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Mineral Nutrition of Grazing Goats in Luzon Island, Philippines

T. Fujihara*, A. B. Serra[1], S. D. Serra[1], and E. A. Orden[1]

Abstract : A 15 years study was conducted to evaluate the influence of plant species, soil characteristics and seasonal changes on the mineral status of forages grazed by goats in Luzon Island, Philippines. About 200 goats of both sex with average body weight 10-25 Kg and age ranging between 1 to 5 of native and cross bred were used. Mineral content of common forage species, distribution of mineral in fibre fraction, ruminal solubilization of mineral elements, blood mineral content of grazing goats and influence of soluble glass mineral bolus (SGB) on blood plasma mineral status were measured. Results showed that different in plant species, soil characteristics and seasonal changes contribute highly to the variation in mineral content of forage grazed by goats. Majority of these mineral elements are found in the non-structural cell components and are therefore degradable as indicated by their relatively high effective ruminal solubility (ERS).

Most species had low phosphorus (P), copper (Cu) and selenium (Se) while some had magnesium (Mg) and Zinc (Zn) levels lower than the critical limit relative to the animals' needs. Subsequently affecting the plasma and serum concentration of grazing goats. Multipurpose tree species such as *L. leucocephala*, *G. sepium* and *S. sesban* showed relatively better mineral profile than other improved forage species. Although judicious concentrate supplementation increased plasma Zn concentration, plasma Cu and blood Se were still below critical level. Grazing upgraded goats showed positive response towards soluble glass mineral bolus (SGB) administration. There was a marked increase in blood Se level of treated does and their offspring. Likewise, milk suckled by kids born to SGB supplemented does contain higher Se level, indicative of active intra-mammary transfer of Se. However, this did not result to significant improvement in the birth weight and growth rate of kids. Results suggests that aside from minimal concentrate supplementation and elevated mineral intake provided by intraruminal SGB administration, the extensive utilization of leguminous tree species could correct mineral imbalances due to their relatively higher mineral content and ruminal solubility.

Key words: Grazing goats, Mineral nutrition, Multipurpose tree, Natural forages, Soluble glass bolus

Introduction

Ruminant production in tropical Asia depends to a large extent on native grassland and fibrous crop residues that are generally low in mineral content. As a result, mineral imbalances that oftentimes resulted to clinical and subclinical signs of mineral deficiencies among grazing animals were reported in various countries. Copper (Cu) and zinc (Zn) deficiencies in blood plasma of cattle were observed in Central Thailand (Vijchulata *et al*. 1983). Kumagai *et al*. (1990) and Prabowo *et al*. (1991) reported Cu deficiency and Cu, Zn and selenium (Se) deficiencies in blood plasma of grazing cattle in Java Indonesia South Sulawesi. Fujihara *et al*. (1992b) reported grazing goats in the Island of Luzon, Philippines suffering from various degrees of Cu and Se deficiencies. After almost a decade, the same result was reported in a follow up

Laboratory of Animal Science, Faculty of Life and Environmental Science, Shimane University, Matsue-shi 690-8504, JAPAN

[1] Department of Animal Science, Central Luzon State University, Science City of Muñoz, Nueva Ecija, 3120, PHILIPPINES

study conducted by Serra *et al*. (1996a,b,c,d; 1997a,b) ; Serra *et al*. (1998) and Orden *et al*. (1999, 2000a,b).

The nutritional implications of mineral imbalances may be present as overt symptoms that are readily identified and corrected or, as marginal deficiencies that are not easily identified but may cause a significant depression in production. Deficiencies may be the result of low concentrations of elements in the soil and plants and, are more likely to occur in grazing animals. Correcting mineral imbalances therefore require a clear understanding of the animals' requirement for specific element and the possible sources within a wide array of natural vegetation, which are generally low in bioavailability. In order to address this problem, it is of utmost importance to provide answers to three basic questions; how much the feeds or diets can offer; how much does the animals need; and how to gauge the gap between needs and provision (Suttle, 2000).

It is more than two decades now, our group which is composed of Japanese animal scientists and local experts spearheaded mineral studies of goats in the Philippines in collaboration with other researchers from the University of Philippines at Los Banos and the Central Luzon State University (CLSU). Our research endeavor concerning mineral nutrition of goats in the Philippines started in 1989. The essence was to investigate mineral content of locally available feed resources and tried to relate it with mineral status of grazing goats using blood mineral concentrations as the basis of identifying critical and deficiency levels.

Currently, there is an on going on-farm trials on the effectiveness of soluble-glass-bolus (SGB) containing micro elements in improving mineral status of grazing upgraded does under different farming systems.

Our concerted research efforts resulted to the generation of valuable information that provided answers to the aforementioned questions, which undoubtedly will alleviate the impact of mineral deficiency on the overall productivity of the animals. We have also identified the constraints and potentials of mineral nutrition of grazing goats in the Philippines. We have selected goats as a point of reference because of its relative importance in the socio-economic well being of the small -holder farmers as up 99% of the country's population keep goat. To date, the population of goat in the Philippines is about 3.05 million. Therefore, improving the nutritional status of this animal could be translated into increased animal productivity and improved nutrition and income of the rural population.

This paper presents the significant findings of our research for the past 15 years.

Experimental Procedures

Luzon Island is in a sub-tropic, and thus, the climate is a monsoon type, *i.e*., there are two typical seasons of dry (October-June) and rainy (July-September). Thus, the most of grasses on pasture in flat areas usually wither on late of the dry season, if there are no irrigation systems.

In this study, the healthy adult goats and kids were sampled about 10 ml of heparinized blood through the jugular vein. The forage samples were generally collected by a hand-picking method whenever the animals were blood sampled on the pasture.

After wet digestion with nitric acid and perchlonic acid, Se in whole blood, dams milk and diets (forage and concentrates) was analyzed by the fluorometric method of Watkinson (1979), and other minerals by using Inductively Coupled plasma Emission Spectroscopy (ICPU-2000, Shimadzu Co. Kyoto, Japan).

Statistical analysis of the data was made by *t*-test and/or ANOVA (Yoshida, 1975), and all calculations were also made using a commercially available computer program (SAS, 1999).

