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Need of Micronutrients

in Dairy Cows

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MICRONUTRIENTS are essential for the health and performance of dairy cows. These micronutrients are cellular antioxidants, preventing peroxidative damage, either in cell membranes (vitamins) or in the cytoplasm (trace elements), and are essential for a well-functioning immune system. The cow's uptake and requirement of micronutrients can also vary due to stage of lactation and health status. The immune system of dairy cows is suppressed around parturition resulting in an increased susceptibility to infectious diseases. This may partly be due to decrease in blood concentrations of vitamins A & E, Cu and Zn. Supplementation of micronutrients in cows results in improved metabolic and immune status, increase in quality and quantity of milk and health of cows.

The Need for Micronutrients

The cow's requirement of micronutrients must be provided in the diet. However, the contents vary substantially between different feedstuffs available, and are influenced by factors like environment, soil type, harvest and storage conditions. The cow's uptake and requirement of micronutrients can also vary due to stage of lactation and health status. Therefore, extra supplementation of micronutrients is sometimes required. Adequate micronutrient intake is particularly important during the late dry period and the early stages of lactation in order to prevent diseases around parturition. Deficiency of micronutrients and toxicities of essential and non essential trace elements are challenging human and animal health. In India, animals are mainly reared on straw-based diets which are low in major nutrients, antioxidant vitamins and trace minerals. On these diets, the cows are under stress especially during periparturient period, this may lead to immunosuppression and can be afflicted with various diseases. Considering these facts, supplementation of antioxidants (combination of micronutrients i.e copper/zinc and vitamin E) to the high producers especially during periparturient period may prove to be beneficial. These anti-oxidants may improve productivity of cows by reducing the stress, thus protecting against the chances of sub-clinical/ clinical mastitis. Each of the elements has at least one major role in the physiological functioning of the animal. Intense mammary gland growth and the onset of copious milk synthesis and secretion during early lactation are accompanied by a high energy demand and an increased oxygen requirement. This increased oxygen demand augments the production of oxygen-derived reactants, collectively termed reactive oxygen species (ROS). Excessive production of free radicals and concomitant damage at cellular and tissue levels are neutralized by cellular antioxidants defense systems in the body. The preventive body antioxidative defense systems can be accomplished by enzymatic (e.g. SOD, GSHPx and Catalase) and non-enzymatic mechanisms (e.g. vitamin E and selenium). Excessive production of free radicals and ROS, and/or a decrease in body antioxidant defense, lead to damage of biological macromolecules and disruption of normal metabolism and physiology. A relationship between the physiological changes associated with parturition and a loss in overall antioxidant potential was established in both humans and dairy cows.

SOME IMPORTANT MICRONUTRIENTS

Vitamin E

Vitamin E has a potential role as an antioxidant that is able to prevent free-radical mediated tissue damage, and as a consequence to prevent or delay the development of certain degenerative and inflammatory diseases. Vitamin E is also involved in immune system function so that supplementation with supra-nutritional levels of the vitamin, at least in some instances, results in

The micronutrients are those components of the diet, which are essential and are required in only relatively small quantities. If these are insufficient in diet, they give rise to specific deficiency diseases, which often have particular clinical and histopathological effects.

improved immune responses. Vitamin E is the generic name of a group of lipid-soluble compounds known as tocopherols and tocotrienols. In nature, they occur under different forms α-, β-, γ- and δ-tocopherols, and α-, β-, γ- and δ-tocotrienols. α-tocopherol is the major stereoisomer found in foodstuffs and in blood of cattle, reaching values as high as 95% of total serum vitamin E. Vitamin E is absorbed in the intestine and transported to the liver in chylomicrons via the lymphatic system. Thereafter, only α-tocopherol preferentially appears in plasma, whereas β-, γ- and δ-tocopherol are secreted into bile. This is due to the α-tocopherol transfer protein (α-TTP), which specifically binds the α-form from β-, γ-, and δ-tocopherols, and it has also a further preference for the RRR stereoisomer. TTP amounts can decline and this is associated with decreased α-tocopherol secretion in low density lipoproteins (VLDLs) from liver and changes in the tissue distribution of the vitamin. Eight different stereoisomers of α-tocopherol exist, i.e. RRR, RRS, RSS, RSR, SRS, SRR, SSR, and SSS, but the RRR-α-tocopherol isomer has the highest biological activity. Vitamin E is an important lipid soluble membrane antioxidant that enhances the functional efficiency of neutrophils by protecting them from oxidative damage following intracellular killing of ingested bacteria.

