Minerals and its impact on fertility of livestock: A review

D.J. Talukdar*, Papori Talukdar and K. Ahmed

Department of Animal Reproduction, Gynaecology and Obstetrics, College of Veterinary Science, Guwahati-781 022, Assam, India.

Received: 07-07-2016  Accepted: 27-09-2016  DOI: 10.18805/ag.v37i4.6464

ABSTRACT

Minerals are essential for growth and reproduction of the livestock. The deficiency of the macro and micro minerals have a great impact on animal’s reproductive physiology and its imbalance causes various problems leading to lowered reproductive efficiency. Adequate minerals supplementation is required as most of the roughages, greens, concentrate and even most of commercial feeds are deficient in trace mineral elements. The best recommendation at present is to provide a feeding program for productive animals which is balanced for all minerals and meets all known requirements.

Key words: Fertility, Livestock, Minerals.

Minerals play an important role in the regulation of reproduction and production of domestic animals. The productive animals most commonly suffer from the nutritional deficiencies due to high production and deficient feeding ultimately leading to poor reproductive performance. Minerals are essential for growth and reproduction and are involved in a large number of digestive, physiological and biosynthetic processes within the body (Close, 1998). The most obvious function is as components of body organs and tissues and to provide structural support. In addition, they act as electrolytes, as constituents of body fluids and as catalysts in both enzyme and hormone systems. They therefore fulfill several important functions for the maintenance of animal growth and reproduction as well as health status (Underwood, 1981).

Proper herd management should be designed to optimize the production of the highest quality product, while minimizing any adverse effects on the health and welfare of the animals (Harmon, 1998). In dairy cattle two key goals are adequate nutrition and adequate mammary health so as to produce wholesome milk. Recent data indicate that micronutrient management will enhance the production of good quality milk. The potential for minerals to play a significant role in herd fertility is indisputable. The mineral elements that are of particular importance are categorised into major or macro minerals (calcium, phosphorous, potassium, sodium, chlorine, sulphur and magnesium) and trace or micro minerals (iron, iodine, copper, manganese, zinc, cobalt, molybdenum and selenium). The minerals that affect reproduction in animal are generally found within the trace element group, although deficiencies of calcium and phosphorus can also affect fertility. Organic minerals have a beneficial role to play in resumption of follicular growth and fertility in animals. Replacing sodium selenite with organic selenium resulted in fewer services per conception in a study using 1800 cows (Lyons, 1993). The use of organic chromium compared with inorganic forms, has been shown to enhance the survival rate and to increase litter size in gilts and sows (Lindemann, 1996). Reproductive problems are frequently reported in association with trace mineral deficiencies, particularly copper, selenium and manganese.

The key to the effectiveness of a mineral supplement is not necessarily its biological availability, but its biological activity (Lyons, 1993). Organic minerals have been shown to have several beneficial effects in ruminant and monogastric animals. There are still discernible differences among chelated minerals, mineral proteins and other organic minerals complexes. Proteinated minerals can possibly improve female reproduction through increased fertilization, lower embryo mortality, improved uterine environment and/or increased intensity of estrous behaviour. The importance of these minerals in reproductive performance of livestock is given below.

Phosphorus (P): There has been much debate and research conducted on phosphorus supplementation, effects on reproductive function (Elrod and Butler, 1993). Decreased fertility rate, decreased ovarian activity, irregular estrous cycles, increased occurrence of cystic ovaries, delayed sexual maturity and low conception rates have been reported when phosphorus intakes are low (Cromwell, 1997). When heifers received only 70-80% of their phosphorus requirements and serum phosphorus levels were low, fertility was impaired (3.7 services per conception). Services per conception were reduced to 1.3 after adequate phosphorus was supplemented (Dunn and Moss, 1992). In another experiment, increasing phosphorus supplementation from 0.4% to 0.6% of the ration had no effect on days to first estrus or services per conception. However, in some instances, responses have been reported

*Corresponding author’s e-mail: dibya26@gmail.com
in the field when phosphorus supplementation was increased to 0.5% or 0.6%. The reason for these differences in response is unclear, but may be related to the availability of the phosphorus that is added to the ration or the actual amount of phosphorus consumed. The ration containing 0.45 to 0.50 percent phosphorus on dry matter basis should be provided to high producing cows (Schweigert and Zucker, 1988).

