Area Specific Mineral Mixtures and Vitamins in the Ration of Dairy Animals for Improved Productivity and Reproduction Efficiency

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"There is urgent need to develop and produce area specific mineral mixtures for different regions, to ensure supplementation of deficient minerals in the ration of dairy animals for improved milk production and reproduction efficiency. Crucial trace minerals (Cu & Zn) could be supplemented in the form of methionine-based chelates for better bioavailability. This would help in increasing productive life and productivity of dairy animals"

INTRODUCTION

The health and degree of productivity of dairy cows and buffaloes are dependent on balanced and adequate quantities of all necessary nutrients to meet their requirements for a given physiological stage. The usual feed nutrients given to livestock are proteins for growth and repair of body tissues, carbohydrates and fats as sources of energy, minerals and vitamins for different metabolic functions including supporting structure of body plus water. Minerals and vitamins are the most important nutrients of lactating animals, which are required in very minute quantity, but have a great role in metabolism, milk production, reproduction and even for microbial fermentation in the rumen. A great deal of information has recently become available for better nutrition strategies for feeding minerals and vitamins to lactating dairy cows and buffaloes. It is likely that deficiency of certain minerals may not affect crop yields but their availability from such forages may be inadequate for requirements of livestock, which obtain most of the minerals required from feeds and fodders (Garg *et al*, 2005a). The concentrations of mineral elements in plants are dependent on the interaction of a number of factors including soil pH, plant species, and stages of maturity, yield and climate. The shedding of the seed is normally responsible for losses of many minerals so the material remaining e.g. the straw is a poor source. Sometimes, there is a difference of minerals content in feeds and fodders between hilly and plain region (Sharma *et al*, 2002) and variation in minerals content in fodder grown in different agro-climatic zones (Garg *et al*, 2004). Therefore, information on the mineral composition of such feeds and fodders is essential for formulating area specific mineral mixture, as recommendations leading to excess may have detrimental effect on the animals (Garg *et al*, 2003a, b).

Problems of mineral deficiency and metabolic diseases in all categories of dairy animals have been reported by many scientists due to lower content and low bioavailability of some essential macro and micro-minerals in different feedstuffs. It includes rickets, osteomalacia, pica, bone, teeth and hoof abnormalities, sway back (neonatal ataxia), depigmentation of skin, parakeratosis, anaemia, still birth, goitre, reduced growth rate, milk yield and fertility. More than 90 per cent of minerals and vitamins deficiency exists at sub-clinical level in livestock (Underwood and Suttle, 1999). Even small imbalances or deficiencies can

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develop into reproductive, health and milk production problems. Hence, vitamin and mineral supplements are essential in the ration of cattle and buffaloes for efficient productive and reproductive performance.

MINERALS AND VITAMINS REQUIREMENT FOR DAIRY ANIMALS

Minerals and vitamins requirement is highly dependent on the level of productivity. Increased growth rates and milk production will greatly increase mineral and vitamin requirements. Improved management practices that lead to improved milk production and growth rates for cattle will necessitate more attention to mineral and vitamin nutrition. Marginal mineral and vitamin deficiencies, under low levels of production, become more severe with increased levels of production and previously unsuspected nutritional deficiency signs usually occur as production levels increase. Low animal productivity may occur as a result of complex climatic, social and economic problems but under nutrition is a common factor in developing countries and marked responses in growth, milk production and reproduction have been observed from mineral and vitamin supplementation (Garg and Bhanderi, 2005). Minerals and vitamins requirement suggested by National Research Council (NRC) for lactating dairy cows is presented in Table 1.

