Animal Nutrition and Feed Technology (2003) 3 : 27-36

Trace Mineral Status of Feeds and Fodder in Dahod and Panchmahal Districts of Gujarat

M.R. Garg*, B.M. Bhanderi and P.L. Sherasia

Animal Nutrition and Feed Technology Laboratory
National Dairy Development Board
Anand-388 001, India

(Received September 12, 2002)

ABSTRACT

A study was undertaken to assess the micro-mineral status of feeds and fodders in Dahod and Panchmahal districts of Gujarat, for formulation of an appropriate area specific mineral mixture. The average copper content was unduly low in straws (4.54 ppm) and green fodders (6.31 ppm), whereas concentrate ingredients were better sources of copper (16.78 ppm), except grains (5.13 ppm). Likewise, zinc was acutely deficient in the surveyed area (average levels < 24.0 ppm) and needed to be supplemented at a level of 80 ppm in the total ration for optimum metabolic functions. Manganese was occasionally deficient in diet of animals, however, iron and cobalt levels in most of feeds were adequate with traditional feeding systems. Molybdenum content in feeds was within the safe limit (average levels < 1.0 ppm) and gave Cu:Mo ratio wider than 3.0. Selenium content in most of the feedstuffs was adequate and its supplementation in the diet was not necessary. From the present survey, it was apparent that the levels of certain microminerals such as copper, zinc and occasionally manganese were deficient. However, the levels of some other mineral elements such as iron, cobalt and selenium were found to be adequate in the surveyed area.

Key words : Zinc, Cobalt, Iron, Copper-molybdenum ratio, Feed, Fodder.

INTRODUCTION

Mineral mixture/supplements are generally not included in the ration of animals in India, except for common salt and calcite/lime stone powder. The essentiality of

*Reprint request: Dr. M.R. Garg, Tel: +91-2692-26245; Fax: +91-2692-60158;
E-mail: mrgarg@nddb.coop

minerals for the growth, health, reproduction, production as well as normal physiological functions of animal body is well documented (Chew, 2000). A common mineral mixture available in the market mostly contains calcium and phosphorus with high fluorine and little amounts of trace minerals, which is used for therapeutic purpose and ration formulations at organised animal farms. However, the productivity of animals is hampered due to deficiency or imbalance of minerals in diet, which in turn is largely affected by the mineral content of the feeds and forages. Straws and stovers form the bulk of the diet of ruminants that are low in most of micronutrients but contain higher silicates, oxalates and tannins, which may interfere in the utilization of other micronutrients. Leguminous crops contain higher levels of minerals compared to that of non-leguminous cultivated fodders. Mineral deficiency or excess is considered an area specific problem due to industrial pollution and/or soil characteristics. Mineral deficiencies of livestock could be related either to low intake of elements due to low level in forages or antagonistic effect between elements (Humphries *et al.*, 1983; Prabow *et al.*, 1989). As indiscriminate supplementation of minerals through mineral mixture/supplements is neither economical nor practical, it will be useful to know the mineral status of feeds and fodder to ascertain the extent of deficiencies/ excesses (Hinders, 1999; Garg *et al.*, 2002). Therefore, present study was undertaken to know the mineral status of Dahod and Panchmahal districts of Gujarat State, so as to suggest area specific mineral mixture for improving productive and reproductive performances of livestock.

MATERIALS AND METHODS

One village from each taluk of Dahod and Panchmahal districts was selected randomly for taking representative samples of feeds and fodders. Total area of Dahod and Panchmahal districts is 8,806 sq.km., distributed into 18 taluks, having 1915 villages. The districts are having annual rainfall of 950 mm, located at 300 meters above mean sea level, having latitude of 22.45° and longitude of 73.45°. Atmospheric temperature ranges from 6 to 44°C during different seasons. Help was sought from village milk producers within the village and Panchmahal District Cooperative Milk Producers' Union, for identification of 4 to 5 farmers. In identification of farmers, land location was considered essentially, one each from Northern, Eastern, Western and Southern directions, to cover soil types on each side of the selected village. The survey was carried out to obtain information on the number of animals, size of land holding, economic condition, fodder and other crops being grown.

