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Derleme / Review

Application of Selenium Nanoparticles Diets in Ruminants

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ABSTRACT: Selenium nanoparticles (Se NPs) are mineral elements with a particle size of 1 to 100 nm prepared by reducing selenate or selenite. Se NPs have a higher effect on glutathione peroxidase enzyme activity, body weight, nutrient conversion efficiency, nutrient utilization, free radical inhibition, meat quality, survival rate, Se content in tissues, rumen microbial activity, stimulation of enzyme activity compared to other selenium sources (sodium selenite, yeast-derived selenium, organic selenium sources) in animal nutrition with their large surface area/volume ratio. In addition, Se NPs exhibit lower toxicity than selenite. Se NPs can be used at lower doses and thus it may have the potential to reduce environmental pollution indirectly. This review aims to provide a summary of the studies conducted on the physical, chemical, and metabolic properties, oxidative stress, antioxidant defense, dietary requirement, deficiency, fertility, sperm quality and performance of Se NPs used in ruminants nutrition.

Keywords: Selenium nanoparticles, Nutrition, Ruminant, Health

Selenyum Nanopartikül Diyetlerinin Ruminantlarda Uygulamaları

ÖZ: Selenyum nanopartikülleri (Se NPs), selenat veya selenitin indirgenmesiyle hazırlanan 1 ila 100 nm partikül boyutuna sahip mineral elementlerdir. Se NPs, sahip olduğu geniş yüzey alanı/hacim oranı ile hayvan beslenmesinde diğer selenyum kaynaklarına (sodyum selenit, maya kaynaklı selenyum, organik selenyum kaynakları) kıyasla selenoenzimlerin yukarı regülasyonu, glutatyon peroksidaz enzim aktivitesi, vücut ağırlığı, besin dönüşüm verimliliği, besin kullanımı, serbest radikal inhibisyonu, et kalitesi, hayatta kalma oranı, dokulardaki Se içeriği, rumen mikrobiyal aktivitesi, enzim aktivitesinin uyarılması üzerinde daha yüksek etkiye sahiptir. Ayrıca, Se NPs selenite göre daha düşük toksisite sergilemektedir. Se NPs daha düşük dozlarda kullanılabilmektedir ve böylece dolaylı olarak çevresel kirlenmeyi azaltma potansiyeline sahip olabilmektedir. Bu derleme, ruminatların beslenmesinde kullanılan Se NPs'nin fiziksel, kimyasal ve metabolik özellikleri, oksidatif stres, antioksidan savunma, diyet gereksinimi, eksikliği, doğurganlık, sperm kalitesi ve performans üzerindeki etkileri hakkında yapılan çalışmaların bir özeti vermeyi amaçlamaktadır.

Anahtar Kelimeler: Selenyum nanopartikülleri, Beslenme, Ruminant, Sağlık

INTRODUCTION

Selenium (Se: from the Greek word "selene" meaning "moon") is discovered by Jöns Jacob Berzelius in 1817, while trying to isolate tellurium in an impure sample (Köhrle, 2004). However, Se has been found to be a necessary trace element for living organisms due to studies by Schwarz and Foltz (Schwarz and Foltz, 1999). Se has organic and inorganic forms. Selenite, selenide, and selenate are inorganic selenium compounds, while selenomethionine, selenium-methylselenomethionine, selenocysteine, and selenocysteine are organic complexes.

Se is a micro element performing vital biological functions in animals (Pelyhe and Mezes, 2013). These functions are the regulation of thyroid hormone metabolism, cell growth, and antioxidant defense systems as well as growth, fertility, and immune system health (Reilly, 2006). Se is also a major component of the glutathione peroxidase (GPx), and thioredoxin reductase (TRx) enzyme families. GPx have a role in the reduction of hydrogen peroxide, protection of cell and cytoplasmic organelles from harmful metabolites. Se takes part in structures of compounds such as

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iodothyronine deionizer enzyme family, selenoprotein P, selenoprotein W, thioredoxin reductase, and selenium binding proteins. Se has performed functional tasks such as protecting cell membrane bonds and structure, regulating prostaglandin metabolism, increasing antibody synthesis, and phagocytosis (Reilly, 2006; Jaramillo, 2006; Marmiroli and Maestri, 2008; El-Ramady et al., 2014).

