Effect of Minerals on Dairy Animal Reproduction - A review

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Abstract
Minerals are very important nutrients for dairy animal production. Deficiency of minerals may leads to certain structural, physiological or immunological disorder affecting growth, production and reproductive health of animals. Minerals deficiency is an area specific problem and supplementation strategy must be revised accordingly. Requirements of minerals for reproduction and immunity are generally higher than maintenance requirement of animals. Supplementation of minerals requires correct knowledge of bioavailability, sources, requirement of animal and mineral interactions with other nutrients. Current review highlighted the recent updates on mineral requirements of dairy animals for reproduction with special reference to their requirements, metabolic functions and mineral interactions.

Key words: Dairy Cows, Immunity, Minerals, Production, Reproduction

Introduction
Minerals are structural components of body and play significant role in activities of enzyme, hormone, as constituents of body fluids and tissues, and as regulators of cell replication and differentiation. Mineral deficiencies, imbalances and toxicity of certain mineral elements may cause reproductive disorders as minerals play an important role in health and reproduction of the livestock (Sharma et al., 2007). After energy and protein, minerals are the major nutrients required and should be given priority in order to optimize reproduction in dairy cattle (Bindari, et al., 2013). Minerals are required in reproductive process because of their role in maintenance, metabolism and growth (Hadiya et al., 2010). The availability of minerals to cattle depends upon the production system, feeding practices, and environment (Singh and Bohra, 2005). Beside energy and protein, deficiency of these elements such as calcium, phosphorus, iron, zinc and copper etc in blood have been reported to be a predisposing factor for the occurrence of retention of placenta and repeat breeding in dairy cows (Sheetal et al., 2014; Kumar, 2014). As per their requirement, minerals are divided in to two categories i.e. macro minerals required in more than 100 ppm in diet and these are calcium, phosphorus, magnesium, potassium, sulfur, sodium and chloride. The second category is trace or micro minerals such as cobalt, copper, iodine, iron, manganese, selenium and

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zinc; and is required in less than 100 ppm diet of animals. Animals obtain minerals through the consumption of natural feeds, fodders and supplementation of inorganic salts in the ration. Mineral deficiencies and imbalances have long been held responsible for low production among cattle and buffaloes fed on crop residues in tropical agro-climatic condition. This paper reviewed current finding with regarding requirement of minerals for reproduction and immunity for better productivity of dairy animals.

1. Calcium (Ca)
Calcium plays a very importance role in structural and physiological functions. Lactating cows must be provided with adequate amounts of Ca to maximize production and minimize health problems. Other function of Ca is to allow the muscle contraction. A reduction in muscle contractility affects rumen function; lower nutrient intake thus leads to negative energy balance. This results in increase in fat mobilization leading to fatty liver syndrome and ketosis. It has been shown that plasma calcium concentration of 5 mg/ml reduces abomasal motility by 70% and the strength of the contraction by 50%. Low calcium concentrations also prevent insulin production, further exacerbating this situation (Goff, 1999). 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. The major concern in feeding of dry cows is to provide adequate Ca and P to avoid occurrence of milk fever. Hypocalcaemia in periparturient animals is major cause of decline in smooth muscle contraction, suppression of dry matter intake, increase in body fat mobilization in the form of non-esterified fatty acids (Martinez et al., 2014), reduction of neutrophil function (Martinez et al., 2012, 2014), and thus leads to an increased incidence of periparturient disease (Martinez et al., 2012). Recent study has demonstrated dietary Ca concentration is not only risk factor for milk fever, the dietary cations, especially K, induce metabolic alkalosis in the prepartum dairy cow and thus reduces the ability of the cow to maintain Ca homeostasis (Goff and Horst, 1997). It is well documented that milk fever increases the incidence of many periparturient disorders such as dystocia, retained placenta, mastitis, displaced abomasum and ketosis (Massey et al., 1993). Hypocalcaemia is also responsible for impaired immune function. It has been suggested that 48 h of parathyroid hormone stimulus is required to mobilize Ca from skeleton (Goff et al., 1986) and this lag phase play important role in the development of milk fever (DeGaris and Lean, 2008). NRC has recommended that Ca content should be 0.65% of the total ration on DM basis for high producing cows.