Results and Discussion

Mineral contents of common forage species

The effect of specie differences on mineral uptake are best measured and observed when plants are grown in pure culture and under uniform soil condition. Nevertheless, the data we gathered from various experimental sites could be used in understanding the mineral contents and their variability among plant species. Tables 1 and 2 show the mean variation of macro and micro mineral contents of some forage species grazed by goats in wet and dry seasons. The various concentrations of mineral elements were compared to the critical levels based on animal needs (McDowell, 1985). Generally, forage grazed by goats showed appreciable level of Ca and Mg while P seems to be lacking (Tables 1 and 2). Moreover, seasonal average exceeds the required levels for goats. We have used sheep in comparing feed mineral content with the

Table 1 Macromineal contents of some forage species collected in pasture area grazed by goats during dry and wet season

Species	Ca	P	Mg	K
	………… g/kg DM …………			
Critical level[1)]	3	2.5	2	0.7
Grasses:				
Axonopus compressus				
Dry season	6.5	1.7	3.4	5.7
Wet season	4.5	2.8	3.5	5.5
Brachiaria mutica				
Dry season	4.18	1.61	2.58	10.86
Wet season	3.90	1.90	2.40	10.70
Cynodon plectostachyum				
Dry season	4.56	2.56	2.63	10.43
Wet season	4.30	2.70	2.50	10.20
Eleusine indica				
Dry season	5.8	2.1	3.3	8.7
Wet season	3.8	3.2	3.4	9.2
Imperata cylindrical	5.50	3.80	2.50	8.3
Pennisetum purpureum				
Wet season	3.40	3.50	1.80	8.7
Rottboellia exaltata				
Wet season	3.0	2.2	1.9	8.6
Mixed samples	7.10	3.0	3.1	
Legumes:				
Gliricidia sepium	1.37	1.80	4.6	10.30
Aeschynomene indica				
Dry season	7.4	1.1	3.2	4.7
Wet season	6.6	2.0	3.7	5.7
Calopogonium muconoides				
Dry season	10.3	1.8	3.6	6.3
Wet season	11.2	2.9	3.8	10
Centrocema pubescens				
Wet season	8.9	1.7	2.0	5.6
Desmodium tortousum				
Wet season	21			
Leucaena leucocephala	1.51	1.4	3.0	6.4
Sesbania Sesban	10.4	2.5	2.2	7.3

[1)] As recommended by McDowell (1985).

animal requirement due to the absence of standard value for goats. Selenium content of dominant pasture species, like C. *plectosthacyus* was only 16.3 μg/kg DM and 27.4 μg/kg DM for *P. purpureum*, low by far from 200 μg/kg DM commonly required by grazing ruminants.

C. muconoides appeared to have high Mn content along with *I. aquatica* (Tables 1 and 2). The latter species also had the ability to absorb large quantities of Co, Mo and Fe. Likewise, *S. acuta* was found to accumulate large amount of Zn and other microelements. These results supports the find-

Table 2 Micromineal contents of some forage species collected in pasture area grazed by goats during dry and wet season

Species	Co	Cu	Fe	Mn	Mo	Zn	Se
	………… g/kg DM …………						μg/kg DM
Critical level[1)]	0.1	10	30	30－40	＞6	30	100
Grasses:							
Axonopus compressus							
Dry season	1.6	9.5	481	35.0	10.2	28.8	
Wet season	1.6	10.9	505	40.0	13.9	44.0	
Brachiaria mutica							
Dry season		10.4				66.3	
Wet season	1.4	9.0	222	54.0	14.7	82.8	
Cynodon plectostachyum							
Dry season		12.1				40.9	
Wet season	1.3	8.8	326	69.0	14.9	77.2	
		16.5				25.9	16.3
Eleusine indica							
Dry season	1.8	7.4	596	41.8	28.8	38.3	
Wet season	2.1	7.7	286	57.7	23.5	70.6	
Imperata cylindrica		13.1				28.4	27.4
Pennisetum purpureum							
Wet season	2.0	7.1	404	33.0	14.4	50.4	
Rottboellia exaltata							
Wet season	2.2	9.7	283	26.2	18.7	26.8	
Mixed samples		14.1				27.9	33.3
Legumes:							
Gliricidia sepium	2.5	6.6	192	43.0	33.0	55.0	
	2.5	6.6	192	43.0		55.1	
Aeschynomene indica							
Dry season	2.6	8.8	427	60.4	21.0	38.0	
Wet season	2.6	10.5	140	75.0	16.9	37.8	
Calopogonium muconoides							
Dry season	1.9	11.5	462	82.3	19.0	53.8	
Wet season	2.6	13.1	400	98.2	24.7	57.0	
Centrocema pubescens							
Wet season	1.5	11.2	393	77.0	15.1	40.4	
Desmodium tortousum							
Wet season	1.8	7.9	347	60.6	23.6	40.4	
Leucaena leucocephala	2.6	8.6	346	57.0		19.0	
	1.7	7.1	772	36.0	20.6	101.3	
Sesbania Sesban							102

[1)] As recommended by McDowell (1985).

ings of Little *et al.*, (1989) that Indonesian herbs and weeds contained high amounts of Cu, Zn, Co, Mn, and Fe than commonly grown grasses and legumes. Some of this species could accumulate great amount of elements even twice higher than what is normally required by livestock (Grace, 1991). Therefore, the presence of some plant species such as *I. aquatica* and *S. acuta* which are known accumulator of large quantities of elements could provide balance of mineral elements gener-

Table 3 Macromineral contents of some forage species collected in lahar-laden areas of Sts. Rita, Concepcion, Tarlac during dry and wet season, 1996-1997

Species	Ca	P	Mg	K
	…………	%	…………	
Critical Level[1]	0.30	.025	0.20	0.20
Grasses:				
Pennisetum purpureum				
Dry season	0.40	0.20	0.16	0.21
Wet season	0.42	0.22	0.18	0.19
Cynodon plectostachyus				
Dry season	0.45	0.28	0.21	0.48
Wet season	0.47	0.22	0.19	0.50
Eleusine indica				
Dry season	0.40	0.18	0.19	0.27
Wet season	0.40	0.19	0.17	0.31
Cynodon dactylon				
Dry season	0.27	0.16	0.23	0.17
Wet season	0.28	0.25	0.20	0.20
Average: Dry season	0.38	0.20	0.20	0.28
Wet season	0.39	0.24	0.18	0.30
SEM	0.02	0.014	0.09	0.038
Legumes:				
Calopogonium mucunoides				
Dry season	0.68	0.09	0.18	0.25
Wet season	0.67	0.14	0.19	0.35
Centrosema pubescens				
Dry season	0.70	0.08	0.19	0.22
Wet season	0.67	0.17	0.21	0.27
Mimosa pudica				
Dry season	0.91	0.37	0.26	0.28
Wet season	0.87	0.29	0.28	0.33
Leucaena leucocephala				
Dry season	1.27	0.19	0.30	0.38
Wet season	1.28	0.18	0.30	0.42
Average: Dry season	0.89	0.18	0.23	0.28
Wet season	0.87	0.19	0.24	0.34
SEM	0.07	0.02	0.016	0.019

[1] As recommended by McDowell (1985).

ally low in most forage species in pasture areas grazed by goats.

