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The Saga of Macrominerals and its Role in Reproduction in Domestic Animals: A Review

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Abstract: A number of inorganic elements are essential for the growth, production and reproduction of animals. In addition, mineral requirements are also influenced by age, parity, stage of pregnancy and stage of lactation. Adequate quantity of minerals are utmost important for proper functioning of various physiological functions in animals. Deficiency and excess both have detrimental effects on production and reproduction; thus significantly affecting the economics of animal husbandry.

Key words: Domestic Animals・Macrominerals・Production・Reproduction

INTRODUCTION

A number of inorganic elements are essential for the growth, production and reproduction of animals [1]. In addition, mineral requirements are also influenced by age, parity, stage of pregnancy and stage of lactation. The inorganic elements are classified according to their requirements in animal body. Those required in greater quantities are referred as macrominerals (calcium. phosphorus, sodium, chloride, potassium, magnesium and sulfur). Macrominerals required in large amount each day and their concentration in diet is expressed as percentage of diet or in grams per kilogram of diet. Macrominerals has role in different physiological functions. Other elements required in much smaller amounts are referred as trace minerals (microminerals) i.e. copper, cobalt, iodine, iron, manganese, molybdenum, selenium, zinc, chromium and fluorine. Their concentration in diet is expressed as parts per million (ppm), which is equivalent to milligram per kilogram of diet or in some cases as parts per billion (ppb), which is equivalent to microgram per kilogram of diet. Adequate quantity of minerals are utmost important for proper functioning of various physiological functions in animals. Deficiency and excess both have detrimental effects on production and reproduction; thus significantly affecting the economics of animal husbandry.

Role of Various Macro Minerals in Animal Reproduction

Calcium (Ca): Calcium is an essential component of skeleton and plays a pivotal role in maintaining homeostasis of vertebrates [2]. The maximum portion of calcium present in the bone as hydroxyapatite (99%) and small fractions present in the cell membrane or endoplasmic reticulum (0.9%), extracellular fluid or serum (0.1%) and in cytosol (0.00002%) [3]. Extracellular calcium exist in three forms i.e. ionized (50%), complexes to anions (5%) such as citrate, bicarbonate, phosphate, or lactate and protein bound (45%). Ionized calcium involved in array of physiological processes such as muscular

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contraction, blood coagulation, enzyme activity, neural excitability, hormone secretion and cell adhesion [2]. In short, calcium serves two primary functions in the body namely maintaining structural integrity of bone and teeth and as a messenger or regulatory ion. There is high concentration gradient (10, 000 folds) between extracellular fluid and cytoplasm, which permits Ca^{2+} to function as a signaling ion to activate intracellular processes. The lipid bilayer of cell membrane has poor permeability to Ca^{2+}; therefore, influx of Ca^{2+} into cytoplasm is controlled by heterogeneous group of calcium channels regulated by membrane potential, cell membrane receptors, or intracellular secondary messengers. Influx of Ca^{2+} into cells regulate cellular function (by interactions with a calcium binding protein, calmodulin; calcium sensitive protein kinase and G-protein linked Ca^{2+}sensing receptors in the cell membrane) and stimulate biological response (such as neurotransmitter release, contraction and secretion).

