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RESEARCH ARTICLE

Effect of Nano-zinc oxide on productive performance, Nutrient digestibility, some blood biochemistry of broilers – a review.

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Abstract

Zinc oxide nanoparticles are mineral salts with particle sizes ranging from 1 to 100 nm. Through the use of nanotechnology, nanoparticles, which have been discovered to have several novel properties different from those of bulk materials or commercial salts of these minerals, can be used as a supplemental source of trace minerals in diets. Feed additives such as trace mineral nanoparticles play an active role in poultry production productivity. Zinc is a trace element that improves broiler growth performance and meat quality. Furthermore, zinc can benefit animals in a variety of ways, including antioxidant, protein synthesis, glandular development, carbohydrate metabolism, and production performance, in addition to acting as a cofactor in over 300 metalloenzymes. Broilers fed a zinc-rich diet showed an improvement in immune response. This study aimed to provide an overview of nano-Zno's impact on broilers' productive performance.

Keywords : Broilers; Nanoparticles; Performance; Zinc oxide.

1. Introduction

The Zinc oxide nanoparticles are mineral salts with particle sizes ranging from 1 to 100 nm (Swain *et al.*, 2016). Through the use of nanotechnology, nanoparticles, which have been discovered to have several novel properties different from those of bulk materials or commercial salts of these minerals, can be used as a supplemental source of trace minerals in diets (Mohapatra *et al.*, 2014). There were three methods for creating zinc oxide nanoparticles. Chemical and physical methods, as well as plant-mediated synthesis. Plant-mediated zinc oxide nanoparticle synthesis is thought to be far safer and less harmful to the environment than chemical and physical methods (Younas *et al.*, 2023). Feed additives such as trace mineral nanoparticles play an active role in poultry production productivity (Fawaz *et al.*, 2019). Zinc is a trace element that improves broiler growth performance and meat quality (Liu *et al.*, 2011; Rajendran *et al.*, 2013). Furthermore, zinc can benefit animals in a variety of ways, including antioxidant, protein synthesis, glandular development, carbohydrate metabolism, and production performance, in addition to acting as a cofactor in over 300 metalloenzymes (Salim *et al.*, 2008). Furthermore, broilers fed a zinc-rich diet showed an improvement in immune response (Sunder *et al.*, 2008). Because nanoparticles have antimicrobial properties and can reduce antibiotic residues in poultry products, they could be used to combat and treat antibiotic-resistant bacteria, especially in humans (Hassanen and Ragab,

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2020). Furthermore, biodegradable polymers of nanoparticles induced potent immune responses after being used as adjuvants or carriers in mucosal types of poultry vaccines (Jin *et al.*, 2019). Nanoparticles are now used as accurate, quick, and cost-effective diagnostic tools for avian pathogen detection (Chen and Neethirajan, 2015).

2. Recommendation levels of zinc in broiler diets

According to NRC (1994), the zinc requirement of broiler chickens is 40 mg/kg of feed. Recently, Eskandani *et al.* (2021) supplemented different sources of zinc (70 mg ZnSO4/kg, 70 mg Zinc amino acid complex/kg, 30, 50, and 70 Nano-ZnO/kg) to broilers diet and recommended that 30 mg Nano-ZnO/kg is the optimal amount and source of zinc. Additionally, Hussan *et al.* (2022) added different levels of Nano-ZnO at a doses of 2.5, 5, 10, 20, and 40 ppm to broilers diet and concluded that 2.5 ppm the optimal level.

Thus, Fathi (2016) supplemented Nano-ZnO at a doses of 10, 20 and 40 mg/kg to broilers diet and recommended 40 mg Nano-ZnO /kg as the best treatment. Mohammadi *et al.* (2015) supplemented different sources of zinc at 80 mg/kg broiler diet, including Zn-methionine, Zn-sulphate, nano-Zn sulfate, nano-Zn methionine, and zinc-nano max, and found that nano-Zn methionine was the best source of zinc for improved broiler performance. Fathi (2016), on the other hand, added zinc oxide nanoparticles to broiler diets at 10, 20, and 40 mg/kg and found that 20 mg/kg is the optimal amount of zinc to improve broiler performance and lower serum cholesterol concentrations. additionally, Ahmadi *et al.* (2013) reported that broiler diets supplemented with 30, 60, 90, and 120 mg nano-ZnO/kg, with the recommended level being 60 to 90 mg/kg.

