights of the treatments were measured in the **sixth week**, and they were (2169.2±52.01) for the first treatment (organic Zn) and (2060.5±21.8) for the second treatment (inorganic Zn). The control group was recorded and had the lowest weight (1979.7±47.03).

Table 2: Effect of supplementation of organic and inorganic Zn on weekly live body weight (gm/birds) of broiler chickens (Mean ±SE).

Weight gm	Control group		First treatment Organic group		Second treatment Inorganic group		LSD
1day	40±0.7	Af	41±0.91	Af	40±0.81	Af	62.9
week1	109.5±4.8	Ae	111±4.52	Ae	104.5±2.02	Ae	
week2	136±5.98	Ae	140±2.64	Ae	134.7±1.25	Ae	
week3	243±6.05	Cd	270.5±10.1	Ad	259.7±4.4	Bd	
week4	621±12.04	Cc	680.5±19.1	Ac	651.7±9.37	Bc	
week5	1188.7±11.4	Cb	1329.7±40.07	Ab	1275.2±49.1	Bb	
week6	1979.7±47.03	Ca	2169.2±52.01	Aa	2060.5±21.8	Ba	

* Values represent mean ± SE for samples.

*Different letters denote to the significant difference at P < 0.05

* The different uppercase letters within the same row indicate a significant difference between the treatments, and the different lowercase letters within the same column indicate a significant difference between the weeks within the same treatment.

Table 3: shows the effect of supplementation of organic and inorganic Zn on weekly feed intake (gm/birds) of broiler chickens (Mean ±SE). In the **first week**, we did not find significant differences in the weekly feed

Al-Qadisiyah Journal of Veterinary Medicine Sciences
(P-ISSN 1818-5746/ E-ISSN 2313-4429)
www.qu.edu.iq/journalvm

intake in the control group (83.5±1.04) and the second treatment (inorganic Zn), so it was (83.5±4.27) and the first treatment (organic Zn) was the lowest value was (78.2±2.28).

In the **second week**, we found that the weekly feed intake was high in the control group (111.5±5.63) compared to the second treatment (inorganic Zn), and it was (106.2±1.03) and the lowest value in the first treatment (organic Zn), and it was (103.5±4.97).

In the **third week**, we observed that the weekly fodder intake values were close in the first treatment (organic Zn) it was (262.5±4.19), and in the second treatment (inorganic Zn), it was (261.7±0.75) and the highest in the control group (264±0.91).

We noticed in the **fourth week** that the weekly feed intake was higher in the control group, so its value was (561.2±15.6) in contrast with the first treatment (organic Zn), was (517.7±22.07) and in the second treatment (inorganic Zn) it was (514.2±8.9).

In the **fifth week**, we observed that the control group's weekly feed consumption was (716.2±3.83) higher than that of the second treatment (inorganic Zn), whose value was (697.5±13.2), and that of the first treatment (organic Zn), whose value was (670.5±5.31).

The weekly intake of the control group seemed to be greater (1280.2±51.3) in the **sixth week** than the consumption of the second treatment (inorganic Zn), the value was (1191.7±12.9), and the lowest value in the first treatment (organic Zn), the value was (1092.7±19.5).

Table 3 : Effect of supplementation of organic and inorganic Zn on weekly feed intake (gm/birds) of broiler chickens (Mean ±SE).

Feed Intake/gm	Control group		First treatment Organic group		Second treatment Inorganic group		LSD 0.05
week1	83.5±1.04	Ae	78.2±2.28	Ae	83.5±4.27	Ae	43.92
week2	111.5±5.63	Ae	103.5±4.97	Ae	106.2±1.03	Ae	
week3	264±0.91	Ad	262.5±4.19	Ad	261.7±0.75	Ad	
week4	561.2±15.6	Ac	517.7±22.07	Bc	514.2±8.9	Bc	
week5	716.2±3.83	Cb	670.5±5.31	Ab	697.5±13.2	Bb	
week6	1280.2±51.3	Ca	1092.7±19.5	Aa	1191.7±12.9	Ba	

* Values represent mean ± SE for samples.
*Different letters denote to the significant difference at $P < 0.05$
* The different uppercase letters within the same row indicate a significant difference between the treatments, and the different lowercase letters within the same column indicate a significant difference between the weeks within the same treatment.