**Calcium (Ca):** Most experimental work relating calcium to reproduction has centered on the effect of the calcium: phosphorus ratio. Controlled experiments demonstrated no effect of altered ratios on reproduction in heifers or lactating cows. Ratios (Ca:P) between 1.5:1 and 2.5:1 for lactating cows should not result in problems. Milking cows should always be provided adequate amounts of calcium to maximize production and minimize health problems. One of the functions of calcium is to allow the muscle contraction. Clearly a reduction in muscle contractility will lead to a decrease in dry matter intake (DMI) as rumen function decreases, leading to severe Negative energy balance (NEB). As consequence, there is an increase in fat mobilization that may result in fatty liver syndrome and ketosis. An excess of ketone bodies can further suppress appetite (Boland et al., 2001), it has been shown that plasma calcium concentration of 5mg/ml reduce abomasal motility by 70% and the strength of the contraction by 50% (Daniel, 1983). Low calcium concentrations also prevent insulin production, further exacerbating this situation (Goff, 1999). Ultimately, milk yield will be reduced and fertility will suffer. Muscle tone in the uterus will also be adversely affected with cows experiencing prolonged calving and retained placenta. Uterine involution may also be impaired giving rise to fertility problems. A major concern in the mineral feeding of dry cows relates to providing optimum levels of calcium and phosphorus in order to decrease the occurrence of milk fever. The ration containing 0.75 to 0.80 per cent calcium on dry matter basis should be provided to high producing dairy animals. Increase calcium to 0.9 to 1.0 percent and magnesium from 0.25 to 0.30 per cent when feeding supplemental fat (Schweigert and Zucker, 1988).

**Selenium (Se):** Selenium is important for normal spermatogenesis and largely as a component of seleno-proteins phospholipid hydroperoxide glutathione peroxidase (PHGPx/GPX4) and Seleno-protein V. Most of the selenium found in the testis is associated with PHGPx/GPX4. It serves as a powerful antioxidant protecting cells from oxidative stress. PHGPx also appears to be involved as a structural protein to provide normal sperm motility (Hemler and Lands, 1980). It has also been shown that a variant to this protein is necessary for normal chromatin condensation and subsequent normal spermatozoa head formation. Both deficiency and excessive selenium have been demonstrated to be detrimental to normal spermatogenesis (Wiltbank et al., 2007). Marginally selenium deficient animals will abort, or calves will be weak and unable to stand or suckle. Research indicates that selenium supplementation reduces the incidence of retained placentas, cystic ovaries, mastitis and metritis (Patterson et al., 2003). In addition, cattle that maintain adequate blood selenium levels have reduced incidence of abortions, still births and peri-parturient recumbency (Pradhan and Nakaghosi, 2003). Compromised selenium status has also been associated with poor uterine involution, and weak or silent heats. In males, selenium supplementation has been shown to increase semen quality (Patterson et al., 2003). Symptoms of chronic selenium toxicity include lameness, sore feet, deformed claws and loss of hairs from tail. In pregnant animals, selenium toxicity will produce abortions, stillbirth and weak and lethargic calves as selenium accumulate in the fetus at the expense of the cow (Patterson et al., 2003). Diets should contain at least 0.1 ppm selenium on a dry matter basis (Pradhan and Nakaghosi, 2003). In some herds, feed sources must be supplemented with selenium injections to maintain blood levels above the recommended 8-10 mg/100 ml. In herds where selenium levels are extremely low, injections are often required to rapidly return blood selenium levels to normal. After injection, feed supplements may provide enough selenium to maintain adequate blood levels in the cow. Blood tests are recommended to confirm selenium status when questions arise.