Further information regarding the amount and types of feeds and fodder being offered to the animals, approximate rate of daily feed intake by individual animals and daily milk yield of the animals were collected from individual farmer, using standard sampling procedure. Total intakes were compared against the requirements on dry matter basis (Campbell *et al.,* 1999; NRC, 2001), so as to identify quantitative deficiency, sufficiency or even excess. The data were analysed statistically as per Snedecor and Cochran (1967).

Composite samples of green fodder, dry fodder, individual concentrate ingredients and the compounded cattle feeds (concentrate mixtures) were collected from all over the surveyed area. Green samples were dried in an oven at 80°C for 24 h and subsequently ground (1 mm). Ground samples of concentrate and fodder were stored in plastic bags until analysed. Samples were digested using 5 ml concentrated nitric acid plus 1 ml concentrated hydrochloric acid by microwave digestion method for preventing evaporation of volatile elements. Total volume of mineral extract after complete digestion of material was made to 25 ml with deionized water. All the samples were analyzed for Cu, Zn, Mn, Fe, Co, Mo and Se using Inductively Coupled Plasma - Optical Emission Spectrometer (Perkin Elmer, OPTIMA - 3300 RL). The word "critical" is used in this paper to note a concentration in feedstuffs below (or above with excesses) what is considered the requirement for animal. This assumes the expected consumption as estimated by the NRC (2001). Total milligrams of minerals consumed per day determine the true adequacy of a mineral, not the forage concentration.

RESULTS AND DISCUSSION

The survey work revealed that amongst dry roughages, straws of rice, maize, bajra, sorghum and wheat were most commonly fed by the farmers of the Dahod and Panchmahal districts in the ration of cows and buffaloes. The concentrate ingredients were usually conventional type and wholesome, which included rice polish, broken rice with bran, maize grain, cottonseed cake, *mung (Phaseolus aureus)* chuni and *bajra (Penisetum typhoides)* grain. The practice of feeding compounded cattle feed and mineral supplements was also followed in certain areas. Some farmers were growing green fodders such as sorghum, maize and lucerne but only in limited areas and restricted quantity of green fodders were fed to milch animals. *Chikodi (Cichorium intybus)* and *bhindi (Abelmoschus esculentus)* green were subsidiary green fodders, fed to milch animals.

Copper (Cu)

Copper content was recorded acutely low in almost all the feedstuffs (Table 1 and 2). Bajra, maize, rice, sorghum and wheat straws were low in copper (4.54 ppm), whereas lucerne green was better source of copper (10.27 ppm). Local grasses, mixtures of different grass species, contained 6.73 ppm Cu. Bajra husk and maize cob without grain were also poor source of Cu (Table 1). In grains, the level was again very low (5.13 ppm). Cottonseed cake, sesame cake, rice polish, *urd (Phaseolus mungo)* chuni, *mung* chuni and wheat bran were relatively higher in Cu

Table 1. Trace mineral content (ppm) in feedstuffs collected from Dahod and Panchmahal districts (DM basis)

