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MACRO AND MICRO MINERALS IN MODULATING IMMUNITY, PRODUCTION AND REPRODUCTION PERFORMANCE OF DAIRY ANIMALS

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ABSTRACT
Minerals are important for production, reproductionand general health of dairy animals. Minerals also involved in protein biosynthesis, defence mechanism, haematopoiesis, metabolism regulation and functioning of hormones and enzymes. Macro minerals include Ca, P, Cl, Na, S and Mg whereas microelements include Zn, Mn, Cr, I, Mb, Co, Cu and Se. Today animals diet mainly roughages, greens, concentrate and commercial feeds are deficient in essential minerals so adequate mineral supplementation is required. Micro minerals have important role in oxidative metabolism, energy metabolism and immune function. Dairy animals require good quality feed with organic minerals. Ogranic minerals have higher bioavailability resulted in better health, improved production, better immune response. Ca and P are main part of skeleton, teeth and small amount is circulated in blood & body fluid.Zn is an important mineral involved in energy metabolism, protein synthesis, carbohydrate metabolism, cell division and nucleic acid metabolism etc. Cu involves in red blood cell maturation, collagen synthesis, immune function, ATP production, hormone formation, iron absorption and metabolism etc. Cois an essential trace-mineral required for synthesis of Vitamin B12. Cow's milk contains approximately 0.5 µg/L vitamin B12 whereas colostrums contains 4 to 10 times more than milk.Vitamin B12 is an essential co factor for function of two enzymes- Methionine synthase and Methylmalonyl–CoA mutase. In ruminants, Methylmalonyl–CoA mutase is involved in metabolism of propionic acid which is a energy source for ruminants. Thyroid hormone is important for metabolism, normal growth and development, skeleton growth, thermogenesis, oxidation, reproduction and cardiovascular health. Selenium functions as an important trace mineral, act as protective and antioxidant by removing free redicals. Iron is an important part of various enzymes such as catalase, peroxidise and cytochrome oxidase. So we can see that minerals plays many functions in the dairy animals body. A dairy owner have adequate knowledge about minerals requirements, metabolic functions and mineral interactions. Over feeding or under feeding directly affects animal health. Adoption of standard scientific feeding is necessary for animal health and economic benefit.

KEYWORDS- Dairy animals, Immune response, Metabolism, Milk production, , Mineral supplementation, Protein synthesis and Reproductive performance.

1. INTRODUCTION

Dairy animals play important role in National economy.A large number of animals in the world consumes mineral and vitamin deficient diet. The grazing livestock population of India receive minimal or no mineral supplementation except common salt (Garg et al., 2005).In many previous studies, Metabolic diseases have been reported in all categories of farm animals because inadequate level of essential minerals in conventional feed and fodder. Minerals are important for growth, production, reproduction and general health regulationsandinvolved in physiological, digestive and biosynthesis process. Minerals also involved in protein biosynthesis, defence mechanism, haematopoiesis, metabolism regulation and functioning of hormones, enzymes and cells (Balamurugan et al., 2017).Mineral imbalance and deficiency results in poor performance and health problems. Previousexperiments showed that excess, deficiency or imbalance concentration of minerals affectsactivity of physiological and biochemical system (Prylipko& Koval, 2021).The minerals are classified into macrominerals(>100 ppm) and micro/trace minerals(<100 ppm)according to requirement. Macrominerals include calcium (Ca), phosphorus (P), chlorine (Cl), sodium (Na), sulfur (S) and magnesium (Mg), whereas microelements include zinc (Zn), manganese (Mn), chromium (Cr), iodine (I), molybdenum (Mb), cobalt (Co), iron (Fe), copper (Cu) and selenium (Se) (NRC, 2001).Some trace minerals nickle (Ni), arsenic (As), silicon (Si), and vanadium (V) etc. are also required at very low concentration. Prasad and Gowda (2005) reported that trace minerals are essential for animals in smaller quantity and at least 9 trace minerals are essential (Fe, Cu, Zn, Mn, I, Co, Se, Mo, Cr).Low reproductive performance of animals may be due to mineral deficiencies and toxicity or imbalance of certain minerals (Sharma et al., 2007). Deficiency and imbalance of essential minerals may result in repeat breeding (Kumar, 2014), abortion (Mee, 2004), retained foetal membranes (Gupta et al., 2005). Weiss (2017) reported that deficiency of minerals leads to immunosuppression. Hypophosphatemia and Hypocalcaemia have been reported as a major factor for dystocia and fetal membranes retention (Roche, 2006). Sordillo et al. *(*1997)found that Zn, Cu and Se regulates immune cell functions in the body. Some minerals reduces oxidative stress during stress condition as itacts as antioxidants(Gressley, 2009).Trace minerals are important for enzyme activity, cell growth, synthesis of DNA and RNA, neurological functions, energy metabolism and protein synthesis. This article discusses mineral requirements and supplementation of dairy animals. This will help to understand the importance of minerals in dairy animals.