**Zinc (Zn):** Zinc is an essential component of over 200 enzyme systems of which the metabolic action include carbohydrate and protein metabolism, protein synthesis, nucleic acid metabolism, epithelial tissue integrity, cell repair, cell division, vitamin A and E transport and utilization (Wichtell et al., 1996). In addition, zinc plays a major role in the immune system and certain reproductive hormones (Capuco et al., 1990). Zinc is known to be essential for proper sexual maturity, reproductive capacity, and more specifically, onset of estrus. Zinc has a critical role in the repair and maintenance of the uterine lining following parturition, speeding return to normal reproductive function and estrus (Goff, 1999). In bulls, a zinc deficiency results in poor semen quality and reduced testicular size and libido (Daniel, 1983). zinc has also been shown to increase plasma beta carotene levels. Increased plasma beta carotene has been directly correlated to improved conception rates and embryonic development (Staats et al., 1988). Improved zinc status also improves fertility by reducing lameness, resulting in cows more willing to show heat and improved mobility and performance of bulls. Inadequate zinc supplementation results in mild to severe claw (hoof) disorders, including weak claws that are more susceptible to inter-digital and digital dermatitis and foot rot (Patterson et al., 2003). The recommended dietary content of zinc for dairy cattle is typically between 18 and 73ppm depending upon the stage of lifecycle and dry matter intake (NRC, 2001). Copper, Cadmium, Calcium and iron reduce zinc absorption and
interfere with zinc metabolism (Patterson et al., 2003). Zinc supplementation also increases the ejaculate volume, sperm concentration, percent live sperm and percent sperm motility in crossbred bulls (Dunn and Moss, 1992). Studying on fertile and infertile male, it was observed that seminal zinc levels were lower for infertile male than fertile male and researchers suggested that poor zinc nutrition may be a risk factor for infertility in male (Daniel, 1983). Zinc supplementation was shown to reduce asthenozoospermia in male by reducing oxidative stress, DNA fragmentation and apoptosis (Daniel, 1983). However, there is conflicting evidence as to the importance of zinc concentrations in the semen and infertility of male.

Copper (Cu): The importance of copper as an essential trace element has been recognized for over 70 years, with the early discovery that Cu was necessary for normal haemoglobin synthesis in young rabbits and rats. Since that time, the importance of Cu for normal growth, production and reproductive performance has been established. The biological role of Cu is exerted through a number of Cu-containing proteins including ceruloplasmin and superoxide dismutase (SOD) (Prohaska, and Lukasewycz, 1990). Copper is also necessary component of number of enzymes including superoxide dismutase, lysyl oxidase and thiol oxidase. These enzymes function to eliminate free radicals that increase tissue susceptibility to bacterial infections, increase structural strength and elasticity of connective tissues and blood vessels and increase strength of horn such as in the claw (Hoof), minimizing lameness (Nix et al., 1981). Reproductive problems that relate to copper deficiency manifest themselves in inhibited conception rate even though estrus may be normal. Symptoms of a copper deficiency include early embryonic death, resorption of embryo, increased retained placentas and necrosis of the placenta (Patterson et al., 2003). Dairy cows with higher serum copper levels had significantly less days to first service, fewer services per conception and fewer days to open (Jousan et al., 2002). Proper copper supplementation of the sire is needed for production of quality semen (Patterson et al., 2003). When Cu is inadequate in animals, physiological and metabolic functions related to the Cu-enzymes may be impaired and, during clinical deficiency, symptoms will appear. Although low Cu content of feedstuffs is a common cause of Cu inadequacy, reducing bioavailability of Cu in ruminants may occur when dietary sulphur, molybdenum, zinc or iron are high (Hemken et al., 1998).

Manganese (Mn): Manganese is an activator of enzyme systems in the metabolism of carbohydrate, fats, protein and nucleic acids (Patterson et al., 2003). Manganese appears to have a vital role in reproduction. It is necessary for cholesterol synthesis (Kappel and Zidenberg, 1999), which in turn is required for synthesis of the steroids, estrogen, progesterone and testosterone. Insufficient steroid production results in decreased circulating concentrations of these reproductive hormones resulting in abnormal sperm in males and irregular estrus cycles in females. The corpus luteum has high manganese content and may be affected by level of manganese supplementation. Also, vaginal manganese concentration is higher in cycling than in anoestrous ruminants. A deficiency in manganese may be associated with suppression of estrus, cystic ovaries and reduced conception rate (Patterson et al., 2003). In pigs, Mn deficiency results in abnormal skeletal growth, increased fat deposition, reproductive problems and reduced milk production.

Cobalt (Co): Cobalt is needed for proper vitamin B12 synthesis. Maintaining adequate vitamin B12 status benefits both the dam and offspring. When adequate, sufficient amounts of vitamin B12 cross the placenta and are present in colostrums (Nix et al., 1981). Milk and colostrums in particular, contain high levels of vitamin B12 which is required for the conversion of propionate to glucose and for folic acid metabolism. Depletion of cobalt and vitamin B12 at parturition causes depressed milk production and colostrums yield and quality (Patterson et al., 2003). Reduced fertility and sub-optimal conditioning of the offspring are noted in a cobalt deficiency. Inadequate cobalt levels in the diet have been correlated with increased early calf mortality. A cobalt deficiency ultimately results in a vitamin B12 deficiency. Manganese, zinc and monensin may reduce cobalt deficiency (Patterson et al., 2003).