3. Productive performance

3.1. Feed intake

Many studies have revealed that zinc can improve broiler feed intake. Hussan *et al.* (2022) observed a significant increased (P<0.05) in the feed intake of broilers fed 2.5 ppm Nano ZnO/kg compared to the control group. Likewise, Fathi (2016) found that supplementing Nano zinc oxide at 10, 20, and 40 mg/kg increased feed intake significantly (P<0.001) compared to a control group. Additionally, Ahmadi *et al.* (2013) discovered that adding 120 mg/kg of Nano-ZnO to the broiler diet significantly (P<0.05) increased feed intake compared to a control group. Thus, Huang *et al.* (2007) indicated that ZnSO4 supplements ranging from 20 to 140 mg/kg significantly increased daily feed intake when compared to the control group. Furthermore, when compared to the control diet, broiler feed intake was significantly (P<0.05) increased in broilers fed diet added with zinc at 60 mg/kg. (Chand *et al.*, 2014). Supplementation of zinc methionine at 7.5 ppm and nano ZnO at 0.06, 0.03, and 0.3 ppm to broiler's diet significantly improved feed intake (Sahoo *et al.*, 2016). Similarly, Ibrahim *et al.* (2017) observed a significant (P<0.05) increase in feed intake of broilers supplemented with 50 mg/kg zinc methionine and Nano-ZnO compared to the control group.

However, Dosoky *et al.* (2022) found that supplementation of Nano-ZnO at levels from 5 up to 80 ppm did not affect the feed intake of broilers during the period from 1 to 35 days of age. Additionally, Zhang *et al.* (2022) indicated that feed intake did not affect in broilers fed diet added with Nano-ZnO at levels 40, 80, and 160 mg/kg. likewise, Hatab *et al.* (2022) found that the body weight of broilers had non-significant affected when broilers were fed a diet added with nano-ZnO at doses of 40 and 60 mg/kg. Supplementation with 40 ppm Nano-ZnO/kg to the diet did not affect broiler feed intake (Badawi *et al.*, 2017). Likewise, when a layer-fed diet was supplemented with 80 mg Nano-ZnO/kg, there was no difference in feed intake value (Abedini *et al.*, 2017). Feed intake did not affect in

Leghorn laying hens fed a diet supplemented with Nano-Zno at a rate of 60 mg/kg (Tsai *et al.*, 2016). Zinc supplementation in broiler diets with two Zinc levels (40 and 80 mg/kg diet) in the form of Zn propionate and Zn sulfate had no significant effect on the feed intake of broilers (Iqbal *et al.*, 2011).

On the other hand, there was a significant reduction in the feed intake of broiler chickens fed diet supplemented with ZnO at 70mg/kg compared to a control group (Kuter *et al.*, 2023). Likewise, Alian *et al.* (2022) found a significant (P<0.001) decrease in feed intake of broilers fed a diet supplemented with nano ZnO at 40 mg/kg compared to a control group. Additionally, Mohammed *et al.* (2023) indicated that feed intake was significantly (P<0.05) reduced when broiler drinking water added with nano-ZnO at 60, 80, 100, and 120 ppm/L compared to the control group. Likewise, Increased Zn levels from 80 to 120 mg/kg diet from different sources of zinc (zinc oxide and zinc sulfate) or organic zinc (zinc-methionine, zinc-lysine, and zinc acetate) significantly (P<0.001) decreased average feed intake (Jahanian *et al.*, 2008).

3.2. Body weight and weight gain

Hussan *et al.* (2022) observed a significant increased (P<0.05) in body weight gain of broilers fed 2.5 ppm Nano ZnO/kg compared to the control group. Likewise, Alian *et al.* (2022) found a significant (P<0.001) improvement in final weight and body weight gain of broilers fed a diet supplemented with nano ZnO at 40 mg/kg compared to a control group. Additionally, Zhang *et al.* (2022) indicated that body weight and weight gain were significantly (P<0.001) higher in broilers fed diet supplemented with Nano-ZnO at levels 40, 80, and 160 mg/kg than in a control group. Body weight and Body weight gain of broilers were significantly improved by dietary supplementation with Nano-ZnO at 20, 40, and 60 mg/kg under heat stress conditions (Abdel-Wareth *et al.*, 2022). Similar findings of increased weight gain were reported in broilers fed nano ZnO addition at 0.06 ppm and organic zinc (zinc methionine) at 7.5 ppm (Sahoo *et al.*, 2016). Additionally, Mohammed *et al.* (2023) indicated that feed intake was significantly (P<0.05) increased at 35 days of age when broilers drinking water added with nano-ZnO at 60 and 120 ppm/L compared to a control group. It was reported that Nano ZnO at 20 and 60 mg/kg could enhance body weight gain when compared to a control (Zhao *et al.*, 2014). When compared to the control group, Chand *et al.* (2014) discovered that zinc supplementation at 60 mg/kg significantly increased (P<0.05) body weight gain and feed intake, as well as improved feed conversion ratio. Similarly, Ibrahim *et al.* (2017) observed a significant (P<0.05) increase in body weight gain in broilers supplemented with 50 mg/kg zinc methionine and Nano-ZnO compared to the control group.

