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Status of Macrominerals of Forages and Goats under Natural Browsing Conditions in the North Western Province of Sri Lanka

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ABSTRACT. *A study was conducted to determine the macromineral nutrition status of forages and, crossbred goats at different physiological conditions, male suckling (<6 month), male growing (6-12 month), male matured (>1 year), female suckling (<6 month), female growing (6-12 month), pregnant (>1 year), milking and dry under the extensive management systems in 3 different agro-climatic zones (dry, intermediate and wet) in the North Western Province of Sri Lanka. No deficiency levels were indicated in forage calcium (Ca), magnesium (Mg) and potassium (K) in all the zones. Forage phosphorus (P) and sodium (Na) were all higher in shrubs, herbs and vines. Deficiency levels were indicated for P and Na in tree leaves and grasses. It appears that ration formulation for range goats in North Western Province should include Na and P. Plasma analysis has shown that Ca levels were lowest in milking and adult animals in all zones. Phosphorus was lower in young animals than old. Magnesium levels increased with age. Plasma K levels were similar in all groups in the dry region but male and female suckling in the intermediate zone and milking and dry animals in the wet zone indicated below the critical value. Plasma sodium levels decreased progressively with age. High corrrelations were found between macromineral contents of forage in the diet and plasma of the animal .*

INTRODUCTION

Nutritional inadequacies often limit animal production in many countries of the world. In the tropics, ruminant livestock production is often restricted by mineral deficiencies, toxicities and imbalances (McDowell, 1985; 1992). The utilization of complete mineral supplementation is very important for many areas as forages and crop residues rarely provide all the necessary minerals in adequate quantities to ruminants under natural feeding systems. Mineral deficiencies result in restricted growth and maturity, reproduction problems, metabolic disorders, low meat and milk production, and general weakness with a predisposition for the occurrence of bacteriological, viral and parasitic diseases (Rojas *et al.*, 1993).

Under many agricultural systems, goats are preferred due to smaller body size and lower feed requirement, early maturity and shorter generation interval, superior prolificacy, ready market, easy management, low input and less capital investment. At present, goats are raised on the biomass available in natural grazing lands and browsing field, where the

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quantity and quality are highly variable. This adversely affects the growth and reproductive performance of goats.

No adequate information is available on mineral nutrition of goats in Sri Lanka. The mineral status of grazing animals is known to depend on the availability of essential minerals from forages which in turn depends on the mineral status of soil on the interplaying of factors such as rainfall, composition of the herbage, its maturity and content of other interfering minerals (Underwood, 1981). Therefore, the objective of this study was to evaluate the macromineral status of forages and goats in the North Western Province of Sri Lanka, under natural browsing conditions.

MATERIALS AND METHODS

The study was conducted at different veterinary ranges covering three agro-climatic zones (dry, intermediate and wet) in the North Western Province of Sri Lanka for the period of 12 months from May 2000 to April 2001. Samples of forages in the browsing fields were collected twice during both rainy (May to June 2000 and Oct. to Dec. 2000) and dry (July to Sep. 2000 and March to April 2001) seasons. The aerial parts of the plants were clipped to include leaves, buds and twigs. Blood samples were collected from the jugular vein of animals into vacutainer tubes containing sodium heparin as an anticoagulant, using stainless-steel needles. Bleeding was carried out early morning taking care to minimize excitement, as these factors are known to affect blood parameters. Blood was obtained from minimum of 6-8 animals at each physiological stage *i.e.*, male suckling (<6 month), male growing (6-12 month), male matured (>1 year), female suckling (<6 month), female growing (6-12 month), female pregnant (>1 year), milking and female dry.

Forage and plasma samples were collected and prepared for analysis according to the techniques outlined by Fick *et al.* (1979). Calcium and Mg of forage and plasma were determined using Atomic Absorption Spectrophotometer (Model AAS Shimadzu AA 6200) according to Duncan (1976), Na and K were detected by Flame Photometry (Model Jenway PFP 7). Phosphorus was analysed by visible Spectrophotometer (Model Shimadzu UV 1201) according to Fiske and Subbarow (1925). Data were statistically analysed using SAS (version 6.04) software package. Statistical means were compared using Duncan's Multiple Range Test (Snedecor and Cochran, 1980).