The normal reproductive process is compromised in case of severe calcium deficiency [4] possibly due to lack of tone of uterine muscle, as calcium sensitizes the tubular genital tract for action of hormones [5]. Majority of infertility problems in cattle [5] and buffaloes [6] are due to nutritional deficiency, calcium appears to affect reproduction indirectly because it affects the incidence of parturient paresis [7]. Plenty of available reports suggest that anestrus, sub-estrus and repeat breeding condition in cattle [8-12] and buffalo [6] might be due to calcium deficiency or imbalance. Stojikovic *et al.* [13] opined that GnRH induced LH release from pituitary is calcium dependent and in case of sub-threshold calcium level (calcium is lower than circulatory calcium) there is failure of LH release. Low level of calcium may increase the incidence of dystocia, retained fetal membranes, tardy uterine involution [14, 15], prolapse of vagina [16], cervix [17], uterus [14, 18, 19] and even rectum [20-22]. Hypocalcemia probably involve in pathogenesis of incomplete cervical dilation during parturition in ruminants [23]. Furthermore, hypocalcemia predisposes the cows for uterine diseases [24], has adverse effect on fertility in term of reduced conception rates and extended interval to pregnancy [25]. Moreover, Curtis *et al.* [15] studied the association between hypocalcemia and peri-parturient disorders and opined that loss of muscle tone associated with hypocalcemia could reduce normal uterine function and hypocalcemic cows have 3.2 times higher incidence of RFM than normal contemporaries. Hypocalcemia reduces muscle contraction, hence, rumen function is compromised which results in in-appetence, thus, negative energy balance (NEB) ensues, consequently to cope up with NEB fat mobilization occur and the end result is fatty liver syndrome and ketosis [26], which further suppress appetite. Pharmacological induction of hypocalcemia by (IV infusion of Na_2 EDTA) reduces the contractile strength and motility of rumen as well as the ruminal dysfunction may occur considerably before the onset of clinical signs of hypocalcemia in sheep [27]. Subclinical hyocalcemia compromises motility of digestive tract in bovines [28] as well as reduces insulin concentrations [29] which results in reduced milk yield and compromised fertility. In spite of hypocalcemia, hypercalcemia is also detrimental to fertility by causing secondary deficiency of other minerals by inhibiting their intestinal absorption [30, 31].

The animal ration preferably should have 0.75 to 0.80 per cent calcium on dry matter basis [32]. In order to maximize milk production and reproductive efficiency, prevention of milk fever should be of cardinal concern. Thus, the cows must be supplied with adequate amount of calcium. Hignett and Hignett [33] mentioned that a minimum calcium-to-phosphorus ratio of 1.5:1 and 2.5:1 for lactating cows is suitable for normal reproductive functioning.

Phosphorus (P): The normal values of phosphorus are 4-8 mg/dl [34], level below 4mg/dl usually indicate phosphorus deficiency [18, 34]. The phosphorus content should be 0.26% and 0.40% of the ration on a dry matter basis for dry cows and high producing dairy cows respectively [35]. Gerloff and Morrow [7] opined that phosphorus deficiency is most frequently associated with reproductive abnormality in cattle. It is necessary for normal energy and phospholipid metabolism as well as skeletal muscle development and milk production. Serum phosphorus level generally reflects intake although they were modified by vitamin D and calcium status. There is no consensus among scientists that hypophosphatemia is a cause of infertility syndrome in bovines [18]; some suggest that hypophosphatemia is associated infertility is characterized by anestrus, sub-estrus, irregular cycles, low conception rate [36-38] and repeat breeding syndrome in absence of other clinical sign of phosphorus deficiency, however, others reported no adverse effect on fertility [39]. Kumar *et al.* [23] observed the effect of GnRH and $PGF_{2á}$ in anestrus crossbred cows and recorded non-significantly lower overall mean phosphorus level in untreated anestrus cows than those of treated contemporaries, furthermore, the value was non-significantly higher in conceived cows as compared with non-conceived one (8.91±0.27 vs 8.55±0.17 mg/dl; p>0.05).

Magnesium (Mg): Adequate supply of dietary magnesium important to safeguard animals health as it is an essential nutrient in animals [40]. All enzymatic reactions involving the utilization and formation of ATP have an absolute requirement for magnesium. It is indispensible for all phosphate transfer reactions, stabilizes the anionic charges on ATP, ADP and AMP, serves as a co-factor for thiamin pyrophosphate requiring reactions and participates in the synthesis of nucleic acid and the utilization of acetyl- CoA (CoA). Through its interaction with phosphoryl groups of membrane phospholipids, its modulation of ATP metabolism and its effect on trans-cellular calcium ion gating, Mg exerts many regulatory effects on cell membrane function, electrical conductivity and hormonal signaling of intracellular processes [41]. Magnesium is indispensable for maintaining normal bone growth, activating various enzyme system, nervous system and degradation of fiber in rumen [42]. Sikka [43] stated that magnesium requirements are more pronounced at the time of occurrence of high energy processes, as magnesium act as co-factor in all the ATP requiring enzymatic process in overall general metabolism, nevertheless reproduction is one of the most dominating process in biological system. In heifers, udder edema can be prevented by feeding 18 mg magnesium oxide 5-6 weeks prior to parturition and high magnesium is needed in early lactation to maintain normal milk output [42]. Moreover, Radostits *et al.* [44] opined that nutritional deficiency of magnesium causes lactation tetany in cows. Kumar *et al.* [23] studied the effect of GnRH and $PGF_{2á}$ in anestrus crossbred cows and recorded non-significantly lower overall mean magnesium level in untreated anestrus cows than those of treated contemporaries, furthermore, the value was non-significantly higher in conceived cows as compared with non-conceived one (3.84±0.11 vs 3.46±0.15 mEq/L; p>0.05).