Table (4) shows the effect of supplementation of organic and inorganic Zn on weekly weight gain (gm/birds) of broiler chickens (Mean ±SE). The results for the first treatment (organic Zn) were greater value (70±3.76) in the **first week** when compared to the second treatment (inorganic Zn), reaching (64.5±1.32) and (69.5±4.27) in the control group. While the results of the second treatment (inorganic Zn) in the **second week** were the highest of the gained weight, its value was (30.2±0.85) and less than the results of the first treatment (organic Zn) (29±2.79), to find the lowest value (26.5±2.32) in the control group. In the **third week** of the experiment, we found that the gained weight was the highest value in the results of the first treatment (organic Zn) (130.5±7.59). In contrast, the results of the second treatment (inorganic Zn) were less than it, its value was (125±3.18), and the lowest value was in the control group where it was (107±2012). In the **fourth week** of the trial, we discovered that the weight gained value was (410±9.7) in the first treatment and (392±6.36) in the second treatment (inorganic Zn), compared to (378±6.01) in the control group. In the experiment's **fifth week**, we found that the weight gained had a value of (649.2±21.4) in the first treatment (organic Zn), followed by (594.7±39.9) in the second treatment (inorganic Zn), then (567.7±8.7) in the control group. In the **sixth week**, we noticed a significant increase in the weight gained in the first treatment (organic Zn), which was (584±35.4), then (570±8.53) in the second treatment (inorganic Zn), while it reached (543.7±15.5) in the control group.

Table 4: Effect of supplementation of organic and inorganic Zn on weekly weight gain (gm/birds) of broiler chickens (Mean ±SE).

weight gain/gm	Control group	First treatment Organic group	Second treatment Inorganic group	LSD0.05

Al-Qadisiyah Journal of Veterinary Medicine Sciences
(P-ISSN 1818-5746/ E-ISSN 2313-4429)
www.qu.edu.iq/journalvm

week1	69.5±4.27	Ad	70±3.76	Ae	64.5±1.32	Ad	42.24
week2	26.5±2.32	Ad	29±2.79	Ae	30.2±0.85	Ad	
week3	107±2012	Bc	130.5±7.59	Ad	125±3.18	Ac	
week4	378±6.01	Bb	410±9.7	Ac	392±6.36	Ab	
week5	567.7±8.7	Ca	649.2±21.4	Ab	594.7±39.9	Ba	
week6	543.7±15.5	Ca	584±35.4	Aa	570±8.53	Ba	

* Values represent mean ± SE for samples.
*Different letters denote to the significant difference at P < 0.05
* The different uppercase letters within the same row indicate a significant difference between the treatments, and the different lowercase letters within the same column indicate a significant difference between the weeks within the same treatment.

Table 5 : shows the effect of supplementation of organic and inorganic Zn on the weekly feed conversion ratio (gm/birds) of broiler chickens (Mean ±SE).The control group reported (0.765±0.02), and the first treatment (organic Zn) had the lowest values, reaching (0.706±0.02), for the feed conversion ratio in the **first week**. The second treatment (inorganic Zn) had the greatest values, reaching (0.797±0.02). In the **second week**, the values of the feed conversion ratio in the first treatment (organic Zn) were the lowest value and were (0.737±0.02) compared to the second and control group (0.788±0.004 and 0.818±0.008), respectively. The feed conversion ratio values for the first treatment (organic Zn) were at their lowest point in the **third week** and were (0.973±0.03), followed by (1.007±0.014) for the second treatment (inorganic Zn) compared to (1.08±0.029) for the control group. In the **fourth week**, the lowest values were in the first treatment (organic Zn), which was (0.764±0.04) followed by the second treatment (inorganic Zn), which amounted to (0.788±0.008) compared to the control group, amounted to (0.905±0.036). The first treatment (organic Zn) had the lowest values in the **fifth week**, and they were (0.504±0.01), while the second treatment (inorganic Zn) and the control group had values of (0.550±0.015 and 0.602±0.003) respectively. The **sixth week** saw the lowest results for the first treatment (organic Zn), which were (0.503±0.006), followed by (0.578±0.001) for the second treatment (inorganic Zn), and (0.646±0.018) for the control group.

Table 5: Effect of supplementation of organic and inorganic Zn on weekly feed conversion ratio (gm/birds) of broiler chickens (Mean ±SE).