2. Minerals Requirement for Dairy Animals

Minerals requirements dependon age (Devi et al., 2011), breed (NRC, 2001),growth rates orlevels of productivity(NRC, 2001) and reproductive performance etc. At early growth stage minerals required for skeleton development and muscle growth. In lactating cowsrequirement increases depend on volume of milk as milk contains high concentration of Ca ((1.1–1.25 g/kg) in milk) and P (0.8–1.0 g/kg). Pregnant cows require minerals for fetal development and preparationfor upcoming lactation. The requirements of different minerals for lactating cow are presented in table 1.

Table 1. Mineral requirements of Lactating cow

Minerals	Requirements
Calcium (%)	0.43-0.77
Phosphorus (%)	0.25-0.49
Magnesium (%)	0.20-0.25
Potassium (%)	0.90-1.00
Chlorine (%)	0.25-0.30
Sodium (%)	0.18-0.20
Sulphur (%)	0.20-0.25
Copper (ppm)	10
Cobalt (ppm)	0.10-0.50
Iron (ppm)	50
Iodine (ppm)	0.60
Manganese (ppm)	40
Zinc (ppm)	80
Selenium (ppm)	0.10-0.30

Source: NRC, 2001, Kearl, 1982, McDowell, 2000.

3.Macro Minerals

3.1Calcium (Ca)

Ca is a main part of skeleton, teeth and small amount is circulated in blood & body fluid. About 98% of body Ca stored in bone (Tinawi, 2021). Animal maintains Ca homeostasis by physiological process in the body. If there is Ca deficiency in the body, intestinal Ca absorption increased, external losses decreases and Ca is moves from skeleton system in extracellular fluid ((Wilkens and Muscher-Banse, 2020). Endocrine system of body mainly parathyroid hormone, calcitonin and 1,25-dihydroxyvitamin D3 helps in maintains of Ca homeostasis. Ca is essential for rumen microbial biomass activity in ruminants. The rumen microbial biomass plays a crucial role in feed digestion which produces Volatile fatty acids (VFA) such as acetate, propionate and butyrate. Ca^{2+} required by *Ruminococcus and Fibrobacter.* Adequate Ca^{2+} concentration required cellulose degradation by ruminococci (Morales and Dehority ,2009). Ca is required for bone formation, blood coagulation, skeletal & smooth muscles contraction, neuromuscular excitability and uterus & uterine involution etc. Ca balance is very crucial during periparturient periodand this time is observed for dramatic physiological and metabolic changes. Ca is important for muscle contraction and deficiency of its causes ruminal atony, low dry matter intake resulted in weakness and negative energy balance condition. Hypocalcaemia conditionresulted in calving difficulties, prolonged estrus, late ovulation, ruminal stasis, uterine prolapse, retained placenta and metritis (Morrow, 1980). In doehypocalcemia condition causes oxidative stress and delay in uterine involution during peri-parturient and level of Ca, P & vitamin D significantly (p<,0.05) decreased whereas total antioxidant level was significantly (p<,0.05) increased (Bayoumi et al., 2021). They also observed lover value of RBC, PCV% and Hb concentration on day -14 before kidding and day zero.

Milk fever is most prevalent within 72 hours after calving and sign may appear 10 days before and after calving or during late lactation (Radostits et al., 2007). Milk fever is metabolic diseasewhere blood calcium concentration level may reduce less than 5 mg/dL (Wubishetet al., 2016)and this condition is characterized by sternal recumbency, low body temperature, slow respiration, rapid heartbeat, weakness, coma and death (Horstet al., 2003). In sub clinical hypocalcaemiaCa concentrationsrange from 5.5 to 8.0 mg/dL(Wubishet al., 2016) without any symptoms. In lactating dairy cows Ca: P ratios between 1.5:1 and 2.5:1 is adequate. A high level of phosphorus retarded absorption of Ca. A high producing dairy cow may secrete about 45-50 g Ca in milk per day. Previously it was found that feeding of Ca more than 1% has not beneficial becausemilk production was not affected and dry matter intake also reduced (Fernandezat el.,1982).The requirement for Ca increases during late gestation because nutritional demand of developing fetus and initiation of colostrum synthesis in mammary glands, providing adequate Ca during transition period improves daily milk yield and total milk yield for 28 day postpartum (Alheloand Serbester, 2024). Ca feeding during dry period reduces the chance of milk fever in dairy animals. Feeding of low Ca diet during dry period (Jesse et al.,2018),feeding of corn silage & grass hay (Angassa, 2019), injection of 10 million IU of vitamin D (Bhanugopan and Lievaart, 2014), borogluconate at a rate of 2 g/100 kg body weight (Goof, 2008) also helpful to avoid occurrence of milk feveraccording to different situations.

