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Review Article

Interactions between Dietary Minerals and Reproduction in farm Animal

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ABSTRACT

The production efficiency of farm animals is largely dependent on their reproductive performance, and there are interactions between reproductive performance and mineral status. Minerals are inorganic nutrients, usually required in small amounts and they play an important role in metabolic processes. For optimal productivity, twenty two (22) beneficial mineral elements have been identified and classified. These include copper, cobalt, potassium, phosphorus, magnesium, manganese, selenium, calcium, iodine, zinc, iron, chlorine, sodium, chromium, molybdenum and among others. Studies have shown that minerals are involved in intracellular detoxification of free radicals, biosynthesis of steroids and cellular metabolism of carbohydrate, protein and nucleic acid. Minerals have beneficial or detrimental effects on animal physiological wellbeing, depending on its balance. Some of the consequences of inadequate (deficiencies) or excesses dietary mineral intake include delayed puberty, impaired spermatogenesis and prolonged postpartum anestrus. The mechanisms by which minerals impinge on reproduction are not completely clear, but evidence exists, that their effects are mainly exerted at the higher neural centres or hypothalamus. Therefore this paper was an attempt to review the interaction between minerals and animal reproduction. It will also review the negative effect of mineral when they are over fed. Furthermore, this review could also serve as a ready source of literature for researchers in animal nutrition and nutritional reproductive physiology

Keywords: Micronutrient; minerals; farm animal; reproduction.

INTRODUCTION

Several factors are known to affect the reproductive performance of farm animals, some of which are biological type, physical environment and nutrition. The relationship between minerals and reproduction is a topic of increasing importance and concern among animal producers and feed manufacturers. Minerals are inorganic substances, present in all body tissues and fluids, and their presence is necessary for the maintenance of certain physicochemical processes which are essential to life. Although minerals yield no energy, they have important roles to play in many biological activities in the body (Malhotra, 1998;

Eruvbetine, 2003). Minerals are involved in metabolic, enzymatic and biochemical reactions needed for feed efficiency, growth and reproduction.

Minerals are broadly classified as macro (major) and micro (trace) elements. The third category is the ultra-trace mineral elements. According to Underwood and Suttle (1999), twenty six mineral elements are essential for animal physiological wellbeing. Macro mineral elements are those required in relatively high concentration in the ration, while micro mineral elements are those needed in the diet in minute concentrations (Esonu, 2006). Eleven of these are classified as macro elements and include carbon, hydrogen, oxygen, nitrogen, sulfur, calcium, phosphorous, potassium, sodium, chlorine and magnesium. The remaining 15 are classified as micro elements and include iron, zinc, copper, manganese, nickel, cobalt, molybdenum, selenium, chromium, iodine, fluorine, tin, silicon, vanadium and arsenic (Underwood and Suttle, 1999). The ultra-trace elements include boron, silicon, arsenic and nickel which have been found in animals and are believed to be essential for these animals.

According to Smith and Chase (2010), the interaction between mineral and reproduction in farm animals have been documented. These reports generally suggest that adequate mineral intake improves production efficiency and reproduction performance parameters in farm animals (Almeida *et al*., 2007; Griffiths *et al*., 2007). Minerals such as copper, zinc, selenium and molybdenum are involved in cellular respiration, maintenance of cell membrane integrity and sequestration of free radicals (Chan *et al*., 1998; Wright, 2012). Excess mineral intake results in loss of body weight and condition, and may delay puberty, reduce ovulation, lower conception rates, interferes with normal ovarian cyclicity by decreasing gonadotropin secretion and increases infertility (Boland *et al*., 2001; Wright, 2012). It was based on this understanding; that we considered it necessary to summarize the evidence available on functions and interactions between minerals and reproduction in farm animals.

Functions of Mineral Elements

The importance of minerals in animal production has been well recognized (Darby, 1976). According Murray *et al*. (2000) and Malhotra (1998) minerals perform four broad functions in animals. These include:

Structural: Minerals can form structural components of body organs and tissues, exemplified by minerals such as calcium, phosphorus and magnesium; silicon in bones and teeth; and phosphorus and sulfur in muscle proteins (Malhotra, 1998; Murray *et al*., 2000). Minerals such as zinc and phosphorus can also contribute structural stability to the molecules and membranes of which they are a part.