F.C.R	Control group		First treatment Organic group		Second treatment Inorganic group		LSD0.05
week1	1.2±0.02	Ae	1.1 ±0.02	Ae	1.2 ±0.02	Ae	42.24
week2	4.2 ±0.008	Ba	3.5 ±0.02	Aa	3.5 ±0.004	Aa	
week3	2.4 ±0.029	Bb	2 ±0.03	Ab	2 ±0.014	Ab	
week4	1.4 ±0.036	Cd	1.2 ±0.04	Ad	1.3 ±0.008	Bd	
week5	1.2 ±0.003	Be	1.03 ±0.01	Ae	1.1 ±0.015	Ce	
week6	1.6 ±0.018	Cc	1.3 ±0.006	Ac	1.5 ±0.001	Bc	

* Values represent mean ± SE for samples
*Different letters denote to the significant difference at P < 0.05

Discussion

Various production performance parameters, such as live body weight, feed intake, weight gain, and feed conversion ratio, indicated statistically significant improvements (P <0.05) depending on the current study's devices. Compared with the control group, the T1 (Organic Zn) and T2 (Inorganic Zn) groups show these improvements. The current study confirms that prior research discovered that adding organic zinc to broilers consumes enhanced growth performance.(36); (27). When compared to the control broilers, the birds given zinc oxide showed significant increases in body weight gain, minimized utilization of feed, and feed conversion ratio. Zn is an important micronutrient for broiler development. Zn deficiency induces diminished appetite, reduced growth, and skin and appendage abnormalities (37). In support of these results, it was found that dietary zinc supplementation increased growth rate and feed efficiency in broiler chicks (17). Organic minerals, instead of inorganic minerals, could enhance feed efficiency in young broilers, according to (38). The findings indicate that zinc quantity and zinc source increase broiler feed efficiency. Most research, however, shows that either organic zinc (28) or inorganic zinc (22) benefits broiler growth performance. In Zn-supplemented groups, average feed intake, body weight, and FCR improved significantly (39). Other studies have shown that broilers fed no Zn diets have lower body weight and feed consumption than those fed Zn-supplemented diets (26). In addition, (40) noted that significant doses of additional Zn (500 to 1500 mg/kg) has negative effect of growth performance.When provided up to 300 mg Zn/kg meals, (41) observed no differences in broiler chicken growth performance. Also, there were no differences in

Al-Qadisiyah Journal of Veterinary Medicine Sciences
(P-ISSN 1818-5746/ E-ISSN 2313-4429)
www.qu.edu.iq/journalvm

feed conversion ratio (FCR), average daily gain (ADG), average daily feed intake (ADFI) or mortality rate in broiler offered diets supplemented with 60 or 120 mg/kg Zn as Zn-Met (42). The feed conversion ratio in organic zinc-supplied birds was significantly improved compared to all other diets, resulting in a numerical increase in the intake of feed. The source of zinc in the diet, in addition to the quantity ingested, had no impact on feed intake or BWG (20). Graded Zn addition to the basal diet indicated no impact on body weight, feed intake, or feed conversion efficiency at four weeks of age (43). Zinc may have improved growth performance (B.W., W.G., F.I., and FCR) by promoting Body and gastrointestinal health, enhancing barrier function and eliminating pathogenic organisms. Based on the results, Zn organic had the biggest effect on growth performance and body weight. Therefore, it has an advantageous impact on the gut and stimulates the creation of digestive enzymes, Enhancing digestion and intestine adaptation. It has been observed that supplemental broiler diets with organic zinc results in beneficial results, including increased weight gain and body weight (44).

Conclusion

Adding 250 mg/Kg from each organic and inorganic zinc to broiler diet leads to enhancing broiler chickens' growth performance.

Conflict of interest

No conflict of interest was found as declared by the authors

References

1-Li W, Wei F, Xu B, Sun Q, Deng W, Ma H, et al. Effect of stocking density and alpha-lipoic acid on the growth performance, physiological and oxidative stress and immune response of broilers. Asian-Australasian J Anim Sci. 2019;32(12):1914-22.
https://doi.org/10.5713/ajas.18.0939

2-Vaarst M, Steenfeldt S, Horsted K. Sustainable development perspectives of poultry production. Worlds Poult Sci J. 2015;71(4):609-20.
https://doi.org/10.1017/S0043933915002433

3-Hicks TM, Knowles SO, Farouk MM. Global Provisioning of Red Meat for Flexitarian Diets. Front Nutr. 2018;5(June):1-11.
https://doi.org/10.3389/fnut.2018.00050

4-Mottet A, Tempio G. Reviews Global poultry production : current state and future outlook and challenges. Worlds Poult Sci J. 2017;73(June):1-12.
https://doi.org/10.1017/S0043933917000071