Se deficiency is quite common in the animal because of the low Se level in some soil and forages. Se deficiency weakens the immune system and cause to important problems such as stiff lamb disease, unthriftiness, poor reproductive performance, impaired immunity, placental retention, exudative diathesis, hepatosis dietetica, deteriorative oxidative reactions, disrupts bone metabolism, osteopenia, low yield, white muscle disease and diarrhea (Moreno-Reyes et al., 2001; Saha et al., 2016). Therefore, Se supplements are generally used in animal feed, taking into account doses. The use of a high concentration of Se may result in chronic poisoning due to its toxicity (Alexander, 2015; Saha et al., 2016). Se supplements could increase live weight gains, wool production, growth rate, and improve the efficiency of the antioxidant system, enhance the disease resistance, and nutritional quality in animal (Mahima et al. 2006). Se uses in organic and inorganic forms, but Se NPs form has attracted attention (Shi et al., 2009; Weixing et al., 2009; Shi et al., 2010; Shi et al., 2011a; 2011b; Wu et al., 2011; Xun et al., 2012; Sadeghian et al., 2012; Kojouri et al., 2012a; Kojouri et al., 2012b; Kojouri et al., 2017; Yaghmaie et al., 2017; Saadi et al., 2019; Kachuee et al., 2019).

Selenium nanoparticles (Se NPs) are mineral elements having a particle size of 1 to 100 nm prepared by the reduction of selenate or selenite. Se NPs, which are bright red, highly stable, soluble, and nano defined size in the redox state of zero (Se°), have been produced for use in animal nutrition (Zhang et al., 2001; Gao et al., 2002). Se NPs have features such as high surface activity, great specific surface area, and high catalytic efficiency. It has been reported that Se NPs have higher efficiency in upregulating selenoenzymes and their toxicity is less than selenite (Zhang et al., 2001; 2005; Jia et al., 2005; Wang et al., 2007; Hu et al., 2012). Therefore, the number of studies on the use of Se NPs has increased in ruminats. The effects of Se NPs in ruminants performance have been presented in Table 1. The purpose of this review is to present the current scenario for studies and findings on the application of Se NPs in ruminants nutrition.

Effects of selenium nanoparticles diets on growth parameters in ruminants

Se is a vital trace element for growth, health, productivity of economically important ruminats such as sheep, goats, cows, and cattle. The deficiency of Se causes many problems such as low sperm quality, scouring, lowered wool production, white muscle disease, exudative diathesis, abnormalities in the spermatozoal mitochondrion, low ATP concentrations, and lower GSH-Px activities (Marin-Guzman et al., 2000; Shi et al., 2010; Pappas and Zoidis, 2012; Mohapatra et al., 2014). Therefore, selenium supplementation is commonly used in ruminant nutrition. Sodium selenite, selenate, Se-enriched yeast are used as selenium sources. Recently, Se NPs have attracted considerable attention for these animals.

Se NPs have been evaluated for growth performance in some ruminants. In boar goats with fed 0.3 ppm Se NPs, the growth performance has not affected compared to control groups (Shi et al., 2009). However, in another study, body weight (BW) and average daily gain (ADG) increased in Taihang black goat with fed 0.3 mg/kg Se NPs (Shi et al., 2011b). It has been reported that weights of kidney and liver organs increased in fetal cashmere goats fed with 0,5 mg/kg Se NPs (Wu et al., 2011). Also, the favourable impact of Se NPs on weight gain reported for lambs (Yaghmaie et al., 2017). In another study, BW and daily body weight gain (DBWG) increased in rabbits fed with 25 mg/kg and 50 mg/kg Se NPs synthesized via a biological way, under heat stress condition. But, BW and DBWG decreased in rabbits fed with 50 mg/kg Se NPs synthesized via a chemical way, under heat stres condition (Sheiha et al., 2020).

