SVU-IJAS SVU-International Journal of Agricultural Sciences
Volume 3 Issue (3) pp.: 159-169, 2021
Print ISSN 2636-3801 | Online ISSN 2636-381X
Doi: 10.21608/SVUIJAS.2021.80159.1116
RESEARCH ARTICLE

Application of zinc oxide nanoparticles as feed additive in broiler chicken nutrition under hot environmental conditions

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Abstract

Nanotechnology has the potential to use in poultry production with new tools for the enhancing the ability of poultry to absorb nutrients and therefore improving growth performance, nutrient digestibility and productive performance of poultry. The essential trace elements play important roles such as nutrients metabolism, antimicrobial and antioxidant. Numerous studies have already used the effects of zinc sources at lower and higher doses on productive performance of broiler chickens. Most of these studies showed slight positive effects, however significant results were rare. Since there are almost unlimited possibilities concerning levels and sources of zinc there is still more research needed. Using zinc as nanoparticles size can be used at lower doses and can provide better result than the conventional zinc sources. Nanoparticles Zinc oxide can act as antibacterial agent, modulates the immunity and production of broilers. Using of Nanoparticles Zinc oxide in broiler nutrition may support and improve the broiler production. Nevertheless, there is still further studies under more standardized conditions needed to evaluate the optimum dosage as well as the exact mode of action of Nanoparticles Zinc oxide. Therefore, the aim of this study is to give an overview on the potential of nanoparticles of zinc oxide as feed additives in broiler diets, in order to evaluate the optimum dosage and observe their influence on feed intake, growth performance, nutrient digestibility, carcass criteria, and physiological responses.

Keywords: Broilers; Nanotechnology; Nutrition; Performances; Zinc.

Introduction

A high environmental temperature in Upper Egypt is one of the most problems that can causes negatively influence of poultry production. Heat stress can extremely trouble the balance between the generation of reactive oxygen types and the antioxidant system (Tan *et al.*, 2010). The oxidative stress result from heat stress led to an increased radical production, which induces oxidative damage and lipid peroxidation to cellular membranes (Mujahid *et al.*, 2007). This cause physiological changes such as depression of feed intake additionally decreased metabolic heat productive performance (Teeter *et al.*, 1985) and reduce growth rate and feed efficiency (Geraert *et al.*, 1992). Pope (1960) showed that heat stress is responsible for energy intake of broilers and this result in decreased growth rate.

Zinc is an essential microelement which can play an important part in performance, meat quality and carcass traits in broiler (Rajendran *et al.*, 2013). Rao *et al.* (2016) indicated that male broiler consumed dietary added with 40 mg/kg Zn was significantly ($P<0.05$) enhancing growth performance and antioxidant responses under heat stress. In addition, Sunder *et al.* (2008) observed an improvement in immune response

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Received: June 11, 2021; Accepted: June 15, 2021; Published online: July 30, 2021

and mineral retention when broiler fed diet added with zinc. Likewise, both adverse effects of cold and heat stress were decreased in layer fed diet supplemented with zinc and vitamin C (Gerzilov *et al.*, 2015). Thus, under heat stress conditions productive performance was improved in broilers fed diet added with 40 mg Zn /kg (Rao *et al.*, 2016).

Egwurugwu *et al.* (2013) indicated that the feed supplementation like nanoparticles of minerals can play an active role in productive performance and reproduction system of animals.

Nanoparticles of Zinc oxide is the specially prepared mineral having particle size from 1 to 100 nm (Swain *et al.*, 2016) it can act as antibacterial, and antioxidant activities and improving broilers performance. The commonly used cereal grains in broilers diets are rich in phytate that may reduce absorption of zinc (Lonnerdal 2000). So that zinc deficiency results in appetite reduction, abnormalities of the skin and growth falling (Brooks *et al.* 2013; Petrovic *et al.* 2010). Supplementation of zinc oxide at 100 ppm / kg diet of male broiler chicks has been significantly enhanced intestinal digestion and nutrients absorption (Ghiasiet *et al.* 2011). Nanoparticle of zinc oxide at 80 ppm is the best source of zinc when compared to organic and inorganic sources of zinc make better performance and immunity of broilers (Bami *et al.*, 2018). Supplementation of Nanoparticle of zinc oxide to layers diet at 20 to 60 mg/kg had been significantly improved nutrient digestibility and enhanced liver and kidney function (Fawaz *et al.*, 2019b).