In our effort to help and contribute to the rehabilitation of lahar-laden areas in Central Luzon, we also conducted trials on the nutritional characteristics and mineral concentrations of dominant pasture species in the affected areas after the eruption of Mt. Pinatubo. The highly varied mineral content of forage species grazed by goats in lahar-laden areas of Sta. Rita, Concepcion, Tarlac is depicted in Tables 3 and 4. Most of the samples had low P, Cu and Se contents, while some species had low Mg and Zn. Iron and Mo were exceedingly high particularly during dry season. The low concentration of P, Mg, Zn, Cu, and Se in some forage grazed by goats in lahar-laden area is indicative of the low quantity and availability of these mineral elements in the soil (Fleming, 1973; Reid

Table 4 Micromineral contents of some forage species collected in lahar-laden areas of Sts. Rita, Concepcion, Tarlac during dry and wet season, 1996－1997

Species	Cu	Fe	Mo	Zn	Se
	………… mg/kg DM …………				µg/kg
Critical Level[1]	10	30	＞6	30	100
Grasses:					
Pennisetum purpureum					
Dry season	8.53	385.00	10.60	16.93	19.47
Wet season	7.40	163.00	17.19	18.90	14.32
Cynodon plectostachyus					
Dry season	7.60	440.00	12.24	32.70	17.23
Wet season	9.20	368.00	8.53	40.60	15.58
Eleusine indica					
Dry season	7.70	531.00	12.53	57.46	19.12
Wet season	9.20	484.00	12.81	42.57	21.24
Cynodon dactylon					
Dry season	7.40	160.00	17.19	18.90	14.32
Wet season	9.20	129.00	17.92	23.87	14.85
Average: Dry season	7.82	379.00	13.05	31.51	15.54
Wet season	9.38	314.00	12.80	32.42	18.73
SEM	0.30	40.20	0.95	3.80	0.98
Legumes:					
Calopogonium mucunoides					
Dry season	9.55	239.00	15.08	17.53	35.16
Wet season	11.45	208.00	18.39	25.56	37.56
Centrosema pubescens					
Dry season	9.80	301.00	6.63	16.28	36.26
Wet season	11.43	218.00	8.25	18.55	38.76
Mimosa pudica					
Dry season	10.42	337.00	26.04	49.45	43.13
Wet season	11.39	281.00	29.77	51.95	45.03
Leucaena leucocephala					
Dry season	8.12	365.00	24.79	42.82	＞100
Wet season	8.36	339.00	23.12	47.64	＞100
Average: Dry season	9.47	311.00*	18.14	31.53	53.64
Wet season	10.61	262.00	19.88	36.00	55.34
SEM	0.40	16.20	2.40	4.30	7.98

[1] As recommended by McDowell（1985）
* Significantly higher seasonal average（$P<0.05$）.

and Horvath, 1980）. Volcanic materials such as ash falls and lahar deposits are inherently infertile with negligible amount of organic matter and clay contents, which are active exchange sites for nutrients.

Data seem to demonstrate that the observed variability in the mineral concentrations of pasture species was affected by the type of soil where they are grown. Supporting the findings of Norton and Poppi（1995）that the reported trace mineral values of tropical forage are more indicative of the soil types and their deficiencies than any other factors. Seasonal changes

Table 5 Correlation coefficients among the factors affecting forage quality and mineral concentrations of selected Philippine forage

Parameters	CP	NDF	ADF	ADL	IVDMD
Grasses					
Ca	0.63	0.85*	−0.65	−0.84*	−0.70
P	0.95**	0.94**	−0.98**	−0.85*	−0.74
Mg	−0.02	−0.40	0.03	0.34	0.30
K	0.20	−0.18	−0.20	0.27	0.35
Cu	0.51	0.16	−0.53	−0.12	−0.06
Zn	0.46	0.12	−0.46	0.05	0.18
Mo	0.32	0.05	−0.33	−0.39	−0.34
Co	−0.38	−0.35	0.35	−0.03	−0.11
Mn	0.88*	0.66	−0.88*	−0.50	−0.35
Fe	−0.06	0.26	−0.02	−0.36	−0.43
Legumes					
Ca	0.47	−0.65*	−0.75*	−0.67*	0.46
P	0.45	−0.38	−0.26	−0.17	0.50
Mg	0.14	−0.38	−0.50	−0.30	0.57
K	0.18	−0.40	−0.48	−0.27	−0.75*
Cu	−0.81**	0.90**	0.93**	0.83**	−0.84**
Zn	−0.22	0.03	−0.17	−0.41	−0.04
Mo	0.09	−0.32	−0.43	−0.23	0.53
Co	0.44	−0.56	−0.57	−0.26	0.52
Mn	0.43	−0.18	0.04	0.16	−0.04
Fe	0.27	−0.26	−0.30	−0.50	−0.17

* ($p<0.05$)
** ($p<0.01$)

also contributed to the variation in the mineral concentration of the forage (Table 3; Serra *et al*., 1997b; Orden *et al*., 1999). Sulfur in legumes was significantly higher ($p<0.05$) during wet season. Marked differences ($p<0.05$) were also noted in Fe and Cu contents; Fe in legumes was higher during dry season while Cu in grasses was higher during wet season. The differences in these mineral concentrations could be attributed to seasonal variations.

Rainfall, temperature and sunlight exert great influence on forage performance by altering leaf to stem ratio, which eventually affects morphology and plant chemical components (Burton and Fales, 1994). Furthermore, the decline in some mineral concentration could probably be due to the natural dilution process, *i.e*., dry matte (DM) production surpasses mineral uptake (Fleming, 1973).

Results on the monthly variation in mineral concentration of paragrass and stargrass grazed by goats at the Small Ruminant Center, CLSU are presented (Table 6 and 7). Species differences and seasonal changes affected the concentrations of Ca, K, P, Cu, and Zn. Only Mg appeared to be unaffected by these factors, its concentration was more or less the same year round. Of all the climatological elements, rainfall was closely associated to this variability.

Caution was made in interpreting the comparison between computed mineral concentration and their critical levels. While values less than the predicted requirement may indicate deficiency level, values above them do not necessarily indicate sufficiency. Not all elements are fully available for use by the microbial population in the rumen of for absorption in the intestines of the animals (Norton, 1994).