Table 1: Mineral and Vitamin Requirements for Livestock[a,b,c]

Particular	Requirements
Calcium (%)	0.43-0.77
Phosphorus (%)	0.25-0.49
Magnesium (%)	0.20-0.25
Sulphur (%)	0.20-0.25
Sodium (%)	0.18-0.20
Potassium (%)	0.90-1.00
Chloride (%)	0.25-0.30
Copper (ppm)	10.00
Zincd (ppm)	80.00
Manganese (ppm)	40.00
Iron (ppm)	50.00
Cobalt (ppm)	0.10-0.50
Iodine (ppm)	0.60
Selenium (ppm)	0.10-0.30
Vitamin A (IU/kg)	3200-3500
Vitamin D3 (IU/kg)	1000-1200
Vitamin E (IU/kg)	15-20

[a] *NRC, 2001.*
[b] *Kearl, 1982.*
[c] *McDowell, 2000.*
[d] *Arora, 1981.*

ANTIOXIDANT AND IMMUNITY ROLES OF TRACE MINERALS AND VITAMINS

Both trace minerals and vitamins play important roles in the health of livestock. For lactating dairy cows and buffaloes, nutrient supplementation for trace minerals and vitamins, go beyond correcting for deficiency but are aimed rather at minimizing stress and optimizing production efficiency. Free radicals can be extremely damaging to biological system. However, these oxidative products can, in turn, damage healthy cells if they are not eliminated from the body of animals (McDowell, 1992). Some vitamins and minerals, which act as antioxidants, serve to stabilize these highly reactive free radicals, thereby, maintaining the structural and functional integrity of cells (Chew, 2000). Therefore, antioxidants are very important to immune defence and health of humans and animals.

Tissue defence mechanisms against free radical damage generally include vitamin C, vitamin E and β–carotene as the major vitamin antioxidant sources. In addition, several metallo-enzymes, which include glutathionine peroxidase (Se), catalase (Fe) and superoxide dismutase (Cu, Zn and Mn) are also critical in protecting the internal cellular constituents from oxidative damage. The dietary and tissue balance of all these nutrients are important in protecting tissue against free-radical damage. The antioxidant function could, at least in part, enhance immunity by maintaining the functional and structural integrity of important immune cells. A compromised immune system will result in reduced animal production efficiency through increased susceptibility to infectious diseases, thereby, leading to increased animal morbidity and mortality.

Table 2: Traditional Feeding Practice for a Dairy Animal Yielding Daily 10 Litres Milk*

Feedstuffs	Quantity (kg)
Green fodder[a] (Sorghum, oat, maize, sorghum, green grasses, lucerne, berseem etc.)	5-10
Dry fodder[b] (Straws of wheat, rice, maize, sorghum, bajra, soyabean etc.)	6-8
Concentrate ingredients[c] (CS Cake, mustard cake, grains of wheat, rice, bajra, barley, maize, sorghum etc.)	1-2
Compounded cattle feed[d]	3-4

* *Garg* et al., *2000, 2002, 2003[a,b], 2004, 2005, Bhanderi et al, 2006.*
[a] Green fodder availability is seasonally and depends on irrigation facilities.
[b] Dry fodder forms bulk of ruminant diet, mainly straws of rice and wheat.
[c] Concentrate ingredients may change place to place, mainly locally available.
[d] Cattle feed is fed depending upon the level of milk yield, may or may not be fortified with minerals and vitamins.

MINERAL STATUS OF COMMONLY USED FEEDS AND FODDERS IN DIFFERENT REGIONS IN INDIA

Livestock feeding in India is traditional in nature and mostly depends upon locally available feed ingredients (Table 2). These feed ingredients are mostly agro-industrial byproducts; vary widely in their minerals and vitamins composition. Availability of green fodder is seasonal and depends upon the rainfall and irrigation facility. Hence, dry roughages like straws of rice, wheat, sorghum, bajra, maize, groundnut, soyabean and local grasses etc., form bulk of the ruminant animals diet. Straws and stovers harvested after maturity contain certain minerals and vitamins at very low levels, but contain excess of silicates, phytates, oxalates and tannins, which may interfere in the utilization of minerals and other nutrients (Garg and Bhanderi, 2005). Supplementation of area specific mineral mixtures and vitamin supplements is not practiced in most parts of the country (Garg *et al*, 2004). Hence, animals depend for their minerals and vitamins requirement on feeds and fodder fed. Most of the feed ingredients available for feeding livestock are deficient in one or other minerals as shown in Table 3. Dairy animals in different agro-climatic regions need to be supplemented with minerals after considering levels of macro and micro-minerals in the feeds and fodders ingested by the animals. Mineral status of commonly used feeds and fodders is given below:

Macro-minerals

The calcium (Ca) content is low in straws and stovers (0.10-0.30%), except groundnut straw (1.20-1.67%). However, leguminous fodders such as lucerne green, cow pea green, moth green and guar green are good source of Ca (1.5-2.50%). Ca content in non-leguminous green fodders such as maize, jowar, bajra, oat and hybrid napier ranges from 0.20 to 0.55 percent. Carrot leaves, chikodi green, sweet potato creepers are subsidiary green fodder fed to milch animals seasonally and are good source of calcium (1.5-2.0%) and other minerals. Tree leaves also contain substantial amount of calcium (1.90-3.10%), but availability is low due to high tannin content. Average calcium deficiency in the ration of milch animals is found to be from 4 to 52 per cent, in different States. Phosphorus (P) content in straws range from 0.09 to 0.20 per cent but grains are high in P (0.25-0.35%) than Ca. P content in green fodders range from 0.15 to 0.45 percent. Cakes (>0.50%) and brans (>1.0%) contain substantial amount of phosphorus but in brans, most of P is in phytic form, which is low bioavailable. Average P deficiency in the ration of milch animals is recorded from 4 to 68 per cent, in different agro-climatic zones. The magnesium (Mg) level in samples of feed and fodder is adequate (average level > 0.35 %). Sodium (Na) level is low in concentrate ingredient (0.04-0.10%) and straws (0.10-0.20%) but high in green fodders (0.20-1.20%). Average Na deficiency

Table 3: Mineral Profiles of Some Feeds and Fodders Fed to Dairy Cows and Buffaloes*

Feedstuffs	(%)				(ppm)			
	Ca	P	Na	S	Cu	Zn	Mn	Fe
Dry fodder (straws of rice, wheat, sorghum, maize, bajra , dry grasses etc.)	0.10-0.30	0.09-0.20	0.10-0.20	0.10-0.15	1.50-7.0	5.0-38	15-109	154-691
Green fodder (sorghum, maize, oat, lucerne, berseem green grasses etc.)	0.20-2.50	0.15-0.45	0.20-1.20	0.06-0.20	4.0-9.0	14-37	27-170	237-1500
Concentrate ingredients (grains of wheat, maize, bajra, sorghum, barley, CS cake, groundnut cake, sesame cake, rice bran, wheat bran & pulse chunies)	0.01-0.27	0.26-0.62	0.04-0.10	0.02-0.34	4.0-25.0	30.0-98.0	7.0-74.0	42.0-701
Mean value**	0.29	0.24	0.074	0.13	6.85	26.0	48	306
Requirements***	0.42	0.34	0.18	0.20	10	80	40	50

* *Garg et al, 2000, 2002, 2003[a,b], 2004, 2005[a,b], Bhanderi et al, 2006.*
** based on analysis of more than 1000 samples.
*** as per standard requirements given in Table 1.

in the ration of milch animals is recorded to be 20 to 55 per cent. The potassium (K) content in feeds and fodder seem to be quite rich (>1.0%), because all samples of feedstuffs are extra ordinarily rich and are far exceeding the requirement level (0.90%). The sulphur (S) content in most of the feedstuffs is 0.10-0.15 per cent, giving wider N:S ratio. Average S deficiency in the ration of milch animals is reported to be from 14 to 48 per cent, in different States. Sulphur supplementation is needed for efficient utilization of nitrogen by rumen microbes and to maintain N:S ratio of 10:1.