However, Zinc supplementation in broiler diets with two Zinc levels (40 and 80 mg/kg diet) in the form of Zn propionate and Zn sulfate had no significant effect on the body weight of broilers compared to a control group (Iqbal *et al.*, 2011). Dosoky *et al.* (2022) found that supplementation of Nano-ZnO at levels from 5 up to 80 ppm to diet did not affect body weight and weight gain of broilers during the period from 1 to 35 days of age. Likewise, Stenclová *et al.* (2016) reported that adding zinc at doses of 120, 40, and 20 mg/kg did not affect broiler chicken live body weight. Additionally, Yogesh *et al.* (2013) revealed that higher levels of Zn from different sources (additive zinc, inorganic zinc, and organic source) had no significant effect on broiler chickens' live body weight.

On the other side, dietary including ZnO at 70 mg/kg reduced significantly body weight gain of broilers compared to a control group (Kuter *et al.*, 2023).

3.3. Feed conversion ratio

There was a significant improvement in the feed conversion ratio of broilers fed 2.5 ppm Nano ZnO/kg compared to the control group (Hussan *et* *al.*, 2022). Likewise, Alian *et al.* (2022) found a significant (P<0.001) decrease in the feed conversion ratio of broilers fed a diet supplemented with nano ZnO at 40 mg/kg compared to a control group. Additionally, Mohammed *et al.* (2023) indicated that the feed conversion ratio was significantly (P<0.05) increased at 35 days of age when broilers drinking water added with nano-ZnO at 60 and 120 ppm/L compared to a control group. Supplementation of zinc methionine at 7.5 ppm and nano ZnO at 0.06, 0.03, and 0.3 ppm to the broiler's diet significantly improved the feed conversion ratio (Sahoo *et al.*, 2016). When compared to non-treated broilers, broilers treated with Nano-ZnO at 10, 20, and 40 mg/kg had a higher feed conversion ratio (Fathi, 2016). Furthermore, Chand *et al.* (2014) discovered that supplementing zinc at 60 mg/kg significantly improved (P<0.05) the feed conversion ratio of broilers compared to the control group. Similarly, Ibrahim *et al.* (2017) observed a significant (P<0.05) decrease in FCR value in broilers supplemented with 50 mg/kg zinc methionine and Nano-ZnO compared to the control group.

However, Zinc supplementation in broiler diets with two Zinc levels (40 and 80 mg/kg diet) in the form of Zn propionate and Zn sulfate had no significant effect on the feed conversion ratio of broilers (Iqbal *et al.*, 2011). The body weight gain did not affect in broilers fed the diet supplemented with ZnO 70mg/kg compared to a control group (Kuter *et al.*, 2023). Additionally, Dosoky *et al.* (2022) found that supplementation of Nano-ZnO at levels from 5 up to 80 ppm to diet did not affect the feed conversion ratio of broilers during the period from 1 to 35 days of age. Likewise, Zhang *et al.* (2022) indicated that the feed conversion ratio did not affect in broilers fed diet added with Nano-ZnO at levels 40, 80, and 160 mg/kg. likewise, Hatab *et al.* (2022) found that the feed conversion ratio of broilers had non-significant affected when broilers were fed a diet added with nano-ZnO at doses of 40 and 60 mg/kg.