RESULTS AND DISCUSSION

Forage analysis

Forages consumed by the goats in the study areas are shown in Table 1. Average values with standard deviation of forage mineral concentrations are given in Tables 2–4.

Forage Ca ranged between 3.3 and 15.6 g kg^{-1} DM with no indication of deficiency based on the criterion of adequacies by NRC (1981). All shrubs had the highest range and grasses had the lowest range of Ca concentration. Most of the shrubs used in the study were legumes, and legumes contain more Ca than do grasses (Norton and Poppi, 1995). All

forages had Ca levels that could meet the adult goat requirement (1.8-3.3 g kg^{-1} DM in the diet; NRC, 1981; Kessler, 1991). Norton and Poppi (1995) also reported that foliage from browse plants that grow in tropical region could provide sufficient Ca to meet the nutritional demand and thereby facilitate optimal livestock performance.

Table 1. Forage samples consumable by goats in the study areas.

Forage species	Common name	DZ	IZ	WZ
Leguminous trees				
Gliricidia sepium	(glyricidia)	x	x	x
Leucaena leaucocephala	(ipil ipil)	x	x	x
Erythrina indica	(erabadu)	x	x	x
Bauhinnia racemosa	(maila)	x	x	-
Tamarindus indica	(siyambala)	x	x	x
Acacia leucophloea	(acacia)	x	x	-
Non leguminous trees				
Artocarpus heterophyllus	(kos)	x	x	x
Ficus bengialensis	(banian tree)	x	x	x
Ceiba pentandra	(kapok)	x	x	-
Feronia limonia	(woodapple)	x	x	x
Manilkara hexaanria	(palu)	x	x	-
Azadirachta indica	(neem)	x	-	-
Morinda citrifolia	(ahu)	x	-	-
Grewia tiliaceae	(damuna)	x	x	x
Shrubs				
Tephrosia purpurea	(katupille)	x	x	-
Phyllanthus polyphyllus	(kooretiya)	x	x	x
Brulelia retusa	(kelia)	x	x	x
Phyllantus reticulatus	(kayile)	x	x	x
Nerium oleander	(kaneru)	x	x	x
Vines				
Merremia umbellata	(maduwel)	x	x	x
Coccinia grandis	(kovakka)	x	x	x
Argyreia populifolia	(ginithilla)	x	x	x
Cardiospermum halicacabum	(valpenele)	x	x	x
Herbes				
Lantana camara	(katuhinguru)	x	x	x
Ocimum sanctum	(madumthala)	x	x	x
Tithonia diversifolia	(wild sunflower)	x	x	x
Mimosa pudica	(nithikumba)	x	x	x
Grasses				
Panicum maximum	(guinea grass)	x	x	x
Pennisetum species		x	x	x
Brachiaria brizantha	(signal grass)	x	x	x
Natural grass		x	x	x

DZ - Dry zone IZ - Intermediate zone WZ - Wet zone

Table 2. Macrominerals of different types of forages (g kg^{-1} DM basis) in the dry zone of the North Western Province.

Species[a]	Ca	P	Mg	Na	K
Legume tree (24)	14.1	2.1	4.5	0.5	13.0
SD	4.3	0.6	3.3	0.7	3.9
Non legume tree (32)	12.2	1.8	3.7	0.4	10.9
SD	3.7	0.7	1.6	0.2	4.2
Shrub (20)	14.7	2.7	3.8	0.7	14.4
SD	1.0	0.2	0.2	0.1	1.8
Vine (16)	12.7	2.5	3.2	1.2	14.0
SD	0.8	0.4	0.2	0.8	1.2
Herb (16)	9.5	2.2	3.1	0.7	12.6
SD	1.2	0.7	2.0	0.1	5.7
Grass (16)	3.6	2.2	2.4	0.4	16.0
SD	1.2	0.7	0.7	0.4	5.7
Mean	11.1	2.3	3.5	0.7	13.5
SD	4.1	0.3	0.7	0.3	1.7
Goat requirement[b] (g kg^{-1} DMI)	1.8-3.3	1.6-3.8	0.8-2.5	0.6	1.8-2.5

[a] - SD-Standard deviation; Numbers within the parenthesis denote number of samples.

