The Copper, Cobalt, Iron, Selenium and Zinc Status of Cattle in the Sanyati and Chinamhora Smallholder Grazing Areas of Zimbabwe

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ABSTRACT : The trace mineral status of cattle in the smallholder grazing areas of Sanyati and Chinamhora in Zimbabwe was evaluated during the rainy and dry seasons of 1994 and 1995. The evaluation was done in terms of mineral concentration in blood plasma. Plasma copper in calves, steers and cows in the dry season was; Sanyati: 0.55, 0.59, and 0.61; Chinamhora: 0.59, 0.58, and 0.60 $\mu g/ml$, respectively versus a normal of 0.65 $\mu g/ml$. In the rainy season, copper was deficient at both sites (averaging 0.56 $\mu g/ml$ and 0.59 $\mu g/ml$ at Sanyati and Chinamhora, respectively). Plasma selenium in the dry season was 0.017, 0.025, and 0.017 $\mu g/ml$ for calves, steers and cows, respectively at Sanyati versus a normal of 0.03 $\mu g/ml$ and therefore considered to be deficient. Iron, zinc and cobalt were found to be generally high and therefore unlikely to be deficient. Copper and selenium are recommended in salt licks in these environments. *(Asian-Aus. J. Anim. Sci. 1999. Vol. 12, No. 4 : 579-584)*

Key Words : Trace Minerals, Status, Cattle, Grazing

INTRODUCTION

A major challenge to cattle nutritionists in most developing countries today is the improvement of the production efficiency of livestock in smallholder areas. This is to ensure an adequate supply of high quality dairy and beef products to a growing economy and population. The quest for greater efficiency has resulted in various research thrusts especially in energy and protein nutrition with little research in trace mineral nutrition. A major problem in formulating precise nutritional requirements for minerals in the smallholder grazing areas is the void in knowledge in this area. The study described herein, is aimed at stimulating interest in mineral nutrition of smallholder livestock in general and trace element nutrition in particular. Sanyati and Chinamhora are major economic centres for smallholder farmers in Zimbabwe, particularly in terms of crop production. However the same farmers have a high quest for information on how they can improve the productivity of their animals for cash benefits and for provision of draft power.

Our ability to monitor trace minerals in livestock has greatly increased with the development of very sensitive analytical procedures (Bicknell, 1995). Trace mineral imbalancies exert a significant effect on the health and productivity of livestock throughout the tropics (McDowell et al., 1993). This is especially so in the smallholder grazing areas were there is no supplementation.

Six trace minerals viz, copper (Cu), zinc (Zn), iron (Fe), cobalt (Go), selenium (Se) and iodine (I) have been found to be very essential for normal livestock growth (Underwood, 1981). After phosphorus, the deficiency of Cu is the most limiting mineral to grazing livestock in the tropics (McDowell et al., 1993). In Zimbabwe, low Cu levels due to molybdenum toxicity have been recorded as a suspected deficient element in some areas (McDowell et al., 1993). Cu deficiency may result from low herbage levels (less than 5 ppm) or if high levels of molybdenum are consumed (Suttle, 1994). Deficiency is undesirable because Cu is important in many enzyme systems. Deficiency can also result in reproductive problems (Bicknell, 1995). The Co requirement of cattle is actually a Co requirement of rumen microorganisms. The microbes incorporate Co into vitamin B_{12}, which is utilised by both the microorganisms and animal tissues. Whole blood contains about 0.9 ng/ml of vitamin B_{12} in calves and 0.5 ng/ml in mature cows (NRC, 1989). Blood levels of Se are very low and difficult to determine. Serum Se in unsupplemented cows range from 15-23 ppb (Langlands et al., 1994). Supplemental Se prevents white muscle disease in calves and lambs (Swecker et al., 1995). Se deficiency has since been implicated in several multifactorial disorders of cattle including infertility, retained placenta, abortion, still-birth, diarrhoea, mastitis, ill thrift-syndrome, neonatal weakness, calf pneumonia, sudden death and immune suppression (Langlands et al., 1994).