3.2 Phosphorous (P)

In 1669, Henning Brand discovered phosphorous (P). Phosphorus is an second important mineral and about 80% is found in teeth and bones (NRC, 2001). Phosphorous plays important role in many biochemical reactions in the body.Ca:P ratio level of 0.75% Ca and 0.45% P and ratio of 1.5: 1 should be maintained in dairy cow feed.Inorganic phosphorous found as phosphate while organic phosphorous as nucleic acid, phytic acid and phospholipid.In rumen P is found mainly in organic farm and it is about200-600 mg/L.Inorganic phosphate (Pi) required for energy metabolism, forms part of nucleotides in DNA and RNA, enzymatic processes like glycolysis, oxidative phosphorylation, ammoniagenesis, signal transduction, bone development and pH buffering. Absorption of phosphate occurs in small intestine (Yoshiko et al., 2007). NRC (2001) recommended a level of 0.36% during early lactation, 0.18% for growing heifer and 0.28% for six month old calf on DMB. These requirements are adequate to support normal health, production and reproduction. Inadequate intake of phosphorus results in irregular estrous cycles, repeat breeding, cystic ovaries, decrease conception rates, increased maturity period and low fertility rate (Cromwell, 1997). Hypophosphatemia is a predisposing factor for postparturient hemoglobinuria and downer cow syndrome (Kachhwaha &Tanwar, 2010). It is important to note that supplementation of higher P than requirements does not affects animals performance.Higher phosphorus level did not improvedmilk yield in HF cow (Tallam et al., 2005) bone growth in Holstein × Jersey crossbred heifers (Esser et al., 2009), carcass characteristics (Erickson et al.,1999) and cell-mediated immune responses in lactating cows (Mullarky *e*t al., 2009) .Lopez et al. (2002) conducted a study to observe the effect of higher P than NRC recommendations and found that excess P has no effect on productive performance. They fed 0.37 (recommended) or 0.57% (Excess) P to 267 Holstein cows (dry basis) for the first 165 day of lactation and found that feeding of higher P had no effect on cow performance and health.Milk production, milk protein and milk fat averaged 35.1 kg/d, 2.90% and 3.92%, for the 0.37% P diet, and 34.9 kg/d, 2.91% and 3.98 % for the 0.57% P diet. Wang et al. (2014) studied the effect of different P level (0.37%, 0.47% and 0.57%) on Forty-five multiparous Holstein dairy cows and reported that health and reproductive parameters were not associated with dietary P content ($P > 0.05$).

Table 2. Health problems and reproductive performance of cows fed diets differing in P content

Items	Low P (0.37%)	Medium P (0.47%)	High P (0.57%)	*P*
Mastitis	3	2	2	0.63
Foot rot	3	4	3	0.72
Retained placenta	4	3	3	0.57
Displaced abomasum	3	2	1	0.64
Udder edema	2	3	3	0.56
Ketosis	3	2	2	0.63
Dystocia	1	0	1	0.55
Total health problems	19	16	15	0.43
Proportion of cows that conceived,%	80.2	88.5	70.5	0.54
Proportion of cows pregnant	75.9	77.5	72.0	0.66
Weight of calves, kg	35.4	37.1	35.8	0.64

Wang et al. (2014)

3.3 Magnesium (Mg)

Magnesium (Mg) is an essential mineral and important for enzyme activity, neurological functions, cell growth, synthesis of DNA and RNA, energy metabolism, protein synthesis and vitamin D metabolism. In animals carbonate, oxide and sulphate are sources for Mg supplementation in which Mg oxide (MgO) is highest Mg concentrated mineral. Mg^{2+} act as a co-factor for many enzymatic reactions, it is essential for conversion of ATP to ADP, activity of protein kinases, glycolytic enzymes and phosphorylation.In most animals body Mg content is ~0.4 g Mg per kg of body weight (Maguire and Cowan, 2002). In dairy animals 70% Mg is found in bone, 29% in body cells and 1% extracellular fluid and blood (NRC, 2001). Magnesium absorbed in the rumen, and K levels impairs its uptake (Goff, 2014).