Iodine (I): Iodine is required for synthesis of thyroid hormone, thyroxin, which regulates the rate of metabolism (NRC, 2001). Prior to regulation of the feeding rate of Ethylenediamine dihydriodide (EDDI), many producer fed iodine compounds to cattle in excess of the nutritional requirement to prevent foot rot (Lopez et al., 2004). Reproduction is influenced through iodine’s action on the thyroid gland. Inadequate thyroid function reduces conception rate and ovarian activity. Thus, iodine deficiency impairs reproduction and iodine supplementation has been recommended when necessary to insure that cows consume 15-20 mg of iodine each day. Excessive iodine intakes have been associated with various health problems including abortion and decreased resistance to infection and disease. Signs of subclinical iodine deficiency in breeding females include suppressed estrus, abortions, still births, increased frequency of retained placenta and extended gestation periods (Hess et al., 2008). Calves born to cows that are marginally deficient in iodine are weak and may be hairless (Patterson et al., 2003). Furthermore, animals that have a subclinical iodine deficiency will also have increased incidence of foot rot and respiratory disease due to suppressed immune responses. One notable characteristic of a clinical iodine deficiency is an enlargement of the thyroid gland, often termed as goiter (Hess et al., 2008).
Iron (Fe): It is required for the synthesis of haemoglobin and myoglobin as well as many enzymes and cytochrome enzymes of electron transport chain (Kumar et al., 2011). Iron functions in transport of oxygen to tissues, maintenance of oxidative enzyme system and is concerned with ferretin formation (Khilare et al., 2007). Deficiency in adult animals is rare due to its ubiquitous presence in the feed stuffs. The reproductive performance of iron deficient animals may be badly affected due to anaemia, reduced appetite and lower body condition. A deficient animal becomes repeat breeders and required increased number of inseminations per conception and occasionally may abort.

Potassium (K): Limited research suggests that feeding high levels of potassium may delay the onset of puberty, delay ovulation, impair corpus luteum (yellow body) development and increase the incidence of anestrus in heifers. Schweigert and Zucker (1988) reported that lower fertility in cows fed with high levels of potassium or diets in which the potassium-sodium ratio was too wide.

Chromium (Cr): Chromium potentiates insulin action, resulting in increased uptake of glucose and amino acids by cells in the body (Short and Adams, 1988). A chromium deficiency in lactating cows may result in increased incidence of ketosis and decreased milk production. Improved energy balance in early lactation may improve reproduction (Patterson et al., 2003). Chromium also plays an important role in the secretion of pregnancy specific proteins from the uterine endometrium which is helpful in preventing early embryonic death. Chromium exerts a significant influence on follicular maturation and LH release. It can possibly lead to lower sperm count and decreased fertility and influences foetal growth and development. (Tuormaa, 2000).

Molybdenum (Mo): Molybdenum is interdependent with Cu with reference to body system of ruminants. Generally lower level of one occurs in presence toxic level of another. Therefore proper balance of Cu and Mo in soil and plants is essential for normal absorption of each other in ruminants (Randhawa and Randhawa, 1994). Molybdenum deficiency decreases libido, reduced spermatogenesis and causes sterility in males and is responsible for delayed puberty, reduced conception rate and anoestrus in females (Kumar et al., 2011).

Salt (Sodium and Chloride): Salt deficiencies can affect the efficiency of digestion and indirectly the reproduction performance of cows (Short and Adams, 1988). Sodium and chloride normally do not appear in feedstuffs in adequate amounts to meet animal requirements and should be provided free choice at all times (Elrod and Butler, 1993).

CONCLUSION
It is clear that the macro and micro minerals have a great impact on animal’s reproductive physiology and its imbalance causes various problems leading to lowered reproductive efficiency. Adequate minerals supplementation is required as most of the roughages, greens, concentrate and even most of commercial feeds are deficient in trace mineral elements. The best recommendation at present is to provide a feeding program for productive animals which is balanced for all minerals and meets all known requirements.

REFERENCES