Normal plasma Zn levels in cattle range from 0.8-1.2 $\mu g/ml$, with one-third of the Zn firmly bound to globulin and the remainder losely bound to albumin (NRC, 1989). Deficiencies are difficult to detect in early stages or in milder forms. Zinc affects reproductive efficacy in both bulls and cows. In the bull, this is mainly a result of degeneration of testicular cells. As a result testosterone production is affected and sperm count is lower with abnormal spermatozoal cells featuring more in the ejaculate. Zinc deficiency in cows lead to non infectious abortions, mummification, low birth weights, anaemia at calving and reduced viability of the calves (Bicknell, 1995).

Iron is an important component of haemoglobin, myoglobin, cytochrome and enzymes catalase and peroxidase. Deficiency is likely to occur in young animals (with high Fe requirements) that are fed milk diets and in animals with excessive blood loss. Milk contains less than 10 ppm Fe. Normal plasma Fe

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concentration is at least 50 μg/ml (NRC, 1989). Excess Fe can cause Cu deficiency (McDowell et al., 1993).

The objective of this study was to measure the trace-mineral content in the plasma of cattle in the Sanyati and Chinamhora smallholder farming areas of Zimbabwe and to characterise the plasma trace-mineral profile in both the rainy and dry seasons.

MATERIALS AND METHODS

Animals and research sites

At least 40 animals of each of the three age groups (calves, steers and lactating cows) were initially identified and ear tagged at each site randomly from a pool of over 500 cattle belonging to volunteer smallholder farmers from Chinamhora and Sanyati. Sanyati is in the low-lying, semi-arid region of north western Zimbabwe, between latitudes 29° and 30° and longitudes 17° and 18°. It receives an average annual rainfall of 350～600 mm, most of which falls during the months of December to March with a mean annual temperature of 26℃. The indigenous cattle breeds reared at this site are predominantly Mashona plus Afrikander crosses. Chinamhora lies north of Harare in climatic region 2b, between latitudes 31° and 32° and longitudes 17° and 18°. It receives summer rainfall from October to April, averaging 800-900 mm annually. Mean temperature is 19℃. Cattle breeds kept are mainly Mashona crosses.

The respective village herds grazed daily throughout the rainy seasons of 1994 and 1995 on an area of about 1000 and 1800 ha of unimproved veld pasture at Chinamhora and Sanyati. During the dry season, the cattle had access to crop residues. The animals did not receive any supplementary feeds and were kept kraaled at night in the villages. In addition to Government sponsored mandatory routine dipping in acaricide for tick control and vaccination for anthrax, the cattle were dosed every three months to control internal parasites. However, dipping was occasionally irregular due to lack of water during the dry season, and especially during the drought year of 1995.

At least 30 animals were left in each group at the end of the trial after some farmers withdrew their animals due to drought. Equal numbers of male and female calves were used in the statistical analysis of data.

Blood sampling

Blood samples in a few drops of EDTA were collected from donor animals by jugular puncture once every month from January 1994 (year 1) to September 1995 (year 2). Sample tubes were then sealed quickly with a rubber stopper and kept at 40℃ in a cooler box containing ice until centrifugation in the laboratory.

Forage sampling

Oesophageal samples were collected simultaneously with blood samples according to the method described by Koster, Meissner and Coertze (1992). Four steers were used at each site. Since the animals were kept in the veld, fistula stoppers were strengthened with resin to avoid the wood cap cracking. The fistulated animals were kept together with the blood donors as one herd. Fistula samples were collected before 10:00 hours and collections made over a 40 minute period.

Sample preparation and analytical methods

Oesophageal samples, including all the fluid in the collection bag, were dried at 60℃ to constant weight for 6 hours, mixing the sample regularly. The dried samples were uniformly mixed and milled in a Wiley mill through a 1 mm mesh. The samples were completely ashed for 6 hours in a muffle furnace at 550℃ and acid digested in 0.05 M HCl to prepare ash solutions.