Micro-minerals

Copper (Cu) is one mineral element, which is acutely deficient in different parts of the country. The Cu content is consistently low in straws (1.5-7 ppm) and green fodders (4-9 ppm), whereas, concentrate ingredients are better source of Cu (12-25 ppm), except grains (4-6 ppm). Average Cu deficiency in the ration of milch animals is found to be from 12 to 66 per cent, in different agro-climatic zones of India. Hence, Cu supplementation is necessary in the ration of milch animals. Likewise, zinc (Zn) is acutely deficient in different agro-climatic zones (average level < 30 ppm) and need to be supplemented at a level of 80 ppm in the total ration for optimum metabolic functions. Cakes (45-60 ppm) and brans (60-98 ppm) are good sources of copper and zinc. Average Zn deficiency in the ration of milch animals is found in the range of 33 to 80 per cent, in different States. Cobalt (Co) is found to be marginally deficient in feedstuffs (0.09-0.6 ppm), in different agro-climatic zones. Co deficiency in the ration of animals ranges from 0-30 per cent, in different States. Manganese (45-80 ppm) and Iron (150-1500 ppm) levels in most of the feeds and fodder are found to be adequate. Molybdenum (Mo) content in feeds is within the safe limit (average level < 1.5 ppm) and giving Cu:Mo ratio wider than 5.0. Selenium (Se) content in most feedstuffs is adequate (average level>1.0 ppm).

A survey work conducted by the NDDB, Anand in the States of Gujarat, Rajasthan, Kerala, Punjab, Maharashtra and Andhra Pradesh indicate that zinc, copper, sulphur, manganese, cobalt are deficient in the ration of animals (Garg *et al*, 2000, 2002, 2003a, b, 2004, 2005a, b; Bhanderi *et*

al, 2006). In several situations, there is deficiency of calcium, phosphorus and sodium, while magnesium, potassium, iron and selenium are adequate in the diet of dairy animals. Based on the mineral mapping work, area specific mineral mixture formulations have been developed for the above States having appropriate levels of Cu, Zn, Co, S and other minerals, which were found to be deficient in total ration of animals.

Overall, it is apparent from mineral studies conducted by NDDB and other institutes that the ration of dairy animals is deficient in calcium, phosphorus, sodium, sulphur, copper, zinc, iodine and cobalt and are required to be supplemented for improving growth, milk production and reproduction efficiency.

SIGNIFICANCE OF MINERALS AND VITAMINS SUPPLEMENTATION FOR MILK PRODUCTION AND REPRODUCTION

There are certain minerals and vitamins, which are required by the animals for milk production and reproduction. The calcium and phosphorus are two macro minerals required by the dairy animals and its requirement increases with increased milk production. Milk contains 0.12 per cent Ca and 0.10 per cent phosphorus per kg and colostrum still rich in calcium (0.14%). Considering its bioavailability, dairy cows required minimum 3.21 g Ca and 1.98 g phosphorus per kg milk yield (NRC, 2001). The requirements of Ca and P are 4.65 g and 2.88 g per kg milk yield, respectively for buffaloes (Kearl, 1982). The requirement of Ca per kg milk yield in buffaloes are higher than cows buffalo milk contain high fat, therefore, high fat diet is required for buffalo which results in fecal Ca losses through formation of insoluble calcium soaps and thus, increases dietary requirements. Milk production is reduced in prolonged Ca and P deficiency because animals are not able to produce milk with low Ca and P. For proper utilization of Ca and P in animal system, vitamin D_3 supplementation is also necessary.

Zinc and vitamin A is important in maintenance of health and integrity of epithelial tissue, such as skin (teats) and mammary tissue, due to its role in cell division and protein synthesis. An additional mode of action for zinc reducing somatic cell count (SCC) is related to zinc's role in keratin formation. Zinc is required for the incorporation of cysteine into keratin. The keratin lining of the teat canal entraps bacteria and prevents their upward movement into the mammary gland. In this way, zinc and vitamin A is important for reducing mammary gland infection (mastitis). Supplementation of optimum protein and zinc increases ovulation and has a role in spermatogenesis in male animals. Likewise, adequate manganese and copper supply in the ration is also necessary to keep the animal in normal cyclicity. Iodine is required for normal foetal development and its deficiency may result into still-birth, abortion, reabsorption of foetus or birth of weak and hairless young ones. Male fertility is also affected and may be resulted into decline in the libido and deterioration of semen quality.