Feed	Cu	Zn	Mn	Fe	Co	Mo	Se	Cu:Mo
[a]Critical level	<8.0	<30.0	<40.0	<50.0	<0.10	>6.0	<0.2	-
Bajra husk (2)	3.12±0.59	16.35±4.69	14.85±1.51	323.50±131.86	0.19±0.11	0.66±0.26	0.49±0.28	4.72
Bajra straw (6)	5.60±0.84	20.60±3.63	40.30±6.65	224.50±17.19	0.26±0.064	0.68±0.20	1.47±0.19	8.23
Bhindi green (2)	5.90±2.51	23.20±9.38	84.20±5.06	145.50±20.82	0.14±0.016	0.47±0.26	2.38±0.50	12.55
Chikodi green (1)	7.00	24.20	64.90	449.00	0.21	0.80	4.70	8.86
Gram pods (1)	9.59	42.60	106.00	529.00	1.15	2.66	5.03	3.60
Local grasses (12)	6.73±1.07	27.00±4.93	62.00±10.78	404.70±102.42	0.87±0.26	0.97±0.15	1.61±0.20	6.93
Lucerne green (3)	10.27±1.66	18.16±1.09	67.63±15.89	691.33±185.45	0.44±0.14	1.27±0.51	5.63±0.32	8.08
Maize cob without grain (9)	4.11±0.62	18.44±1.74	16.98±5.66	264.43±79.41	0.90±0.69	0.54±0.26	0.96±0.64	7.61
Maize green (6)	4.04±0.23	14.52±2.85	32.21±1.84	237.61±55.35	0.11±0.024	0.64±0.16	1.40±0.19	6.31
Maize straw (29)	5.23±0.47	16.41±2.43	36.38±3.27	198.40±20.44	0.18±0.03	0.97±0.17	1.97±0.19	5.39
Mung pods (1)	10.20	23.50	63.30	1060.00	0.57	3.12	5.71	3.26
Rice straw (24)	4.18±0.45	8.45±1.19	109.75±16.05	252.17±28.24	0.22±0.028	0.95±0.13	1.25±0.14	4.40
Sorghum green (7)	4.00±0.32	17.15±3.05	26.88±4.24	531.82±381.10	0.14±0.03	0.83±0.13	1.49±0.26	4.81
Sorghum straw (16)	4.70±0.54	14.53±1.76	28.14±3.30	154.21±24.77	0.12±0.019	0.63±0.095	1.48±0.21	7.46
Soyabean pods (1)	7.97	12.20	46.60	434.00	0.52	0.80	6.24	9.96
Tuar pods (2) (*Cajanus indicus*)	9.03±2.47	20.06±0.58	51.11±23.73	283.46±88.85	0.17±0.06	1.87±0.86	2.95±1.28	4.82
Wheat straw (6)	3.02±0.98	5.92±2.08	14.96±2.96	215.50±28.83	0.29±0.085	0.97±0.21	1.37±0.30	3.11

Figures in parentheses indicate no. of samples analysed; [a]Critical level: concentrations below which are low or considered deficient or excessive in the case of Mo (McDowell *et al.*, 1993), based on requirements for cattle (NRC, 2001)

Table 2. Trace mineral content (ppm) in feedstuffs collected from Dahod and Panchmahal districts (DM basis)

Feed	Cu	Zn	Mn	Fe	Co	Mo	Se	Cu:Mo
[a]Critical level	< 8.0	< 30.0	< 40.0	< 50.0	< 0.10	> 6.0	< 0.2	
Compounded cattle feed (20)	12.37±0.44	50.67±7.16	91.52±4.12	806.60±38.91	2.74±0.37	1.43±0.20	5.08±0.22	8.65
Bajra grain (5)	6.06±0.66	31.96±4.66	22.16±4.85	69.16±10.36	0.24±0.036	0.71±0.15	1.00±0.57	8.53
Cottonseed cake (2)	14.70±0.49	43.25±0.94	17.83±0.60	290.50±17.55	0.63±0.036	0.66±0.07	1.28±0.016	22.27
Mahua cake (1)	6.46	30.3	11.90	265.00	0.21	0.21	1.26	30.76
Maize grain (22)	5.14±0.40	28.83±1.89	13.75±2.21	63.50±3.71	0.62±0.21	0.41±0.033	0.16±0.044	12.53
Mung chuni (2)	13.10±0.81	37.80±2.77	26.20±4.98	321.50±52.66	0.46±0.081	1.82±0.21	2.09±0.33	7.19
Puwad cake (2)	19.45±6.24	43.35±0.61	30.45±5.18	556.00±66.13	1.44±0.25	2.01±0.25	3.45±0.22	9.67
Broken rice with bran (4)	30.40±3.40	31.15±1.40	65.57±20.40	529.00±86.74	1.81±0.35	1.31±0.24	0.58±0.15	23.20
Rice polish (5)	13.02±0.60	52.75±3.98	103.6±11.38	457.75±24.66	0.65±0.031	0.28±0.043	0.27±0.11	46.50
Sesame cake (1)	32.20	101.00	31.50	350.00	0.30	1.45	7.42	22.20
Sorghum grain (1)	4.07	12.90	30.40	535.00	0.21	1.02	0.77	3.99
Urd chuni (3)	14.53±1.70	35.46±2.98	56.46±11.91	2000.00±429.60	1.61±0.33	0.88±0.14	2.21±0.19	16.51
Wheat bran (6)	13.15±0.58	61.58±3.92	91.15±5.20	263.50±58.37	0.39±0.097	0.98±0.13	1.18±0.36	13.41
Wheat grain (3)	5.25±0.58	28.21±0.52	19.13±5.95	57.34±6.11	0.61±0.18	0.22±0.028	0.46±0.003	23.86