Blood samples were centrifuged at a speed of 3000 rpm for 20 minutes. The supernatant plasma was decanted into crucibles and was first dried in a forced draught oven at 60℃ for 6 hours, and then ashed in a muffle furnace at 550℃ followed by HCl acid digestion as for herbage samples to prepare ash solutions. The ash solutions were analysed for Cu, Fe, Se, Zn and Co using the Inductively Coupled Plasma Emission Spectrometry (Unicam 701 series).

Statistical analyses

Blood plasma mineral data were analysed within region using analysis of variance (GLM, SAS, 1990) using a model that accounted for the effects of year, season (rainy and dry) and production group i.e. calves, steers and lactating cows. Data for forage were analysed using a model that accounted for the effect of season. The rainy season was roughly from mid November to April, and the dry season was from May to November. The homogeneity of all parameters at each time of sampling was tested by Barlett's test (Snedecor and Cochran, 1980).

RESULTS AND DISCUSSION

Figures 1 to 5 show the trace mineral profiles for growing steers in both the wet and dry months. Generally plasma Zn, Co and Se concentrations (figures 3, 4 and 5), were highest in the wet months and lowest in the dry months. This trend corresponds with the seasonal supply of nutrients from the natural pastures as shown by the mineral concentrations in the forages (table 1), and offers clear strategies for supplementation. In the wet months, natural pastures are normally at their best in terms of quality, quantity and species variability. Towards the dry month, the mineral levels in the forage decline from the high values recorded during the rainy season. This is associated with leaf shedding as a result of the withering of the mature plant. The scenario is also a reflection of the translocation of nutrient reserves into roots, fruit structures and stem bases of perennial grasses, rendering them largely unavailable to cattle.

Table 1. Trace mineral concentration (ppm) in forage samples obtained through oesophageal fistula

Mineral	Site	Rainy Season	Dry Season
Iron	Chinamhora	261 ± 6	180 ± 10
	Sanyati	263 ± 11	112 ± 14
Copper	Chinamhora	10 ± 0.3	7 ± 0.6
	Sanyati	13 ± 0.4	8 ± 0.5
Zinc	Chinamhora	77 ± 2.7	45 ± 0.9
	Sanyati	89 ± 2.0	56 ± 1.9
Selenium	Chinamhora	6 ± 0.04	2 ± 0.01
	Sanyati	8 ± 0.02	2 ± 0.02
Cobalt	Chinamhora	4.5 ± 0.1	1.5 ± 0.02
	Sanyati	3.9 ± 0.2	1.2 ± 0.04

The picture was different with Cu and Fe (figure 1 and 2) Levels in both cases were lowest during the wet months and highest in the dry months This is mainly because Cu and Fe are important minerals in haemoglobin formation and function, respectively, which are easily lost if animals are heavily infested with ticks (McDowell et al., 1993). In the rainy season, tick infestation is higher than in the dry season and in situations where dipping is erratic, significant blood losses occur which means that these two minerals are also lost. In the soil these elements forms into solutions easily and it is possible to have them lost through leaching during the rainy season. As a result there is an inadequate supply to the forage so consumed by grazing cattle.