Physiological**:** Minerals occur in body fluids and tissues as electrolytes concerned with the maintenance of osmotic pressure, acid-base balance, membrane permeability and transmission of nerve impulses. Sodium, potassium, chlorine, calcium and magnesium in the blood, cerebrospinal fluid and gastric juice provide examples of such functions.

Catalytic**:** In biological system, mineral elements are mostly bound to proteins, forming metalloproteins. Minerals can also act as catalysts in enzyme and endocrine systems, as integral and specific components of the structure of metalloenzymes and hormones or as activators (coenzymes) within those systems. The number and variety of metalloenzymes and coenzymes identified has continued to increase since the late 1990s as shown in Table 1.

Regulatory**:** They regulate cell replication and differentiation; for example, calcium ions influence signal transduction and selenocysteine influences gene transcription, leading to its nomination as ‘the 21st amino acid’.

Sources of Minerals in Animal Production

Natural feed ingredients contain some minerals, but in intensive animal production system, supplemental minerals are provided in various forms including common salt, trace mineralized salt, oyster shell, limestone, bone meal, plant ash and a wide variety of other forms (Oso *et al.*, 2011; Okoli *et al*., 2014). Majority of the minerals used in supplementing intensively farmed animals come from rock and often are thought of as inert, inorganic substances (Table 2).

Table 1: Some important metalloenzymes and metalloproteins in animals

Metal	Metalloenzymes or metalloproteins	Functions
Cu	Superoxide dismutase	Dismutation of superoxide radical
Cu	Ceruloplasmin	Copper transport
Cu	Hephaestin	Iron absorption
Cu	Lysyl oxidase	Lysine oxidation
Cu	Cytochrome oxidase	Terminal oxidase
Fe	Hepcidin	Iron regulating hormones
Fe	Hemoglobin	Oxygen transport in the blood
Fe	Catalase	Protection against hydrogen peroxide
Fe	Succinate dehydrogenase	Oxidation of carbohydrates
Mn	Pyruvate carboxylase	Pyruvate metabolism
Mn	Superoxide dismutase	Antioxidant by removing superoxide radical
Mn	Glycosyl aminotransferases	Proteoglycan synthesis
zn	Alkaline phosphatase	Hydrolysis of phosphate esters
Zn	Phospholipase A2	Hydrolysis of phosphatidylcholine
Zn	Carbonic anhydrase	Formation of carbon dioxide
Se	Selenocysteine	Selenium transport and synthesis of selenoenzymes
Se	Type 1 and 2 deiodinases	Conversion of tetraiodothyronine to triiodothyronine
Se	Glutathione peroxidases (four)	Removal of H_20_2 and hydroperoxides

Source: Georgievskii *et al*., (1982)

These naturally occurring minerals are usually mined in their most unstable states and thereafter processed or used directly in animal feed (Rodrigues, 2010). Other mineral containing binders used in animal production include activated charcoal, which is prepared from wood, vegetables or other organic materials. Charcoal and plant ash are the residue of burnt plant parts like the bark, wood, saw dust, leaves, woody debris, pulp, husk and other plant debris (Ndhlovu, 2007; Rodrigues, 2010).

Research has shown that organic mineral sources are more bioavailable; however, production responses to supplementation have been variable. Positive responses to organic mineral supplementation are most likely during stressful periods in the production cycle (i.e. calving and weaning), or when mineral antagonists (i.e. sulfur, molybdenum, iron, or aluminum), are present in large amounts. However, most inorganic mineral elements are usually not readily bioavailable to the animal mainly due to antagonism amongst themselves (copper - molybdenum - sulphur complex) and other nutrients resulting in reduced absorption (Soetan *et al*., 2010). According to Power and Horgan (2007), animal nutritionists and feed producers have tended to solve this problem by increasing the quantity of the mineral element sources included in the feed, with resultant reduction in bioavailability, increased fecal residues and attendant environmental problems.

Generally, only a fraction of the minerals ingested by an animal is effectively absorbed, while most are bound to other components such as fiber and excreted (Underwood and Suttle, 1999).

Mineral Bioavailability

Generally, feeding animal with a ration that is high in a particular mineral does not mean the body will absorb the entire mineral during digestion (Table 3). In fact, the amount of the mineral that is ultimately available for use by the animal body depends on the nature of mineral (organic versus inorganic) and the amount the body can absorb and retain (bioavailability).