Grass tetany (Hypomagnesimic tetany) is caused by low levels of Mg (<0.65mmol/L plasma). This condition is more prone in lactating cows due to higher mobilization of Mg in milk. Clinical sign of disease appears when Mg level falls below 0.8 mg/dl (Khan, 2010). The symptoms of grass tetany are neuromuscular irritability, salivation,uncertain gait, grinding of the teeth, ataxia, recumbency, convulsions and tetanic muscle spasms (Sjollema, 1932) whereas in chronic condition sign are weight loss, unthriftiness and drop in milk production (Cronin, 2006). Dietary factors may be responsible for clinical signs of grass tetany in cows. Grass tetany condition may result when animals fed lush grass pasture with low concentration of Mg (<0.2 %DM). The treatment of grass tetany by intravenous 200 to 500 ml injection of calcium magnesium gluconate. Bell et al. (1978) recommended Mg enema for early recovery. During lactation period a cows should be fed a minimum of 13 to 15 g/head/d to prevent Mg deficiency (Allison, 2003).

3.4 Sulphur (S)

It is essential for growth of ruminal microbes, boosts synthesis of amino acids (cysteine, cystine, methionine, taurine and homocysteine) and vitamins (biotin and thiamin). The dietary sulphur requirement is 0.20% of diet dry matter for dairy cattle (NRC 2001). Methionine, thiamin, and biotin cannot be synthesized in the body so animals depends on either through diet or microbial synthesis in the rumen. Example of some sulphur concentration in feeds are presented in table 3.

Table 3. Sulphur concentration of various feed ingredients

Feed ingredients	% of DM	Feed ingredients	% of DM
Alfalfa	0.26	Meat and bone meal	0.39
Barley	0.12	Linseed meal	0.37
Corn silage	0.14	Sorghum	0.11
Blood meal	0.77	Oats	0.19
Brewers grains	0.38	Soyabean hull	0.12
Cotton seed	0.23	Soyabeans	0.31
Corn	0.10	Sunflower seed	0.21
Feather meal	1.39	Fish meal	1.16
Corn gluten feed	0.44	Wheat	0.15
Safflower meal	0.32	Whey	1.15

Nutrient Requirements of Dairy Cattle, 7th Ed., NRC (2001)

The nitrogen-to-sulphur (N:S) ratio should be 10:1 for microbial protein synthesis. Excessive sulfur intake can interfere in the absorption of copper and selenium. Inadequate supply of sulphur leads to low feed intake, anorexia, protein deficiency, diarrhoea, emaciation and restlessness etc. Sulphur deficiency can result in reduced feed intake, impaired microbial digestion, slower growth and poor wool quality (McDonald et al., 2011). Excess sulphur supplementation will have negative effects on animals including reduced animal performance, low in milk production and a disease condition polioencephalomalacia (PEM). Polioencephalomalacia (PEM), a neurological disorder leading to incoordination, blindness, and death (Gould, 1998).Other symptoms of PEM are muscle tremor, drooling, ataxia, teeth grinding, strabismus, seizures, recumbence, lethargy and opisthotonus etc. PEM was known as a disorder caused by thiamine deficiency for a long time. PEM can have many causes in animals including lead poisoning (Christian and Tryphonas, 1971), salt poisoning (Lindley, 1977), plants ingestion with rich thiaminases (Pritchard and Eggleston, 1978) etc.

4. Micro Minerals

4.1 Zinc (Zn)

Zn is an important mineral involved in energy metabolism, protein synthesis, carbohydrate metabolism, cell division, nucleic acid metabolism, vitamin A & E transportation and maintaining epithelial cell integrity etc. Availability of inorganic Zn to fed to dairy cattle are mainly found as Zn oxide (ZnO) and Zn sulfate ($ZnSO_4$). These inorganic salts have been used because of their high rumen solubility and low cost (Nollet et al., 2007).Zn is a component of epidermis rapidly dividing cells essential for keratinization of skin, skin nucleic acid, collagen synthesisand wound healing thus its deficiency leads to parakeratosis, weaken skin, alopecia, loss of hair, dermatitis at ears and lesions of coronary bands etc. (Oberleas and Harland, 2008). Holstein dairy calves fed Zn deficiency diet for 8.5 weeks had skin parakeratosis, lesions feet, inflammation in nose and mouth with low dry matter intake (Miller and Miller, 1962).

