Review Article

Role of Selenium in Ruminants Health and Reproduction

Abstract

Selenium (Se) which was earlier classified as a toxic element, has now been proved to be an essential mineral required for proper health, immunity, and reproductive functions of animals. Se status of animals and plants varies markedly around the world as a result of different geological conditions and the concentrations of Se in plant material are highly correlated with those in the soil. Se deficiency has been linked to many health problems in young animals such as increased neonatal mortality, decreased sucking reflex, weakness, higher occurrence of infectious diseases and white muscle disease. In recent years, there has been considerable interest in the use of Se in ruminant diets. Different forms of Se routinely used for dietary supplementation are inorganic, organic and nano Se.

Keywords: Selenium, neonatal mortality, energy metabolism, animal health

Introduction

Minerals are inorganic substances that cannot be synthesized in body, but are required in small amount to support different metabolic functions of body [1]. 22 minerals are needed for animals. Out of these minerals, 15 are micro minerals and 7 macro minerals [2].Trace minerals, though required in small quantities (less than 100 mg/kg dry matter) have critical roles in immune function, oxidative and energy metabolism in ruminants which are directly or indirectly involved in growth, production and reproduction [3]. They include cobalt, copper, iodine, iron, manganese, molybdenum, Se and zinc [4]. Among these, Se is currently acknowledged to be an essential dietary trace element required for various body functions such as growth, reproduction, immune system and protection of tissue integrity [5]. Some minerals such as Nickle, Chromium, arsenic and Vanadium are known to clearly have a role in animal health but the exact biochemical nature is unknown and its essentiality have weak evidences [6] [7] [8] [9].

Status of Selenium

The Se status of animals and plants varies markedly around the world as a result of different geological conditions and the concentrations of Se in plant material are highly correlated with those in the soil. Agricultural production system in developing countries is under pressure to fulfil the requirement of growing population, which has led to indiscriminate use of fertilizers resulting in severe deficiency of micro minerals in soil. The deficiency of Se in soil and crop plants has been reported in many countries like India, China, Turkey and Pakistan [10]. The concentrations of Se in plant material are highly correlated with those in the soil. Fertilization of soil with Se increases Se concentrations in plants [11]. The Se status in animals and plants varies markedly around the world as a result of different geological conditions. High Se concentrations are associated with some phosphatic rocks, organic rich black shales, coals, and sulphide mineralization, whereas most other rock types contain very low concentrations. Globally Se deficient soils are far more widespread than are seleniferous ones [12].Animal health is affected by Se deficiency or excess in the diet, the intake of Se being dependent on the amount of Se taken up by plants as bioavailable Se [13].

Chemical Nature

Se is a naturally occurring metalloid element that is essential to human and animal health in trace amounts but is harmful in excess. It was first identified in 1817 by the Swedish chemist, Jons Jakob Berzelius. It has chemical and physical properties intermediate between metals and non-metals and is similar to those of sulphur, arsenic and tellurium, all of which are in Group VI of the periodic chart of the elements [14]. Like Sulphur, Se can exist in different oxidation states as selenide (2-), Se (0), selenite (4+) and selenate (6+), respectively. It behaves antagonistically with Copper and Sulphur in humans and animals inhibiting the uptake and function of these elements [15].

Essentiality of Selenium

Se which was earlier classified as a toxic element, has now been proved to be an essential mineral required for proper health, immunity, and reproductive functions of animals. The essentiality of Se was proved for the first time from the work that liver necrosis in rats [16]. and exudative diathesis in chicks could be prevented by supplements of Se. Se is required to maintain normal physiological functions and provides a significant dietary source of antioxidant defenses [17]. It is present in all cells and tissues and is necessary for maintaining the vital functions of humans and animals. The content of Se in the organism is naturally very low, the majority of Se being bound in tissues and blood in the form of selenoproteins. It is a component of at least 25 selenoproteins with antioxidant, anti-inflammatory and chemoprotective properties [18].. The most important are glutathione peroxidases (GSH-Px-1, GSH-Px-6), thioredoxin reductases (TrxR1–TrxR3), iodothyronine deiodinases(ID1–ID3), selenophosphate synthetase, Selenop, and selenoprotein W. This element acts as a cofactor of the GSH-Px family of enzymes which protect against oxidative stress. Specifically, Se-dependent GSH-Px enzyme recycles glutathione, reducing lipid peroxidation by catalysing the reduction of peroxides, including hydrogen peroxide. In general, all these enzymes in their reduced state catalyse the breakdown of lipid hydroperoxides and hydrogen peroxides in cells [19]. GSH-Px and selenoprotein P are also involved in the regulation of the inflammatory response.