Distribution of minerals in fiber fractions

Knowing too well that nutrient digestibility and availability in forage largely depend on their affinity to the various fiber fractions, results on the distribution of mineral elements in the neutral detergent fiber (NDF) and acid detergent fiber (ADF), acid detergent lignin (ADL) fractions of eight forage species collected from the pasture area of the experimen-

Table 6 Effective ruminal solubility of some macrominerals in selected Philippine forage species (%)

Forage	Ca	P	Mg	K
Grasses:				
Para	48.4	84.2	83.2	96.7
Star	67.7	85.7	85.3	98.2
Napier	50.9	83.4	85.0	98.2
Creeping Legumes:				
Calopo	35.8	57.1	71.9	87.5
Centrocema	32.9	59.8	95.1	89.9
Tree Legumes:				
Gliricidia	53.6	69.8	92.3	93.2
Leucaena leucocephala	58.1	69.9	78.8	94.9
Sesbania	52.7	70.7	79.5	97.7
Mean	50.0	72.6	83.9	94.5
SEM	0.2	0.2	1.3	0.1
LSD[2] ($p < 0.05$)	1.9	0.7	NS[3]	0.4

[1] Average passage rate: 1.9%/h; ranges of disappearance rate: 0.4 to 1.2%/h for Ca, 0.1 to 1.6%/h for P, 0.7 to 2%/h for Mg, and 0.1 to 2%/h for K.

[2] Least significant difference.

[3] The F-test was not significant.

Table 7 Effective ruminal solubility of some microminerals in selected Philippine forage species (%)

Forage	Cu	Mn	Mo	Zn
Grasses:				
Para	60.8^{e}	76.9^{b}	80.7^{d}	76.8^{b}
Star	74.2^{c}	84.0^{a}	91.7^{bc}	80.5^{ab}
Napier	70.5^{d}	64.0^{cd}	92.9^{ab}	77.0^{b}
Creeping Legumes:				
Calopo	54.5^{f}	29.9^{f}	75.9^{e}	30.1^{d}
Centrocema	89.9^{a}	60.3^{d}	66.0^{f}	70.5^{c}
Tree Legumes:				
Gliricidia	88.0^{ab}	65.9^{c}	95.1^{a}	81.7^{a}
Leucaena leucocephala	44.6^{g}	40.6^{e}	79.7^{d}	71.6^{6}
Sesbania	86.1^{b}	64.1^{c}	89.3^{c}	82.3^{a}
Mean	71.1	60.7	83.9	71.3
SEM	1.5	2.8	1.7	1.4

[1] Effective ruminal solubilization (%) was calculated according to Rooke et al. (1993) : $ERS = a + (1-a) \times kd/(kp + kd)$, where a is the proportion of minerals rapidly solubilized, kd is the fractional rate of mineral disappearance from nylon bags and kp is the rate of passage of particulate material. Average particulate passage rate, 1.9%/h (Serra et al., 1996x) ; average of disappearance rate: 1.28%/h for Cu, 1.01%/h for Mo, and 1.28%/h for Zn.

[a,b,c,d,e,f,g] Means within column having different superscripts differ ($p < 0.05$).

tal farm of CLSU are presented in Table 5. There was a marked species differences ($p<0.01$) in the different fiber components of *P. maximum, C. plectosthacyus, C. muconoides, C. pubescence, G. sepium, L. leucocephala* and *S. sesban*. This had greatly influenced the wide variability of mineral distribution to the different fiber fractions. The NDF fraction contained the following proportions of the total mineral originally present (%); Ca, 0.7; P, 14.3; Mg, 1.9; K, 3.7; Cu, 16.4; Zn, 2.9; Mo, 9.3; Co, 16.2; Mn, 5.6, and 81.3 for Fe. On the other hand the ADF fractions had the following mineral concentrations; Ca, 0.2; P, 4.4; Mg, 0.7; K, 1.8; Cu, 32.3; Zn, 1.1; Mo, 8.9; Co, 4.7; Mn, 5.4, and 36.8 for Fe.

Factors affecting forage quality such as crude protein, fiber fractions (NDF, ADF and ADL) and *in vitro* digestibility (IVDMD) were found to be either positively or negatively associated with various mineral concentrations (Serra, *et al*., 1996y, 1997a). About 75% of minerals in grasses and 45% of minerals in legumes were positively correlated ($p<0.05$) to the CP and IVDMD. Conversely, 55, 80 and 75% of the forage minerals were negatively correlated to the NDF, ADF and ADL fractions, respectively (Table 5). Apparently, most of the mineral elements reside in the non-structural cell components of the forage materials. Results suggests that majority of these minerals are available due to their non-affinity to ligno-cellulose components which are known to be slowly degradable or possibly undegradable in the rumen.

Ruminal solubilization of mineral elements

In assessing mineral requirements of animals, both the quantity of elements and their bioavailability were considered. The former can be determined chemically while the latter is more difficult to assess. One technique to gauge availability is the nylon bags incubated in the rumen of surgically modified ruminants (*in situ*). This technique measures the extent and rate of release of mineral elements in the rumen where most of the organic matter is digested.

The *In situ* trials that we conducted involved eight forage species that are commonly fed to goats (Serra *et al*., 1996x). The values we are presenting hereto are the effective ruminal solubilization (ERS) wherein we considered particulate passage rate and disappearance at different hour interval of the various elements (Tables 6 and 7). We obtained an average particulate passage rate of 1.9%/h. Effective ruminal solubility of macro elements showed that K was the most soluble followed by Mg, P and Ca. For micro minerals, Mo was the most soluble, followed by Zn, Cu and Mn. Although there was a marked difference ($p<0.05$) in the ruminal solubility of mineral elements across species, the ERS values were found to be relatively high.

As pointed out earlier, majority of the elements we analyzed and subjected to *in situ* degradation were not attached to either the NDF and ADF fractions of the forage. Their close affinity to the non-structural components could have resulted to their high ruminal solubility. Even Cu, which was found to be 32.5% attached to the lingo-cellulose components of the different forage samples showed more than 70% ERS (Serra *et al*., 1997a). Result suggests that other factors, such as rumen environment (Durand and Kawashima, 1980) formation of complexes between elements and organic ligands (Grace, 1991) could limit mineral solubility in the rumen rather than their close association to fiber fractions, which are either slowly or totally insoluble. However, not all complexes are insoluble because some trace elements combine with amino acids, which provide faster absorption in the gut, though it might result to competition in the site of absorption between the elements and the carrier (Butler and Jones, 1973). Apparently, those mineral fractions that are insoluble in the rumen, especially those in *C. muconoides* and *L. leucocephala* will solubilize in the lower gut due to its lower pH (Keith and Bell, 1981). It is also interesting to note that ERS of mineral elements in grasses and tree legumes is higher than creeping legumes, like *C. muconoides* and *C. pubescence*.