2. Phosphorus (P)
It is the second most abundant mineral element in the body with 80 to 85% of P found in the teeth and bones. Phosphorus is involved in a number of metabolic reaction and energy transfer within the body. It is required for normal milk production, growth, and efficient use of feed and by the rumen microorganisms
in the digestion of cellulose and synthesis of microbial protein. A deficiency of P leads to decline in fertility rate, feed intake, milk production, ovarian activity, irregular estrous cycles, increased occurrence of cystic ovaries, delayed sexual maturity and low conception rates (Cromwell, 1997). Hypophosphatemia have been a contributing factor for typical periparturient diseases of dairy animals such as the downer cow syndrome and postparturient hemoglobinuria (Gahlawat et al., 2007; Kacchwaha and Tanwar, 2010). Increasing phosphorus supplementation from 0.4% to 0.6% of the ration had no effect on days to first estrus or services per conception. NRC (2001) has revised the recommendation for dairy cattle from 0.3 to 0.4%. Increasing the concentration of dietary phosphorus above requirement (more than 0.38-0.40%) does not improve reproductive performance (Amaral-Philips, 2015). A recent study reported that lowering dietary P from 0.57 to 0.37% did not negatively affect milk production, but did significantly reduce P excretion into environment (Wang et al., 2014).

3. Selenium (Se)

Selenium is regarded as an important trace element and its deficiency is associated with poor growth, fertility and health in dairy animals (Weiss et al., 1990). It is involved in normal spermatogenesis and is an essential component of a range of selenoproteins, including glutathione peroxidase, thioredoxin reductase and iodothyronine deiodinase. It also plays a vital role in protecting both the intra- and extracellular lipid membranes against oxidative damage and protects milk lipids from oxidation (Bhattacharyya et al., 1988). Both deficiency and excess Se have been demonstrated to be detrimental to normal spermatogenesis (Wiltbank et al., 2007). A low levels of Se in diet leads to effect on antioxidant system with subsequent detrimental consequences in terms of animal health (Spears, 2000). A marginal Se deficiency in pregnant animals will lead to abortion, or calves will be weak and unable to stand or suckle. Se supplementation reduces the incidence of retained placentas, cystic ovaries, mastitis and metritis. Low Se has also been associated with poor uterine involution, and weak or silent heats. In males, Se supplementation has been shown to increase semen quality (Puls, 1994). Symptoms of chronic Se toxicity include lameness, sore feet, deformed claws and loss of hairs from tail. In pregnant animals, selenium toxicity will produce abortions, stillbirth, weak and lethargic calves as selenium accumulate in the fetus at the expense of the cow (Patterson et al., 2003). Vitamin E and Se supplements in diets have a protective effect against acute infections mammary gland (Ata and Zaki, 2014). The dietary requirement of Se for most of the species is about 0.1 ppm. Revised requirement of selenium for better immune response in dairy animals is 0.3 ppm (Weiss, 2002). There are two major sources of Se for animals: Se naturally originating from plants, in the form of seleno-amino acids, including selenomethionine and selenocysteine and inorganic Se in the form of selenite or selenite. Selenized yeast has been reported as more bioavailable source of Se as compared to Se selenite (Juniper et al., 2006).
4. **Zinc (Zn)**

Zinc is an essential component of over 200 enzyme systems involved in metabolism of carbohydrate, protein and nucleic acid metabolism, epithelial tissue integrity, cell repair and division, vitamin A and E transport and their utilization. In addition, Zn plays a major role in the immune system and certain reproductive hormones (Capuco et al., 1990). Zinc has a critical role in the repair and maintenance of the uterine lining following parturition, speeding return to normal reproductive function and estrus. In bulls, a Zn deficiency results in poor semen quality and reduced testicular size and libido (Daniel, 1983). Zn has also been shown to increase plasma β-carotene level which is correlated to improvement in conception rates and embryonic development (Short and Adams, 1988). A good Zn status also improves fertility by reducing lameness, cows more willing to show sign of heat and improved mobility and performance of bulls. A severe Zn deficiency in cattle results in slow growth, reduced feed intake, loss of hair, skin lesions that are most severe on the legs, neck, head and around the nostrils, excessive salivation, swollen feed with open, scaly lesions, and impaired reproduction (Spears, 1994). A deficiency of Zn in males reduces testicular development and sperm production (Martin et al., 1994). Zn deficiency has been observed in ruminants fed on deficient feedstuffs (Sharma and Joshi, 2005). The recommended dietary content of Zn for dairy cattle is typically between 18 and 73 ppm depending upon the stage of lifecycle and dry matter intake. Cu, Cd, Ca and Fe reduce Zn absorption and interfere with its metabolism (Patterson et al., 2003). Requirement of Zn in diet of dairy cows is 40 ppm (NRC, 2001). A Zn supplementation study as ZnSO₄ and Zn propionate in the diet of crossbred cattle bulls reported improved semen quality in terms of quantitative and qualitative characteristics of semen and organic form of Zn (Zn propionate) showed a better response in improving sperm per ejaculate, mass motility and semen fertility test like bovine cervical mucus penetration (Kumar et al., 2006).

