



Selenium nanoparticles in rabbit nutrition. a review

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Abstract

The ability of the animal gut to absorb the trace elements and other nutrients, therefore, improving the growth performance of animals. Nanoparticles of Selenium (Nano-Se) promote growth performance of rabbits and it can act as antioxidants, antibacterial agents, improving the immunity system of the rabbits. Moreover, Se is one of the critical nutritional factors necessary for the normal functioning of the immune system and maintenance of gut health, growth, and organ functions. Numerous studies have demonstrated that a deficiency in Se could lead to serious disruptions in animal performances such as growth, digestion, liver damage, pancreatic fibrosis, cystic ovaries, and thyroid metabolism dysfunction. Furthermore, sufficient Se supplementation in rabbits tends to maintain good health and productive performance. The levels of Se in the rabbit diets vary widely according to dietary ingredients and selenium supplementation, ranging from 0.05 to 2.0 mg/kg diet. Since there are almost unlimited possibilities concerning the dosage of Se there is still more research needed. This review gives an overview of the mode of action, recommendation levels of Nano-Se, and their effects on growth performance, nutrient digestibility, carcass criteria and blood biochemical of rabbits.

Keywords: Nanotechnology; Selenium; Mechanism; Performances; Rabbits

1. Introduction

Appropriate animal diet and living environment play a key role in animal health and performance. Thus, optimizing these factors is important for increasing rearing efficiency, which can positively determine the quality of production of rabbit origin. Over the last decade, nanotechnology has received the attention of many researchers due to its promising agricultural and food applications. Nanotechnology provides new solutions in animal nutrient delivery and health protection, and, indeed, it has the large potential to improve animal production systems (Horky et al., 2016). This interest is mainly caused by the unique physicochemical properties of

nanoparticles, which refer to their small size (1–100 nm), high stability, hydrophobicity, and large surface area. Nanoparticles can be used as an additional source of trace minerals in the rations which have been found to have many novel properties different from those from other selenium (Se) sources (Mohapatra et al., 2014). Dietary Se is an essential trace element for animal growth, immunity, hormones, fertility, biochemical criteria, and metabolism as well as external and internal organs functions (Mohapatra et al., 2014; Surai, 2006). Supplementation of Se enhances the growth performance and antioxidant status of animals (Mahima et al., 2012). The Se can be added to the diets in the form of inorganic, organic, and nanoparticles; however, nanoparticles of Se (Nano-Se) have comparable efficiency, high bioavailability, strong adsorbing ability, and low toxicity

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compared with other Se sources (Wang *et al.*, 2021). Nanotechnology offers an opportunity to mediate these issues as Nano-particles possess different physical and chemical properties than other forms of minerals. Supplemented Nano-Se on growing rabbits at 50 mg/kg significantly increased growth performance and carcass criteria of rabbits compared to control (Sheiha, 2020). The selenium levels in the rabbit diets ranged from 0.05 to 0.4 mg/kg in non-supplemented to about 1 mg with supplementation of 0.6 mg selenium yeast or 0.6 mg sodium selenite/kg diet (Abdulrashid and Juniper, 2016; Amer *et al.*, 2018; De Blas and Mateos, 2010; NRC, 1977; Abdel-Wareth *et al.*, 2019). Since there are almost unlimited possibilities concerning the dosage of Se there is still more research needed. This review gives an overview of the mode of action, recommendation levels of Nano-Se, and its effects on growth performance, nutrient digestibility, carcass criteria, and blood biochemical metabolic profile of rabbits.

2. The mode of action Selenium

Limited literature is available regarding the mode of action effects of Nano-particles in rabbit nutrition. Response of rabbits performances are shown in figure 1. Nano-particles have higher physical activity and chemical neutrality. Bioavailability can be enhanced by increasing the surface area of respective minerals by making their Nano-particles. Owing to the potential advantages of Nano-particles, interest in exploring their potential use and efficacy in animal production has increased significantly in this decade (Hassan *et al.*, 2019). Nano-particles are one of the most innovative technologies to produce materials and different elements with changes in texture, structure, and enhanced quality at the molecular level (Usama, 2012). This technology is contributing significantly to the production, processing, storage, transportation, traceability, security, and safety of food (Otlis

