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Mini Review

Influence of Mineral Supplementation on the Sperm Production and Quality in Ruminants

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Abstract

This study aimed to review the main minerals and their functions on the sperm production and quality in ruminants. Among the most important macroelements for sperm activity, some characteristics of sodium, potassium, chlorine, calcium, phosphorus and magnesium are addressed. In relation to microelements with great importance for the reproductive activity of ruminants, some peculiarities of selenium, zinc and manganese are described.

Keywords: *Macroelements; Microelements; Semen; Ovine; Bovine*

Introduction

Reproductive efficiency is the main component for animal production to become economically viable and can be influenced by several factors, such as breed, age, health and nutrition. Among the components of the diet, minerals have a major impact on reproductive efficiency in ruminants.

Although there are several minerals that participate in several metabolic and physiological processes in animals, only 15 are essential, with seven mineral macroelements (sodium, chlorine, calcium, phosphorus, magnesium, potassium and sulfur) and eight microelements (iodine, iron, copper, cobalt, manganese, molybdenum, zinc and selenium). According to Alonso., *et al*. [1], of all the minerals indicated as essential, one of the most important for reproduction is selenium.

Microminerals are essential elements in metabolism at all stages of animal development, being extremely important in reproductive processes. Among the important minerals of a diet are: chromium, cobalt, manganese, selenium, zinc, iodine, arsenic and nickel, being considered essential for all animals [2]. The microminerals copper, zinc, cobalt and selenium are present in small concentrations and are important for the most diverse functions of the organism, including reproductive activity [3-5].

Mineral supplementation of animals can be performed by incorporating the element into the diet, water, mineral supplementation, intraruminal bolus or injectable solutions [6,7]. The concentration and availability of minerals in the body's tissues and fluids may change with the ingestion of unbalanced diets or with excess minerals. Physiological functions can be altered causing injuries and structural disorders, which vary according to the mineral element, degree of duration of the deficiency, toxicity of the diet and intrinsic factors of the animals, such as age, sex and species [8].

Mineral requirements in ruminants vary according to the type and level of production, the age of the animal, the breed and degree of adaptation of the animals, the level and chemical form of the mineral in the food, and its relationship with other nutrients of the diet [9].

The present study aimed to describe the main functions of some minerals on the production and sperm quality of ruminants.

Main minerals related to ruminant reproduction

Sperm activity is totally dependent on the ionic environment. Seminal plasma has an ionic composition that varies between species and also between animals of the same species [10].

Among the most important macroelements for sperm activity, some characteristics of sodium, potassium, chlorine, calcium, phosphorus and magnesium will be addressed. In relation to microelements with great importance for the reproductive activity of ruminants, some peculiarities of selenium, zinc and manganese will be described.

According to NRC [11], the availability of minerals varies according to the type of forage, concentrate and inorganic sources. Table 1 lists the mineral requirements for beef and dairy cattle.

Minerals	Beef cattle		Dairy cattle		Growth
	Pregnant	Lactation	Transition	Lactation	
Calcium (%)	0.16 to 0.27	0.28 to 0.58	0.44 to 0.48	0.53 to 0.80	0.40 to 0.80
Phosphorus (%)	0.17 to 0.22	0.22 to 0.39	0.22 to 0.26	0.44 to 0.32	0.22 to 0.50
Potassium (%)	0.60	0.60	0.51 to 0.62	1.00 to 1.24	0.60
Sodium (%)	0.06 to 0.08	0.10	0.10 to 0.14	0.19 to 0.34	0.06 to 0.08
Manganese (ppm)	40	40	16 to 24	12 to 21	20
Selenium (ppm)	0.10	0.10	0.3	0.3	0.10
Zinc (ppm)	30	30	21 to 30	43 to 73	30

Table 1: *Mineral requirements for beef and dairy cattle.*
Source: NRC [11].

Concentrations of chlorides, sodium and potassium were directly related to the maintenance of sperm excitability, ideal seminal pH and osmotic pressure inside and outside the sperm cell [12]. Sodium and potassium are considered to be the main electrolytes that influence sperm viability and are found in high concentrations in epididymides [13]. The estimation of these constituents can be used to predict semen quality, sperm freezability and fertility of bulls, helping to select breeders for use in artificial insemination programs [14].

Sodium and potassium when in low concentrations can cause a decline in fertility. This situation, however, is uncommon and can occur, in the case of sodium, when there is no supplementation of the diet with common salt. Like calcium, these elements are responsible for sperm motility. Potassium is correlated with sperm concentration and the percentage of live sperm in the ejaculate, whereas sodium acts to maintain osmotic pressure. Both potassium and sodium help in regulating the pH of the ejaculate [15].

Calcium is an essential element, an important regulator of sperm physiology, which is present in higher concentrations in seminal plasma than in blood, with an especially prostatic, epididymal origin and, to a lesser extent, from the vesicular glands. The intracellular concentrations of this cation regulate motility and hyperactivation of sperm, chemotaxis, capacitation, acrosome reaction, sperm egg binding and fusion, in addition to embryo metabolic activation [16-18].

The capacitation process depends on changes in membrane permeability linked to the transport of calcium ions [19]. The lower fertility of frozen bull semen after thawing was related to the higher concentration of intracellular calcium, probably caused by damage induced by cryopreservation [20]. Calcium triggers the acrosome reaction in mammalian sperm. Various evidences show that it is involved differently in motility, depending on the stage of sperm maturation [21]. The concentrations of total and ionized calcium are positively correlated with the ejaculate volume, attributing to the accessory sexual glands the role of main sources of calcium in the seminal plasma [22].