Several factors directly or indirectly affect the concentrations of minerals in plants and hence the amounts available for animals that depend on plants for feeds. Soil condition has been reported to influence the mineral compositions of feed ingredients (Kavanek and Janicek, 1969). For example, feeds grown on selenium enriched soils are good sources of selenium and may be used in diet formulation for non ruminants such as poultry in order to supply selenium (Merck, 1986). In addition, if an animal is deficient in a certain mineral, such as calcium, it will absorb a greater percentage of that mineral from feed. Similarly, if your body has an adequate amount of a mineral, it will absorb less of it from feed. Because some minerals can be toxic in high amounts, this ability to adjust the amount absorbed helps prevent the body from accumulating excessive amounts. Minerals often compete with each other for absorption in the gastrointestinal tract. Some minerals, such as calcium, magnesium, iron, copper, and zinc, are absorbed in their ionic state.

Table 2: Mineral supplements used in animal production

Compounds	Mineral present
Calcium carbonate	40% Ca
Limestone powder	38.5% Ca
Calcite powder	39% Ca
Dolomite stone	22.3% Ca ; 12.8 Mg
Dicalcium phosphate	23.3% Ca; 18.5% P
Magnesium carbonate	21 - 28 % Mg
Magnesium oxide	54 - 60% Mg
Magnesium sulphate	9.8 - 17% Mg
Zinc carbonate	52% Zn
Zinc chloride	48% Zn
Zinc sulphate	22 - 36 Zn
Potassium iodide	69% I
Calcium iodate	63% I
Copper sulphate	25% Cu
Cupric chloride	37.25% Cu
Cobalt sulphate	21% Co
Cobalt chloride	24.7% Co
Ferrous sulphate	26 - 30% Fe
Sodium chloride	39% Na ; 51% Cl

Source: Chopra and Kanwar (1991)

Table 3: General bioavailability of some minerals in forage plants used in feeding farm animals

Nutrient	Bioavailability
Phosphorus	60 - 65
Potassium	85 - 90
Calcium	30 - 35
Magnesium	15 - 20
Sulphur	85 - 90
Sodium	<0.05
Chloride	85 - 90

Source: http://mississippiforages.com

These minerals have the same ionic charge, so they compete for the same protein carriers during absorption. Thus, too much of one mineral (such as calcium, Ca^{+2}) can cause a decrease in the absorption and metabolism of another mineral (such as magnesium, Mg^{+2}), leading to an imbalance (Franklin *et al*., 1997). The degree to which each mineral is absorbed and utilized by the animal depends on the amount of both minerals in the intestinal tract at the time of absorption (Franklin *et al*., 1997). Mineral deficiencies or imbalances in soils or forages have been implicated, in part, for low animal production, and poor reproductive performance in the developing regions of the world (Alector and Omodara, 1994).

The bioavailability of minerals can also be reduced if the minerals are attached to binders such as oxalates or phytates and such bound minerals will pass through the intestinal tract unabsorbed, and be eliminated in the faeces (Osagie, 1998; Ogbuewu *et al.*, 2014). This call for adequate processing of plant based feed ingredients used in formulating animal ration in order to reduce their anti-nutritional factors (Soetan and Oyewole 2009). The levels of these substances in plants vary with the specie, part used and post-harvest treatment. Oxalate acid and phytate has the ability to bind divalent metals such as calcium and magnesium thereby interfering with their metabolism (Blood and Radostits, 1989). Chelates bind many elements making them nutritionally unavailable, thereby inducing dietary secondary deficiencies (Nelson *et al*., 1968). Zinc may be complexed with calcium-phytate and lead to inefficient utilization of dietary zinc. Adequate calcium intake will compensate for the reduced availability of calcium, but this will aggravate the zinc deficiency and such a relationship has frequently led to parakeratosis in pigs. Phytic acid reduces the absorption of calcium from the gastro-intestinal tract and consequently implicated in the development of rickets when chicks are fed cereals such as sorghum. Zinc and iron deficiency symptoms have been reported in birds (Lease, 1966) when fed diets high in phytic acid.

Mechanisms Involved In Mineral Mediated Impacts on Reproduction

The mechanisms of minerals mediated impact on reproduction are still not fully understood, because of the complexity of the neuro-hormonal dialogue and the equally complex nutrients partitioning involved. Nevertheless, some advances have been made, and interesting possibilities put forward. Some of these nutrient mediated effects act directly on the gonads and other reproductive organs, while others produce similar effects indirectly via the hypophyseal - pituitary -gonadal axis.