Figures in parentheses indicate no. of samples analysed; [a]Critical level: concentrations below which are low or considered deficient or excessive in the case of Mo (McDowell *et al.*, 1993), based on requirements for cattle (NRC, 2001).

content (16.78 ppm). Copper content below the critical level of 8 ppm (Cuesta *et al.*, 1993) was found in most of the green and dry fodders. Hence, copper supplementation is needed to the level of 10 ppm in the total ration (NRC, 2001), so as to avoid sub clinical and clinical problems of Cu deficiency (McDowell, 1992). Average copper deficiency was recorded 34.28 per cent in the ration of cows and buffaloes, in the surveyed area (Table 3). Clinical and sub clinical syndromes could occur in animals due to its deficiency. Sub clinically, the problems of poor growth rate, coarse hair coat and infertility may be encountered in cows and buffaloes. Adequate dietary level of copper reduced the incidence of mastitis and increased the killing ability of neutrophils (Harmon and Torre, 1994).

Zinc (Zn)

Zinc was recorded consistently low in almost all the collected feed samples, a picture very similar to other districts of Gujarat (Garg *et al.*, 2000, 2002). The

Table 3. Per cent deficiency of various micro minerals in the ration of cows and buffaloes

Taluk	Animal type	Av. milk yield (kg)	Cu	Zn	Mn	Fe
Shehera	Cow	7.00	20.40	61.50	Adequate	Adequate
	Buffalo	5.50	18.27	65.66	Adequate	Adequate
Lunavada	Cow	15.00	24.86	67.32	Adequate	Adequate
	Buffalo	7.75	27.38	70.19	1.33	Adequate
Godhra	Cow	3.00	59.58	84.00	Adequate	Adequate
	Buffalo	7.25	29.06	54.06	Adequate	Adequate
Dahod	Cow	11.33	16.11	67.46	Adequate	Adequate
	Buffalo	9.75	12.93	67.99	Adequate	Adequate
Jhalod	Cow	10.75	41.00	72.26	Adequate	Adequate
	Buffalo	5.50	43.80	80.31	Adequate	Adequate
Santrampur	Buffalo	7.00	36.79	65.14	12.83	Adequate
Devgadh Baria	Cow	4.25	52.34	77.26	8.75	Adequate
	Buffalo	5.25	50.14	75.15	5.25	Adequate
Kalol	Cow	6.66	50.95	83.91	18.57	Adequate
	Buffalo	9.00	32.91	76.31	3.87	Adequate
Halol	Cow	4.00	28.60	58.67	Adequate	Adequate
	Buffalo	3.66	35.27	60.72	Adequate	Adequate