Important role of selenium in health and reproduction

The ability of Se to improve the immune response in farm animals is well documented [20]. Se deficiency has been reported to decrease humoral immune response and neutrophil killing activity in cattle without any clinical signs [21]. Moreover, [22]. reported that dietary Se supplementation increases antibody titre, neutrophils killing activity and reduces morbidity and mortality in beef cattle. Se improves phagocytosis in white blood cell populations. It might have been a boost in the passive immunity by enhancing immunoglobulin G (IgG) absorption in the new born lamb [23]. The improvement of immune cell functioning is likely due to the enhanced antioxidant status [24].Se performs significant functions in the male reproductive systems which are regulated by selenoproteins, especially GSH-Px4 (Glutathione peroxidase) and SELENOP (Selenoprotein-P) (Qazi et al., 2019). GSH- Px4 is distinctly expressed in testes and has both an antioxidant as well as a structural role; the latter context is evident from a fact that it constitutes over 50% of mitochondrial capsule (as an oxidatively inactivated protein) in midpiece of mature sperm [25].In an early stage of spermatogenesis, GSH-Px4 is believed to protect the developing sperm from oxidative stress-induced DNA damage, however, in the later phase, through cross linkage with proteins in midpiece region, it provides the integrity to the sperm midpiece by becoming a structural component of mitochondrial sheath circumventing the flagellum, which is an essential component for sperm stability and motility.

SELENOP serves as a transport protein for Se and is also expressed in vesicle like structures in the basal region of the Sertoli cells [26].Male reproductive tissues are constantly exposed to reactive oxygen species (ROS) generated as products of normal metabolism, and during the fertilization process spermatozoa normally pass through an area of high oxygen level [27]. Mammalian spermatozoa membranes have a high content of polyunsaturated fatty acids and are highly susceptible to lipid peroxidation caused by reactive oxygen species (ROS) overproduction [28]. ROS induced damages decreased both semen quality and sperm function. High ROS concentrations lead to pathologic changes in sperm cells by intensifying lipid peroxidation, which eventually results in their motility and viability loss [29]. Several defence mechanisms including antioxidant help in counteracting ROS detrimental effects and maintain sperm motility and viability [30]. The activity of the cytoplasmic antioxidant enzymes in sperm cells is very low [31], and the small amount of the cytoplasm in their heads and tails makes them susceptible to oxidative stress Unlike spermatozoa, seminal plasma is a vital source of antioxidants, including glutathione peroxidase (GSH-Px), superoxide dismutase (SOD), uric acid and vitamin E [32]. Activity of Se-dependent phospholipid hydroperoxide GSH-Px (PH-GSH-Px, GSH-Px4) is very pronounced in late (meiotic) spermatogenic cells, where it acts as a structural protein in sperm heads, whereas the nuclear form GSH-Px4 contributes to chromatin condensation [33].

Se also helps in testicular growth and development of seminiferous tubules, spermatogenesis, steroidogenesis in testes, synthesis and secretion of follicular stimulating hormone (FSH) and luteinizing hormone (LH) [34]. Supplementation of Se has been found to improve semen quality by increasing antioxidative defence of seminal plasma in buck [35], boar [36] Boer goats [37] ram [38] and cockerels [39]. Se deficiency has been linked to many health problems in young animals such as increased neonatal mortality, decreased sucking reflex, weakness, higher occurrence of infectious diseases and white muscle disease [40]. It may also result in immune and endocrine disorders, especially thyroid dysfunction [41].

Supplementation sources and its bioavailability

The bioavailability of Se is associated with its forms. Generally, Se is utilized as inorganic, organic and nano forms. Form of Se supplementation has an important bearing on its possible ameliorative effects and/or on general wellbeing and development of organisms [42]. Both form and the total intake of Se are equally important with regards to the potential health- related effects. It has been reported that organic forms of Se have greater bioavailability compared to the inorganic forms [43].because sodium selenite and sodium selenate must first be converted to hydrogen selenide and then to selenophosphate before they can be utilised in selenoprotein synthesis [44]. The most common inorganic Se sources are sodium selenite (SS) and sodium selenate, which are usually provided in mineral premixes or injected. Organic Se sources are seleno-amino acids (e.g. selenomethionine (Se-Met) and selenocysteine), which are found in Se yeast or in feeds grown on Se-rich soils. Recently, elemental nano-Se has attracted a wide spread attention to its high bioavailability and low toxicity [45] [46]. Nano minerals improve the bioavailability due to its novel characteristics such as high surface activity, a lot of surfaces active centers, strong adsorbing ability and high catalytic efficiency [47]. Nano-Se has efficient functions on animal growth, reproduction and immunity systems [48]. In sheep, Nano- Se had improved ruminal fermentation, nutrient digestibility [49]. In addition, some reports on rats and mice demonstrated that Nano-Se had higher efficiency than sodium selenite and other Se sources in up-regulating selenoenzymes, exhibiting lower toxicity [50]. Subsequent studies also pointed out that Nano-Se has more beneficial effects to improve activity of glutathione peroxidase, blood biochemical indices with lower toxicity comparing with organic or inorganic Se sources [51].

Conclusions:

Adequate essential trace mineral intake and absorption is required for a variety of metabolic functions including immune response, reproduction and growth. Se is recognized as an essential trace element, and its deficiency has been associated with impaired growth, fertility, and health in farm animals. Diets for ruminant animals are often of plant origin and the Se concentration within plants can be extremely variable. Consequently, concentration of dietary Se can be deficient, and Se supplementation may be required. Supplementation of trace elements in animal diets has long been practiced to ensure optimum growth production and improve immune response. In recent years, there has been considerable interest in the use of Se in ruminant diets. Different forms of Se routinely used for dietary supplementation are inorganic, organic and nano Se. There are reports of improved growth, better production performance, reproduction and health in ruminants fed inorganic, organic and nano Se.

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