Table 4: Importance of mineral elements in animal reproduction

Mineral	Mechanism and metabolic functions	Interaction between minerals and reproduction
Sodium and potassium	Sodium and potassium are the principal cations in extracellular and intracellular fluids respectively. They regulate plasma volume and acid-base balance, preserves normal irritability of muscles and cell permeability, activates nerve and muscle function and involved in Na^+/K^+-ATPase (Malhotra, 1998; Murray *et al*., 2000).	Sodium and potassium is responsible for the maintenance of osmolarity and activity of spermatozoa (Ahmad and Chaudhry, 1980). Additionally, it regulates sperm motility and the acrosome reaction (Barfield *et al.*, 2005). Insufficient intake of sodium has been linked to general infertility and embryonic mortality in several farm animals (Dittman, 2008). Limited study suggests that feeding high levels of potassium may delay the onset of puberty, delay ovulation, impair corpus luteum development and increase incidence of anestrus in heifer. Smith and Chase (2010) reported lower fertility in cows fed high level of potassium or diets in which the K - Na ratio is too wide.
Sulfur (S)	Vitamin B complex (biotin and thiamin) and coenzyme A contain sulfur in their molecules (Malhotra, 1998). Connective tissue, skin, hair and nails are rich in sulfur. Proteins vary widely in sulfur content, depending on their amino acid composition. Ruminants that depend largely on non protein nitrogen sources, such as urea or ammonium phosphate, may need supplemental inorganic sulfur, which is utilized by the microorganisms for synthesis of methionine and cystine.	Tumenbaevish *et al.* (2012) revealed that the S - containing compounds increased mobility and survivability of the absolute rate of cryopreserved spermatozoa. According to Zhang *et al.* (2006) spermatogenesis was affected in the testes of male rats after SO_2 administration, as demonstrated by structural and functional changes of the testicular tissue together with disturbances in the hypothalamic-pituitary testicular axis (Holstein *et al*., 2003).
Magnesium (Mg)	Magnesium is the second most prevalent intracellular cation, which is essentially involved in the metabolic activity of the cell. It is an active component of several enzyme systems in which thymine pyrophosphate is a cofactor. Mg is an essential activator for the phosphate-transferring enzymes myokinase and creatine kinase. It also activates pyruvic acid carboxylase, pyruvic acid oxidase, and the condensing enzyme for the reactions in the citric acid cycle. It is also a constituent of bones, teeth, enzyme cofactor, (kinases, etc) (Murray *et al*., 2000).	The presence of Mg is necessary for capacitation, hyperactivation and acrosome reaction of spermatozoa (Semczuk and Kurpisz, 2006). Studies have shown that the Mg level in the seminal plasma increases with sperm concentration but has no significant relationship with sperm motility (Wong *et al*., 2001). On the other hand, positive effects of Mg on the motility, morphology and concentration of spermatozoa were reported by Marzec-Wróblewska *et al.* (2012). Kaludin and Dimitrova (1986) found a direct proportional correlation between Mg content and ram spermatozoa motility. Eghbali *et al.* (2010a) showed that the magnesium content in the seminal plasma was positively associated with the total antioxidant status of semen.
Phosphorus (P)	Phosphorus plays a key metabolic role and has more physiological functions than any other mineral (Marzec-Wróblewska *et al.*, 2012). It functions as a constituent of bones, teeth, adenosine triphosphate (ATP) and nucleic acids. Generally, P plays a major role in the maintenance of osmotic pressure, buffer capacity and acid-base balance.	Inadequate intake of P has been associated with decreased fertility rate, feed intake, milk production, decreased ovarian activity, delayed sexual maturity and low conception rates has been reported (Cromwell, 1997). Phosphorus is also needed for the maintenance of glycolysis and motility (Flerchinger and Erb, 1955). The phosphorus concentration detected in the seminal plasma of active bulls by Machal *et al.* (2002) was positively correlated with quantity and quality parameters of bovine semen.