Phosphorus plays an important role in fertility, as it participates in energy (ATP) transfer processes and as a second messenger (cAMP). Phosphorus deficiency in males can lead to testicular degeneration [23]. cAMP is related to sperm motility and capacitation [24]. The participation of phosphorus in cAMP and phospholipids can influence the action of reproductive hormones. In males, phosphorus infertility usually occurs after the onset of other signs of deficiency [23].

Magnesium is an important cation observed in almost all enzymatic systems, it seems to have a key role in spermatogenesis, particularly in sperm motility, by inducing adenyl cyclase activity [24]. Although magnesium is found in high concentrations in semen, its role in sperm quality has not yet been fully elucidated. Important changes in magnesium concentration seem to be related to the abnormal function of sperm and their fertilizing capacity, however, no significant differences were detected in the concentrations of these cations in the semen of normospermic, oligospermic or azoospermic men [25]. It is also known that magnesium is considered a marker of seminal gland secretion and that it acts as an intracellular calcium antagonist [21].

Selenium is an important mineral in metabolic functions, an antioxidant in spermatogenesis and participates as a component of numerous selanoproteins [26]. Very small amounts of selenium are necessary to maintain good health in animals [27]. Its supplementation improves reproductive activity, being important for spermatogenesis and testicular development [28]. Selenium, a non-metal, is present in the Earth's crust at an average of 90 µg/kg and the levels are higher in volcanic rocks and sedimentary soils and can subsequently accumulate in several plants [27].

Selenium sources can be organic or inorganic. Selenomethionine and selenocysteine are organic forms, derived from plant and animal foods, while sodium selenate and sodium selenite are inorganic sources [29].

Barbosa and Souza [26] described that selenium is an important mineral in metabolic functions, an antioxidant in spermatogenesis and participates as a component of numerous selenoproteins including the enzyme glutathione-peroxidase (GPX1; GPX3; GPX4; GPX5), protecting sperm during maturation. The lack of these selenoproteins during spermatogenesis can lead to a decrease in the ejaculate quality, fertility rates and a decrease in the libido of bulls.

Selenium is absorbed mainly in the duodenum through a co-transport system with amino acids, catabolized and incorporated into glutathione-peroxidase. These selenoproteins are transported to the liver and converted to selenoprotein P and distributed to various organs such as the brain, kidneys, heart, spleen, muscles and gonads [30].

Selenium deficiency causes low milk and wool production in sheep [31,32] and low seminal quality in bulls [33]. This deficiency can result in a subclinical condition leading to muscle weakness in neonates, immunosuppression, reduced weight gain and score, infertility, abortion and retained placenta [34], decreased testis and, in the long run, can cause atrophy of the seminiferous tubules [35]. The high percentage of changes in head, tail and azoospermia, induced by selenium deficiency, can interfere with sperm motility and increase the incidence of sperm with changes in the intermediate part [33,36]. Although selenium deficiency can occur in all species, ruminants appear to be more susceptible to the disease, with more severity in small ruminants [37-39].

Studies have shown that selenium is necessary for the maintenance of male fertility and its deficiency can cause changes in sperm morphology as an altered and fragile intermediate part with the mitochondria, being irregularly wrapped around the flagellum [40,41]. In addition, this deficiency induces a lower production of selenoprotein, impairing the gametogenesis of the male, in addition to altering the morphology of spermatozoa that present with: tail alteration, head deformations, deformations of the intermediate part, with even structural rupture; decreased number in the ejaculate (oligospermia); presence of dead sperm (necrospermia) and low resistance to the thermoresistance sperm test [42]. Thus, selenium is essential for sperm motility, due to its antioxidant effect, acting mainly on the mitochondria of the intermediate part of the sperm [43].

In another study carried out in sheep, supplementation with selenium decreases the percentage of sperm defects, however, it had no direct effect on the ejaculate volume, sperm swirling, total motility, vigor and the concentration [44]. According to Moya., *et al*. [45], diets supplemented with selenium have been associated with reduced damage to sperm DNA in sheep.

Zinc originates mainly from the prostate, and plays a key role in sperm motility, exercising protective and antioxidant activity. It is also considered an antimicrobial factor against gram-negative and positive bacteria [46]. Deficiency of this element can lead to failures in spermatogenesis, atrophy of seminiferous tubules, and therefore hypogonadism and high incidence of changes in sperm morphology, in addition to impairing the production of luteinizing hormone (LH), follicle stimulating hormone (FSH) and testosterone. Damage of a zinc-deficient diet is much more pronounced in young animals, especially during the puberty phase, than in adults [15,47].

Calves, at eight months of age, which received adequate levels of zinc from birth to weaning have, on average, double the scrotal circumference, in relation to those calves that had a deficient diet, in addition to better semen quality at 24 months of age [48].

Manganese is involved in the protection of the plasma, acrosomal and mitochondrial membranes of sperm against free radicals, which have a high oxidative action and can cause damage to sperm membrane and DNA [49]. The deficiency of this mineral can affect sperm production, decreasing the concentration and motility of sperm, causing a testicular degeneration, increasing the number of abnormal sperm, but does not affect libido. This is because this mineral acts as a cofactor in enzymatic systems, as a constituent of several metalloenzymes and in the synthesis of reproductive hormones [50].

Conclusion

Adequate mineral supplementation is the way to meet the daily needs of farm animals, and is essential, as it contributes to improving sperm production and quality in ruminants, and thus improving the cost: benefit ratio in the animal production system.

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