Selenium is vital for insulin-like growth factor 1 (IGF-I) which represents peptide hormone in the liver and develops the proliferation, migration and morphogenesis of hair follicle cells. IGF I has important a role for some of the growth hormone (GH) functions and thus, it is involved in growth and development (Hosnedlova et al., 2017). The condition of hair follicles in goats is important for cashmere production. Wu et al. (2011) reported that the number of secondary hair follicles and the secondary to primary follicle (S/P) ratio increased in fetus cashmere goats fed with Se NPs.

Effects of selenium nanoparticles diets on digestive in ruminants

Dietary Se increase GSH-Px activity of rumen microorganisms. These microorganisms use Se to synthesize protein and cell wall components. Microbial protein synthesis may contribute to an increase in the production of total volatile fat acids, the rumen microbial population and decrease ammonia N (Arshad et al., 2020).

Researchers have studied the relationship between nutrient digestibility and Se NPs in ruminants. Digestibility dry matter (DM), organic matter (OM), crude protein (CP), ether extract (EE) and aNDF in total tract increased with Se NPs addition (Shi et al., 2011; Xun et al., 2012). In situ ruminal ED of *Leymus chinensis*, DM and aNDF also increased with increasing Se NPs addition (Shi et al., 2011; Xun et al., 2012). It has been suggested that Se NPs promote the activity of bacteria decomposing proteins, and the production of proteolytic digestive enzymes (Shi et al., 2011; Xun et al., 2012).

Ruminants such as sheep, cows, and cattle are vital protein sources. Therefore, efforts to increase digestive activity in the rumen are important for adequate and balanced ruminal fermentation. The use of Se NPs is an important issue for researchers to develop a rumen microbial ecosystem and ruminal fermentation and to ensure safe and quality animal production (Huang et al., 2003; Shi et al., 2011a; Xun et al., 2012). The pH balance and rumen microbial population are vital for balanced rumen fermentation. Lower pH harms fiber digestion because it prevents attachment of bacteria to plant cell walls. Shi et al. (2011a) reported that Se NPs addition improves rumen fermentation by increasing microbial fermentation and ruminal pH in sheep. The researchers have stated that the use of 3.0 g/kg dietary dry matter Se NPs, which is determined as the optimum dose, increase propionate production, mean ruminal pH, ammonia N content, and total volatile fatty acids. However, Xun et al. (2012) reported that Se NPs addition decrease mean ruminal pH, ammonia N content molar proportion of propionate in sheep. This situation is associated with a high dose of Se NPs (Shi et al., 2011a; Xun et al., 2012).

There is a linear correlation between urinary purine derivates and ammonia N concentration. Urinary excretions of PD (allantoin, uric amino acids acid, xanthine, and hypoxanthine) reduce the concentration of ruminal ammonia N. It has been showed that the increase of total PD urinary extraction and decrease of ruminal ammonia N concentration in sheep fed with Se NPs (Shi et al., 2011a; Xun et al., 2012). However, when Se NPs compared to yeast Se, daily urinary excretion of uric acid, xanthine, hypoxanthine did not affected by selenium sources (Xun et al., 2012).

Effects of selenium nanoparticles diets on antioxidant status in ruminants

The increase of reactive oxygen species and weakness of antioxidant defense mechanism causes oxidative stress (Sadeghian et al., 2012). Huang et al. (2003) reported that Se NPs can play a role in the removal of free radicals and the protection of DNA against oxidation, depend on size. In studies on oxidative stress and antioxidant defense mechanism, reduced production of thiobarbituric acid reactive substances (TBARS) values are evaluated as an indicator of oxidative stress and lipid peroxidation. In the study, which reported a decrease in TBARS values after 20 days in sheep fed Se NPs, it has been suggested that Se NPs show better antioxidative activity than sodium selenite (Sadeghian et al., 2012). Also, it has been reported that TBARS values in treated with Se NPs and sodium selenite higher than the control group on day 30 (Sadeghian et al., 2012).