5. **Copper (Cu)**

Copper is a necessary component of number of enzymes including superoxide dismutase, lysyl oxidase and thioloxidase. Action of these enzymes is to scavenge free radicals and thus prevent tissue susceptibility to infections, increase structural strength of connective tissues and blood vessels, and increase strength of horn and hooves. Cu also plays an important role in the immune system. Cu and Zn have a significant correlation with reproductive hormones (progesterone and estradiol) (Prasad et al., 1989). A Cu deficiency in cattle is generally due to the presence of dietary antagonists, such as S, Mo and Fe that reduce Cu bioavailability. Deficiencies of Cu have also been associated with retained placenta, embryonic death and decreased conception rates and anestrus (Mudgal et al., 2014). Dairy cows with higher serum Cu levels had significantly less days to first service, fewer services per conception and fewer days to open. Proper copper supplementation of the sire is needed for production of quality semen. Feeding a total of 10 to 15 ppm copper in the ration dry matter or supplementing with 10 ppm copper
should meet dairy cattle needs. If rations contain antagonists such as elevated Fe, S, or Mo, replacing 35 percent of supplemental copper with organic copper sources improved Cu availability. The following mineral ratios may be helpful in maintaining Cu levels in blood: Zn: Cu 4:1, Cu: Mo 6:1 and Fe: Cu 40:1 (Hutjens, 2000). Amino acid chelates of Cu, Mn and Zn have been reported to reduce services per conception significantly in dairy cows (Bosseboeuf et al., 2006).

6. Manganese (Mn)

Manganese is an essential nutrient for dairy animals like other minerals. There is large variation in Mn levels in feedstuffs. Fodders were generally adequate in Mn but concentrate ingredients may be deficient (Bhanderi et al., 2014). Generally, legume and grass hays have more Mn than corn or corn silage and Mn is reported to be more available in hay than silage (Puls, 1994). Mn is an activator of enzyme systems in the metabolism of carbohydrate, fats, protein and nucleic acids. Mn 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 Mn content and thus may be influenced by Mn deficient diet. Concentration of Mn in vagina is higher in cycling than in anoestrous animals. A deficiency of Mn may be associated with suppression of estrus, cyclic ovaries and reduced conception rate (Patterson et al., 2003). The maintenance requirement for absorbed Mn was set at 0.002 mg/kg of body weight (1.2 mg/day for an average Holstein cow), the growth requirement was set at 0.7 mg/kg of growth, pregnancy requirement was set at 0.3 mg/d, and the lactation requirement was set at 0.03 mg/kg of milk (NRC, 2001). Gestating cattle may need up to 50 mg of Mn/Kg of DM because it helps in skeletal cartilage and bone formation of fetus (Schefers, 2011) and this value is higher than 40 mg of Mn/Kg of DM recommended by NRC (1989).

7. Iodine (I)

Iodine is an essential trace element for dairy animals. Iodine is incorporated into the thyroid hormones, which have multiple functions as cell activity regulators. Iodine deficiency affects reproductive capacity, brain development and progeny as well as growth. I requirement is important in the development of fetus and maintenance of general basal metabolic rate by synthesis of thyroid hormone. Iodine deficiency leads to delay in puberty, suppressed or irregular estrus (Puls, 1994), failure of fertilization, early embryonic death, still birth with weak calves, abortion, increased frequency of retained placenta in females and decrease in libido and deterioration of semen quality in males (Sathish Kumar, 2003). Recently, Pattanaik et al. (2011) reported that 0.1 mg/d extra supplementation of I as effective strategy to counteract functional disorders of the thyroid and associated adverse effects induced in goats by feeding of leucaena leaf meal. Inadequate thyroid function reduces conception rate and ovarian activity. Thus, I deficiency...
impairs reproduction and iodine supplementation has been recommended when necessary to insure that cows consume 15-20 mg of iodine each day. Recently, Excessive I 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 placentas and extended gestation periods (Hess et al., 2008). A number of studies have reported beneficial effect of lugol’s iodine in treatment of silent estrus, repeat breeding and conception rate (Pandey et al., 2011; Ahmad and Elsheikh, 2014).