and Yalcin, 2008). Trace elements like Se with potent antioxidant potential possess wide applicability as feed additives to alleviate oxidative stress in living systems (Hassan *et al.*, 2019). Selenium plays a major role in anti-oxidative mechanism, male reproduction, thyroid metabolism, muscle development, and anti-carcinogenesis (Rayman, 2005). Nano-Se results in higher Se retention and glutathione S-transferase activity due to its smaller size and higher bioavailability (Peng *et al.*, 2007). Recently, a possible mechanism for the conversion of Nano-Se to selenite has been proposed in monogastric animals suggesting that gut microbes can convert Nano-Se into selenite, Se-phosphate, or H₂Se ultimately leading to the synthesis of selenoproteins (Surai *et al.*, 2017).

The nanoparticle affects the cellular intake and allows them to easily pass through the stomach wall and diffuse into body cells quicker than common elements with larger particle sizes. The *in vitro* absorption of nanoparticles with a diameter of 0.1 µm was found to be higher than 1 and 10 µm nanoparticles (Desai *et al.*, 1997). Nanoparticles especially nanomaterials of Se and Zn have a higher surface-area-to-volume ratio, providing more surface area for contact with the mucosal tissues and cells. Better absorption of nanoparticles into the mucosal surface increases the particle residence time in the gut. When a Nano mineral is introduced into a biological medium, such as blood or mucus, proteins adsorb on its surface, giving it a unique “biological identity”, which may have an impact on the nanoparticles' distribution as well as their potential toxicity (Abdelnour *et al.*, 2021). Moreover, this study will serve as a brainteaser for further investigation to explore the mode of action of Nano-Se and its optimal levels for increasing product performance and intestinal integrity while reducing intestinal permeability.

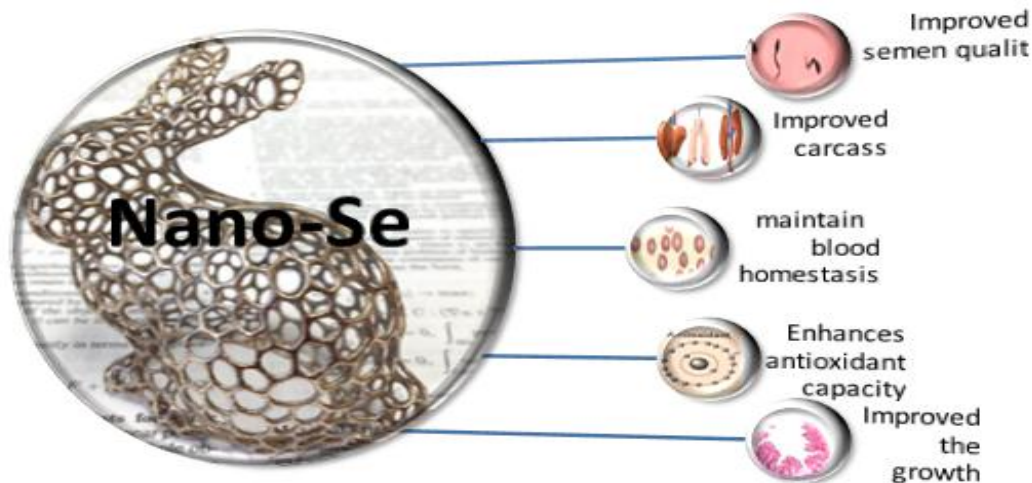


Figure 1. Response of rabbits to Nano-Se supplementations

Based on the studies mentioned above, Nano-Se supplementation can have many health benefits such as improved production performance, growth, feed efficiency, antioxidant status, and immune status, when present in rabbit diets compared to inorganic Se sources. Nevertheless, high doses of Nano-Se can cause the hyperaccumulation of Se in tissues and oxidative stress or toxicity. Therefore, Nano-Se should be included in rabbit diets in optimum doses to formulate nutritionally balanced feeds. The mechanism of Nano-Se conversion remains unclear, and the gut microbiota is thought to play a key role in this process. The application of Nano-Se showed promising results in enhancing the oxidative status of the cell induced by a reduction in glutathione and superoxide dismutase levels (Hassanin *et al.*, 2013). Nano-Se was likely employed in various researches as a ROS scavenger to protect against the oxidative damage in cells' sperm.