The relation between magnesium supply and milk fever is not extensively studied but any decrease responsiveness to an acute drop in plasma Ca was observed in hypomagnesemic cows [45]. Moreover, Van der Braak *et al.* [46], observed slower mobilization of Ca in cows fed magnesium deficient ration during the dry period. Lean *et al.* [47] opined that increase magnesium content in prepartal ration significantly reduced the incidence of milk fever. Furthermore, Goff [48] postulated that sensitivity of PTH receptors is decreased in hypomagnesemic cows (PTH is an important hormone for calcium homeostasis). Thus, in order to get optimum production and reproduction, ration must be supplemented with adequate amount of Mg to eschew the deficiency.

Sodium and Chloride (Na and Cl): As in case for most other nutrients, dietary requirements for Na and Cl increases significantly during lactation [41]. The sign of Na or Cl deficiency have been well documented in cattle and include lethargy, anorexia, weight loss, hypogalactia, neuromuscular and cardiovascular dysfunction, depraved appetite [49-52] and compromised renal function [51-53]. Thus, sodium and chloride deficiency indirectly affect the reproduction. Moreover, Aines [54] studied the effect of withheld of sodium chloride for long time in dairy cattle and observed that effect becomes very evident after calving. Lactation caused rapid loss of weight because the appetite was poor. Milk secretion declined and ceased. The cows become cachectic and failed to estrum. On per rectal examination ovaries were found to be small and inactive; an occasional small 3/8 to ½ inch follicle was palpated. Estrum did not return until salt was supplied and the appetite, nutritive state and body condition improved. For dairy cattle, salt requirement can be easily met by adding 1% salt to the grain and availability of salt as free lick [42].

Potassium (K): Potassium is major intracellular cation of the body. The physiological functions of potassium are maintenance of electrolyte balance, enzyme activator and proper functioning of muscle and nerve. Moreover, potassium is required for normal secretion of insulin. The deficiency of potassium is characterized by weakness of muscles, musculature of female genital tract, anoestrus, cyclic irregularity, long inter-calving intervals in cows and still born or weak expelled calves [42]. Furthermore, Excessive dietary potassium is a major factor increasing the susceptibility of dairy cattle to severe hypocalcemia at calving [1]. The potassium absorbed from the diet induces a mild metabolic alkalosis, which interfere the ability of tissue to recognize PTH, thereby interfering with calcium homeostasis, which might have an indirect effect on reproduction.

Sulfur (S): About 0.15 % of the body weight is the sulfur. The sulfur is found in chondroitin sulfate and amino acids methionine, cysteine (cystine), homocysteine and taurine and in the B vitamins thiamine and biotin. Indeed, a sulfur deficiency is deficiency in the sulfur containing amino acids, thiamine, or biotin [1]. Ruminants needed certain amount of dietary sulfur to provide the rumen microbes with the material needed to synthesize the cysteine, methionine, thiamine and biotin that in turn used by ruminants.

CONCLUSION

Mineral has an important bearing in reproduction of domestic animals. Deficiency as well as excess of the minerals results in compromised reproductive function. In order to maximize reproductive efficiency and to get optimum economic return, the ration of animal should contain adequate quantity of minerals. Furthermore, it is suggested that area specific mineral mixture should be made available in a particular area to prevent any deficiency of mineral in domestic animals.

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