Fresh green forage is an excellent source of vitamin E and usually contain 80-200 IU of vitamin E/kg DM (Table 1). However, concentrates and stored forages (hay and silages) are generally low in Vitamin E. Plasma concentrations of α-tocopherol or vitamin E decrease dramatically in dairy cows fed stored forages in late gestation and early lactation. The lowest plasma alpha tocopherol concentrations are generally observed between 1 week prepartum and 2 weeks postpartum. Plasma vitamin E concentrations drops to levels that reduce the immune response around parturition if vitamin E status is inadequate. Research has indicated that a plasma alpha tocopherol concentration of approximately 3 μg/ml is needed to maximize health and immune response in dairy cows. The functions of vitamin E and selenium are related and that responses in animal health to supplementation of either nutrient can depend on the animal's status of the other nutrient. Supplementing vitamin E during the dry period has reduced the incidence of mastitis in cows fed diets low or marginal in selenium in some studies.

Selenium (Se)

Selenium functions as a component of at least 25 different selenoproteins. In these proteins, sulfur (S) is replaced with Se, which allows the proteins to donate hydrogen and take part in reduction reactions. Selenoproteins include the enzyme iodothyronine deiodinase which is important in regulating metabolism and glutathione peroxidase and thioredoxin reductase which are important components of antioxidant and immune systems. It also plays a vital role in protecting both the intra- and extra-cellular lipid membranes against oxidative damage. The majority of Se in body tissues and fluids is present as either selenocysteine, which functions as an active center for selenoproteins, or selenomethionine, which is incorporated into general proteins and acts as a biological pool for Se. The selenium requirement of dairy cattle is approximately 0.3 mg/kg DM. Although the requirement for selenium is low, feedstuffs produced in many areas are deficient in selenium. Selenium functions in the antioxidant system as a component of the enzyme glutathione peroxidase. Selenium naturally present in legume hay is less available than selenium in grass hay or concentrates.

Selenium toxicity: Poisoning of ruminant stock with Se is not common, but can occur in the areas having seleniferous soils. Acute poisoning, which results in death from respiratory failure, can result from sudden exposure to high Se intakes. Chronic forms of the condition include dullness, stiffness of the joints, loss of hair from the tail, and hoof deformities.

Vitamin A and β-Carotene

Vitamin A and its precursor- β-Carotene are important in maintaining epithelial tissue health and play a vital role in mucosal surface integrity and stability. These functions may affect cow resistance to pathogen entry into the mammary gland as well as resistance to post entry. β-Carotene functions as an antioxidant, reducing superoxide formation within the phagocyte, and it is an important free radical scavenger. Cows with higher California mastitis test (CMT) scores had significantly lower plasma vitamin A and β-Carotene concentrations than cows with CMT scores, indicating no mastitis. Vitamin A deficient animals are more susceptible to bacterial, viral, and parasitic infections than animals with sufficient vitamin A. A deficiency of vitamin A can cause abortions and increased incidence of retained placenta in cows, and increased morbidity and mortality in calves. Beta-carotene is the major precursor of vitamin A that occurs naturally in feedstuffs. Fresh green forage is an excellent source of β-carotene. Much of the β-carotene in silages and hays is lost during harvest and storage. Cereal grains and grain-byproducts are extremely low in β-carotene. Diets based on good quality silage or fresh forage provide adequate β-carotene and in that case it is not economical to supplement it in the diet. If low quality forage is fed, supplementation should be given to the cows. Supplementation of vitamin A is likely not needed in excess of normal recommendations. The level recommended is 110 IU/kg BW/day for milking cows.

Zinc

Zn is an essential trace mineral which is found to be an integral component of over 300 enzymes in metabolism and is widely distributed throughout the body as a component of metalloenzymes and metalloproteins. Zinc plays an integral role in regulating gene expression, consequently impacting a wide variety of body functions including cell division, growth, hormone production, metabolism, appetite control, and immune function. Severe zinc deficiency greatly impairs immune responses and reduces disease resistance but dairy cattle severe zinc deficiency would be very rare. A marginal deficiency of zinc has been observed in dairy cows. Lactating dairy cows require 45 to 65 mg zinc/kg of DM. Zinc content in various feed and fodders have been shown in Table 1. Zn is implicated in maintaining the epithelial barrier to infection, but reports vary as to its role in udder health. As a normal physiologic process, the blood Zn level declines around calving due to reduced DMI, transfer of Zn to colostrum and increased stress. Stressors such as parturition and microbial infections decrease the blood Zn concentrations due to redistribution of Zn from blood to tissues, especially the liver. Since teat skin is the first line of defense, any deterioration in the health of epithelial tissue enhances the ability of bacteria to penetrate and cause infection. Zinc is also required for keratin production. Keratin is a wax-like substance secreted into the teat-end opening. The keratin lining of the teat canal entraps bacteria and prevents their upward movement into the mammary gland through its bactericidal properties. Approximately 40% of keratin in the teat canal is regenerated after each milking, therefore, the ability to efficiently reproduce keratin is important in the defense against mastitis in cows.