Blood mineral content of grazing goats

To assess the mineral status of the different classes of goats grazing under different pasture conditions, we used the whole blood concentration for Se and plasma levels for other elements. This diagnostic component of determining adequacy or deficiency is the most important. Due to the difficulty of determining how much the feed can offer and the animal needs, the animal's response was used as a reliable arbitrator on the occurrence of mineral imbalance. The biochemical support for diagnosis has relied upon indices of storage and transport rather than function, in which the latter being the last to show abnormality during deficiency (Suttle, 2000). Although we realized the need for flexibility in interpreting the results coming from blood mineral contents, we have relied mainly on this parameter in assessing animals' response towards dietary mineral

Table 8 Macromineral concentration of grazing goats as influenced by season and concentrate feeding

Region	Season	Without supplement			With supplement[1]		
		Calcium (90)[5]	Magnesium (15)	Phosphorus (40)	Calcium (90)	Magnesium (15)	Phosphorus (40)
Los Baños	Rainy	91.2+2.3[2]	27.1+1.1	71.5+4.7	——	——	——
		(82.8−103.7)[3]	(23.2−32.8)	(53.0−89.9)	——	——	——
		(62.5)[4]	(0)	(0)	——	——	——
	Dry	94.8±1.7	28.4±1.0	81.3±2.3	——	——	——
		(78.5−127.8)	(21.2−43.6)	(57.6−107.0)	——	——	——
		(19.1)	(0)	(0)	——	——	——
Muñoz	Rainy	75.6±0.9	23.9±0.7	87.1±0.8(13)[6]	101.2±2.7	25.6±0.8	84±4.6
		(69.3−83.4)	(19.3−29.1)	(65.9−109.8)	(80.7−120.5)	(20.2−28.8)	(59.5−106.7)
		(100)	(0)	(0)	(8)	(0)	(0)
	Dry	93.8±3.4	24.8±0.6	81.8±2.6(11)	93.9±2.5	26.5±1.2	78.6±4.0
		(71.6−126.7)	(22.0−26.7)	(72.0−92.1)	(77.8−126.8)	(20.4−33.7)	(57.0−109.3)
		(50.0)	(0)	(0)	(27)	(0)	(0)
Baguio	Rainy	——	——	——	90.8±4.4	23.7±2.9	82.7±2.4
		——	——	——	(76.3−113.2)	21.2−33.1)	(73.2−93.2)
		——	——	——	(44)	(0)	(0)
	Dry	——	——	——	92.9±2.6	27.2±1.3	85.0±4.6
		——	——	——	(79.5−109.3)	(21.2−36.9)	(53.4−112.9)
		——	——	——	(29)	(0)	(0)

[1] The goats were supplemented with some concentrates.
[2] Mean±S.E. of number of goats used.
[3] The figures in parenthesis are range of values.
[4] Percentage of blood samples less than the lower limit in plasma level.
[5] The lower limit suggested by NRC (1984).
[6] The number of goats used with supplement in Muñoz.

availability. The validity of using blood concentration to study specific nutrient seems dependent on the physiological factors affecting serum level, it could be used as yardstick in assessing nutritional state of a particular animal (Herdt, 1995).

In the first study conducted, on three different experimental sites (CLSU, UPLB and Baguio), we found out that more than 50% of the animals had low blood Ca, Cu, Zn, and Se levels in spite of the apparently sufficient amount in forage they grazed (Tables 8 and 9). Moreover, even with concentrate supplementation plasma Ca and Cu were below the critical level of 90 mg/L and 0.6 mg/L, respectively. Conversely, plasma Zn and blood Se improved with concentrate supplementation (Tables 8 and 9). The plasma Mg and P were satisfactory, with the lower limit of the normal level in goats. The low plasma Cu content even with its adequacy in the forage and concentrate feeding suggests that the unstable characteristics of Cu and its interaction with known antagonist like Mo might have existed. From this initial finding, we have come up with the conclusion/recommendation that an appropriate mineral supplementation strategy should be adopted to address this problem.

While this problem occurred in more favorable pasture areas in different parts of Luzon Island, the poor soil condition in lahar-laden areas of Central Luzon contributed further to the low blood mineral concentration of the animals (Table 10). Plasma Ca, Cu, Zn and blood Se level among goats grazing in lahar-laden areas were also low. This could be attributed to the insufficient supply of these mineral elements in the for-

Table 9 Micromineral concentration of grazing goats as influenced by season and concentrate feeding

Region	Season	Without supplement			With supplement[4]		
		Selenium (20)[5]	Copper (0.6)	Zinc (0.6)	Selenium (20)[5]	Copper (0.6)	Zinc0.6)
Los Baños	Rainy	14.3±5.31[a]	1.10±0.15	1.88±0.27	——	——	——
		(5−21)[2]	(0.41−1.70)	(0.89−31.6)	——	——	——
		(87.5)[3]	(25)	(0)	——	——	——
	Dry	29.3±14.6[b]	1.30±0.05	1.02±0.09	——	——	——
		(3−66)	(0.77−1.52)	(0.49−1.95)	——	——	——
		(34.1)	(0)	(0)	——	——	——
Muñoz	Rainy	13.3±2.8[c]	1.12±0.08	1.02±0.0513(13)[7]	54.1±38.3[d]	1.00±0.09	1.03±0.04
		(9−19)	(062−1.59)	(0.66−1.47)(12)[6]	(9−144)	0.41−1.70)	0.64−1.22)
		(100	(0)	(0)	(16.6)	(15)	(0)
	Dry	27.3±12.8[de]	1.12±0.07	1.38±0.48(11)	68.3±16.3[f]	1.16±0.04	1.69±0.09
		(7−56)	(0.63−1.80)	(0.42−4.46)[(12)]	(43−103)	(0.97−1.44)	(1.29−2.32)
		(56.6)	(0)	(13)	(0)	(0)	(0)
Baguio	Rainy	——	——	——	41.3±29.1	1.25±0.05	1.72±0.06
		——	——	——	(7−91)	(0.97−1.43)	(1.49−2.01)
		——	——	——	(33.1)	(0)	(0)
	Dry	——	——	——	53.3±26.1	0.65±0.06	1.23±0.15
		——	——	——	(7−110)	(0.28−1.09)	(0.65−2.08)
		——	——	——	(12.6)	(47)	(0)

[1] Mean±S.E. of number of goats used.
[2] The figures in parenthesis are range of values.
[3] Percentage of blood samples less than the lower limit in plasma level.
[4] The goats were supplemented some concentrates
[5] The lower limit suggested by NRC (Se,Cu) (1984) and McDowell (Zu) (1985).
[6] The number of samples for Se analysis.
[7] The number of goats used with supplement in Muñoz.
[a,b,c−d,e−f] :Significantly different ($p<0,01$)

age (Tables 2 and 3). But, the extremely high amount of Mo and Fe in the forage could have also contributed to this effect. Particular attention should be given on the level of Se as dry season average was very close to the lower limit and significant number of animals was below the critical level. In addition, the amount of S in the soil might further aggravate the condition. The low plasma Ca observed in almost 40% of the animals could have been due to low availability of Ca (Ward and Harbers, 1982) in the forage although supply was sufficient.