8. Cobalt (Co)
Ruminants need cobalt to meet the vitamin B$_{12}$ requirements of both the ruminal bacteria and the host animal. Vitamin B$_{12}$ is a water-soluble vitamin produced by rumen microbes. A depletion of cobalt and vitamin B$_{12}$ at parturition through colostrums causes depressed milk production and colostrums yield and quality (Patterson et al., 2003). Early lactation cows have reduced vitamin B$_{12}$ status due to increased demands of lactation (Girard and Matte, 1999). Co deficiency is associated with an increased incidence of silent heats, a delayed onset of puberty, nonfunctional ovaries, and abortion. Inadequate cobalt levels in the diet have been correlated with increased early calf mortality. Mn, Zn, I and monensin may reduce cobalt deficiency. The recommendation for cobalt requirement in dairy cows varies between 0.10 mg/kg DM (NRC, 2001) and 0.20 mg/kg DM (GfE, 2001). Cobalt supplementation of up to 50 mg daily in Holstein cow have been reported to improve feed digestion in heat stress depression in feed digestibility, fat yield and milk yield (Karkoodi, 2010). Recent studies reported that oral Co acetate administration to lactating cows and ewes decreased milk concentrations of fatty acids containing a cis-9 double bond, and inhibition of stearoyl-coenzyme A desaturase activity (Frutos et al., 2014), thus play an important role in mammary lipogenesis in ruminants and responsible for the majority of cis-9,trans-11 conjugated linoleic acid and a significant amount of cis-9 18:1 secreted in bovine (Mosley et al., 2006).

9. Potassium (K)
Potassium is the third most abundant mineral element in the animal body after Ca and P. Potassium concentrations in cells exceed the concentration of Na by 20 to 30 times. Outside the cell the reverse is true. K is about 5% of the total mineral content of the body. The dairy cow’s minimum requirement for K is 0.90% to 1.0% of the ration on DM basis (NRC 2001). The maximum tolerable level is about 3.0%. Feeding high levels of K may delay the onset of puberty, delay ovulation, effect corpus luteum development and increase the incidence of anestrous in heifers. In dry period during the last 2 to 3 weeks prepartum can predispose the fresh cow to milk fever, displaced abomassum, uterine problems, and other metabolic disorders (DeGaris and Lean, 2008). The K requirement for gestating and lactating sows is 0.20 percent. K requirement increases in diets with higher Na and Cl levels. Ruminants have a higher K requirement than non-ruminants. K is essential for rumen microorganisms. The suboptimal level of K in
the ration decreases feed intake in ruminants. The K requirement in tropical summer is increased as high as 1.9% for high producing cows.

10. Chromium (Cr)

Chromium improves sensitivity of insulin, resulting in increased uptake of glucose and amino acids by cells in the body (Short and Adams, 1988). Dietary energy intake in early lactation does not meet energy demands for maintaining body reserves and milk yield (Coppock, 1985). A low serum insulin, high glucagon and growth hormone (Herbein et al., 1985), and high plasma NEFA concentrations (Grummer, 1993) in early lactation dairy cows indicates high catabolic activities and negative energy balance. This leads to increased gluconeogenesis and glycogenolysis in the liver and increased mobilization of protein reserves from muscle tissue (Collier et al., 1984). This metabolic pattern starts near parturition (Vazquez-Anon et al., 1994). Several studies reported insulin resistance begins before parturition and continues during early lactation. Thus, during the periparturient period, insulin resistance may be an important factor in the initiation of catabolic activities (Holstenius, 1993). At this stage, Cr supplementation (0.5 ppm) may enhance the action of insulin and, consequently decrease NEFA and liver triglyceride concentrations in blood and improve glucose tolerance, which may result in improvement of performance and production during the periparturient period.

11. Salt (NaCl)

Salt contains sodium (Na) and chloride (Cl) and is often supplemented in concentrate or as free lick. Na is an essential element for animals but is not required by plants. Na functions in maintaining osmotic balance, in cellular uptake of glucose and in amino acid transport (NRC, 1989). Lactating dairy animals in the tropics may require more Na due to the hot and humid climatic conditions. The daily salt requirements for dairy cattle are met easily by adding 1 percent salt to concentrate mixture and offering additional salt lick. Lactating cows need 2 g salt/kg milk production. Dry cows need 40 g salt daily or 0.3% Na per kg DM. Salt deficiencies can affect the efficiency of digestion and indirectly the reproduction performance of cows. Na and Cl content of feedstuffs often are not enough to meet animal requirements and should be provided free choice at all times (Elrod and Butler, 1993). Thiangtum et al. (2011) recommended 1.2 g of Na/kg of DM for dairy cows under tropical conditions.

Conclusion

Fertility in dairy animals is affected by a number of factors such as nutrient intake, physiological conditions, management and climatic conditions. Mineral requirements of animal depend upon age, species, breed, physiological conditions of animals. Supplementation of minerals to meet normal growth and production requirement is of utmost importance. Mineral requirement for reproduction and immunity have recently been explored in number of studies. However, mineral interactions, toxicities and bioavailability from different sources must be taken into account in dairy animal nutrition. The organic
sources of minerals to minimize environmental pollution with concurrent demand for higher bioavailability of minerals for immunity and better reproduction need to be explored.

References