Zn has also role in sexual maturity, development of reproductive capacity in males and maintenance of estrus, pregnancy and lactation cycles in females. Zn involved in spermatogenesis and secretion of male hormone testosterone. It is having a crucial role in maintenance of plasma beta carotene level which is necessary for higher conception rate and embryonic development (Staats et al., 1988). Deficiency of Zn will lead to abnormal oestrus, decreased fertility and abortions (Hidiroglou, 1979). Zn deficient diet male sheep had atrophy of the seminiferous tubules with complete stoppage of spermatogenesis (Underwood &Somers, 1969). Mastitis is a major health problem of dairy cattle. Higher somatic cell count (SCC) is a indicator of udder health, it results in damage of mammay gland and reduction in milk yield. Low Zn supplementation leads to increased SCC with higher incidence of mastitis (Galton, 1990). Gaafar et al. (2010) conducted a study to observe the effect of Zn methionine supplementation and found that Zn methionine supplementation (5 g/ head/ day) to lactating Friesian cows reduces SSC, recovery time and mastitis therapy cost. NRC (2001) suggested 30 ppm (20-40 ppm) level of Zn to be adopted to alleviate the Zn deficiency in animals. The recommended dietary Zn amount of 52.8 ppm for lactating dairy cows (NRC, 2021). Improved immune response and reduced lipid peroxidation were observed in buffalo calves with 80 and 140 ppm Zn supplementation with the highest value was found at 140 ppm (Parashuramulu et al., 2015). Zn plays an important role in humoral and cell mediated immune responses and essential for antioxidant defense system.Zn involved in supporting immune system and reproductive hormones activity (Miller et al., 1988). Zn has a significant role in antibodies such as immunoglobulin IgG, IgAandIgM and its deficiency leads todecrease immunoglobulin production (Perryman et al., 1989).Zn containing superoxide dismutase and metallothionein scavenges free radicals and reduces oxidative (Cherian and Kang, 2006). Zn deficiency leads to oxidative damage of cell membranes caused by free radicals. Zinc deficiencies can decrease immune response by compromising NK cell activity and phagocytosis activity (Haase and Rink, 2009).

4.2 Copper (Cu)

Copper (Cu) is an essential element for dairy animals and act as a co-factor enzymatic reactions, it involves in Red blood cell maturation, collagen synthesis, immune function, ATP production, hormone formation, iron absorption and metabolism etc. Ruminants are susceptible to Cu toxicity and sheep are most sensitive. Boughton and Hardy first reported about Cu poisoning in 1934 (Boughton and Hardy, 1934). The required copper for dairy cattle ranges between 9 and 16 ppm (NRC, 2001). Copper metabolism occurs within the rumen and ruminants have no efficient regulation system for Cu. As ruminants poor mechanism for Cu absorption and excess Cu accumulated in liver. It results in hepatic damage, cell necrosis, haemolysis, diarrhoea, vomiting and convulsions and death (NRC, 2005). Molybdenum with sulphur forms molecule thiomolybdate (TM) which binds with Cu and inhibits Cu absorption because bind Cu is insoluble and not absorbed in rumen. This antagonist effect was also observed with iron and Zn (Minervino et al., 2018).

Copper deficiency caused delay in onset of puberty, low conception, repeat breeding, increased incidence of retention of placenta and early embryonic mortality (Underwood, 1981). Chronic Cu poisoning in sheep caused incoordination, tachycardia, irregular pulse, aggression, tachypnoea, blindness, dementia, tetraparesis and aggression (Giadinis *et al.*, 2009). Cu deficient diet in sheep had embryonic loss, inhibition of embryonic implantation and fetal death (Hidiroglou, 1979). Naziroğlu *et al.* (1998) studied the mineral content in 148 aborted ewes and found that cause of abortion, had been very low levels of micronutrients, mainly Cu.

In acute Cu poisoning clinical signs consist of severe gastroenteritis, bluish-green diarrhoea with mucus, excessive salivation, tachycardia, low body temperature, abdominal pain and death (Thompson, 2018). Mudgal *et al.,* (2014) reported that Cu plays a crucial role in normal reproductive physiology of buffalo and supplementation of copper sulphate pentahydrate ($CuSO_4 . 5H_2O$) in anestrous buffalo cows at 3 g/ week/ head for two months and estrus was observed in 80% of the animals.

4.3 Cobalt (Co)

Cobalt (Co) is an essential trace-mineral required for synthesis of Vitamin B12 as ruminants cannot produce it themselves. Vitamin B12 is important co factor for protein and energy metabolism. Ruminants required higher amount of vitamin B12 than non ruminants. Cow's milk contains approximately 0.5 µg/L vitamin B12 whereas colostrums contains4 to 10 times more than milk (Viglierchio et al., 2000). Vitamin B12 is found in cells mitochondria as 5′-deoxyadenosylcobalamin, whereas methylcobalamin in plasma and small amount in cells. Co is required in small concentrations as 0.11 mg/kg for dairy cattle (NRC, 2001). Co is found as cobalt sulphate, cobalt chloride and cobalt glucoheptonate. Vitamin B12 is an essential cofactor for function of two enzymes- Methionine synthase and Methylmalonyl–CoA mutase. In ruminants, Methylmalonyl–CoA mutase is involved in metabolism of propionic acid which is a energy source for ruminants. Raths et al. (2023) stated that B12 is required for propionate production, a key precursor for glucose in dairy cows. Ruminal microorganism play important role in synthesis of Vitamin B12, mainly *Selenomonas ruminantium* and *Megasphaera elsdenii* produces highest amount of Vitamin B12 (Brito et al., 2015).