Use of soluble-glass-mineral-bolus (SGB)

Knowing fully well that the dominant pasture species browsed by goats in some parts of Luzon were low which adversely affected the blood mineral profile of the animals. An introduction of SGB (COSECURE, Pilkington Release Systems, Denbigh, North Wales, UK) containing Co, Se, Cu, P, Na and Mg was done where plasma mineral content of grazing goats did not improve even with concentrate supplementation. Similar with other studies (Buckley *et al*., 1986; Hidoroglou *et al*., 1987; Zervas, 1988; and Matsui *et al*., 1992), the effects of SGB in the blood mineral level of grazing goats were immediate.

One month after SGB administration, there was a remarkable increase ($p<0.01$) in blood Se of treated goats (Table 11). The three-fold increase in blood Se level, which was maintained until the end of the trial suggests that the release of Se from the bolus was fairly constant. On the other hand, there was no marked improvement in the plasma Cu content one month after SGB supplementation. It was only in the second month when significant increase ($p<0.05$) in the concentration of Cu in the blood plasma occurred. After one year,

Table 10 Blood mineral concentration of goats grazing in lahar-laden areas of Sta. Rita, Conceptcion, Tarlac, Philippines, dry and wet season, 1996－1997

	Ca	P	Mg	Cu	Zn	Se
		----------------	mg/L	----------------		---μg/L---
Critical level[1]	90	40	15	0.6	0.6	20
Mineral concentration[2]						
Dry Season	94.58±2.61	65.14±3.38	30.05±1.11	1.01±0.61	100±0.61	21.66±1.21
Range	72.3－119.30	41.30－90.86	21.89－28.52	0.42－1.58	0.34－1.86	12.50－46.66
Wet Season	100.03±3.34	63.59±3.37	29.40±1.09	1.18±0.96	1.15±0.98	24.16±1.66
Range	78.0－130.5	42.13－96.15	23.90－39.20	0.55－1.29	0.48－1.92	17.50－53.33
Percent of animals below						
Critical Concentrate (n=30)						
Dry Season	33.3	0	0	30.0	23.3	40.0
Wet Season	46.7	0	0	10.0	3.3	26.7

[1] As recommended by McDowell (1985).
[2] Mean±SEM.

Table 11 Monthly plasma Cu and blood Se concentration of Philippine goats treated and untreated with intraruminal soluble glass bolus

	Cu (μmol/L)		Level of significance	Se (μmol/L)		Level of significance
	Untreated	Treated		Untreated	Treated	
1992						
Oct	11.85	12.3	ns	0.27	0.28	ns
Nov	13.2	12.4	ns	0.25	0.8	**
Dec	17.7	20.2	ns	0.28	0.82	**
1993						
Jan	16.2	21.1	*	0.29	0.85	**
Feb	16	21.3	*	0.29	0.87	**
Mar	16.8	22.5	**	0.31	0.92	**
Apr	20.1	25.6	**	0.3	0.87	**
May	23.2	27.8	**	0.26	0.83	*
June	22.1	25.9	*	0.3	0.86	**
July	22.2	5.7	*	0.31	0.92	*
Aug	20.4	24.5	*	0.29	0.79	**
Sept	21.4	24.7	*	0.28	0.87	**
Oct	21.5	26.6	*	0.29	0.97	**
Mean	19.23	23.11	**	0.28	0.88	**

ns not significant ($p>0.05$)
* $p<0.05$
** $p<0.01$

mean plasma level was 23.11 μmol/l, significantly higher than those in the control group (Table 11).

Subsequently, the administration of SGB did not result to significant ($P>0.05$) differences in plasma Ca, Mg, Na and Fe concentration between the control and treated groups. The insignificant effect of SGB-Se on plasma Mg supports the conclusion of Batra and Hidiroglou (1993) that intraruminal administration of 30 g Se pellets did not influence plasma level of Mg in dairy cattle. Molybdenum was affected more by supplementation than plasma P, K and Zn. Plasma Mo concentration was reduced significantly ($p<0.01$) by mineral supplementation; counteracting the possible contribution of high Mo of the available pasture species.

The changes in monthly body weight of does treated and untreated with SGB are shown in Table 12. Live weight of goats was not affected by the treatment. Although there was

Table 12 Correlation coefficient in Se content of whole blood and milk of goats

Parameters	Blood Se of does	Milk Se of does
Blood Se of kids	0.93**	0.87**
Milk Se of does	0.88**	

** $p < 0.01$

Table 13 Birth weight, gain in weight and average daily gain (kg) of kids as influenced by maternal treatment of soluble glass bolus−Se administered intraruminally

Parameters	Untreated	Treated	Significance level
Birth weight	1.89±0.31	1.94±0.25	ns
Gain in weight	13.96±1.08	14.22±0.83	ns
Average Daily Gain	0.116±0.009	0.119±0.007	ns

ns not significant

Table 14 Selenium content (μg/L±SD) of goat's milk and whole blood of does and their kids, as influenced by Se Soluble Glass Bolus administered intraruminally

Parameters	Untreated	Treated	Significance level
Does' blood	38.65±2.87	78.32±5.48	P<0.01
Does' milk	3.42±0.63	6.87±1.65	P<0.01
Kids' blood	7.42±2.34	35.47±4.12	P<0.01

significant improvement in the blood concentration of some mineral elements, SGB did not affect body weight. The same result was observed with the birth weight and growth rate of kids born to SGB-supplemented does (Orden *et al*., 2000a). As expected, blood Se concentration of kids (Table 13) were lower because it is very unusual for neonates to have higher serum Se levels than those in their dams (Herdt, 1995). The high serum Se levels of kids indicate that the elevated supply of Se in the does from the treated group was able to cross the placental membrane and be absorbed by the fetus (Perry *et al*., 1977).

In spite of the clear indications of maternal Se transfer from the mother as the blood Se of the treated kids was significantly higher ($p < 0.01$), the improvement in Se status of the dam did not influence the birth weight and growth performance of their offspring. Average kid birth weight and daily gain (ADG) at four months of age was not significantly higher in the treated group. These findings are contrary with the earlier findings of Spears *et al*. (1986) who observed a slight increase in the adjusted weaning weights of calves born to cows with marginal Se deficiency after receiving Se + Vita. E injection. The reported variation in growth response towards Se supplementation among ruminants could be attributed to variations in Se bioavailability due to differences in environment and genetic factors and various dietary vitamin E intakes.

The two-fold increase in the Se content of milk also contributed to the higher blood Se of the kids in as much that the Se status of ruminants is closely associated to dietary Se supply (White and Somers, 1977). The significantly higher milk Se in SGB treated group, suggests that there is a steady transfer of Se from the does' blood to milk, and the highly significant correlation between Se levels in blood and milk of does reflects the positive effect of SGB supplementation (Table 14) (Serra *et al*., 1996a; Orden *et al*., 2000b). Moreover, the significantly higher ($p < 0.01$) milk Se of SGB treated does indicate possible intramammary transfer.