The affirmative result of Nano-Se administrations on semen traits could be owing to the possible role of these minerals as a co-factor in the activities of several antioxidant enzymes and the protective functions against reactive oxygen species. The increase in blood antioxidant minerals is

usually associated with particular improvements in the antioxidant status of animals and, thus, the health status of animals. Nano-Se increased serum Se and superoxide, catalase, and glutathione peroxidase compared with provided Se yeast and sodium selenite (Shi *et al.*, 2011).

The Se is an important dietary micronutrient required for the normal body functions and metabolism of animals (Keen *et al.*, 2004) it plays a significant role in the catalytic processes within the enzyme system that consists of a variety of enzyme activities linked with the metabolic, endocrine, and immune systems. Supplementation of Se prevents cell damage and plays an important role in the development, fertility, and immune functions of humans and other vertebrates, including fish (Hoffmann and Berry, 2008), maintenance of growth, health, and some biochemical metabolic profile (Edens and Sefton, 2016). Dietary organic Se supplementation in postpartum mice enhanced Se deposition in the liver, blood, and mammary gland (Wang *et al.*, 2021). Trace elements play an essential role in animal diet. Selenium is one of the critical nutritional factors necessary for the normal functioning of the immune system (Sharadamma *et al.*, 2011).

Selenium generally acts as a co-factor in an animal's body and is an essential part of many enzymatic chemical structures (selenoproteins). Glutathione peroxidase is the first selenoprotein identified in physiological systems with antioxidant activities (Back, 2013). Selenium plays a major role in anti-oxidative mechanism, male reproduction, thyroid metabolism, muscle development, and anti-carcinogenesis (Rayman, 2005). Nano-Se has also been shown to enhance the antioxidant capacity of the liver by reducing the amount of oxidized GSH-Px in the liver while increasing reduced GSH-Px levels. However, the reverse was observed in the case of their respective levels in the blood (Salah-Eldin *et al.*, 2015). Recently, an exciting study reported significant improvement in gut health of birds fed with a medium dose of Nano-Se at 0.9 mg/kg by increasing the abundance of beneficial bacteria and production of butyric acid along with other short-chain fatty acids. This shows the potential of Nano-Se to modulate the gut microbiome to directly influence the immune system, intestinal health, and integrity as well as served as a brainteaser for further investigation to explore the potential of optimal Nano-Se levels for increasing intestinal integrity while reducing intestinal permeability (Hassan *et al.*, 2020). Functions of proteins expressed indicated that a higher dose of Nano-Se supplementation induced dietary stress at the cellular level altering the carbohydrate and fatty acid metabolism (Peng *et al.*, 2007). Nano-Se has higher bioavailability and relatively low toxicity compared to other selenium forms (Suchy *et al.*, 2007). The Se can be supplemented in the form of organic, inorganic, and nanoparticles; however, nanoparticles of selenium possess comparable efficiency, high bioavailability, high catalytic efficiency, strong adsorbing ability, and low toxicity compared with other selenium sources (Wang *et al.*, 2021). Selenium improves the productive performance and antioxidant status of animals (Mahima *et al.*, 2012).