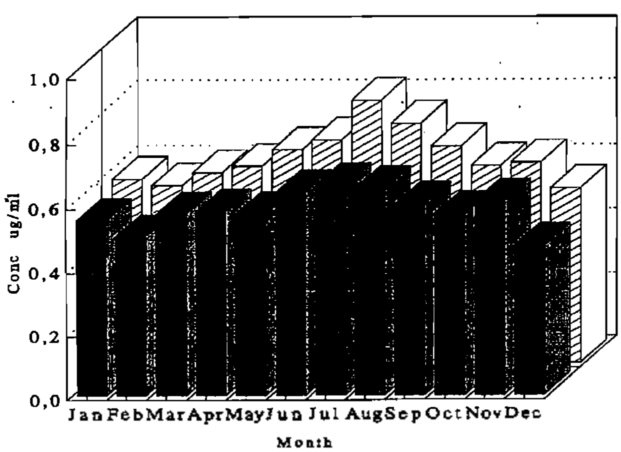

Figure 1. Mean monthly plasma copper concentrations in growing steer (Jan, 1994-Sept, 1995)

In order to give farmers sound advice, it is necessary to know these practical indicators of nutrient availability, such that together with the biological data discussed below, it becomes easy and accurate to determine when the animals need trace mineral supplementation.

Table 2 and 3 show the trace mineral concentration of blood plasma collected from three classes of cattle from Sanyati and Chinamhora, respectively.

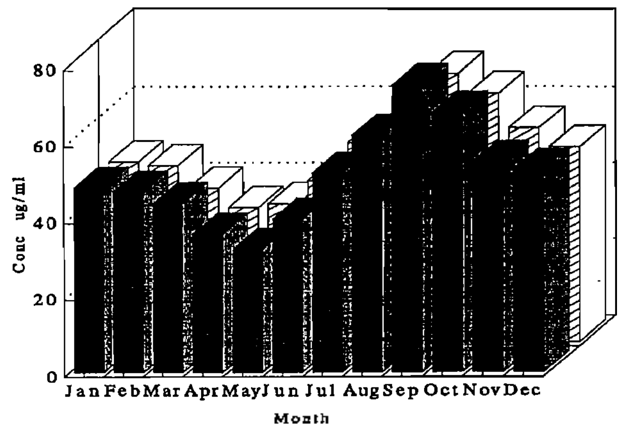

Figure 2. Mean monthly plasma iron concentrations in growing steer (Jan, 1994-Sept, 1995)

Table 2. Trace mineral concentration[1] (ug/ml) of blood plasma at Sayanti

Mineral	Year	Season	Age class			SED[2]
			Calves	Steers	Lactating cows	
Cu	1	rainy	0.50	0.60	0.64	0.05
		dry	0.66	0.74	0.65	0.04
	2	rainy	0.60	0.57	0.57	0.02
		dry	0.83	0.72	0.82	0.06
Fe	1	rainy	39.00	55.00	51.39	2.10
		dry	43.02	75.25	55.89	3.56
	2	rainy	33.33	53.02	60.18	2.11
		dry	42.69	62.73	63.25	0.13
Zn	1	rainy	1.62	1.60	1.58	0.010
		dry	1.58	1.57	1.54	0.003
	2	rainy	1.59	1.59	1.58	0.002
		dry	1.60	1.55	1.55	0.004
Co	1	rainy	0.73	0.93	0.72	0.06
		dry	0.62	0.82	0.67	0.04
	2	rainy	0.66	0.92	0.84	0.10
		dry	0.60	0.88	0.76	0.12
Se	1	rainy	0.030	0.061	0.031	0.006
		dry	0.015	0.028	0.016	0.005
	2	rainy	0.040	0.045	0.036	0.003
		dry	0.018	0.022	0.017	0.005

Normal critical levels for grazing beef cattle under tropical conditions: Cu (0.65 μg/ml)[3]; Fe (50 μg/ml)[4]: Zn (0.8-1.2 μg /ml)[4]; Co (0.2 ng/ml)[4]; Se (0.03 μg/ml)[4].

[1] Means are based on the following number of samples for year 1 and 2 (rainy 150, dry 180) for both Sanyati and Chinamhora.

[2] Standard error of differences between means.

[3] Jarrige, 1989; McDowell et al., 1993.; [4] NRC, 1989.