Conclusion

The lower mineral contents of forage affected the mineral status of goats grazing in different pasture areas of Luzon Island. Although average blood mineral concentrations were above the critical limit, some of the animals exhibited low plasma Cu and Zn, and blood Se due to insufficient supply of these mineral elements in the forage. The extremely high amount of Mo and Fe in the forage could have also contributed to this effect. Particular attention should be given on the serum-Se level as mean values were very close to the lower limit and significant number of animals was below the critical level. Even the concentrate supplementation failed to correct mineral in balance as some animals exhibited low mineral level in the blood. Low plasma Ca was observed in about 50 % of the experimental animals.

The use of SGB was effective in increasing plasma mineral content, particularly in the case of Se. Likewise, the increase in Cu intake minimized the possible adverse effects of excessive forage Mo concentration.

The higher blood Se among kids and milk-Se produced by treated does proved further that maternal and intra-mammary transfer increased when supply is elevated. However, this improvement in blood mineral content of the dam did not subsequently increased birth weight and growth rate of their offspring.

Other factors, such as rumen pH and the presences of phytates could have influenced the low plasma Ca level. The high forage concentration and ERS of some elements indicated that they are not attached to undegraded fiber components and are therefore available in the rumen.

Results indicate that the mineral derived by the animals from the pasture have direct effects in their mineral status. Hence, the legumes with better mineral profile, like *Leucaena, Gliricidia & Sesbania* and other form of supplement could provide most of the mineral. Although SGB administration increased blood Se, it failed to give positive effect on body weight and growth rates of kids born from treated does. Further studies on Cu and Se availability to grazing animals should be undertaken to determine their interaction with the excessive forage Mo and Fe.

References

Barta, T. R. and Hidiroglou, M. (1993) The effect of selenium supplementation on plasma sulfur, magnesium and selenium profiles of dairy cows. Canadian Journal of Animal Science, 73: 997-1000.

Buckley, W. T., Huckin, S. N., Fisher, L. J. and Eigendorf, G. K. (1986) Effect of selenium supplementation on copper metabolism in dairy cows. Canadian Journal of Animal Science, 66: 1009-1018.

Burton, D. R. and Fales, S. L. (1994) Plant environment and quality. In: Fahey, G. C. Jr., D. Martens and L. E. Moser (Eds). Forage Quality, Evaluation and Utilization. pp. 155-199. Amer. Soc. of Agro. Inc., Crop Sci. Soc. of Amer. Inc., Soil Sci. Soc. Amer. Inc. Madison, WI 5731 1 USA.

Butler, G. W. and Jones, D. I. H. (1973) Mineral Biochemistry of Herbage. In: G. W. Bulter and R. W. Bailey (Eds.) Chemistry and Biochemistry of Herbage Vol. 2, pp. 127-163. Academic Press, London, UK.

Durand, M and Kawashima, R. (1980) Influence of minerals in rumen microbial digestion, In: Y. Ruckebusch and P. Thivend, eds., *Digestive Physiology and Metabolism in Ruminants*, pp. 375-408. MTP Press, Lancaster, England, UK.

Fleming, G. A. (1973) Mineral composition of herbage. In: G. W. Butler and W. Bailey (Eds.). Chemistry and Biochemistry of Herbage. pp. 529-566. Academic Press, London, UK.

Fujihara, T., Matsui, T., Hayashi, S., Robles, A. Y., Serra, A. B., Cruz, L. C. and Shinizu, H. (1992a) Mineral status of grazing Philippine goats. I. The nutrition of calcium, magnesium and phosphorus of goats in Luzon Island. Asian-Australasian Journal of Animal Sciences, 5: 383-388.

Fujihara, T., Matsui, T., Hayashi, S., Robles, A. Y., Serra, A. B., Cruz, L. C. and Shinizu, H. (1992b) Mineral status of grazing Philippine goats. II. The nutrition of selenium, copper and zinc of goats in Luzon Island. Asian-Australasian Journal of Animal Sciences, 5: 389-395.

Grace, N. D. (1991) Micromineral kinetics and animal requirements. In: Ho, Y. W., H. K. Wong, N. Abdullah, and Z. F, Tajuddin (eds.). Recent Advances on the Nutrition of Herbivores, pp. 153-162. MSAP, Malaysia.

Herdt, T. H. (1995) Blood serum concentration of selenium in female Ilama (*Lama glama*) in relationship to feeding practices, region of United States, reproductive stage and health of offspring. Journal of Animal Science, 73: 337-344.

Hidiroglou, M., Proulx, J. and Jolette, J. (1987) Effect of intraruminally administered selenium soluble glass boluses on selenium status in cows and their calves. Journal of Animal Science, 65: 815-820.

Keith, M. O. and Bell, J. M. (1987) Effect of pH and canola meal on trace mineral solubility *in vitro*. Canadian Journal of Animal Science, 67: 587-590.

Kumagai, H., Ishida, H., Katsumata, M., Yano, H., Kawashima,

R. and Jachija, J. (1990) A study on nutritional status of macro minerals of cattle in Java, Indonesia. Asian-Australasian Journal of Animal Sciences, 3: 7-13.

Little, D. A., Kompiang, S. and Petheram, R. J. (1989) Mineral composition of Indonesia rumiant forages. Tropical Agriculture (Trinidad), 66: 33-37.

Matsui, T., Harumoto, T., Yano, H. and Kawashima, R. (1992) Use of soluble glass bolus to provide a supplement of copper and selenium for grazing cows. Animal Science and Technology, 63: 585-590.

McDowell, L. R. (1985) Nutrition of Grazing Ruminants in Warm Climates. pp. 168-169. Academic Press Inc. San Diego, C.A., USA.

Norton, B. W. (1994) The nutritive value of tree legumes. In: R. C. Gutteridge and H. Shelton (Eds.). Forage Tree Legumes in Tropical Agriculture. pp. 177-191. CAB International. Wallingford Oxon OX 10 8DE, UK.

Norton, B. W. and Poppi, D. P. (1995) Composition and nutritional attributes of pasture legumes. In: J. P. F. D'Mello and C. Devendra (Eds). Tropical Legumes in Animal Nutrition. pp. 30-62. CAB International. Wallingford Oxon OX 10 8DE, UK.

NRC. (1984) Nutrient Requirements of Sheep. (6th Ed). pp. 11-25. National Academy Press. Washington D. C., USA.

Orden, E. A., Serra, A. B., Serra, S. D., Aganon, C. P., Cruz, E. M., Cruz, L. C. and Fujihara, T. (1999) Mineral concentration in blood grazing goats and some forage in Lahar laden areas of central Luzon, Philippines. Asian-Australasian Journal of Animal Sciences, 12: 422-428.