Neutrophils are polynuclear cells, which are the body's first defense barrier. There is a linear relationship between the phagocytic activity of these cells and oxidative pressure. Besides, oxygen-free radicals can be released due to the respiratory burst and activation of the NADPH oxidase enzyme can be increased in the cell surface. These materials are toxic and destructive (Bernard et al., 2006; Hodgson et al., 2006). Se NPs can reduce toxic material (Kojouri et al., 2012a). Se NPs increased neutrophil counts on day 10 in sheep. This data provide that Se NPs have a strong effect on intracellular activities (Sadeghian et al., 2012). Se has important antioxidant effects due to its part of the active center of the GPx. It has been reported that Se deficiency causes structural disorders in spermatozoal mitochondria, low ATP concentrations, lower GSH-Px activities, low sperm concentrations, reduced sperm motility and sperm with a high incidence of cytoplasmic droplets. (Marin-Guzman et al., 2000; Shi et al., 2010). Se NPs possesses equal efficacy in increasing the activities of GPx in plasma and liver (Sadeghian et al., 2012). Se NPs increased the hepatic GSH level more strongly than selenite (Li et al., 2008). Serum, whole blood Se and GSH-Px activity were increased in goats fed with 0.3 ppm Se NPs. Se concentration also increased in liver, spleen, kidney, lung and testis in goat (Shi et al., 2009; Kachuee et al., 2019). Also, testicular and semen GSH-Px activities, spermatozoal ATPase concentrations, testis Se content increased in goat fed with 0.3 mg/kg DM Se NPs. The ATPase level provides information about the ATP level and metabolism (Shi et al., 2010). In another study, serum GSH-Px, superoxide dismutase (SOD), catalase (CAT), Se retention of whole blood, serum increased in Taihang black goat with fed 0.3 mg/kg Se NPs (Shi et al., 2011b). In another study, serum GSH-Px, superoxide dismutase (SOD), catalase (CAT), Se retention of whole blood, serum increased in Taihang black goat with fed 0.3 mg/kg Se NPs (Shi et al., 2011b). The effect of Se NPs on the antioxidant mechanism has been tried to be determined by molecular studies. In a study conducted with fetus cashmere goats, it has been reported that the addition of 0.5 mg/kg Se NPs increases GSH-Px, IGF-I and IGF-1R expressions. In addition, in this study, an increase and a decrease has been observed in the SOD and the malondialdehyde (MDA) levels, respectively (Wu et al., 2011). MDA is generally used as a vital indicator to measure the degree of lipid peroxidation. The use of Se NPs increased the level of T-AOC associated with antioxidant capacity (Wu et al., 2011). Se NPs increased GPx levels and reduce oxidative stress in lambs (Yaghmaie et al., 2017). Increases in Se concentration and GPx activity may depending on the source of selenium. For example, in lambs, sodium selenite showed higher Se concentration and GPx activity peaks compared to Se NPs with a single dose of Se at 0.055 mg/kg (Saadi et al., 2019).

Dietary Se NPs increased the HDL concentration (37.33 vs 30.37 mg/dL), while decreased LDL (25.53 vs 32.27 mg/dL) in lambs. Also, the concentrations of T4 (1.59 vs 1.23 nmol/L) and GPx (447.39 vs 239.24 kat/Lµ) were also increased with Se NPs diets. In this study, the combined diet of Se NPs and conjugated linoleic acid (CLA) had not a significant effect on these values PPARγ isoforms are portion of the organising effects of dietary fatty acids on gene expression and interfere in the fat storage and is seen to be great in adipose tissue. SCD1 is one of the genes studied to change the ratio of saturated / unsaturated fatty acids. Se NPs increased the expression of GPX1 and SEPW 1 (the gene encoding Selenoprotein W protein) in the liver. The combined diet of Se NPs and CLA differently had important impacts on the expression of GPX1, SEPW1, PPARβ1, and SCD1 genes. (Ghaderzadeh et al., 2019). Se NPs developed the antioxidant situation in dairy cows by promoted plasma Se and GSH-Px with enhance of gene expression. The total milk Se concentration and mammary gland mRNA expression levels of GSH-Px 1, 2, and 4; thioredoxin reductase 2 and 3; and selenoproteins W, T, K, and F were improved in cows fed with Se NPs (Han et al., 2020).