[b] - Recommended requirements by NRC (1981), Underwood (1981), Kessler (1991)

Table 3. Macrominerals of different types of forages (g kg^{-1} DM basis) in the intermediate zone of the North Western Province.

Species[a]	Ca	P	Mg	Na	K
Legume tree (24)	12.9	2.0	4.5	0.5	11.5
SD	4.6	0.5	3.1	0.5	3.9
Non legume tree (24)	11.1	1.4	3.1	0.4	9.7
SD	3.7	0.4	1.4	0.3	2.9
Shrub (16)	15.6	2.5	3.6	0.6	15.1
SD	3.2	0.2	0.3	0.1	2.2
Vine (12)	11.7	2.2	2.8	0.6	14.2
SD	3.2	0.6	0.5	0.2	3.4
Herb (16)	11.0	3.0	2.7	0.7	16.9
SD	3.0	0.6	0.4	0.1	3.3
Grass (16)	3.3	1.6	1.9	0.4	12.4
SD	1.5	0.5	0.7	0.2	6.1
Mean	10.9	2.1	3.1	0.5	13.3
SD	4.1	0.6	0.9	0.1	2.6
Goat requirement[b] (g kg^{-1} DMI)	1.8-3.3	1.6-3.8	0.8-2.5	0.6	1.8-2.5

[a] - SD-Standard deviation; Numbers within the parenthesis denote number of samples.

[b] - Recommended requirements by NRC (1981), Underwood (1981), Kessler (1991)

Table 4. Macrominerals of different types of forages (g kg^{-1} DM basis) in the wet zone of the North Western Province.

Species[a]	Ca	P	Mg	Na	K
Legume tree (16)	16.1	2.8	4.0	0.4	16.4
SD	5.6	0.7	1.7	0.3	6.9
Non legume tree (16)	10.3	1.9	3.7	0.4	10.9
SD	3.7	0.4	1.2	0.2	4.1
Shrub (16)	15.2	2.7	3.6	0.6	15.6
SD	2.1	0.3	0.4	0.2	4.4
Vine (12)	11.9	2.4	2.6	0.6	13.2
SD	3.8	0.1	1.0	0.2	0.7
Herb (16)	8.8	2.6	2.8	0.7	13.3
SD	0.9	0.7	0.5	0.3	1.0
Grass (16)	3.4	2.0	2.1	0.4	12.8
SD	1.6	0.7	0.8	0.4	5.2
Mean	10.9	2.4	3.1	0.5	13.7
SD	4.6	0.4	0.7	0.1	2.0
Goat requirement[b] (g kg^{-1} DMI)	1.8-3.3	1.6-3.8	0.8-2.5	0.6	1.8-2.5

[a] - SD-Standard deviation; Numbers within the parenthesis denote number of samples.

[b] - Recommended requirements by NRC (1981), Underwood (1981), Kessler (1991)

Generally, low concentrations of P in forage species have been found in all zones except in shrub, herbs and vine. Regardless of species the average values of Ca to P ratios in forages were greater than the range of 1:1 and 2:1 which is ideal for growth and bone formation (McDowell *et al.*, 1993).

All forages analyzed contained adequate Mg in relation to its critical levels of 0.8-2.5 g kg^{-1} DM. However, K concentration ranged from 9.7-16.9 g kg^{-1} DM, which seemed to be due to selective uptake from the soil and was as much as 11 times more than Na (Garg *et al.*, 1999). The daily adult goat requirement of K ranges 1.8-2.5 g kg^{-1} DM in their diet (NRC, 1981; Underwood, 1981; Kessler, 1991). It seems that forages that grow in tropical regions contain K as much as ten times the required levels (Greene *et al.*, 1987; Barnes *et al.*, 1990). This may become a problem because high K concentrations can interfere with Na retention, absorption and Mg utilization (Underwood, 1981). Concentration of Na ranged from 0.4-1.2 g kg^{-1} DM. Na levels of tree leaves and grasses in all zones were below the critical level of 0.6 g kg^{-1} DM suggested by NRC (1981). Shrubs, herbs and vines had adequate Na concentrations based on the critical level. All forage plants in all zones contained adequate levels of Ca, Mg and P and similar results were obtained for Na and P in shrubs, vines and herbs. All forages analysed had sufficient levels of Na and P in the dry region while these elements were deficient in intermediate and wet zones of the North Western Province. Therefore, to overcome this deficiency a mixture of forages or a "cocktail diet" should be allowed. The Na requirement of goat is higher than of cattle. In

general, farmers practice feeding Na as common salt, as a salt block or any other licking device. This helps to overcome the dietary Na limitations.