4. Carcass

The relative weight of the liver was significantly (P<0.05) higher in broilers fed 30 to 90 nanoparticles of Zn Oxide than in the control group, but the weight of the gizzard, pancreas, proventriculus, and heart was not affected (Ahmadi *et al.*, 2013). Additionally, in comparison to the control group, diets treated with zinc oxide nanoparticles at 20, 40, and 60 mg/kg significantly improved dressing percentage and decreased belly fat percentage (Abdel-Wareth *et al.*, 2022). Saleh *et al.* (2018) discovered a significant reduction in the relative weight of abdominal fat in broilers fed a diet supplemented with zinc methionine at 50 and 100 mg/kg, but the liver weight did not change when compared to the control group. Thus, Mohammadi *et al.* (2015) discovered that supplementing different zinc sources such as Zn-methionine, Zn-sulphate, nano-Zn sulfate, Nanoparticles of Zn methionine, and zinc-nano max at 80 mg/kg had no effect on the relative weight of gastrointestinal, heart, and liver weight, but there was a significant reduction in the relative weight of abdominal fat in broilers when compared to the control group.

5. Nutrient digestibility

There were non-significant changes between treatment in dry matter, ether extract, crude fiber and Crude protein digestibility of broilers fed diet added with Nano- ZnO at doses of 5, 10, 20, 40, 60, and 80 ppm from one to 35 days of age (Dosoky *et al.*, 2022). The broilers treated with nano zinc oxide at a dose of 40, and 60 mg/kg had considerably (P<0.01) greater ether extract and crude protein and crude fiber digestibility when compared to the control group (Abdel-Wareth *et al.*, 2022). When compared to the control group, the layer treated with Nano-ZnO 20, 40, and 60 mg/kg had a significantly higher dry matter and crude protein digestibility (Fawaz *et al.*, 2019b). Furthermore, Rao *et al.* (2016) found that feeding male broilers 40 mg/kg Zn significantly (P<0.05) improved the nutrient digestibility of ether extract and crude protein under heat stress compared to a control group. Moreover, in comparison to the control group, ether extract, and zinc absorption were significantly ($P<0.05$) improved in broilers fed a diet supplemented with 50 mg/kg zinc methionine or Nano-ZnO (Ibrahim *et al.*, 2017). Furthermore, Saleh *et al*. (2018) discovered that dry matter and crude protein digestibility were significantly higher when broilers fed diets supplemented with zinc methionine at 50 and 100 mg/kg compared to the control group. Japanese quail-fed diet added with 30 or 60 mg/kg zinc sulfate had linearly ($P<0.05$) higher dry matter, ether extract, and crude protein digestibility when compared to the control group (Sahin *et al.*, 2009; Sahin and Kucuk, 2003).

6. Blood biochemistry

6.1. Liver Function

Several authors have investigated the impact of dietary including Zinc on the blood biochemistry of broiler chickens. Researchers discovered lower serum concentrations of Alanine aminotransferase (ALT) and aspartate aminotransferase (AST) in broilers or laying hens fed Zinc supplemented diets when compared to controls. Mohammed *et al.* (2023) indicated that serum concentration of ALT and AST was significantly ($P<0.05$) reduced at 35 days of age when broilers drinking water added with nano-ZnO at 60, 80, 100, and 120 ppm/L compared to a control group. Fawaz *et al.* (2019b) found that ALT and AST levels were reduced linearly ($P<0.001$) in layers fed a diet supplemented with Nano-ZnO at 20, 40, and 60 mg/kg compared to the control group. El-Katcha *et al.* (2018) discovered that serum concentrations of AST and ALT activities were significantly ($P<0.05$) lower in layers fed a diet supplemented with 30 mg of Zn Oxide Nanoparticles/kg diet compared to a control group. Additionally, Mahmood *et al.* (2023) indicated that serum concentration of ALT and AST were significantly ($P<0.05$) decreased in broilers fed diets supplemented with Nano-ZnO at 40 mg/kg or Zinc sulfate at 110 mg/kg compared to a control group. Thus, Dosoky *et al.* (2022) found that supplemented Nano-ZnO at levels from 5 up to 80 ppm to diet significantly ($P<0.05$) decreased serum concentration of ALT and AST of broilers consumed Nano-ZnO at 5 and 40 mg/kg during the period from 1 to 35 days of age. Ibrahim *et al.* (2017) discovered that adding Nanoparticles of Zn Oxide to broiler diets at 50 mg/kg had no effect ($P>0.05$) on serum concentrations of (ALT) and (AST) compared to the control group. Likewise, Fathi (2016) discovered that serum activities of ALT and AST did not show any effect in broilers-fed diets containing nanoparticles of Zinc Oxide at 10, 20, and 40 mg/kg. On the other hand, Hatab *et al.* (2022) observed that serum concentration of AST and ALT was significantly ($P<0.05$) higher in broilers fed diet added with nano-ZnO at the dose of 60 mg/kg than in the control group.