5-M'Sadeq SA, Wu SB, Choct M, Swick RA. Influence of trace mineral sources on broiler performance, lymphoid organ weights, apparent digestibility, and bone mineralization. Poult Sci. 2018;97(9):3176-82.
https://doi.org/10.3382/ps/pey197

6-El-Husseiny OM, Hashish SM, Ali RA, Arafa SA, Abd El-Samee LD, Olemy AA. Effects of feeding organic zinc, manganese and copper on broiler growth, carcass characteristics, bone quality and mineral content in bone, liver and excreta. Int J Poult Sci. 2012;11(6):368-77.
https://doi.org/10.3923/ijps.2012.368.377

7-Bao YM, Choct M, Iji PA, Bruerton K. Effect of organically complexed copper, iron, manganese, and zinc on broiler performance, mineral excretion, and accumulation in tissues. J Appl Poult Res. 2007;16(3):448-55.
https://doi.org/10.1093/japr/16.3.448

8-Favero A, Vieira SL, Angel CR, Bess F, Cemin HS, Ward TL. Reproductive performance of Cobb 500 breeder hens fed diets supplemented with zinc, manganese, and copper from inorganic and amino acid-complexed sources. J Appl Poult Res. 2013;22(1):80-91.
https://doi.org/10.3382/japr.2012-00607

9-Untea AE, Olteanu M, Maros I, Criste RD. Decrease of Cu and Fe concentrations from broiler droppings using dietary organometallic compounds. Biotechnol Anim Husb. 2011;27(3):759-68.
https://doi.org/10.2298/BAH1103759U

10-Echeverry H, Yitbarek A, Munyaka P, Alizadeh M, Cleaver A, Gamelo-Jaimes G, et al. Organic trace mineral supplementation enhances local and systemic innate immune responses and modulates oxidative stress in broiler chickens. Poult Sci. 2016;95(3):518-27.
https://doi.org/10.3382/ps/pev374

11-Bao YM, Choct M. Trace mineral nutrition for broiler chickens and prospects of application of organically complexed trace minerals: A review. Anim Prod Sci. 2009;49(4):269-82.
https://doi.org/10.1071/EA08204

12-Muszyński S, Tomaszewska E, Kwiecień M, Dobrowolski P, Tomczyk A. Effect of Dietary Phytase Supplementation on Bone and Hyaline Cartilage Development of Broilers Fed with Organically Complexed Copper in a Cu-Deficient Diet. Biol Trace Elem Res. 2018;182(2):339-53.
https://doi.org/10.1007/s12011-017-1092-1

13-Hoang BX, Han B, Shaw DG, Nimni M. Zinc as a possible preventive and therapeutic agent in pancreatic, prostate, and breast cancer. Eur J Cancer Prev. 2016;25(5):457-61.
https://doi.org/10.1097/CEJ.0000000000000194

14-Naz S, Idris M, Khalique MA, Zia-Ur-Rahman, Alhidary IA, Abdelrahman MM, et al. The activity and use of zinc in poultry diets. Worlds Poult Sci J. 2016;72(3):159-67.
https://doi.org/10.1017/S0043933915002755

Al-Qadisiyah Journal of Veterinary Medicine Sciences
(P-ISSN 1818-5746/ E-ISSN 2313-4429)
www.qu.edu.iq/journalvm

SC. YRVSC [Internet]. 2017;112(6):59-65. Available from: http://dx.doi.org/10.1016/j.rvsc.2016.09.007
https://doi.org/10.1016/j.rvsc.2016.09.007

26-Sarvari BG, Seyedi AH, Shahryar HA, Sarikhan M, Ghavidel SZ. Effects of dietary zinc oxide and a blend of organic acids on broiler live performance, carcass traits, and serum parameters. Brazilian J Poult Sci. 2015;17(12):039-46.
https://doi.org/10.1590/1516-635XSPECIALISSUENutrition-PoultryFeedingAdditives039-046

27-Ao T, Pierce JL, Power R, Dawson KA, Pescatore AJ, Cantor AH, et al. Alltech-University of Kentucky , Nutrition Research Alliance , Lexington , KY , Evaluation of Bioplex Zn ® as an Organic Zinc Source for Chicks. Int J Poult Sci 5. 2006;5(9):808-11.
https://doi.org/10.3923/ijps.2006.808.811