Requirements: Cu: 10 ppm; Fe: 50 ppm; *Zn: 80 ppm; Co: 0.50 ppm; Mn: 40 ppm; Se: 0.30 ppm (NRC, 2001; *Arora, 1981) zinc content in straws of bajra, maize, rice, sorghum and wheat was acutely low (13.18 ppm). Amongst the green fodders, local grasses had the highest Zn content (27.00 ppm) followed by *chikodi* green (24.20 ppm), *bhindi* green (23.20 ppm), lucerne green (18.16 ppm), sorghum green (17.15 ppm) and maize green (14.52 ppm), showing that levels of Zn were not adequate even in cultivated green fodders for optimum metabolic functions (Table 1). In grains, Zn level was 25.47 ppm, whereas, cottonseed cake, *mung* chuni, rice polish, sesame cake, *urd* chuni and wheat bran contained 55.30 ppm Zn (Table 2). Zinc content was found below the critical level (30 ppm) in most of the dry and green fodders. For milch cows and buffaloes yielding 3 to 15 litres of milk per day, deficiency of Zn in the ration was recorded to the extent of 84 per cent (Table 3). Parakeratosis, mastitis, night blindness and reproductive failure are the ailments, which may result from its deficiency (McDowell, 1992; Singh and Pachauri, 2001). To overcome Zn deficiency, its level should be 80 ppm in the total ration (Arora, 1981), so as to avoid sub-clinical and clinical problems.

Manganese (Mn)

Manganese is one element, which is found to be adequate in many geographical zones of India. From this surveillance, it was apparent that most of the feed ingredients, particularly straws were rich source of Mn (53.64 ppm), except wheat straw (Table 1). Amongst the green fodders, *bhindi* had the highest Mn (84.20 ppm), followed by lucerne green (67.63 ppm), local grasses (62 ppm), maize green (32.21 ppm) and sorghum green (26.88 ppm). Grains of bajra, maize, sorghum and wheat contained 21.36 ppm Mn, whereas rice polish, mixture of broken rice and bran and wheat bran were rich sources of Mn (86.77 ppm; Table 2). *Urd* chuni contained higher Mn (56.56 ppm) than *mung* chuni (26.20 ppm). Cottonseed, mahua and sesame cakes were poor source of Mn (20.41 ppm). *Gram*, *mung* and soyabean pods (without seeds) contained 71.96 ppm Mn. The Mn content in most of the fodders was found above the critical level (40 ppm), whereas, concentrate ingredients were found to contain Mn below the critical level, except grain by-products. Adequacy of Mn in total ration was recorded in most of the talukas, as reported earlier in Mehsana district (Garg *et al.,* 1999), except Santrampur, Devgadh Baria, Kalol and Lunavada (Table 3).

Iron (Fe)

The iron levels as estimated in the samples of crop residues were adequate (290.45 ppm). Out of the green fodders, lucerne green contained 691.33 ppm Fe, whereas in rest of the green fodders, it averaged around 341 ppm (Table 1). In grains, the level was very low in comparison to cottonseed cake, mahua cake, rice polish and wheat bran (Table 2). The high Fe concentration in most of the feedstuffs could probably further interfere with the copper absorption and metabolism (Youssef *et al.,* 1999). The Fe content in most of the feedstuffs was found above the critical level (50 ppm) and requirements of Fe were being met with the traditional feeding system in the surveyed area (Table 3).

Cobalt (Co)

The cobalt level in feedstuffs was found to be very similar to Fe. Most of the feeds contained adequate amounts of Co (Table 1 and 2). The cobalt content in straws and green fodder was 0.21 and 0.34 ppm, respectively. Concentrate ingredients were also found to be good source of cobalt (0.64 ppm), as reported earlier in Junagadh district (Garg *et al.,* 2002).