Calcium	Calcium is the most abundant mineral in the body and 99% is found in the skeleton; however, small proportion of body calcium that lies outside the skeleton is important to survival (Suttle, 2010). During blood clotting, calcium activates the conversion of prothrombin to thrombin. Calcium also activates large number of enzymes such as adenosine triphosphatases, succinic dehydrogenase, lipase among others. It is also required for membrane permeability, normal transmission of nerve impulses and in neuromuscular excitability. Reduced extracellular blood calcium increases the irritability of nerve tissue, and at very low levels it may cause spontaneous discharges of nerve impulses leading to tetany and convulsions (Malhotra, 1998; Murray *et al*., 2000).	Calcium is required in many physiological processes as a regulator in all living cells, including sperm cells. Spermatozoa are highly differentiated cells with the plasma membrane being the major cellular component, involved in diverse and complex functioning of the sperm cell to achieve fertilization. Many of these functional processes are made effective by the transport of ions across the plasma membrane through ion channels, with various types of Ca channels being the most studied in the sperm behavior (Publicover *et al.*, 2007; Yeung and Cooper, 2008). According to Eghbali *et al.*, (2010a), calcium present in the seminal plasma of buffalo bulls plays an important role in preserving spermatozoa motility and viability, as well as antioxidant status by protecting the sperm cells oxidative damage. On the other hand, negative correlation between the calcium content in the seminal plasma and spermatozoa motility was found in bovine semen (Machal *et al.*, 2002). Results of Asadpour (2012) showed that high levels of calcium were associated with lower percentage of motile sperm in rams.
Manganese (Mn)	Cofactor of phosphohydrolases, phosphotransferases, hydrolase, decarboxylase, and transferase enzymes (Murray *et al*., 2000). It is involved in glycoprotein and proteoglycan synthesis and is a component of mitochondrial superoxide dismutase. Manganese is involved in the synthesis of proteoglycans in cartilage. Mn is a part of enzymes involved in urea formation, pyruvate metabolism and the galactotransferase of connective tissue biosynthesis (Chandra, 1990).	Heifers fed the inadequate manganese diet were older in age when they showed signs of estrus than heifers supplemented with manganese, and they also exhibited lower conception rates. In cattle and sheep, lack of dietary manganese reduced conception rate in females (McDowell, 2003). Hansen *et al.* (2006a, b) fed pregnant heifers diets deficient enough in Mn to result in deformed calves, but did not observe any effect on plasma cholesterol concentrations or conception rates. Manganese deprivation has also been shown to restrict testicular growth in rams (Masters *et al*., 1988).
Cobalt (Co)	Cobalt is required as a constituent of vitamin B_{12} and its metabolism. In addition to its role in vitamin B_{12}, cobalt is also a cofactor of enzymes involved in DNA biosynthesis and amino acid metabolism (Arinola *et al*., 2008).	Depletion of cobalt at parturition results to a decline in milk production (Patterson *et al*., 2003). Pedigo *et al.* (1988) showed that chronic exposure to cobalt dramatically affected the male mice fertility in dose-dependent manner, while acute administration had minimal effects. Likewise, continuous exposure of male mice to cobalt (400 ppm) in drinking water resulted in a reproducible, sequential pattern of seminiferous tubule degeneration (Anderson *et al*., 1992). Generally, the number of pregnant females was significantly decreased in the exposed mice. Also, the number of viable fetus was decreased in females impregnated by exposed males at the three different concentrations of cobalt.
Chromium	There is extremely strong evidence that chromium is nutritionally essential because its defined biochemical function. A naturally occurring, biochemical active form of chromium called low-molecular-weight chromium-binding substance plays a role in carbohydrate and lipid metabolism.	Stahlhut *et al.* (2006) and Aragon *et al*. (2001) found that in beef cows placed on chromium supplementation had an increased pregnancy rate and reduced interval from calving to first estrus. In contrast, mice administered with chromium oxide (CrO_3) produced increased number of abnormal sperm cells (Acharya *et al.*, 2006). The diameters of seminiferous tubules in exposed rats were smaller. Chromium treatment also disrupted spermatogenesis, leading to accumulation of prematurely released spermatocytes and spermatids in the lumen of seminiferous tubules (Anderson and Polansky, 1981).

