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Effects of Macro and Micro Minerals on Reproduction in Dairy Cattle A Review

C. Velladurai*, M. Selvaraju, R. Ezakial Napolean
Department of Animal Reproduction Gynaecology and Obstetrics
Veterinary College and Research Institute, Namakkal-2, Tamil Nadu, India

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. In dairy cows, minerals requirements are influenced by several factors including age, stage of pregnancy and stage of lactation. 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.

Keywords: Dairy Cattle, Macro and Micro Minerals, Production, Reproduction

I. 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 (M. C 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 (Y. R. Bindari, *et al*, 2013). 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 (A. S. Kumar, 2014). As per their requirement, minerals are divided in to two categories i.e. macro minerals required in large quantities (more than 100 ppm) in diet and these are ***calcium, phosphorus, magnesium, potassium, sodium and chloride.*** The second category is trace or micro minerals such as ***cobalt, copper, iodine, manganese, selenium, zinc, molybdenum, chromium, iron, sulfur, silicon and vanadium***; and is required very small amount (less than 100 ppm) diet of animals. Minerals such as arsenic, beryllium, lead and tungsten are toxic to the 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. This paper reviewed current finding with regarding requirement of minerals for reproduction and immunity for better productivity of dairy animals.

II. MACRO MINERALS

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. 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, reduction of neutrophil function and thus leads to an increased incidence of periparturient disease (N. 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. Hypocalcemia 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 (J. P. Goff, 1999) and this lag phase play important role in the development of milk fever (P. J. DeGaris and I. J. Lean, 2008). NRC has recommended that Ca content should be 0.65% of the total ration on DM basis for high producing cows.

The Ca: P ratio, alteration may affect ovarian function through its blocking action on pituitary gland. This results in prolongation of first estrus and ovulation, delayed uterine involution, increased incidence of dystocia, retention of placenta and prolapse of uterus (Sathis Kumar, 2003). Moreover low calcium level in blood is also associated with anoestrus whereas excess of calcium can affect the reproductive status of animal by impairing absorption of phosphorus, manganese, zinc, copper and other elements from gastro intestinal tract. Milking cows should always be provided adequate amounts of calcium to maximize production and minimize health 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. Prevention of milk fever is an important consideration in maximizing reproductive efficiency (J. P. Goff, 1999).

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. 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 (N. Martinez *et al*, 2012). Hypophosphatemia have been a contributing factor for typical periparturient diseases of dairy animals such as the downer cow syndrome and postparturient hemoglobinuria (S. Kachhwaha and R. K. 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. 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 (C. Wang *et al*, 2014).

This mineral has been most commonly associated with decreased reproductive performance in dairy cows. Inactive ovaries, delayed sexual maturity and low conception rates have been reported when phosphorus intakes are low. In a field study 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. Phosphorus is stated to be one of important element for normal sexual behavior (Sathish Kumar, 2003). Delayed onset of puberty and silent or irregular estrus in heifers, failure of estrus and long inter calving period in cows and still born or weakly expelled calves or even embryonic death due to lack of uterine muscle tone are reported to be some of important clinical manifestation exhibited by the animals from phosphorus deficient areas. On the contrary the excess of phosphorus renders the endometrium susceptible for infection (S. Chaudhary and A. Singh, 2004). Reduced fertility and reduced or delayed conceptions are the prime signs of phosphorus deficiency and this can be overcome with proper phosphorus supplementation. Whereas moderate deficiency may lead to repeat breeding condition and poor conception rate (Sathish Kumar, 2003).

3. 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. Deficiency of potassium is well known to cause muscular weakness and thereby affect the musculature of female genital tract causing impairment in the normal reproductive process (S. Chaudhary and A. Singh, 2004). 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 of high levels of potassium (5% DM basis) may delay the onset of puberty, delay ovulation, impair corpus luteum (yellow body) development and increase the incidence of anestrus in heifers. Lower fertility was noticed in cows fed high levels of potassium or diets in which potassium-sodium ratio was too wide. In dry period during the last 2 to 3 weeks prepartum can predispose the fresh cow to milk fever, displaced abomasum, uterine problems, and other metabolic disorders (P. J. DeGaris and I. J. Lean, 2008). K requirement increases in diets with higher Na and Cl levels. 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 (S. Chaudhary and A. Singh, 2004).

4. Magnesium (Mg)

Magnesium usually does not have direct impact on the reproductive status of animals, since in body it remains in almost antagonistic relation with calcium and any disturbance in Ca-P-Mg homeostasis can impart some influence on reproduction. Moreover reduced reproductive efficiency encountered loss of appetite due to magnesium deficiency (Sathish Kumar, 2003).

5. Salt (NaCl)

Salt contains sodium (Na) and chloride (Cl) and is often supplemented in concentrate or as free lick. These elements are indirectly related to reproduction in animals as the deficiency of sodium can affect the normal reproductive physiology by preventing the utilization of protein and energy. Na functions are maintaining osmotic balance, cellular uptake of glucose and amino acid transport (NRC, 2001). 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 (C. C. Elrod and E. R. Butler, 1993). W. Thiangtum *et al*. (2011) recommended 1.2 g of Na/kg of DM for dairy cows under tropical conditions.

III. Trace or Micro Minerals

1. Copper (Cu)

Copper is one of the important trace mineral for reproduction point of view as such its deficiency is reported to be responsible for early embryonic death and resorption of the embryo (J. K. Miller et al, 1988), increased chances of retained placenta and necrosis of placenta (L. O'Dell, 1990) and low fertility associated with delayed or depressed estrus (J. K. Miller et al, 1988). In addition to this, proper copper supplementation is must for quality semen production (R. Puls, 1994). Copper treatment is reported to improve conception rate as the copper treated cow require 1 service and the untreated cow require 1.15 services per conception (A. P. Hunter, 1977). Cu also plays an important role in the immune system. Cu and Zn have a significant correlation with reproductive hormones (progesterone and estradiol) (C. S. 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 (V. 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. 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 (M. F. Hutjens, 2000).