Plasma analysis

Average values with standard deviation of plasma mineral concentrations are shown in Tables 5-7. Plasma Ca and P levels of all groups of animals at different physiological states were within the normal range. For Ca levels, young animals (male suckling and growing, female suckling and growing) had higher values than adults (male matured, milking and dry animals), whereas the opposite was true for P levels. Both plasma Ca and P levels were high in pregnant animals.

Table 5. Plasma macromineral concentration (mg dl^{-1}) of crossbred goats in the dry zone of the North Western Province.

Physiological stage[a]	Ca	P	Mg	Na	K
Male suckling (28)	11.7	4.1	2.1	161.0	4.1
SD	1.6	0.2	0.2	3.1	0.3
Male growing (24)	11.5	4.2	2.3	139.7	4.2
SD	1.1	0.4	0.3	9.7	0.4
Male matured (32)	8.7	6.7	3.5	137.5	4.7
SD	0.9	1.7	0.3	8.9	0.5
Female suckling (24)	12.2	3.7	2.2	161.2	4.1
SD	1.1	0.6	0.2	10.4	0.3
Female growing (28)	12.7	4.2	2.3	162.0	4.1
SD	1.3	0.4	0.3	9.8	0.3
Pregnant (24)	11.4	5.4	3.1	140.5	4.6
SD	2.7	1.2	0.2	2.3	0.5
Milking (24)	7.7	4.3	2.6	138.0	4.4
SD	0.7	0.5	1.1	9.1	0.3
Dry (24)	8.8	6.1	3.2	165.5	4.2
SD	0.8	0.8	0.8	8.9	0.4
Mean	10.6	4.8	2.7	150.7	4.3
SD	1.9	1.0	0.5	12.7	0.2
Critical level[b]	< 8	< 4.5	< 1.8	< 140	< 4

[a] - SD-Standard deviation; Numbers within the parenthesis denote number of samples.
[b] - Critical level according to McDowell *et al.*, 1984

The critical level of Ca in blood plasma analysis is 8 mg dl^{-1} (McDowell, 1985). In the present study, with adequate Ca in the forages, plasma analysis indicated that Ca deficiency among goat was unlikely. This can be expected because the forage diet that goats browse are mostly legumes, which are rich in Ca compared to grasses. The mean Ca

content in the plasma of milking animals was lower in the dry zone compared to intermediate and wet zones of the North Western Province. This may be due to short supply of forage that commonly prevailing in the dry zone. The mean P concentration in plasma of crossbred goats was higher than the suggested critical value of 4.5 mg dl^{-1} (McDowell, 1985), but certain groups of animals (particularly young female suckling in dry zone, male and female suckling in the intermediate and wet zones) exhibit P deficiency. This deficiency may be due to low P in the diet. Suckling animals mainly depend on milk, and very little forage is consumed. Often the available milk for their nourishment is inadequate. This can lead to low P levels in suckling animals.

Table 6. Plasma macromineral concentrations (mg dl^{-1}) of crossbred goats in the intermediate zone of the North Western Province.

Physiological stage[a]	Ca	P	Mg	Na	K
Male suckling (28)	11.7	3.9	2.2	161.0	3.9
SD	0.95	0.6	0.2	6.1	0.3
Male growing (32)	11.7	4.5	2.4	158.2	4.3
SD	1.5	0.5	0.3	6.9	0.3
Male matured (32)	8.6	6.3	3.1	140.0	4.7
SD	0.9	1.9	0.5	12.1	0.1
Female suckling (24)	11.5	3.7	2.5	171.0	3.9
SD	2.1	0.7	0.3	11.2	0.1
Female growing (32)	12.5	5.1	2.3	166.0	4.1
SD	1.2	1.3	0.4	12.6	0.3
Pregnant (24)	12.4	7.5	3.6	137.7	4.1
SD	0.8	0.8	0.8	10.8	0.6
Milking (32)	9.1	4.8	2.5	140.0	4.2
SD	0.6	0.7	0.5	1.8	0.5
Dry (24)	9.3	6.3	3.2	141.0	4.1
SD	0.3	1.1	0.9	10.5	0.3
Mean	10.9	5.3	2.7	151.8	4.2
SD	1.6	1.2	0.5	13.6	0.3
Critical level[b]	< 8	< 4.5	< 1.8	< 140	< 4