Table 3. Trace mineral (μg/ml) concentration[1] of blood plasma at Chinamhora

Mineral	Year	Season	Age class			SED[2]
			Calves	Steers	Lactating Cows	
Cu	1	rainy	0.63	0.64	0.64	0.01
		dry	0.75	0.65	0.70	0.02
	2	rainy	0.55	0.53	0.55	0.05
		dry	0.70	0.75	0.84	0.01
Fe	1	rainy	25.22	54.12	51.05	1.08
		dry	41.01	70.92	60.88	0.05
	2	rainy	31.23	49.00	55.87	0.11
		dry	42.00	60.84	58.78	0.12
Zn	1	rainy	1.56	1.55	1.46	0.010
		dry	1.60	1.43	1.26	0.017
	2	rainy	1.68	1.03	1.71	0.080
		dry	1.54	1.41	1.25	0.070
Co	1	rainy	0.68	1.03	0.71	0.18
		dry	0.65	0.95	0.67	0.05
	2	rainy	0.70	1.06	0.64	0.11
		dry	0.66	0.93	0.57	0.05
Se	1	rainy	0.031	0.045	0.074	0.007
		dry	0.016	0.031	0.018	0.003
	2	rainy	0.044	0.038	0.044	0.006
		dry	0.022	0.019	0.021	0.002

Normal critical levels for grazing beef cattle under tropical conditions: Cu (0.65 μg/ml)[3]; Fe (50 μg/ml)[4]; Zn (0.8-1.2 μg/ml)[4]; Co (0.2 ng/ml)[4]; Se (0.03 μg/ml)[4].

[1] Means are based on the following number of samples for year 1 and 2 (rainy 150, dry 180) for both Sanyati and Chinamhora.

[2] Standard error of differences between means.

[3] Jarrige, 1989; McDowell et al., 1993.

[4] NRC, 1989.

Copper status

Copper was deficient in cattle in both sites during the rainy season. The average plasma Cu levels across all age classes of cattle were: at Sanyati, 0.56 μg/ml; and at Chinamhora, 0.59 μg/ml versus the critical level of 0.65 μg/ml (Jarrige, 1989). Cu concentrations were found to be significantly higher in the dry season at Sanyati (p=0.01) and at Chinamhora (p=0.03) than the rainy season (figure 1). This agrees with the results of Grant (1989) who reported that Cu concentration tended to be highest in the dry months of June and July and lowest in the rainy months of December to February. Cu is one of the most critical trace minerals in livestock because it is necessary for haemoglobin formation, iron absorption from the small intestine, iron mobilisation from tissue stores, and connective tissue metabolism.

Plasma from calves showed lower (though not significant) Cu concentrations than steers and lactating cows. Goodrich et al. (1972) reported that the extent of Cu absorption may be influenced by age, some hormones, pregnancy and some diseases. Also several nutrient inter-relationships have a profound effect on the absorption of this element. Hill and Matrone (1970) noted that Zn and Ag are antagonistic to Cu absorption.

Copper deficiency is wide spread for grazing ruminants throughout the world (McDowell, 1985). In Zimbabwe Cu (in the form of molybdenum toxicity) is recorded as a suspected deficient element in some areas (McDowell et al., 1993). Simple Cu deficiency which is likely to occur when Cu levels in herbage are less than 5 ppm, is comparatively uncommon in grazing ruminants because of selective grazing behaviour (Van Soest, 1982). Most deficiencies are "conditioned" by the presence of dietary factors which interfere with the utilisation of Cu by the animal.