Effects of selenium nanoparticles diets on blood parameters in ruminants

Analysis results related to the relationship between Se NPs and hematological parameters have been reported. Red blood cell (RBC) count, packed cell volume (PCV) value, hemoglobin (Hb) concentration, and white blood cell (WBC) counts are among hematological parameters. Sadeghian et al. (2012) reported that Se NPs increased WBC on days 20 and 30 in sheep.

Some researchers have studied the relationship between selenium sources and iron (Fe), zinc (Zn), copper (Cu), molybdenum (Mo), manganese (Mn), cobalt (Co) (Kojouri et al., 2012b; 2017; Yaghmaie et al., 2017; Kachuee et al., 2019). Kojouri et al. (2012b) evaluated the effects of Se NPs and sodium selenite on iron homeostasis, the expression of transferrin and transferrin binding receptor genes in Lori-Bakhtiary sheep. Transferrin and its receptor gene expression resulted in a significant increase with the use of 1 mg/kg Se NPs. However, transferrin expression and its receptor gene expression reduced after 20 days due to improved total iron-binding capacity and decreased serum iron concentration. In another study, Kojouri et al. (2017) stated that 1mg/kg Se NPs improved serum selenium, copper, manganese concentration and reduce serum zinc concentration in Lori–Bakhtiary sheep. Se NPs showed no effects on Cu, Zn, Fe in lambs (Yaghmaie et al., 2017). Se NPs decreased serum Cu concentration in goats and their kids (Kachuee et al., 2019). Se NPs and other Se sources have effects on these elements but these effects depend on a chemical or physical variety of body.

Effects of selenium nanoparticles diets of spermatozoa in ruminants

Shahin et al. (2020), stated a favorable impact of the involvement of Se NPs diets to semen extender for increasing the cryotolerance of camel epididymal spermatozoa. They stated that Se NPs could increase the progressive motility, sperm membrane integrity, and vitality and reduce the apoptosis of sperm when frozen and thawed. The favorable impact can be an outcome of size of Se NPs result in developed bioavailability and later decreasing refuse liberation of harmful matters (especially ROS). Se NPs have also demonstrated positive effects on cryopreservation of sperm, semen purification, and preservation treatments. Se NPs (0.5 and 1 µg/mL) in extender showed positive effects on motility, acrosome and ram sperm membrane integrity protection compared to control group (Hozyen and Al-Shamy, 2018). Nateq et al., (2020) stated that 1 µg/ml Se NPs increased the percentage of viability, total and progressive motility, plasma membrane integrity, and reduced acrosome membrane damaged and abnormal sperms according to others groups (2 µg/ml Se NPs and control group). But, there is a requirement to research Se concentrations, compounds of diverse cryoprotectants, and confirmation of post-thaw ruminants sperm fertility.

Table 1. The effects of Se NPs diets in ovine-bovine nutrition

SN	Ovine species	Nano Se size	Dose	Time	Additive	Remarks	Effect	References
1	Boer Goat	60-80 nm	0.3 ppm	12 weeks		Se levels in liver, spleen, kidney, lung, and testis	+	Shi et al., 2009
						Se levels in serum and blood		
						Liver GPx		
						Growth performance	Ns*	
2	Holstein Cow	---	0.15, 3 mg/kg	--	Vitamin E (5000, 10000 IU)	Se and vitamin E levels in plasma	+	Weixing et al., 2009
						GPx in serum, TAOC		
						MDA, ROS	-	
3	Boer Goat	60-80 nm	0.3 mg/kg	12 weeks		Testicular Se level	+	Shi et al., 2010
						Semen and testicular GPx		
						ATPase activity		
						Semen quality	Ns	
5	Sheep	60- 80 nm	0.3, 3, 6 g /kg	80 days		Nutrients digestibility	+	Shi et al., 2011a
						Propionate		
						Total ruminal volatile fatty acids levels		
						Rumen microbial activity		
						Molar proportion of acetate and butyrate	Ns	
						Ruminal pH	-	
6	Black Goat	60-80 nm	0.3 mg/kg	90 days		Se levels in blood and serum	+	Shi et al., 2011b
						Serum GPx, SOD, CAT		
						Se retention of whole blood, serum		
7	Cashmere Goats	10-50 nm	0.5 mg/kg	from 30 days prior to gestation to fetal day 110		Ammonia N content	+	Wu et al., 2011
						Ratio of acetate to propionate		
						Expression of GPx, IGF-1 and IGF- 1R		
						IGF-I, Se and TAOC in both fetal serum and skin		
						GPx, SOD		
						Weights of fetal liver and kidney tissues	Ns	
						Secondary hair follicles and the secondary to primary follicle ratio	-	
8	Sheep	80-200 nm	1 mg/kg	30 days		Total	+	Sadeghian et al., 2012
						Ruminal volatile fatty acids concentration		
						Ruminal pH		
						Ammonia N concentration		
						Molar proportion of propionate	Ns	
						Ratio of acetate to propionate	-	
9	Sheep	80-200 nm	1 mg/kg	30 days		The neutrophil counts	+	Kojouri et al., 2012a
						TBARS		
10	Sheep	<220 nm	1 mg kg	30 days		WBC, PCV, RBC	+	Kojouri et al., 2012b
						Lymphocyte counts	Ns	
						Chemotactic activity	-	
						Respiratory burst activity		
						Iron binding capacity at 20 day		