2. Cobalt (Co)

Cobalt deficiency is associated with an increased incidence of silent heat, nonfunctional ovaries, delayed onset of puberty, decreased conception rate, abortion and delayed uterine involution (Sathish Kumar, 2003). 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). 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 (K. Karkoodi, 2010). Infertility is likely to arise as secondary consequences of debility conditions such as severe cobalt deprivations through reduced general metabolism.

3. 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 (R. 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). 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 (B. W. 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 (P. Pandey *et al*, 2011).

4. Manganese (Mn)

Manganese 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 (L. C. Kappel and S. 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. Deficiency cause poor fertility problem in male and female. It is responsible for silent estrus, anoestrus or irregular estrus (L. Corrah, 1996), reduced conception rate (H. H. Patterson *et al*, 2003), birth of deformed claves and abortions in females and absences of libido and improper or failure of spermatogenesis in males (Sathish Kumar, 2003). Post-partum anestrus in dairy cows has proven to be reduced following manganese supplementation (L. Corrah, 1996). 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 (J. Schefers, 2011).

5. Selenium (Se)

Selenium is an important trace element and its deficiency is associated with poor growth, fertility, health in dairy animals and (W. P. Weiss *et al*., 1990). Both deficiency and excess Se causes weak, silent or irregular estrus, retained fetal membranes, early embryonic death, still birth or weak offspring and abortions in females (S. S. Randhawa and C. S. Randhawa, 1994) and detrimental to normal spermatogenesis and reduced sperm mortality in males (M. C. 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 (J. W. Spears, 2000). A marginal Se deficiency in pregnant animals will lead to abortion, or calves will be weak and unable to stand or suckle. Selenium toxicity will produce abortions, stillbirth, weak and lethargic calves (H. H. Patterson *et al*., 2003). Low Se has also been associated with poor uterine involution, and weak or silent heats. Se deficiency in dry cows has been reported to cause retained placenta.

Se supplementation reduces the incidence of retained placentas, cystic ovaries, mastitis, metritis and Improvement in conception rate, at first service in females (T. J. McClure et al, 1986). In males, Se supplementation has been shown to increase semen quality (R. Puls, 1994). 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 (W. P. Weiss, 1990). Vitamin E and Se supplements in diets have a protective effect against acute infections mammary gland (N. Ata and M. S. Zaki, 2014). Retained placenta decreased in an Ohio study when selenium deficient herds received supplemental selenium (50 mg) and Vitamin E (680 IU) injections at 20 days prior to calving or were fed with 1 mg of selenium per day concluded that retained placenta was reduced by selenium supplementation. In herds where selenium levels are extremely low, injections are often required to rapidly return blood selenium levels to normal. After injection, feed Zinc supplements may provide enough selenium to maintain adequate blood levels in the cow (Sathish Kumar, 2003)

6. Zinc (Zn)

Zinc is an essential component 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. Zn has also been shown to increase plasma β-carotene level which is correlated to improvement in conception rates and embryonic development (R. E. Short and D. C. Adams, 1988).

Zinc is known to be essential for proper sexual maturity (development of secondary sexual characteristics), reproductive capacity (development of gonadal cells) in males and all reproductive events (estrus, pregnancy and lactation), more specific with onset of estrus in female. Among these decreased fertility and abnormal reproductive events are of prime importance in females (Sathish Kumar, 2003). A deficiency of Zn in males reduces testicular development and sperm production, poor semen quality and libido (G. B. Martin *et al*, 1994). Apart from this zinc has a critical role in repair and maintenance of uterine lining following parturition and early return to normal reproductive function and estrus (L. W. Greene et al, 1998).

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, around the nostrils, scaly lesions and impaired reproduction (J. W. Spears, 2000). The recommended dietary content of Zn for dairy cattle is typically between 18 and 73 ppm depending upon the stage of life cycle and dry matter intake. Cu, Cd, Ca and Fe reduce Zn absorption and interfere with its metabolism (H. H. Patterson *et al*, 2003). Requirement of Zn in diet of dairy cows is 40 ppm (NRC, 2001).

7. Molybdenum (Mo)

The reproductive performances affected due to molybdenum deficiency are decreased libido, reduced spermatogenesis and sterility in males and delayed puberty, reduced conception rate and anoestrus in females (Sathish Kumar, 2003).

8. Chromium (Cr)

Effect of insulin is potentiated by chromium by increasing the uptake of glucose and amino acids by the cells in the body (B. J. Stoecker, 1990) thereby improves the energy balance which in early lactation leads to improved reproduction. Moreover chromium also exerts a significance influence on follicular maturation and luteinizing hormone release (S. Chaudhary and A. Singh, 2004). A low serum insulin, high glucagon and growth hormone (J. H. Herbein *et al*, 1985), and high plasma NEFA concentrations (R. R. 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 (R. J. Collier *et al*, 1984). This metabolic pattern starts near parturition (M. 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 (P. 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.

IV. CONCLUSION

Efficient production in domestic animals requires that the essential nutrients in a diet be provided in appropriate amounts and in forms that are most biologically useful. The minerals that affect reproduction in cattle are generally found within the trace element group, although deficiencies of calcium and phosphorus can also affect fertility. 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, production and reproduction requirement is of utmost importance. Mineral requirement for reproduction and immunity have recently been explored in number of studies.

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