3. The recommendation levels of Se in rabbit diets

The Se levels in the rabbit diets vary widely according to dietary ingredients and Se supplementation, ranging from 0.05 to 0.4 mg/kg in non-supplemented to about 1 mg with supplementation of 0.6 mg Se yeast or 0.6 mg sodium selenite/kg diet (Abdulrashid and Juniper, 2016; Amer *et al.*, 2018; De Blas and Mateos, 2010; NRC, 1977; Saleh *et al.*, 2013; Strucklec *et al.*, 1994; Zhang *et al.*, 2011). Also, Din and Noha (2019) recommended that supplemented 0.1 and 0.3 mg Nano-Se/kg and 30 mg/kg and 60 mg/kg Nano-ZnO on growing rabbit diets improved rabbit performances. Al-Khafaji and Ibrahim (2019) recommended that supplemented 2mg/kg and 3 mg/kg Nano-Se and 1.5 mg/kg Nano-Se +150 mg VE) on growing rabbits' diets improved rabbit performances. Emara (2019) recommended that supplemented intra muscularly injected once a week 4 ml solution of Nano-Se on growing rabbit's diets improved rabbit performances. Furthermore, Abdel-Wareth *et al.* (2019) recommended that supplemented 400 µg/kg Nano-Se with or without 700 mg/kg garlic oil on growing rabbit diets significantly improved rabbit performances. Abd Allah *et al.* (2020) recommended that supplemented 0.3 mg 0.3 mg Nano-Se/ kg and+ 0.3 mg Nano-Se /kg + 250 mg Vit.E/ kg on growing rabbit's diets improved rabbit performances. Sheiha (2020) recommended that supplemented 25 and 50 mg of Nano-Se /kg and CH25 and CH50, with 25 and 50 mg of Nano-Se /kg on growing rabbit diets improved rabbit performances. Qin *et al.* (2016) recommended that supplemented 0.3 mg/kg Nano-Se to growing rabbit's diets improved rabbit performances.

4. Body weight and body weight gain:

Supplemented Nano-Se to growing rabbits diets at 0.1 and 0.3 mg Nano-Se/kg revealed that Nano-Se significantly increased BW and BW gain of rabbits compared with control (Din and Noha, 2019). Moreover, Mahmoud *et al.*, (2016) reported that supplemented Nano-

Se to growing broilers diets at 0.3mg/kg resulted in Nano-Se significantly improved BW and BW gain of broilers compared with control. Al-Khafaji and Ibrahim (2019) found that supplemented Nano-Se to growing broilers diets at 1mg/kg and 2 mg/kg and 3 mg/kg revealed that Nano-Se significantly improved BW and BW gain of rabbits compared with control. Supplemented Nano-Se to growing rabbits significantly increased BW and BW gain of rabbits compared with control (Emara, 2019). Furthermore, supplemented Nano-Se significantly improved BW and BW gain of broilers compared with control (Saleh and Ebeid, 2019; Ibrahim et al., 2020). Also, Abd Allah et al., (2020) reported that supplemented 0.3 mg/kg Nano-Se to growing rabbits diets significantly improved BW and BW gain of rabbits compared with control. Abdel-Wareth et al. (2019) reported that supplementation of Nano-Se at 400 µg/kg with or without 700 mg/kg garlic oil significantly improved BW and BW gain and BW and BW gain of rabbits compared with control. Addition of ad 25 and 50 mg of Nano-Se/kg) significantly increased BW and BW gain of rabbits compared with control (Sheiha, 2020).

5. Feed intake and feed conversion ratio:

Supplementations of Nano-Se at 0.1 and 0.3 mg/kg and Nano-ZnO at 30 mg/kg and 60 mg/kg to growing rabbits diets at (significantly improved feed intake and feed conversion ratio of rabbits compared with control (Din and Noha, 2019). Mahmoud et al. (2016) demonstrated that the addition of 0.3 mg/kg of Nano-Se to growing broilers diets significantly improved feed intake and feed conversion ratio of broilers compared with control. Supplementations of Nano-Se with or without vitamin E significantly improved feed intake and feed conversion ratio of rabbits compared with control (Al-Khafaji and Ibrahim, 2019). Feed intake and feed conversion ratio of growing rabbits were significantly improved by supplementation of Nano-Se compared with control (Emara, 2019).

Supplemented Nano-Se to the rabbit diets significantly improved feed intake and feed conversion ratio of broilers compared with control (Saleh and Ebeid, 2019; Ibrahim et al., 2020). Sheiha (2020) demonstrated that supplemented Nano-Se to growing rabbits at 25 and 50 mg/kg significantly improved feed intake and feed conversion ratio of rabbits compared with control. Nano-Se supplementation may be led to the improvement in growth performance of growing rabbits by increasing the final body weight and daily gain in the growing rabbits. Such as supplemented Nano-Se at 400 µg/kg with or without 700 mg/kg garlic oil to rabbit diets significantly improved feed intake and feed conversion ratio of rabbits compared with control (Abdel-Wareth et al., 2019).