Table 1. continues

11	Sheep	60-80 nm	4 mg/kg	25 days		ED of L. chinensis DM and aNDF	+	Xun et al., 2012
						Propionate		
						Total Purine derivates		
						Allantoin		
						Ruminal pH	-	
						Ammonia		
12	Lori–Bakhtiary Sheep	---	1 mg/kg	30 days		The expression of transferrin and transferrin binding receptor at 10, 20 day	+	Kojouri et al., 2017
						Transferrin saturation percent	-	
13	Lamb	-	0.1 mg/ kg	63 days		Zinc levels	+	Yaghmaie et al., 2017
						Se in plasma and erythrocytes	Ns	
14	Ram	40 nm	0.5, 1 and 2 µg/ml	At 4 °C for 2h after cooling 90 min		Sperm motility %	+	Hozyen and El-Shamy, 2018
						Tail DNA %	Ns	
						Tail moment		
						Acrosome defect %	-	
						MDA		
15	Ossimi Lambs		0.3 mg/kg	4 months		FBW, ADG, FI,	+	Ibrahim and Muhamed, 2018
						DM, OM, CP, CF, EE, NDF, NFE, DCP, TDN		
						Total protein, globulin, glucose, T-AOC, GSH-Px, Testosterone		
						FC	-	
16	Moghani Lambs		1 and 2 mg/kg	90 days	Conjugated linoleic acid (CLA) 15 mg/kg	HDL, LDL, VLDL, Cholesterol	NS	Ghaderzadeh et al., 2019
						T3, T4		
						GPx, Glucose, TG,		
						TP		
						GPX1	+	
						SEPW1		
						PPARβ1		
						SCD1		
17	New Zealand White rabbits	60 -80 nm	4 mL (in week)	2 months		SOD, GPx, GSH, ATP, T-AOC, AST	+	Eid et al., 2019
						Serum IgG and IgM, T3, T4		
						GSSG, NO, MDA, 8-OHdG, ALT	-	
18	Khalkhali Goat	45 nm	0.6 mg head/day	4 weeks		GPx in erythrocyte	+	Kachuee et al., 2019a
						Se, GPx levels in blood	-	
19	Khalkhali Goat	45 nm	0.6 mg/head/day	4 weeks		Serum IgG concentration, colostrum IgG, and blood IgG	+	Kachuee et al., 2019b
						Serum and blood selenium concentrations	+	
20	Lamb	-	0.05, 0.1 mg/kg	20 days		Stearoyl-CoA desaturase enzyme	+	Esmaeeli et al., 2020
21	Dairy Cow		0.3 mg/kg	30 days		Plasma Se levels and GSH-Px activity, SelT	+	Han et al., 2020
						GPX1, GPX2, GPX4, THXNRD3		