Iron (Fe)	Iron is an essential component of a group of heme proteins active in oxygen transport or as enzymes within the redox system.	In general, semen contains a certain amount of Fe, as its physiological level is required for a normal spermatozoa production and functions. According to Eghbali *et al.* (2010b), the total Fe content of the buffalo seminal plasma was highly associated with sperm motility and viability. Fe content within the seminal plasma is important for the preservation of sperm motility and viability after ejaculation, and its presence will help spermatozoa to maintain their functions. According to Knazicka *et al.* (2012) lower concentrations of iron (II) sulphate (≤ 250 µmol / dm^3) sustained the spermatozoa motility and energy metabolism, which are key factors supporting the spermatozoa function. Increased Fe concentration can affect negatively the morphology and DNA integrity of spermatozoa (Perrera *et al*., 2002; Massányi *et al*., 2004).
Copper	Copper is a constituent of enzymes like cytochrome c oxidase, plasma monoamine oxidase, erythrocuprin (ceruloplasmin), tyrosinase, cytosolic superoxide dismutase among others. It is necessary for the growth and formation of bone, formation of myelin sheaths in the nervous systems, helps in the incorporation of iron in hemoglobin, assists in the absorption of iron from the gastrointestinal tract (Chandra, 1990). Copper is essential for proper functioning of enzymes involved in the synthesis and maintenance of elastic tissue, mobilization of iron stores, preservation of the integrity of mitochondria, and detoxification of superoxide (Dobrzanski *et al*., 1996).	Copper deficiency in the form of copper - iron (Suttle, 1986), copper - zinc, and copper - phytate (Smart *et al*., 1981) complexes impairs reproductive efficiency in animals. Reproductive disorders associated with a copper deficiency in grazing ruminants include: delayed or depressed estrus, and long post - partum return to estrus period; anoestrus, abortion and fetal resorption (Corah and Ives, 1991). Abnormal levels of copper may affect spermatocytogenesis with regard to the sperm production, maturation and fertilizing capacity (Wong *et al.*, 2001; Cheah and Yang, 2011). Copper rich diets enhance spermatozoa motility (Cheah and Yang, 2011) and it may also act on the pituitary receptors which control the release of luteinizing hormones (LH).
Molybdenium	Molybdenium is an ubiquitous trace element found in feed ingredients, drinking water and is present in synthetic vitamin/mineral premix (Vyskocil and Viau, 1999). It is a constituent of at least three mammalian metaloflavoproteins (xanthine oxidase, aldehyde oxidase and sulphite oxidase) as well as in nitrate reductase (Padney and Singh, 2002), all of which are involved in protein synthesis, metabolization of fats and carbohydrates, detoxification of preservatives and sulfites. It also helps in mobilization and utilization of iron store in the body, with subsequent direct effects on biological processes controlling growth and reproductive performance (Padney and Singh, 2002).	Reproductive disorders such as decreased libido and sterility in bull calves caused by tissue damage and reduced spermatogenesis in males (Thomas and Moss, 1951) and delayed puberty, reduced conception rate, and anoestrus in females (Phillipo *et al*., 1987), have been linked to high dietary intakes rather than to a deficient intake of molybdenum. An interesting observation reported earlier by Wise and Ferrell (1984), was a reduction in the LH ovulatory peak in molybdenum supplemented animals, to the extent that exogenous LH given to spike the peak had no effect on conception rates. Decreased activities of testicular enzymes related to the germinal epithelium and Sertoli cells indicate damage to these particular cell types by different doses of Mo in a dose dependent manner (Pandey *et al.*, 1999). Working *et al.* (1985) reported that male rats administered Mo was able to impregnate unexposed females but comparatively in lower number. The recorded decrease in male fertility has been attributed to a direct cytotoxic action on the testes resulting in an increase in sperm abnormalities and function.