This study aimed to give an overview on impact of zinc oxide as nanoparticles in broiler chickens diets under upper heat climate conditions, to explore the mode of action of zinc nanoparticles and its effect on broilers performance, nutrient digestibility, and some blood biochemistry.

Mode of action of zinc in poultry nutrition

Zinc is an important nutrient for animals and humans, which can act as antioxidant, glandular development, poultry performance, protein and carbohydrate metabolism and cofactor in more than 300 metalloenzymes (Salim, 2008). It is essential for enzyme structure, bone development and fast growth (Tüzün, 2018).

Reduced appetite and feed intake is one of the first deficiency of zinc signs observed in poultry by impairing of taste. Chester and Quarterman (1970) indicated that the animal food intake increased within 1-2 hours of zinc supplementation. O'Dell and Reeves (1989) reported that changes in appetite are related to changes in the concentrations of amino acid derived neurotransmitters in the brain. Kennedy *et al.* (1998) reported that key enzymes required for metabolism of carbohydrate may be lacking because the zinc dependent messenger RNA needed to synthesize these enzymes has reduced expression. Also, high levels of zinc in certain diets may enhance health of poultry independent of its role on the immune system.

Some researchers have demonstrated that zinc supplementation may improve productive performance through a systemic effect via the blood rather than the enteric effects in the small intestine. Fawaz *et al.* (2019a) indicated that zinc including in dietary can reduce the adverse impact of heat stress. Likewise, both adverse effects of cold and heat stress were decreased in layer fed diet supplemented with zinc and vitamin C (Gerzilov *et al.*, 2015). Thus, under heat stress conditions productive performance was improved in broilers fed diet added with 40 mg Zn /kg (Rao *et al.*, 2016). Sunder *et al.* (2008) demonstrated that supplementation of Zn to broilers diet was important for support immune response and mineral retention. plasma concentration of cortisol, nitric oxide levels and levels of pro-inflammatory were increased by decreased the level of zinc (Chen *et al.*, 2006).

Dreno *et al.* (1992) indicated that zinc is a strong anti-inflammatory property because due to its roles in activation of natural killer cells and reducing reactive oxygen species synthesis.

Recommendation levels of zinc in broiler diets

According to, NRC (1994) recommended 40 mg/kg of feed as Zn requirement of broiler chickens. In recent years, Mohammadi *et al.* (2015) added different sources of zinc Zn-methionine, Zn-sulphate, nano-Zn sulphate, nano-Zn methionine and zinc-nano max at 80 mg/kg broiler diet and indicated that nano-Zn methionine the best source of zinc to improved performance of broilers. However, Fathi *et al.* (2016) Supplemented of zinc oxide nanoparticles at 10, 20 and 40 mg/kg to broilers diet and indicated that 20 mg/kg is the optimal contained of zinc to improved broilers performance and reduced serum concentration of cholesterol. Likewise, Fathi. (2016) who added Nano- ZnO at 10, 20 and 40 mg/kg to broilers diet and indicated that 20 mg/kg is the best level of zinc oxide nano particles. Furthermore, Ahmadi *et al.* (2013) noted that supplementation of 30, 60, 90 and 120 mg nano-ZnO/kg to broilers diet and the recommended level were 60 from 90 mg/kg of diet.