6. Blood biochemistry:

An increase of total protein by Nano-Se (0.3 mg/kg) diet may be due to Se can improve plasma lipoproteins i.e. decline the LDL, HDL, cholesterol, and plasma triglycerides (Iizuka et al., 2001). Shunyi et al. (2016) reported that blood total protein was not significantly affected by Nano-Se supplementation to growing rabbit's diet. Shunyi et al. (2016) reported that the blood biochemistry of rabbits, including concentrations of cholesterol, HDL, and triglyceride were not significantly affected by supplementation of Nano-Se or sodium selenite. Also, Shunyi et al. (2016) reported that the blood biochemistry of rabbits, including concentrations of alanine aminotransferase (ALT) and aspartate aminotransferase (AST) were not significantly affected by supplementation of Nano-Se or sodium selenite. Furthermore, Se is known to have important roles in reproductive functions and development, immunocompetence, and aging. The Se is an essential trace mineral and has a profound effect on performance and immunity. The Se and vitamin E deficiency together in poultry causes exudative diathesis, pancreatic dystrophy, and nutritional muscular dystrophy. The Se is also, an integral part of

the enzyme known as glutathione peroxidase which is involved in the cell antioxidant defense mechanism and prevents the cells from free radical damage McDowell (1992). On the other hand, Mohapatra *et al.* (2014) found that liver enzymes were insignificantly influenced by Nano-Se (0.15, 0.30, and 0.60 ppm) supplementation compared with the control. Selim *et al.* (2015) found that increasing supplemental Nano-Se level from 0.15 to 0.30 ppm in broiler diets resulted in an increase in plasma creatinine level compared with the control group without any significant differences.

Qin *et al.* (2016) reported that supplemented Nano-Se at 0.3 mg/kg Nano-Se and 0.3 mg/kg to growing rabbits diets significantly improved total protein, AST, and ALT of rabbits compared with control. Also, Din and Noha (2019) showed that Nano-ZnO and Nano-Se significantly improved total protein, cholesterol, AST, ALT albumin, globulin, urea, and creatinine of growing rabbits compared with control. Shokraneh (2019) reported that Nano-ZnO and Nano-Se significantly improved, ALT, AST, triglycerides, superoxide dismutase, glucose, cholesterol, and total protein of broiler compared with control. Supplemented Nano-Se at 400 µg/kg with or without 700 mg/kg garlic oil significantly improved liver and kidney functions of rabbits compared with control. Likewise, Sheiha (2020) found that Nano-Se significantly enhanced liver and kidney functions of rabbits compared with control. Saleh and Ebeid (2019) indicated that Nano-Se significantly improved glucose, AST, ALT, triglycerides, superoxide dismutase, and cholesterol of broilers compared with control. Nano-Se significantly decreased triglycerides, superoxide dismutase, and malondialdehyde of rabbits compared with control (Sheiha, 2020). Nano-Se significantly increased the Red Blood cells and White Blood cells of broilers compared with control (Ibrahim *et al.*, 2020).

7. Carcass characteristics:

Nano-ZnO and Nano-Se significantly increased carcass criteria, kidneys, heart, liver, and head of rabbits compared with control (Din and Noha, 2019). Saleh and Ebeid (2019) reported that Nano-Se significantly improved carcass traits and decreased internal organs of broilers compared with control.

Nano-Se significantly improved kidneys, liver muscles, and blood serum of rabbits compared with control (Abd Allah *et al.*, 2020). *In ovo* injection of Nano-Se did not affect ($P > 0.05$) carcass, breast, thigh, totally edible, heart, gizzard, liver, spleen, thymus, bursa of broilers compared with control (Ibrahim *et al.*, 2020). Sheiha (2020) found that Nano-Se significantly increased carcass liver, heart, lungs, kidneys, and spleen of rabbits compared with control.

Conclusion

It can be concluded that the levels of Se in the rabbit diets vary widely according to dietary ingredients and Se supplementation, ranging from 0.05 to 2.0 mg/kg diet. Supplementation of Nano-Se improved growth performance, nutrient digestibility, carcass criteria, blood biochemical of rabbits. Since there are almost unlimited possibilities concerning the dosage of Se there is still more research needed.

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