Table 1. continues

22	Holstein Dairy Cow			28 days		Blood serum albumin	-	Hashemi et al., 2020
						Blood serum bilirubin		
						Dry matter intake	Ns	
23	Lamb	50 nm	0.055 mg/kg	8 weeks		Se and GPx in plasma, blood and erythrocytes	+	Saadi et al., 2020
24	Tibetan Gazelle	-	0.5, 1, 1.5 mg/kg	30 days		Se in blood and hair	+	Shen et al., 2020
						GSH-Px, SOD, CAT, T-AOC		
						MDA	-	
25	Lamb		0.1 mg/kg (7 days)	28 days		Se in serum	+	Kojouri et al., 2020
						TBARS, Weight gain		
						Copper and zinc in serum	-	
26	Lamb	30 nm	1 and 2 µg/ml	2 months		Total motility for sperm	+	Nateq et al., 2020
						Progressive motility for sperm		
						Viability for sperm		
						Plasma membrane integrity for sperm		
						MDA, Acrosome membrane damage for sperm	-	
27	Rabbit		25 and 50 mg/kg (for biosynthesis)	8 weeks	Heat stres	BW, DBWG, Carcass percentage	+	Sheiha et al., 2020
						FI, IFNγ	Ns	
						FCR, GGT, TG, IL-4	-	
						NO, MDA, SOD		
						GSH, CAT, Lactic acid bacteria	+	
						Total Bacteria Caunt	-	
						Total Yeasts and Molds Caunt		
						Salmonella and *Shigella, Esherichia coli*		
						Total Enterococci Count		
28	Rabbit		25 and 50 mg/kg (for chemical synthesis)	8 weeks	Heat stres	BW, DBWG, FI	-	Sheiha et al., 2020
						FCR	Ns	
						IFNγ, Carcass percentage	+	
						GGT, TG, IL-4	-	
						NO, MDA, SOD	-	
						GSH, CAT, Lactic acid bacteria	+	
						Total Bacteria Caunt	-	
						Total Yeasts and Molds Caunt		
						Salmonella and *Shigella, Esherichia coli*		
						Total Enterococci Count		

*Ns, no significant differences ($p > 0.05$). ***SN:** Serial No; **GSH-Px**: Glutathione peroxidase; **GSSG:** Glutathione disulphide; **SOD:** Superoxide dismutase; **CAT:** Catalase; **TBARS**: Thiobarbituric acid reactive substances; **MDA**: Malondialdehyde; **IGFI**: Insulin-like growth factor 1; **IGFI-R**: Insulin-like growth factor 1 receptor; **NO:** Nitric oxide; **8-OHdG:** 8-hydroxy-2'-deoxyguanosin; **T3:** Triiodothyronine; **T4:** Thyroxine; **AST:** Aspartate aminotransferase, **ALT:** Alanine aminotransferase; **RBC:** Red blood cell; **WBC:** White blood cell; **PCV:** Packed cell volume; **DM:** Dry matter; **OM:** Organic matter; CP: Crude protein; **CF:** Crude fiber; EE: Ether extract; **NDF:** Neutral detergent fiber; **ADF:** Acid detergent fiber; **FC:** Feed conversion; **FI:** Feed intake; **DCP:** Digestible crude protein; **TDN:** Total digestible nutrients; **GGT:** Glutamyl transferase; **TG:** Triglyceride; **IL-4:** interleukin 4; **IFNγ:** İnterferon-gamma; **GSH:** Reduced glutathione; **HDL:** High density lipoprotein; **LDL:** Low density lipoprotein; **T3:** Triiodothyronine.

CONCLUSIONS

Based on the information given in this review, it can be suggested that Se NPs promotes growth, antioxidant mechanism, immunological defense, and rumen fermentation in ruminants. Also, Se NPs can be used more effectively when compared to inorganic or organic Se resources. Therefore, Se NPs, as a substitute to the conventional Se sources, can be a good alternative in ovine-bovine feeding. Further extensive research for exploring absorption mechanisms, distribution, metabolic pathways, excretion, safety, optimum dose/form of Se NPs is proposed the best utilization of nano material based application of Se feeding in ovine-bovine.

Statement of Conflict of Interest

Authors have declared no conflict of interest.

Authors' Contributions

The contributions of authors are equal.

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