Co deficiency in sheep and cattle is known as bush disease, debilitating disease, salt sickness, coast disease, wasting disease, bush-sickness or Grand Traverse disease etc. (Viglierchio et al., 2000). The reduced activity of methylmalonyl CoA mutase, causes reduced blood glucose and increased pyruvate level. The elevation of pyruvate and methylmalonate in the blood causes anorexia, weight loss and emaciation (Viglierchio et al., 2000). Signs of Co deficiency range from hyporexia, reduced growth and weight loss to liver steatosis, anemia, diarrhoea, impaired immune function, impaired reproductive function, fatty liver degeneration and even death.Signs of Co toxicosis include weakness, emaciation, salivation, shortness of breath, reduced absorption of food, mild polycythemia, excessive urination, defecation and increased haemoglobin, increased PCV and elevated Co in the liver of ruminants (McDowell, 2012).

4.4 Manganese (Mn)

Manganese (Mn) required for several physiological processes. It is integral part of many enzymes and required for tissue development, blood coagulation, bone formation cholesterol synthesis and activation of different enzymes. It is also involved in digestion, reproduction, immune function and regulation of cell activity. Mn is required as 13 and 40 ppmdepending upon stage of the life cycle (NRC, 2001). It is also recommends as 16 to 18 mg of Mn/kg during gestation and 12 to 14 mg of Mn/kg of DM for lactating cows NRC (2001). Different minerals as Ca, P, K, Mg, Co and Fe etc decreases the availability of manganese (Miller *et al.*, 1988). Mn containing enzymes (Mn superoxide dismutase, arginase, phosphoenolpyruvate decarboxylase, glutamine synthetase etc.) helps in reduction of oxidative stress towards free radicals (Hindman 2023).

Mn deficiency causes abortion in cows and heifer and birth of abnormal calves. In new born calves Mn deficiency leads to short leg bone, twisted legs, enlarged joint and skeleton abnormalities (McDowell et al., 2003). Mn involved cholesterol synthesis which is required for synthesis of testosterone, progesterone, estrogen ((Kappel and Zidenberg, 1999). In males deficiency of Mn, leads to absence of normal libido, reducedspermatozoa motility and decreased number of spermatozoa in ejaculate (Satish Kumar, 2003).In the female animal Mn deficiency causes poor follicular development, delayed ovulation, increased embryonic mortality and reduced conception rate (Corrah, 1996).

4.5 Iron (Fe)

Iron is essential for synthesis of haemoglobin and myoglobin for transportation of O_2. It is component of various enzymes such as catalase, peroxidise and cytochrome oxidase (Khillare et al., 2007). Iron mainly stored in liver, muscles, erythrocytes and macrophages. Iron deficiency occurs mostly in young calves because cow milk contains low Iron. Prenatal Iron deficiency is also a major cause for anemia in dairy calves at birth. At birth iron deficiency in calves has adversely affects on calf growth and health (Royet al., 1964). Calf diarrhea is a common health problem in neonatal calves and iron deficiency anemia interfere in gut activity and function leading to diarrhoea (Okabe et al., 1996).

Iron deficiency can be treated by iron supplementation via different routes. Green et al. (1993) suggested Intramuscular injection of 200 mg iron. We can use ferrous sulphate orally@2-4g daily for 2 week to adult cattle (Sharma et al., 2001). Administration of ferrous sulphate 250 mg/calf/day resulted in significant increase of serum iron, total protein, globuline, thyroid, hormones, phagocytosis activity and body weight (Eisa and Elgebaly, 2010).

4.6 Molybdenum (Mb)

Mb is an essential trace element discovered in 1778 by Karl Scheele. It is important for oxidase enzyme system (NRC, 2007). It is a component of xanthine oxidase, sulfite oxidase, aldehyde oxidase and other key enzymes. It is also essential for protein metabolism, sulfur metabolism, hydrolysis of phosphate esters and transport of iron. Molybdenum status can is assay by liver and plasma Mo concentrations. The normal liver Mo concentrations at 0.14-1.40 mg/kg wet weight and plasma concentrations of 0.1-0.10 mg/L wet weight (Puls, 1994).When Mb absorbed as molybdate it will be excreted in urine whereas thiomolybdates will mainly be excreted in the feces (Underwood and Suttle, 1999).Mb requirements for sheep and goats is 0.5 and 0.1 mg/kg DM (NRC, 2007). Mbdeficiency causes decreased libido, impaired spermatogenesis and sterility in male animals and delay in age at puberty, decreased conception rate and anoestrus in females (Sathish Kumar, 2003).