6.2. Kidney Function

In comparison to the control group, dietary inclusion of Nano-ZnO at 20, 40, and 60 mg/kg quadratically decreases ($P<0.05$) serum creatinine concentration (Fawaz *et al.,* 2019b). Likewise, Dosoky *et al.* (2022) found that supplemented Nano-ZnO at levels from 5 up to 80 ppm to broilers diet and observed that a level of 40 mg/kg significantly increased serum concentration of creatinine during the period from 1 to 35 days of age compared to a control group. Likewise, Hatab *et al.* (2022) observed that the serum concentration of uric acid was significantly ($P<0.05$) lower in broilers fed a diet added with nano-ZnO at the dose of 60 mg/kg than in the control group, however, the serum concentration of creatinine did not affect. A significant reduction was observed in broilers fed diet added with Nano-ZnO AT at 20, 40 and 60 mg/kg compared to control group (Abdel-Wareth *et al.*, 2022). However, Fathi (2016) found that serum Creatine kinase concentrations were unaffected in broilers-fed diets containing nanoparticles of Zn Oxide at 10, 20, and 40 mg/kg. Dosoky *et al.* (2022) found that supplementation of Nano-ZnO at levels from 5 up to 80 ppm to diet did not affect the serum concentration of uric acid in broilers during the period from 1 to 35 days of age. Abdel-Wareth *et al.* (2022) observed that broilers fed diets containing nanoparticles of Zinc Oxide from 20 up to 60 mg/kg had no effect on serum uric acid concentrations.

6.3. Total cholesterol

When compared to the control group, broilers fed a diet supplemented with 50 mg/kg zinc methionine or nanoparticles of Zinc Oxide had significantly lower serum total cholesterol concentrations (Ibrahim *et al.,* 2017). Similarly, Zhao *et al.* (2016) reported that the addition of Nanoparticles of Zn Oxide at 100 and 200 mg per kg significantly ($P<0.05$) decreased the serum total cholesterol of the layer when compared to the control group. Likewise, Hatab *et al.* (2022) observed that serum concentration of total cholesterol was significantly ($P<0.05$) lower in broilers fed a diet added with nano-ZnO at the dose of 40 and 60 mg/kg than in a control group. However, Badawi *et al.* (2017) indicated that adding 40 ppm Nano-ZnO/kg to the diet of broilers did not affect serum total cholesterol concentrations when compared to the control group. Furthermore, there were non-significant changes between treatments in serum concentration of total cholesterol when broilers were fed a diet added with Nano- ZnO at doses of 5, 10, 20, 40, 60, and 80 ppm from one to 35 days of age (Dosoky *et al.,* 2022). Torki *et al.* (2015) found that layer-fed diets supplemented with 40 mg Zn/kg diet did not affect serum total cholesterol.

7. Total protein

Mahmood *et al.* (2023) indicated that serum concentration of total protein was significantly ($P<0.05$) increased in broilers-fed diets supplemented with Nano-ZnO at 40 mg/kg or Zinc sulfate at 110mg/kg compared to a control group. However, Dosoky *et al.* (2022) found that supplementation of Nano-ZnO at levels from 5 up to 80 ppm to diet did not affect the serum concentration of total protein, globulin, and albumin of broilers during the period from 1 to 35 days of age. Additionally, Fathi (2016) found that adding 10, 20 and 40 mg/kg Nano-ZnO/kg to the diet of broilers did not affect serum total protein concentrations when compared to the control group. Relative to the control group, it was discovered that broilers' serum total protein concentrations were unaffected by the addition of 2.5, 5, 10, 20, and 40 ppm Nano-ZnO/kg to their diet (Hussan *et al.*, 2022).

8. Conclusion

It could be concluded that zinc oxide nanoparticles has the potential to be used as an alternative to other sources of zinc, enhancing the performance and health of broiler chickens. But in order to maximize meat production, nutrient digestibility, and bird health, further standardized study is still required to assess the precise mechanism of action and define the ideal food inclusion level.

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Data presented in this study are available on fair request from the respective author.
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The authors disclosed no conflict of interest

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