Zinc (Zn)	Zinc is distributed widely in plant and animal tissues and occurs in all living cells. It functions as a cofactor and is a constituent of many enzymes like lactate dehydrogenase, alcohol dehydrogenase, glutamic dehydrogenase, alkaline phosphatase, carbonic anhydrase, carboxypeptidase, superoxide dismutase, retinene reductase, DNA and RNA polymerase. Zn dependent enzymes are involved in macronutrient metabolism and cell replication (Arinola, 2008). As a constituent of several metalloenzymes, zinc is involved in several enzymatic reactions associated with carbohydrate metabolism, protein synthesis and nucleic acid metabolism.	Zinc is known to be essential for sexual maturity and onset of estrus. Zinc plays a role in epithelial integrity, meaning that zinc is essential for maintaining the lining of the reproductive organs. Evidence suggests that seminal Zn has an important role in the physiologic functions of the sperm cell and that its reduced levels result in low seminal quality and subsequent chances of fertilization (Colagar *et al*., 2009). Zn is a vital component of enzymes involved in steroidogenesis and has shown to act indirectly through the pituitary to regulate the gonadotropic hormones (Hurley and Doane, 1989). Dietary zinc deficiency (less than 5 ppm) impairs reproduction in males and females (Underwood and Somers, 1969). Testicular growth is greatly impaired in male lambs (Underwood and Somers, 1969) and bull calves fed zinc deficient diets (< 3 ppm). According to Kumar *et al.* (2006), experiments with Zn-supplement-fed bulls led to a higher semen volume, sperm concentration, percentage of live sperm and motility. Growing ram lambs fed a zinc deficient diet for 20 - 24 weeks were incapable of producing sperm. Adequate zinc levels are vital for repair of the uterine lining following calving, return to normal estrus cycles and maintenance of the uterine lining necessary for implantation of embryos. Inadequate zinc levels in cattle have been associated with abortion, fetal mummification, lower birth weights and prolonged labor. Zinc supplemented ewes consumed about 15% more feed than the controls, had a higher fertility rate, were more prolific (89% vs. 40%), and produced heavier lambs at birth (4.0 vs. 2.9 kg) and at weaning (17.7 vs. 14.2 kg).
Selenium	Selenium is a constituent of glutathione peroxidase (Murray *et al*., 2000). It is also a constituent element of the entire body defense system that protects the living organism from the harmful action of free radicals. Organic selenium is more thoroughly resorbed and more efficiently metabolized than its inorganic equivalent, which is poorly resorbed and acts more as a prooxidant provoking glutathione oxidation and oxidative damage to the DNA (Schrauzer, 2000; Wycherly *et al*., 2004).	Selenium deficiency has been linked to reproductive problems in rats, mice, chickens, pigs, sheep, and cattle (Combs and Combs, 1986), as selenium is required for normal testicular development and spermatogenesis in rats (Behne *et al*., 1996), mice, and pigs (Combs and Combs, 1986). Selenium deficiency in female sheep results in high embryonic death, and reduced number of ewes becoming pregnant when exposed to rams (Underwood and Suttle, 1999). Increased incidence of retained placenta is common in dairy cows receiving inadequate selenium. Cows with retained placenta have a higher incidence of uterine infections following calving. Reduced viability of sperm has been seen in selenium-deficient bulls (Underwood and Suttle, 1999). Marginal selenium deficiencies can result in impaired fertility, silent heats, cystic ovaries and the birth of unthrifty kids with poor immunity. In males, Se deficiency has resulted in reduced semen viability (Slaweta *et al*., 1988). In hens, selenium deficiency reduces both egg production and hatchability. In cows and ewes it leads to high embryonic mortality. Rats fed low selenium based diets, gave birth to pups which were almost hairless, grew slowly and failed to reproduce when mature. In all instances, selenium added to the basic diet restored both growth and reproductive capability (Underwood, 1977). Experiments on rodents have shown that selenium is vital for maintaining the integrity of sperm mitochondria (McConnell and Burton, 1981). Also that selenium deficiency leads to a reduced testicular growth.

Minerals can act as catalysts in enzyme and endocrine systems, as integral and specific components of the structure of metalloenzymes and hormones or as activators (coenzymes) within those systems. Selenium functions as cofactor of the glutathione peroxidase (GSH-Px) enzyme systems responsible for regulating extra and intra-cellular hydroperoxidase (Burk and Hill, 1993). Evidence exists (Wise and Ferrell, 1984; Phillipo *et al*., 1987) that over supplementation of molybdenum affect the frequency of hormone episodes; hence, the well known effect of delayed puberty of excess dietary molybdenum. It is through such and similar mechanisms that the effects of the minerals reviewed below are mediated on reproductive events in farm animals (Table 4).

CONCLUSION

Considerable information is available on the interactions between mineral and reproduction in both male and female farm animals. Some of the information is contradictory because we are dealing with a biological system that is prone to intrinsic variability. Although there are gaps in our knowledge about the nature of interactions, we have sufficient data on important positive interactions. These need to better exploited to enhance reproductive efficiency of farm animals. On the other hand, over supplementation is of no benefit to the animal and it ultimately results in added cost for the operation, reduced fertility, increased fecal residues with attendant environmental problems.

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