Effect of Nanoparticles of Zn Oxide on growth performance of broilers

Several studies indicated that supplementation of different level and sources of zinc to broilers diets have been improved productive performance. Such as, Rao *et al.* (2016) reported that supplementation of 40 mg/kg Zn to broiler diets significantly ($P<0.05$) improved growth performance responses under heat stress. Likewise, Sahin *et al.* (2005) showed that supplementation of Zinc picolinate at 30 or 60 mg/kg significantly improved growth performance of quails exposed to heat stress. In addition, Supplementation of Nanoparticles of Zn Oxide at 100 mg/kg to broiler diets significantly improved feed conversion ratio compared to control (Ramiah *et al.*, 2019). Fathi *et al.* (2016) reported that supplementation of Nanoparticles of Zn Oxide at 10, 20 and 40 mg/kg had a significant ($P<0.001$) increased feed intake and body weight gain as well as improved feed conversion ratio compared to non-treated broilers. Also, Ahmadi *et al.* (2013) found that addition of 120 mg/kg of Nanoparticles of Zn Oxide to broiler dietary significantly increased ($P<0.05$) feed intake. Likewise, Huang et al. (2007) observed that supplementation of $ZnSO_4$ from 20 up to 140 mg/kg were significantly improved daily feed intake compared to control group. However, supplementation of 40 mg Nanoparticles of Zn Oxide/kg had been not affected feed intake of broiler (Badawi *et al.*, 2017). Also, there was not different in feed intake value when layer fed diet added with 80 mg Nanoparticles of Zn Oxide/kg (Abedini *et al.*, 2017). Thus, feed intake did not affect in Leghorn laying hens received diet supplemented with Nanoparticles of Zn Oxide at 60 mg/kg (Tsai et al., 2016). In addition, Hafez *et al.* (2017) noted that supplementation of Nanoparticles of Zn Oxide at 40 and 80 mg/kg did not influence feed intake. However, Saleh *et al.* (2018) observed a significant reduction on feed intake in broilers consumed diet supplemented with zinc methionine at 50 and 100 mg/kg when compared to control group. Thus, Mohammadi *et al.* (2015) observed that supplementation of Nanoparticles of Zn sulphate at 80 mg/kg had been significantly ($P < 0.01$) reduced feed intake compared to control group.

Zhao *et al.* (2014) found that body weight was significantly increased ($P < 0.05$) in broilers fed diet supplemented with 20 and 60 mg/kg of nano- ZnO. Chand *et al.* (2014) found that supplementation of zinc at 60 mg/kg had been significant increased ($p<0.05$) body weight gain and feed intake and improved feed conversion ratio of broilers compared to control group. Likewise, Ibrahim *et al.* (2017) who supplemented 50 mg/kg from zinc methionine and Nano-ZnO and observed a significant (P<0.05) increased in body weight gain and feed intake as well as improved feed conversion ratio of broilers compared to control group. In addition, Saleh *et al.* (2018) indicated that average daily body weight gain, feed conversion ratio and feed intake were significantly improved in broilers fed diet supplemented with zinc methionine at 50 and 100 mg/kg than that control group. In addition, Hafez *et al.* (2017) reported that supplementation of Nanoparticles of Zn Oxide at 40 and 80 mg/kg to broilers diet significantly improved body weight gain and feed conversion ratio of broilers. However, Mohammadi *et al.* (2015) observed that supplementation of different sources of zinc Zn-methionine, Zn-sulphate, nano-Zn sulphate, nano-Zn methionine and zinc-nano max at 80 mg/kg did not influence feed conversion ratio.

Effect of Nanoparticles of Zn Oxide on nutrient digestibility of broilers

Dry matter and crud protein digestibility were significantly increased in layer treated with 20, 40 and 60 mg/kg compared to control group (Fawaz *et al.*, 2019b). Rao *et al.* (2016) indicated that male broiler consumed dietary added with 40 mg/kg Zn was significantly (P<0.05) improved nutrient digestibility of crude protein and ether extract under heat stress. Furthermore, ether extract and zinc absorption were significantly (p<0.05) improved in broilers fed diet supplemented with 50 mg/kg from zinc methionine or Nano-ZnO compared to control group (Ibrahim *et al.*, 2017). In addition, Saleh *et al.* (2018) noted that dry matter and crud protein digestibility were significantly higher in broilers fed diet supplemented with zinc methionine at 50 and 100 mg/kg than that control group. Dry matter, ether extract and crude protein digestibility were linearly increased when Japanese Quail fed diet supplemented with 30 or 60 mg/kg of zinc sulphate compared to control group (Sahin *et al.*, 2005; Sahin and Kucuk 2003).

Effect of Nanoparticles of Zn Oxide on blood parameters of broilers

Serum zinc concentration was significantly (P<0.01) increased in layer fed diet added with 80 mg/kg when compared to control diet (mao *et al.*, 2017). Also, Idowu *et al.* (2011) observed that plasma zinc concentration was significantly increased (P<0.05) in layer fed diet supplemented with 140 mg/kg of zinc oxide. However, plasma Zn concentration was non-significantly affected In layer consumed diet supplemented with supplementation of 80 mg Nanoparticles of Zn Oxide /kg (Abedini *et al.*, 2017).