4.7 Iodine (I)

Iodine is crucial trace mineral plays important role in synthesis of thyroid hormones, thyroxine (T_4) and triiodothyronine (T_3). Thyroid hormone is important for metabolism, normal growth and development, skeleton growth, thermogenesis, oxidation, reproduction and cardiovascular health. The dietary iodine requirement is 0.8 mg/kg dry matter for lactating goats and 0.5 mg/kg dry matter for other flocks (NRC, 2007). The normal liver Iodine concentrations as 0.094 mg/kg wet weight, milk concentrations between 3-25 µg/L and protein bound iodine between 3.0-5.3 µg/dL (Puls, 1994). Enlarged thyroid gland, weak calves, poor conception rate, retained placentas have been reported due to Iodine deficiency (McDowell, 2003). Goiter is a physiological response of thyroid gland resulted in hypertrophy and hyperplasia of glands. Goitre affects the survivability of lambs and kids and related sign were decreased surfactant secretion, impaired thermoregulation, reduction in cardiac output, and arrhythmia (Singh et al., 2002). Singh et al. (2006) reported that synthetic sodium thyroxine at a dosage of 0.2 mg/day to goat (16-20 kg) effectively reduces the sign of deficiency.

4.8 Selenium (Se)

Selenium functions as an important tracemineral, act as protective and antioxidant by removing free redicals.Se found in inorganic (selenite ($Se4^+$), selenate ($Se6^+$), and selenide ($Se2^{-}$) and organic forms in which selenite or selenate are obtained by plants. Both form of Se easily crosses placenta. In most of the species Se requirement is 0.1-0.3 ppm. NRC (2001) recommended a 0.2-0.3 ppm of Se in the diet. Se has a important role in thyroid gland activity for synthesis, metabolism, and regulation of thyroid hormones.Se deficiency leads retained placenta and poor fertilization, abortion, mastitis and metritis (Reddy, 2018).In cows retained placenta at parturition was observed with low Se feed and fodder (Triner et al., 1969). Supplementation of 0.2 ppm sodium selenite to murrah heifer for 120 day results in higher conception rate and reduced age at first calving (Ganie et al., 2014). Se supplementation can lower the chance of *Staphylococcus aureus* mastitis by inhibition of NLRP3 inflammasome (Jinget al., 2020).Selenium is important for fertility and seminal parameters (Parilloet al., 2014).Se supplementation in bulls improved semen quality parameter, protecting sperm from oxidative damage, membrane integrity, viability and postthaw motility. It is also play crucial role in production and maintaining of sex steroid hormones mainly testosterone, progesterone and estradiol. In males, Se deficiency can cause a malfunction of the testosterone and spermatozoon synthesis, results in infertility (Rayman et al., 2012).White muscle disease" (WMD) caused by Se and/or vitamin E deficiency. It involves muscle damage and Ca salt deposition in muscle fibers in affected part. According to involment of muscle fibers symptoms may be lameness, difficulty in walking, unable to take feed and water, respiratory distress, pneumonia and heart failure and death. Radostits *et* al. (2000) stated that bronchopneumonia and diarrhoea could be secondary complications of WMD. Supplementation of Se-deficient forages for long time is a risk factor for development of White muscle disease ((Maas et al., 2016).

Chronic Se toxicity is divided into alkali disease and blind staggers (Rosenfeld and Beath,1964). Alkali disease occurs when any animals consume seleniferous forages with higher Se (5 to 40 mg Se/kg) over extended intervals. When a animal consume plants over a period of time in which Se is present in water-soluble form, it is called blind staggers. Symptoms of alkali disease include lameness, hoof changes, lack of vitality, rough coats, emaciation, dullness and hair loss. Blind staggers is characterized by wanders in circle, anorexia, impaired vision, abdominal pain, laboured respiration, salivation, emaciation, teeth grinding and death. It is important to note that supplementation of higher Se leads to chronic selenium toxicity include loss of tail hair, lameness, sore feet, rocket shaped hoofs and abnormality in claws (Patterson et al., 2003).