Molybdenum (Mo)

The molybdenum levels as estimated in the samples of feeds and fodder were within the safe limit (0.81 ppm). Amongst the green fodders, lucerne green (1.27 ppm) had the highest Mo content followed by sorghum green (0.83 ppm), *chikodi (Cichorium intybus)* (0.80 ppm) and maize green (0.64 ppm). Local grasses contained 0.97 ppm Mo, whereas gram and *mung* pods (without seeds) were high in Mo (Table 1). Grains of bajra, maize, sorghum and wheat contained 0.59 ppm Mo. Cottonseed cake, broken rice with bran, *mung* chuni, sesame cake and wheat bran were still higher in molybdenum levels (1.24 ppm). Gram *(Cicer arietinum)* and *mung* pods contained highest Mo level (2.89 ppm). The lowest and highest Cu:Mo ratios in the feedstuffs were 3.11 and 46.50, respectively (Table 1 and 2). Even though the overall mean for forage Mo (0.83 ppm) was considerably below the suggested critical toxic level of 3 ppm (McDowell *et al.,* 1984), there is some concern due to the unusually low Cu levels observed in the forages. A ratio of less than 2:1 for Cu:Mo has been suggested (Miltimore and Mason, 1971) as a possibility for a Cu-Mo conditioned deficiency. There was not an overall Cu to Mo ratio of less than 2:1, but on individual evaluation of samples, narrower ratio was observed for some feedstuffs.

Selenium (Se)

The selenium content of crop residues varied from 0.49 to 6.24 ppm (Table 1 and 2). Amongst the green fodders, lucerne had the highest Se content (5.63 ppm), followed by *chikodi* (4.70 ppm), sorghum green (1.49 ppm) and maize green (1.40 ppm). Grains had around 0.60 ppm Se, whereas sesame cake was exceptionally high in Se (Table 2). Selenium acts as an antioxidant and is necessary for growth and fertility in animals. It is also a component of glutathione peroxidase, an enzyme that inactivates oxygen radicals such as hydrogen peroxide and prevents them from causing cellular damage (Spears, 2000; Engle, 2001). The minimum dietary Se requirements of all classes of ruminant livestock ranges from 0.10 to 0.30 ppm (NRC, 1980). Accepting the minimum requirements of 0.30 ppm Se, which is the level considered adequate for preventing deficiency in dairy cattle (NRC, 2001), most of the feedstuffs under investigation would satisfy requirement of Se. Therefore, its supplementation in mineral mixture is not advocated.

Mineral status of feeds and fodder depends upon the interaction of number of factors, such as soil type, soil pH, plant species, stage of harvesting, crop yield, intensity of agricultural system, climate, season of the year, fertilization application and rate (Anon, 1992; McDowell *et al.*, 1993). On the other hand, there are many factors that could affect an animal's response to mineral supplementation such as duration, concentration and bioavailability of mineral supplementation, the absence or presence of dietary antagonists, type of accompanying feed, environmental factors and breed difference in mineral metabolism (Engle, 2001). Recommending supplemental trace mineral mixtures without considering the trace mineral levels in the feedstuffs may cause more harm than good.

CONCLUSION

It is apparent that milch cows and buffaloes in various talukas of Dahod and Panchmahal districts are not able to meet their mineral requirements of Zn, Cu and occasionally Mn. Other minerals such as iron, cobalt and selenium were adequate in the ration of milch cows and buffaloes with the prevailing feeding system.

REFERENCES

Anonymous. 1992. *British Geological Survey Technical Report,* WC/92/60. Report on the mineral status of animals in some tropical countries and their relationship to drainage geochemical maps of minerals in those countries. Centre for Tropical Veterinary Medicine (CTVM), Edinburgh University, UK.

Arora, S.P. 1981. Zinc and vitamin A relationship in metabolism. In: *Trace Elements in Man and Animals:* TEMA 4 (Ed. J.M. Gawthorne). Springer-Verlag, Berlin, p. 572.

Campbell, M.H., Miller, J.K. and Schrick, F.N. 1999. Effect of additional cobalt, copper, manganese and zinc on reproduction and milk yield of lactating dairy cows receiving bovine somatotropin. *Journal of Dairy Science*, 82: 1019-1921.

Chew, B.P. 2000. Micronutrients play role in stress, production in dairy cattle. *Feedstuffs*, 72:11-15.