Advantages of Feeding Mineral Mixture

- Helps in improving growth rate in growing animals.
- Helps in curing reproductive disorders.
- Helps in improving fertility and reducing inter-calving period.
- Improves efficiency of feed utilization.
- Improves milk and fat yield.
- Helps minimizing the incidence of certain metabolic diseases.
- Better immune response, hence better resistance against infectious diseases.
- Calves born are healthy.
- More effective and economical, if it is area specific.

MANUFACTURING OF AREA SPECIFIC MINERAL MIXTURES

After generating information on the dietary mineral status, area specific mineral mixture could be formulated incorporating deficient minerals at appropriate proportion and excluding minerals, which are adequate in feeds and fodder, thus, reduce the cost of supplements. Mineral elements exist in many chemical forms such as sulphates, carbonates, chlorides, oxides, etc.

There is considerable difference in the bioavailability of mineral elements provided from different sources. The form of minerals chosen for use should depend on the their biological value, cost and availability in the area, stability and type of diet used. Di-calcium phosphate (DCP) is first choice of mineral ingredients used for compounding mineral mixture for supplementing Ca and P to livestock. However, it is necessary that the level of fluorine content is kept as low as possible to prevent its being toxic to livestock. DCP should be of genuine and good quality and should not be of animal origin. Due to spread of Mad Cow Disease or Bovine Spongiform Encephalopathy (BSE) in many European countries, following feeding of bovine origin ingredients to ruminants, Bureau of Indian Standards (BIS) does not permit use of animal origin ingredients in mineral mixture/cattle feed.

In manufacturing mineral mixture for proper utilization in the tissue, it is necessary to consider their bioavailability (defined as the percentage of total nutrients in feedstuffs, which are actually utilized by the animals for various production purposes), compatibility, solubility, particle size, density and chemical stability. Mineral mixture should be formulated using DCP ($CaHPO_4.2H_2O$) and sulphate form of mineral salts, except magnesium oxide. The different mineral salts, which could be used for mineral mixtures are DCP (Ca & P), calcite powder (Ca), magnesium oxide (Mg), ferrous sulphate (Fe), zinc sulphate (Zn), potassium iodide (I), sodium thiosulphate (S), copper sulphate (Cu), cobalt sulphate (Co) and manganese sulphate (Mn).

Concerned agencies in the country need to manufacture area specific mineral mixtures, using highly bioavailable salts. Supplementing crucial trace minerals in the form of methionine-based chelates is better option for curing these deficiency problems in animals. National Dairy Development Board, Anand has been providing technical assistance and technology to the dairy cooperatives, for establishment of mineral mixture plant for manufacturing good quality/area specific mineral mixtures.

CONCLUSION

Lactating dairy cows and buffaloes have much greater needs for minerals and vitamins, which are mostly fed on feeds and fodder deficient in minerals and vitamins. These deficiencies vary from region to region, amongst different States and within the States. Supplementation of minerals and vitamins in the ration is not practiced in most parts of the country. Mineral mixtures available in the market at a very high price are not formulated in accordance with the regional deficiencies and mostly mineral salts used are of cheaper quality, having low bioavailability. Many a times, tag value does not match with the actual analysis. Hence, there is urgent need to develop and produce area specific mineral mixtures for different regions, to ensure supplementation of deficient minerals in the ration of dairy animals for improved milk production and reproduction efficiency. Crucial trace minerals (Cu & Zn) could be supplemented in the form of methionine-based chelates for better bioavailability and retention. This would help in increasing productive life and productivity of dairy animals.

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