Zinc toxicity: The toxic effects of an excess dietary intake of Zinc (Zn) are depressed feed intake and induced Cu deficiency. However, the ruminants have a high tolerance for this element and poisoning will be very rare.

Table 2. Suggested feeding levels in total diet

Vitamin E	1000 IU/day for dry cows, 1500 IU/day for dry buffaloes
	500 IU/day for lactating cows
Selenium	0.3 ppm
Copper	20 ppm
Zinc	60-80 ppm

Copper

Cu is a component of ceruloplasmin, which facilitates iron absorption and transport. In addition, Cu is considered as an important part of superoxide dismutase, an enzyme that protects cells from the toxic effects of oxygen metabolites produced during phagocytosis. Therefore, supplementation of copper at 11 mg/kg DM to lactating cows was recommended. Elevated sulfur (greater than 0.30%) in the diet reduces bioavailability of copper even if molybdenum levels are low. High concentrations of iron (250 mg/kg DM or higher) also reduces bioavailability of copper. Depigmentation or bleaching of hair is usually the earliest visual sign of copper deficiency. Loss of hair pigmentation in copper-deficient cattle is associated with a rough hair coat. Copper deficiency can also result in fragile bones, anemia, sudden death due to heart failure, and reduced immune response. The ability of neutrophils to kill microorganisms is reduced during copper deficiency. Table 2 shows the suggested feeding levels of some micronutrients in total diet of the cows.

Biotin

B-vitamins are synthesized by rumen microorganisms. In the past several centuries, average milk production of dairy cows has increased considerably. It is likely that their B-vitamin requirements increased accordingly and that ruminal synthesis alone may not be sufficient to meet the present needs, even though mature ruminant animal's rumen microflora could synthesize a certain amount of B-vitamins. A number of long-term studies indicate that biotin supplementation can reduce the prevalence of hoof lesions and lameness in dairy cows. Biotin has usually been supplemented at 20 mg/cow/day, and several months of biotin supplementation is needed before hoof health improvements are observed. The mechanism leading to the positive overall production response with B-vitamin supplementation was due to improvements in metabolic efficiency of intermediary metabolism, rather than increased metabolic activity.

Bioavailability of Micronutrients

The meaning of the term bioavailability describes mineral absorption by and/or retention within the animal. Theoretically, a mineral supplement that is more bioavailable than another will provide a greater proportion of absorbed minerals to support animal production and health. An additional benefit of a more bioavailable mineral is that less can be fed to the animal, potentially reducing feed mineral use and mineral losses to the environment. Table 3 shows the bioavailability of some mineral sources.

Effect of Micronutrients on Health and Milk Yield

Metabolic and oxidative stress around calving was reduced by supplementation of vitamin E and zinc in cows. There was increase in

Table 1. Vitamin E and Zn content of feeds and fodders

Feed/Fodder	Vitamin E (mg/kg)	Zinc (ppm)
Mustard cake	10.41	-
Wheat bran	10.56	59
Oats fodder	3.38	35
Berseem fodder	26.50	33
Wheat straw	0.80	16
Concentrate mixture	8.00	53

Table 3. Relative bioavailability of some mineral sources

Element	Source	Bioavailability
Selenium	Sodium selenite	High
Copper	Copper oxide	Low
	Copper carbonate	Intermediate
	Copper sulfate	High
Zinc	Zinc oxide	High
	Zinc sulfate	High
Iron	Iron oxide	Unavailable but may interfere with absorption of other minerals

leptin and insulin hormones, increase in glucose levels, decrease in NEFA levels, improvement in immunity of cows and increased milk production in cows supplemented with vitamin E and zinc as compared to control group of cows. In cows supplemented with vitamin E and Zn, the overall increase in milk yield was 3.61 kg, in vitamin E supplemented group, the increase was 1.1 kg and in Zn supplemented group milk yield increased by 0.73 kg. Supplementation of vitamin E in lactating cows has shown considerable improvement in flavour scores.

SUMMARY

Supplementation of micronutrients in cows results in improved metabolic and immune status, increase in quality and quantity of milk and health of cows. Before supplementation for dairy cows, dairy farmers should get their animal feeds tested and their rations evaluated by a competent dairy cow nutritionist and a reliable laboratory to be sure of the required level of supplementation. While inadequate intake and absorption of certain nutrients may not give required results, supplementation above requirement can be expensive or in some cases toxic. Therefore, supplementation of micronutrients to cows is also economically beneficial in terms of increased profit from more milk production.

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