Cuesta, P.A., McDowell, L.R., Kunkle, W.E., Bullock, F., Drew, A., Wilkinson, N.S. and Martin, F.G. 1993. Seasonal variation of soil and forage mineral concentrations in North Florida. *Communication in Soil Science and Plant Analysis*, 24: 335-347.

Engle, T.E. 2001. Trace minerals, vitamins aid preventative nutrition. *Feedstuffs*, 73: 11-18.

Garg, M.R., Bhanderi, B.M., Sherasia, P.L. and Singh, D.K. 1999. Mapping of certain minerals in feeds and fodders in the Mehsana district of Gujarat state. *Indian Journal of Dairy Science*, 52: 69-77.

Garg, M.R., Arora, S.P., Bhanderi, B.M., Sherasia, P.L. and Singh, D.K.2000. Mineral status of feeds and fodders in Kaira district of Gujarat. *Indian Journal of Dairy Science*, 53: 291-297.

Garg, M.R., Bhanderi, B.M. and Sherasia, P.L. 2002. Mineral status of feeds and fodders in Junagadh district of Gujarat. *Indian Journal of Animal Nutrition*, 19: 57-62.

Harmon, R.J. and Torre, P.M. 1994. *Proceedings of National Mastitis Council*, USA, pp. 54.

Hinders, R. 1999. Research needed to determine correct trace minerals levels. *Feedstuffs*, 71: 10.

Humphries, W.R., Phillipo, M., Young, B.W. and Bremer, I. 1983. The influence of dietary Fe and Mo on Cu metabolism in calves. *British Journal of Nutrition*, 49: 77-85.

McDowell, L.R., Conrad, J.H. and Ellis, G.L. 1984. Mineral deficiencies and imbalances and their diagnosis. In: *Symposium on Herbivore Nutrition in Sub-tropics-Problems and Prospects*. (Eds. F.M.C. Gilchrist and R.I. Mackie), Pretoria, South Africa, pp. 67-88.

McDowell, L.R. 1992. *Minerals in Animal and Human Nutrition*. Academic Press, San Diego, CA, pp. 49-51.

McDowell, L.R., Conrad, J.H. and Glen Hembry, F. 1993. *Minerals for Grazing Ruminants in Tropical Regions*. Animal Science Department, Centre for Tropical Agriculture, University of Florida. The U.S. Agency for International Development and Caribbean Basin Advisory Group (CBAG).

Miltimore, J.E. and Mason, J.L. 1971. Copper to molybdenum ratio and molybdenum and copper concentrations in ruminant feeds. *Canadian Journal of Animal Science*, 51:193-200.

NRC. 1980. *Mineral Tolerances of Domestic Animals*. National Research Council, National Academy of Sciences, Washington, DC.

NRC. 2001. *Nutrient Requirements of Domestic Animals. Nutrient Requirements of Dairy Cattle*. 7th rev. ed. National Academy of Sciences, National Research Council, Washington, DC.

Prabow, A., Salam, R., McDowell, L.R., Wilkinson, N.S. and Kawashima, T. 1989. Effect of soil ingestion and mineral supplementation on performance and mineral utilization in lambs. *Proceedings of International Meeting on Mineral Nutrition and Mineral Requirements*, Kyoto, Japan, pp. 32-42.

Singh, S.V. and Pachauri, S.P. 2001. Zinc, immunity and mastitis. *Pashudhan*, 16:1.

Snedecor, G.W. and Cochran, W.G. 1967. *Statistical Methods*. 6th ed., Oxford and IBH Publishing Co., New Delhi, India.

Spears, J.W. 2000. Micronutrients and immune function in cattle. *Proceedings of the Nutrition Society*, 59: 587-594.

Youssef, F.G., McDowell, L.R. and Brathwaite, R.A.I. 1999. The status of certain trace minerals and sulphur of some tropical grasses in Trinidad. *Tropical Agriculture*, 76: 57-62.