Iron status

Plasma Fe showed a marked seasonal effect (at Sanyati (p=0.006) and at Chinamhora (p=0.01)). Concentrations generally increased towards the wet months and were highest in the month of September (figure 2). A decrease was noticed towards the end of the rainy season (April to May). This coincided with the period when natural pastures were mature. According to Grant (1989) this could be of practical significance in communal areas where there is no dosing and poor dipping regimes. Blood-sucking parasites and worm burdens tend to lower Fe plasma concentration depending on level of infestation. Dipping was generally erratic in Zimbabwe during the year 1995 due to the drought and, at some point, scarcity of acaricides. Calves were deficient in Fe and also showed lower ($P<0.05$) plasma Fe than steers and lactating cows. Based on research by Bremner and Dalgarno (1973) and Matrone et al., (1957) and the summary by NRC (1989), the Fe requirement of calves is thought to be about 100 ppm (100 μg/ml), while 50 ppm (50 μg/ml) appears adequate for older cattle. An Fe deficiency is likely to occur in young animals (with high iron requirements) that are fed milk diets (milk contains less than 10 ppm iron) and in animals with excessive blood loss.

Zinc status

Plasma Zn levels were not affected by seasonal trends (at Sanyati, p=0.18; and at Chinamhora, p=0.19). The lowest levels were found in August to late October (figure 3) probably due to limited available grazing. Levels were lower at Sanyati than at Chinamhora (p=0.04). This was not surprising because there is generally less grazing at Sanyati than at Chinamhora since the site is semi arid. Calves showed higher ($p<0.05$) plasma Zn concentrations than steers and lactating cows. Requirements of dietary Zn vary according to age and growth rate (Skate et al., 1973). This is because Zn absorption decreases with age and as growth rate increases. Normal plasma Zn levels range from 0.8 to 1.2 μg/ml (NRC, 1989). All the plasma samples from the two sites were greater than 1.2 μg/ml. Therefore Zn deficiency is unlikely. However, situational deficiencies may occur because absorption and/or utilisation of Zn is affected by many elements which include Cd, Ca, Fe, Mg, Mnr Mo, and Se (Ivan and Grieve, 1975).

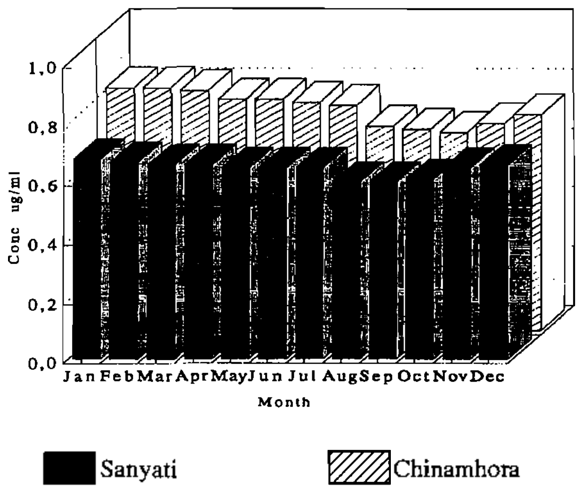

Figure 3. Mean monthly plasma zinc concentrations in growing steer (Jan, 1994-Sept, 1995)

Cobalt status

Plasma Co also tended to be lowest towards the end of the rainy months and into the dry months (figure 4) although season effects and age effects were not significant (p>0.10).

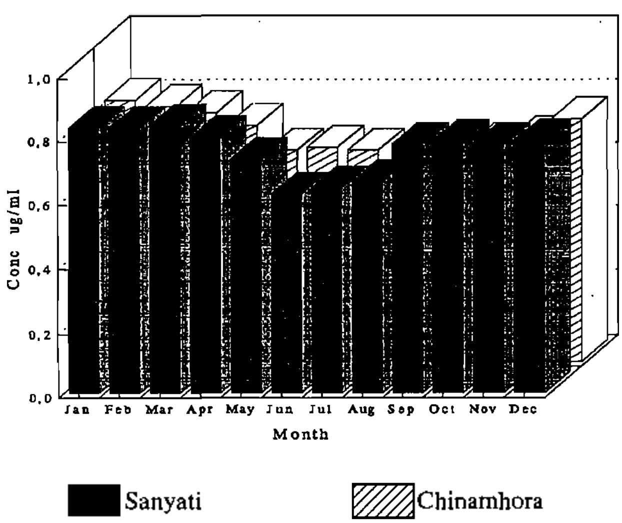

Figure 4. Mean monthly plasma cobalt concentrations in growing steer (Jan, 1994-Sept, 1995)