[a] - SD-Standard deviation; Numbers within the parenthesis denote number of samples.
[b] - Critical level according to McDowell *et al.*, 1984

Plasma magnesium levels were high in old animals compared to young. Magnesium levels were particularly low in milking animals. Potassium plasma levels were similar in all physiological stages in the dry region but male and female suckling in the intermediate zone and, female milking and dry animals in the wet zone indicated the levels below the critical value. Plasma Na level changed according to the age whereas K level remained unchanged. There was low plasma Na levels in adult animals compared to the young. Ahmed *et al.* (2000) reported that the decline of sodium contents with age, in part

at least owing to a decrease in extracellular volume. It has been shown that plasma Ca levels tend to decrease with age while P levels tend to increase (Church and Pond, 1988). The percentage of Ca and P in the body and their proportion in the skeleton increases throughout the prenatal and postnatal life as ossification of the skeleton process to maturity (Toverud *et al.*, 1976). Low plasma Mg levels in young animals was due to the fact that uptake of Mg by young animals was more rapid than by old animals (Breibart *et al.*, 1960). Since young animals have more water content than old animals, more Mg ions are adsorbed on the surface of bone crystal resulting in low Mg ions in the blood (Fontenot *et al.*, 1989).

Table 7. Plasma macromineral concentrations (mg dl^{-1}) of crossbred goats in the wet zone of the North Western Province.

Physiological stage[a]	Ca	P	Mg	Na	K
Male suckling (24)	12.0	4.0	2.5	163.0	4.05
SD	1.4	0.5	0.3	4.5	0.2
Male growing (24)	12.2	4.6	2.4	159.0	4.07
SD	2.0	0.4	0.5	15.6	0.43
Male matured (24)	8.6	6.8	3.9	142.5	4.4
SD	1.4	1.1	0.6	3.4	0.5
Female suckling (24)	12.6	3.5	2.2	154.5	4.02
SD	1.6	0.9	0.4	13.4	0.2
Female growing (24)	11.9	4.2	2.5	143.8	4.1
SD	1.3	0.8	0.2	4.9	0.46
Pregnant (32)	13.8	7.2	3.9	144.3	4.8
SD	1.4	0.4	0.7	2.2	0.6
Milking (32)	8.3	5.6	2.5	136.7	3.6
SD	1.5	1.3	0.5	8.4	0.5
Dry (24)	8.6	5.7	3.1	144.8	3.1
SD	0.7	1.5	0.8	3.9	0.7
Mean	11.0	5.2	2.9	148.5	4.0
SD	2.2	1.3	0.7	9.1	0.5
Critical level[b]	< 8	< 4.5	< 1.8	< 140	< 4

[a] - SD-Standard deviation; Numbers within the parenthesis denote number of samples.
[b] - Critical level according to McDowell *et al.*, 1984.

According to the criterion of adequacy indicated by McDowell *et al.* (1984) no deficiency level of plasma macrominerals was observed in any animal in all the zones. As macromineral profile is affected by physiological state, in crossbred goats reared and maintained under extensive management system a reduced level of plasma Ca, P and Mg could be observed in milking animals.

Relationship of minerals

High correlations were found between forage and plasma mineral contents; Ca (r^2=0.81), P (r^2=0.97), Mg (r^2=0.97), Na (r^2=0.90) and K (r^2=0.98). Feeding different combination of forage species to the goats could improve the mineral status.

CONCLUSIONS

This study suggests that the forage species tested in the three zones of the North Western Province of Sri Lanka, contained sufficient levels of minerals such as Ca, Mg and K to support body requirement of goats at different physiological stages. However, there were differences in forage Na and P contents in different zones. Goats reared under extensive system showed no deficiency in macromineral concentrations. Plasma contents of Ca, P, K and Na indicated deficient levels in animals at certain physiological stages in some zones.

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