28-Zhao J, Shirley RB, Vazquez-Anon M, Dibner JJ, Richards JD, Fisher P, et al. Effects of chelated trace minerals on growth performance, breast meat yield, and footpad health in commercial meat broilers. J Appl Poult Res [Internet]. 2010;19(4):365-72. Available from: http://dx.doi.org/10.3382/japr.2009-00020
https://doi.org/10.3382/japr.2009-00020

29-Batal AB, Parr TM, Baker DH. Zinc bioavailability in tetrabasic zinc chloride and the dietary zinc requirement of young chicks fed a soy concentrate diet. Poult Sci [Internet]. 2001;80(1):87-90. Available from: http://dx.doi.org/10.1093/ps/80.1.87
https://doi.org/10.1093/ps/80.1.87

30-Jahanian R, Rasouli E. Effects of dietary substitution of zinc-methionine for inorganic zinc sources on growth performance, tissue zinc accumulation and some blood parameters in broiler chicks. J Anim Physiol Anim Nutr (Berl). 2015;99(1):50-8.
https://doi.org/10.1111/jpn.12213

31-Jahanian R, Moghaddam HN, Rezaei A. Improved broiler chick performance by dietary supplementation of organic zinc sources. Asian-Australasian J Anim Sci. 2008;21(9):1348-54.
https://doi.org/10.5713/ajas.2008.70699

32-Salim HM, Lee HR, Jo C, Lee SK, Lee BD. Supplementation of graded levels of organic zinc in the diets of female broilers: Effects on performance and carcase quality. Br Poult Sci. 2011;52(5):606-12.
https://doi.org/10.1080/00071668.2011.616485

33-Salim HM, Lee HR, Jo C, Lee SK, Lee BD. Effect of dietary zinc proteinate supplementation on growth performance, and skin and meat quality of male and female broiler chicks. Br Poult Sci. 2012;53(1):116-24.
https://doi.org/10.1080/00071668.2012.658757

34-National Research Council 1994. Nutrient Requirements of Poultry : Ninth Nutrient Requirements of Poultry. Vol. Ninth Revi. 1994. 176 p.

15-Salim HM, Jo C, Lee BD. Zinc in broiler feeding and nutrition. Avian Biol Res. 2008;1(1):5-18.
https://doi.org/10.3184/175815508X334578

16-Tsai YH, Mao S., Li MZ, Huang J., Lien TF. Effects of nanosize zinc oxide on zinc retention , eggshell quality , immune response and serum parameters of aged Highlight : Anim Feed Sci Technol. 2016;213(3):99-107.
https://doi.org/10.1016/j.anifeedsci.2016.01.009

17-Zhao C-Y, Tan SX, Xiao XY, Qiu XS, Pan JQ, Tang ZX. Effects of dietary zinc oxide nanoparticles on growth performance and antioxidative status in broilers. Biol Trace Elem Res. 2014;160(6):361-7.
https://doi.org/10.1007/s12011-014-0052-2

18-Nguyen HTT, Morgan N, Roberts JR, Wu SB, Swick RA, Toghyani M. Zinc hydroxychloride supplementation improves tibia bone development and intestinal health of broiler chickens. Poult Sci. 2021;100(8):101-254.
https://doi.org/10.1016/j.psj.2021.101254

19-Parashuramulu S, Nagalakshmi D, Rao DS, Signals R, Kumar K. Effect of Zinc Supplementation on Antioxidant Status and Immune Response in Buffalo Calves Effect of Zinc Supplementation on Antioxidant Status and Immune Response in Buffalo Calves. Anim Nutr Feed Technol. 2015;15(2):179-88.
https://doi.org/10.5958/0974-181X.2015.00020.7

20-Star L, van der Klis JD, Rapp C, Ward TL. Bioavailability of organic and inorganic zinc sources in male broilers. Poult Sci. 2012;91(12):3115-20.
https://doi.org/10.3382/ps.2012-02314

21-Wang G, Liu LJ, Tao WJ, Xiao ZP, Pei X, Liu BJ, et al. Effects of replacing inorganic trace minerals with organic trace minerals on the production performance , blood profiles , and antioxidant status of broiler. Poult Sci. 2019;98(7):2888-95.
https://doi.org/10.3382/ps/pez035

22-Huang YL, Lu L, Luo XG, Liu B. An optimal dietary zinc level of broiler chicks fed a corn-soybean meal diet. Poult Sci. 2007;86(12):2582-9.
https://doi.org/10.3382/ps.2007-00088