Plasma Co of about: 0.2 ng/ml are indicative of a Co deficiency although there is considerable individual variability (NRC, 1989). All the plasma samples analysed in this study had Co concentration higher than 0.2 ng/ml, hence Co deficiency is unlikely at Sanyati and at Chinamhora. Co deficiency is very rare as dietary requirements for ruminants are very low at 0.10 ppm. Co toxicity in ruminants is equally rare because toxic levels are above 300 times the requirement levels (NRC, 1989).

Selenium status

Se deficiencies were found in the Sanyati area where some animals had concentrations as low as 0.015 ug/ml especially during the dry months (figure 5). A plasma Se level of 0.03 μg/ml is considered to be the cut off point (McDowell, 1985; Mbwiria et al., 1986). However as far as could be established, none of the known deficiency symptoms such as white muscle disease, or retained placentas are prevalent at Sanyati. At Chinamhora all the concentrations obtained were above the critical deficiency limit. Sanyati receives lower annual rainfall than Chinamhora (< 400 mm vs 600 mm). Elsewhere Grant (1989) reported that, low Se concentration in plasma was associated with high rainfall areas while the highest concentrations were associated with low rainfall areas which is quite the opposite of what is reported here. Se requirement of cattle depends on the amount of vitamin E in the diet (Underwood, 1981). Unfortunately, Se levels in the soil and herbage samples were not determined in this study due to technical problems in the laboratory and the differences between the results reported here and those reported by Grant (1989) are difficult to explain.

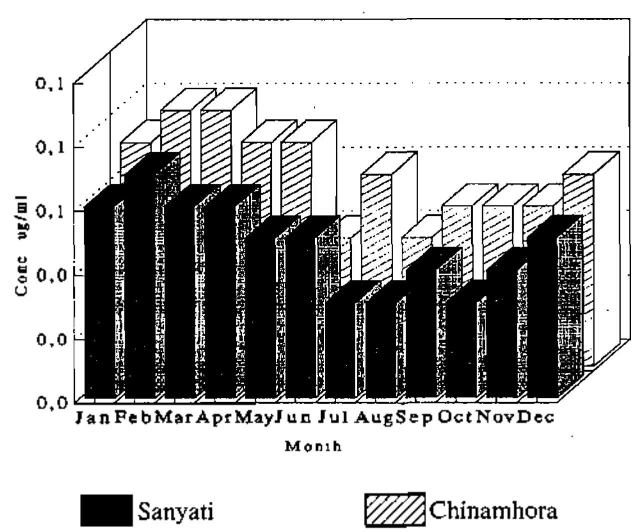

Figure 5. Mean monthly plasma selenium concentrations in growing steer (Jan, 1994-Sept, 1995)

CONCLUSION

The present study has shown that cattle grazing native pastures in the smallholder farming areas with no mineral supplementation, receive adequate amounts of Fe, Zn and Co. They however receive inadequate amounts of Cu in the rainy Se in the dry season. Farmers in these environments are therefore advised to include selenium and copper in salt licks when feeding their livestock. More work needs to be done over at least five continuous years rather than the two years as in this study. This will generate a more reliable database.

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REFERENCES

Bremner, I. and A. C. Dalgarno. 1973. Iron Metabolism in the veal calf. 2. Iron requirements and the effects of copper supplementation. Br. J. Nutr. 30:76-78.

Bicknell, D. V. M. 1995. Trace minerals and reproduction. Zimbabwe Herd book. 21(6):19.

Fairweather-Tait, S. and R. F. Hurrell. 1996. Bioavailability of minerals and trace elements. Nutr. Res. Rev. 9:295-324.