Ibrahim *et al.* (2017) found that supplementation of Nanoparticles of Zn Oxide at 50 mg/kg to broilers diet did not affected (P>0.05) serum concentration of aspartate aminotransferase (AST) and Alanine aminotransferase (ALT) compared to control group. However, Fawaz *et al.* (2019b) indicated that ALT and AST were linearly (P<0.001) decreased in layers fed diet supplemented with Nanoparticles of Zn Oxide at 20, 40 and 60 mg/kg compared to control group. Likewise, El-katcha *et al.* (2018) found that serum concentration of AST and ALT activities were significantly (P>0.05) decreased in layers fed diet supplemented with 30 mg of Nanoparticles of Zn Oxide/kg diet. Serum concentration of aspartate aminotransferase (AST) and Alt were linearly (P<0.01) decreased in layer consumed graded level of Nanoparticles of Zn Oxide at 20, 40 and 60 mg/kg compared to control group (Fawaz *et al.*, 2019b). However, Fathi *et al.* (2016) Observed that serum activities of ALT, AST was non- significant affect in broilers fed diet added with Nanoparticles of Zn Oxide at 10, 20 and 40 mg/kg.

Dietary inclusion of Nanoparticles of Zn Oxide at 20, 40 and 60 mg/kg quadratically decrease ($p<0.05$) serum concentration of creatinine compared to control group (Fawaz *et al.*, 2019b). However, Fathi *et al.* (2016) indicated that serum concentration of Creatine kinase was non- significantly affected in broilers fed diet added with Nanoparticles of Zn Oxide at 10, 20 and 40 mg/kg.

Serum concentration of total cholesterol was significantly reduced in broilers fed diet supplemented with 50 mg/kg from zinc methionine or Nanoparticles of Zn Oxide compared to control group (Ibrahim *et al.*, 2017). Likewise, Zhao *et al.* (2016) who reported that serum total cholesterol of layer was significantly ($P<0.05$) decreased by addition of Nanoparticles of Zn Oxide at 100 and 200 mg per kg when compared to control group. Thus, Badawi *et al.* (2017) demonstrated that supplementing 40 ppm Nanoparticles of Zn Oxide /kg to broilers diet did not affect serum concentration of total cholesterol compared with control group. In addition to, Torki *et al.* (2015) indicated that serum total cholesterol was not affected when layer fed diet supplemented with 40 mg Zn/kg diet.

Yang *et al.* (2012) indicated that thyroxine (T4) and estrogen hormone concentrations did not affected in layer fed diet supplemented with 30 mg/kg Zn however, triiodothyronine (T3) was significantly ($P <0.005$) decreased compared with control group.

Mao and Lien (2017) indicated that addition of Nanoparticles of Zn Oxide at 80 mg/kg diet significantly increased serum concentration of zinc compared to control group. Thus, Idowu *et al.* (2011) noted that plasma concentration of zinc was significantly ($P<0.05$) higher in layer fed diet with 140 mg/kg from zinc sulphate, zinc proteinate and zinc carbonate. likewise, Torki *et al.* (2015) reported that plasma concentration of zinc was significantly ($P<0.05$) increased by addition of zinc to broilers diet compared with control group. However, supplementation of 80 mg/kg Nanoparticles of Zn Oxide to hens diet did not changed plasma Zn concentration (Abedini et al., 2017).

Effect of Nanoparticles of Zn Oxide on carcass criteria and internal organs of broilers

Relative weight of liver was significantly higher in broilers fed from 30 up to 90 Nanoparticles of Zn Oxide that than control group however gizzard, pancreas, proventriculus and heart weight were not affected (Ahmadi *et al.*, 2013). Saleh *et al.* (2018) found a significant reduction on relative weight of abdominal fat in broilers consumed diet addition with zinc methionine at 50 and 100 mg/kg hsowever, liver weight did not affect when compared to control group. Mohammadi *et al.* (2015) observed that supplementation of different sources of zinc Zn-methionine, Zn-sulphate, nano-Zn sulphate, Nanoparticles of Zn methionine and zinc-nano max at 80 mg/kg did not influence relative weight of gastrointestinal, heart and liver weight, however, there was a significant reduction on relative weight of abdominal fat in broilers compared control group.

Conclusion

Generally, it can be concluded that Nanoparticles of Zn Oxide has the potential to be considered as an alternative to other sources and improving productive performance and health status of broiler chickens. Nevertheless, there is still further research under standardized conditions needed to evaluate the exact mechanism of action and to determine the optimal dietary inclusion level in order to optimize meat production, nutrient digestibility and health status of birds.

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