23-Rao SVR, Prakash B, Raju MVLN, Panda AK, Kumari RK, Reddy EPK. Effect of Supplementing Organic Forms of Zinc, Selenium and Chromium on Performance, Anti-Oxidant and Immune Responses in Broiler Chicken Reared in Tropical Summer. Biol Trace Elem Res. 2016;172(2):511-20.
https://doi.org/10.1007/s12011-015-0587-x

24-De Grande A, Leleu S, Delezie E, Rapp C, De Smet S, Goossens E, et al. Dietary zinc source impacts intestinal morphology and oxidative stress in young broilers. Poult Sci [Internet]. 2020;99(1):441-53. Available from: http://dx.doi.org/10.3382/ps/pez525
https://doi.org/10.3382/ps/pez525

25-Jarosz Ł, Marek A, Grądzki Z, Kwiecień M, Kalinowski M. Department of Veterinary Prevention and Avian Diseases , Institute of Biological Bases of

Al-Qadisiyah Journal of Veterinary Medicine Sciences
(P-ISSN 1818-5746/ E-ISSN 2313-4429)
www.qu.edu.iq/journalvm

40-Kim WK, Patterson PH. Effects of dietary zinc supplementation on broiler performance and nitrogen loss from manure. Poult Sci. 2004;83(1):34-8.
https://doi.org/10.1093/ps/83.1.34

41-Bou R, Guardiola F, Tres A, Barroeta AC, Codony R. Effect of dietary fish oil, α-tocopheryl acetate, and zinc supplementation on the composition and consumer acceptability of chicken meat. Poult Sci. 2004;83(2):282-92.
https://doi.org/10.1093/ps/83.2.282

42-Akbari R, Bakhshalinejad R, Shafiee M. Effect of dietary zinc and α-tocopheryl acetate on broiler performance, immune responses, antioxidant enzyme activities, minerals and vitamin concentration in blood and tissues of broilers. Anim Feed Sci Technol [Internet]. 2016;221(11):12-26. Available from: http://dx.doi.org/10.1016/j.anifeedsci.2016.08.016
https://doi.org/10.1016/j.anifeedsci.2016.08.016

43-Sunder GS, Panda AK, Gopinath NCS, Rama Rao S V., Raju MVLN, Reddy MR, et al. Effects of higher levels of zinc supplementation on performance, mineral availability, and immune competence in broiler chickens. J Appl Poult Res. 2008;17(1):79-86.
https://doi.org/10.3382/japr.2007-00029

44-Burrell AL, Dozier WA, Davis AJ, Compton MM, Freeman ME, Vendrell PF, et al. Responses of broilers to dietary zinc concentrations and sources in relation to environmental implications. Br Poult Sci. 2004;45(2):225-63.
https://doi.org/10.1080/00071660410001715867

35-Al-Fayyad HA, Naji SA-H. A study the effect of supplementation vitamin C and dietary calcium on: I-Some productive performance in two different strains of broiler chicks under heat stress conditions. AL-Qadisiya Journal of Vet.Med.Sci. 2010. vol(9) No.1. 10-19.
https://doi.org/10.29079/vol9iss2art100

36-Hess JB, Bilgili SF, Parson AM, Downs KM. Influence of Complexed Zinc Products on Live Performance and Carcass Grade of Broilers. J Appl Anim Res. 2001;19(1):49-60.
https://doi.org/10.1080/09712119.2001.9706709

37-Sahraei M, Janmmohamadi H, Taghizadeh A, Ali Moghadam , Gholam Abbas Seyed R. Estimation of the Relative Bioavailability of Several Zinc Sources for Broilers Fed a Conventional Corn-Soybean Meal Diet. Japan Poult Sci Assoc. 2013;50(1):53-9.
https://doi.org/10.2141/jpsa.0120022

38-Nollet L, Klis JD Van Der, Lensing M, Spring P. The Effect of Replacing Inorganic With Organic Trace Minerals in Broiler Diets on Productive Performance and Mineral Excretion. J Appl Poult Res. 2007;16(4):592-7.
https://doi.org/10.3382/japr.2006-00115

39-Chand N, Naz S, Khan A, Khan S, Khan RU. Performance traits and immune response of broiler chicks treated with zinc and ascorbic acid supplementation during cyclic heat stress. Int J Biometeorol. 2014;58(10):2153-7.
https://doi.org/10.1007/s00484-014-0815-7