Goodrich, R. D., J. C. Meiske and A. D. Tillman. 1972. Some aspects of copper as an essential nutrient. Proc. Minnesota Nutri. Conf. pp. 169.

Grant, C. C. 1989. Development of a system classifying and monitoring the availability of minerals to cattle in the ranching areas of S.W.A./Namibia. PhD thesis. University of Pretoria.

Hill, C. H. and G. Mantrone. 1970. Chemical Parameters in the study of in vive and in vitro interaction of transition elements. Feed Proc. 29:1474.

Ivan, M. and C. M. Grieve. 1975. Effects of zinc, copper and manganese supplementation of high-concentrate ration digestibility, growth and tissue content of Holstein calves. J. Dairy Sci. 58:410-417.

Jarrige, R. 1989. Ruminant nutrition recommended allowances and feed tables. John Libbey and Co. Ltd; 13 Smith Yard. Summerley Street. London. England.

Koster, H. H., H. H. Meissner and R. J. Coertze. 1992. Voluntary intake and quality of diet selected by cattle grazing bana grass, kikuyu, and forage sorghum. S. Afr. J. Anim. Sci. 22(1):36.

Langlands, J. P., D. E. Donald, J. E. Bowles and A. J. Smith. 1994. Selenium concentration in the blood of ruminants grazing in northern New South Wales. IV. Relationship with tissue concentrations and wool production of merino sheep. Austr. J. Agric. Res. 45(8):1701-1714.

Matrone, G., C. Conley, G. H. Wise and R. K. Waugh. 1957. A study of iron and copper requirements of dairy calves. J. Dairy Sci. 40:1437-1439.

Mbwiria, S. K., J. O. Dickinson and J. F. Bell. 1986. Blood selenium concentrations of sheep and goats from selected areas of Kenya. Trop. Anim. Hlth and Prod. 18:159-165.

McDowell, L. R. 1985. Nutrition of Grazing Ruminants in Warm Climates. ed. Academic Press. Orlando. Florida.

McDowell, L. R., J. H. Conrad and F. G. Hembry. 1993. Minerals for grazing ruminants in Tropical regions. Animal Science Department. Centre for Tropical Agriculture. Bulletin Second Edition. University of Florida. pp. 2-70.

MINISTRY OF HEALTH AND CHILD WELFARE. 1996. National iodione deficiency diagnosis. FAO report.

National Research Council. 1989. Nutrient requirements of dairy cattle. 6th Revised Edition. National Academy Press, Washington D. C.

SAS. 1990. ver. 6. User's Guide. Statistical Analysis System. Fourth Edition. SAS Institute Inc., Cary. NC. USA.

Snedecor, G. W. and W. G. Cochran. 1980. Statistical Methods. Iowa State Uni. Press. Ames Iowa. USA.

Skate, P. E., W. J. Miller and R. P. Gentry. 1973. Zinc metabolism and homeostasis in ruminants as affected by dietary energy intake and growth rate. Proc. Soc. Exp. Biol. Med. 142:494.

Suttle, N. F. 1994. Meeting copper requirements of ruminants. Recent Adv. Anim. Nutr. pp. 173-187.

Swecker, W. S., C. D. Thatcher, D. E. Eversole, D. J. Blodgett and G. G. Schurm. 1995. Effects of selenium supplementation on colostral IgG concentration in cows grazing selenium deficiency pastures and on post suckle serum IgG concentration in their calves. Am. J. Vet. Res. 56(4):450-453.

Underwood, E. J. 1981. The mineral nutrition of livestock. Commonwealth Agric. Bur. London.

Van Ryssen, J. B. J., S. Van Malsen and J. G. Van Blerk. 1985. The iodine content of fresh milk samples in Natal and the effect of iodophor teat dips on milk iodine content. J. S. A. Vet. Assoc. 56(4):181-185.

Van Soest, P. J. 1982. In: Nutritional ecology of the ruminant. Cornell University Press. NY. USA. pp. 309-324.