4.9 Chromium (Cr)

Cr is a essential micro mineral demonstrated by Schwarz and Mertz (1992) in rats. Cr may be present in diets in the form of inorganic or organic compounds. The bioavailability of inorganic Cr is low and it is about 1-3% whereas organic Cr has 15-30% bioavailability (Forbes and Erdman, 1983). Inorganic Cr forms insoluble Cr oxide. It has been reported [43] that the bioavail- ability of inorganic Cr is between 1 and 3% while organic Cr is about 10 to 30 times more available (15 to 30%) It has been reported [43] that the bioavail- ability of inorganic Cr is between 1 and 3% while organic Cr is about 10 to 30 times more available (15 to 30%) It has been reported [43] that the bioavail- ability of inorganic Cr is between 1 and 3% while organic Cr is about 10 to 30 times more available (15 to 30%) It has been reported [43] that the bioavail- ability of inorganic Cr is between 1 and 3% while organic Cr is about 10 to 30 times more available (15 to 30%) It has been reported [43] that the bioavail- ability of inorganic Cr is between 1 and 3% while organic Cr is about 10 to 30 times more available (15 to 30%) It has been reported [43] that the bioavail- ability of inorganic Cr is between 1 and 3% while organic Cr is about 10 to 30 times more available (15 to 30%) It has been reported [43] that the bioavail- ability of inorganic Cr is between 1 and 3% while organic Cr is about 10 to 30 times more available (15 to 30%) It has been reported [43] that the bioavail- ability of inorganic Cr is between 1 and 3% while organic Cr is about 10 to 30 times more available (15 to 30%) It has been reported [43] that the bioavail- ability of inorganic Cr is between 1 and 3% while organic Cr is about 10 to 30 times more available (15 to 30%) Forbes RM, Erdman JJW (1983) Bioavailability of trace mineral elements. Ann Rev Nutr 3:213–231. https://doi.org/10.1146/ annurev.nu.03.070183.001241 Forbes RM, Erdman JJW (1983) Bioavailability of trace mineral elements. Ann Rev Nutr 3:213–231. https://doi.org/10.1146/ annurev.nu.03.070183.001241 Forbes RM, Erdman JJW (1983) Bioavailability of trace mineral elements. Ann Rev Nutr 3:213–231. https://doi.org/10.1146/ annurev.nu.03.070183.001241 Forbes RM, Erdman JJW (1983) Bioavailability of trace mineral elements. Ann Rev Nutr 3:213–231. https://doi.org/10.1146/ annurev.nu.03.070183.00124 Hexavalent chromium ($Cr6^{+}$) compounds are absorbed better in intestine than trivalent chromium ($Cr3^{+)}$ compounds. Cr is excreted in urine and small amount is eliminated in hair, respiration and bile. Amino acids, oxalate, ascorbic acid and high carbohydrate in diets increases Cr absorption while antacids (natrium hydrogen carbonate, magnesium hydroxide) reduces Cr concentrations in the blood (Hunt and Stoecker, 1996). Cr helps in control in appetite, hypoglycaemia and protein intake as it is a part of glucose tolerance factor (GTF). Previously many research shows that Cr increases nutrient utilization, reduces oxidative stress, improves immune system, and boosts milk yield and reproductive performance (Lashkari et al.,2018). Cr supplementation in goat resulted in increased daily weight gain, ottal weight gain and decreased blood cholesterol level (Mondal et al., 2007).

4.10 Potassium (K)

Potassium (K) along with Na and Cl plays important role in osmatic pressure andacid-base balance. It is also required for protein synthesis, O_2 and CO_2 transportation, water balance, enzyme reactions, membrane potential, muscle contraction and cell growth.Potassium (K) is the major cation of the intracellular fluid than extracellular fluid (3.9–5.8 mmol/L extracellular versus 150–160 mmol/L intracellular) (Goff, 2004).

Dairy cow may suffer from hypokalemic syndrome when the serum K value decreases than normal value of 3.9 to 5.8 mmol/L (Constable et al., 2017). Peek et al., (2000) reported that hypokalemia in dairy cow occurs due to metabolic alkalosis, abomasal disorders, hyperinsulinemia, sympathetic activation and excess administration of bicarbonate etc. Bairwaet al. (2023) studied about hypokalemic syndrome in dairy cows where clinical sign were ruminal atony, sterna recumbancy, pale pink mucus membrane, S-shaped neck, anorexia, tachycardia and scanty dung. Significantly ($p<0.01$) higher values of monocytes, aspartate aminotransferase, creatinine phosphokinase, Magnesium, glucose with significant ($p<0.01$) decreased values of potassium and chloride were also observed. Diet with higher level of potassium or wide ratio of potassium and sodium caused lower fertility in cows (Schweigert and Zucker (1988).

5. CONCLUSION

Mineral requirement of a dairy animal depends on age, breed, production stage and physiology of animal. Macro and micro minerals are essential for animal's reproductive physiology and to achieve high milk production, better reproductive performance and general herd health.

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