Orden, E. A., Serra, A. B., Serra, S. D., Nakamura, K., Cruz, L. C. and Fujihara, T. (2000a) Direct effects of copper and selenium supplementation and its subsequent effects on other plasma minerals, body weight and haematcrit count of grazing Philippine goats. Asian-Australasian Journal of Animal Sciences, 13: 323-328.

Orden, E.A., Cruz, E. M. and Fujihara, T. (2000b) Selenium supplementation in grazing goats: Effects on blood and milk selenium and growth performance of kids born to does receiving selenium-soluble-glass-bolus. Proc. 7th Int. Conf. Goats. Vol. 1: 101-103. (15th -21st, May, 2000. France).

Perry, T. W., Peterson, R. C. and Beeson, W. M. (1977) Selenium in milk from feeding small supplements. Journal of Dairy Science, 60: 1698-1700.

Prabowo, A., McDowell, L. R., Wilkinson, N. S., Wilcox, C. J. and Conrad, J. H. (1991) Mineral status of grazing cattle in South Sulawesi, Indonesia. 2. Micro minerals. Asian-Australasian Journal of Animal Sciences, 4: 121-130.

Reid, R. L. and Horvath, D. J. (1980) Soil chemistry and mineral problems in farm livestock. Animal Feed Science and Technology, 5: 95-167.

Rooke, J. A., Akinsoyinu, A. O. and Armstrong, D. G. (1983) The release of mineral elements from grass silages incubated in sacco in the rumen of Jersey cattle. Grass Forage Science, 38: 311-316.

SAS. (1999) *Stat View*, 3rd edn. SAS Institute, Cary, NC. USA.

Serra, A.B., Orden, E. A., Cruz, L.C., Nakamura, K., Harumoto, T. and Fujihara, T. (1993) Mineral status of Philippine goats. Journal of Animal Science, 71: 293 (Abstract).

Serra, A. B., Serra, S.D., Nakamura, K., Orden, E. A., Cruz, L.C. and Fujihara, T. (1996a) Effect of selenium in soluble glass bolus on selenium content of milk and blood of goats. Biological Trace Element Research, 55: 207-212.

Serra, A.B., Serra, S.D., Fujihara, M., Orden, E.A., Cruz, L. C., Ichinohe, T. and Fujihara, T. (1996b) Monthly nutrient variation of Paragrass (*Brachiaria mutica*) and Stargrass (*Cynodon plectostacyum*) collected from pastures grazed by goats. Asian-Australasian Journal of Animal Sciences, 9: 203-210.

Serra, S. D., Serra, A. B., Ichinohe, T. and Fujihara, T. (1996c) Ruminal solubilization of macrominerals in selected Philippine forages. Asian-Australasian Journal of Animal Sciences, 9: 75-81.

Serra, S. D., Serra, A.B., Ichinohe, T. and Fujihara, T. (1996d) Amount and distribution of dietary minerals in selected Philippine forges. Asian-Australasian Journal of Animal Sciences, 9: 139-147.

Serra, S. D., Serra, A. B., Ichinohe, T. and Fujihara, T. (1997a) Ruminal solubility of trace elements from selected Philippine forages. Asian-Australasian Journal of Animal Sciences, 10: 378-384.

Serra, A. B., Serra, S. D., Orden, E. A., Cruz, L. C., Nakamura, K. and Fujihara, T. (1997b) Variability in ash, crude protein, detergent fibre and mineral content of some minor plants species collected from pastures grazed by goats. Asian-Australasian Journal of Animal Sciences, 10: 28-34.

Serra, A. B., Serra, S. D., Orden, E. A., Ichinohe, T. and Fujihara, T. (1998) Mineral content and ruminal solubility of *Leucaena leucocephala, Gliricidia sepium* and *Sesbania rostrata*. Proc. VIII WCAP., Vol. I: 26-27. (Seoul, Korea)

Spears, J. W., Harvey, R. W., and Segerson, E. C. (1986) Effects of marginal selenium deficiency and winter protein supplementation on growth, reproduction and selenium status of beef cattle. J. Anim. Sci. 63: 586-594.

Suttle, N. F. (2000) Minerals in livestock production. 9th Ani. Sci. Congress of the Asian-Australasian Assoc. of Animal Prod. Soc. In conjunction with the 23rd Biennial Confederation of the Australian Soc. Of Anim. Prod. And the 15th Annual Sympsium of the Univ. of Sydney Dairy Research Foundation.

Vijchulata, P., Chipadpanich, S. and McDowell, L. R. (1983) Mineral status of cattle raised in the villages of central Thailand. Tropical Animal Production, 8: 131-137.

Ward, G. and Harbers, L. H. (1982) Effect of pH on extractability of calcium and oxalate from alfalfa leaflets. Jornal of Dairy Science, 65: 154-160.

Watkinson, J. H. (1966) Fluorometric determination of selenium in biological material with 2, 3 diaminonaphthalene. Analytical Chemistry, 38: 92-97.

White, C. L. and Sommers, M. (1977) Sulphur-selenium studies in sheep. I. The effects of varying dietary sulphate and selenomethionine on sulphur, nitrogen, and selenium metabolism. Australian Journal Biological Science, 30: 47.

Yoshida, M. (1975) Design of experimental for animal husbandry. pp. 173-185. Yokendo Co., Tokyo. (in Japanese)

Zervas, G. (1988) Use of soluble glass boluses containing Cu, Co, and Se in the prevention of trace-element deficiencies of goats. Journal of Agricultural Science, Cambridge, 110: 155-158.

Zorbas, Y. G., Yaroshenko, Y. N., Kuznetsov, N. K. and Ivanov, A. L. (1997) Daily Zn supplementation effect on Zn deficiency in rats during prolonged restriction of motor activity. Biological Trace Element Research, 60: 101-113.

フィリピン、ルソン島における放牧ヤギの無機物栄養

藤原　勉・Alexander B. Serra・Sarome D. Serra・Edgar A. Orden

要約：本研究では、フィリピン、ルソン島において放牧されているヤギの無機物栄養に対して、採食草種、それらの生育する土壌の特徴および季節的な変化の影響を15年間に亘って調査した。調査対象としたヤギは、平均体重10～25kg、1～5歳令の固有種および交雑種の雌雄合わせて約200頭であった。各種牧草の無機物含量、それら草種の繊維分画中無機物の分布、牧草中無機物の第一胃内分解性、放牧ヤギの血中無機物濃度および血漿中無機物含量に対する可溶性無機物ガラス製剤（SGB）投与の影響について査定した。その結果、草種による差異、更に土壌の特徴や季節的な変動はヤギが採食する放牧草の無機物含量の変動に大きく影響している事が示された。また、無機物の大部分は植物の細胞質内に存在しており、それらの比較的高い第一胃内分解性によって示される様に、可溶性である事が明らかになった。今回の調査地域での大部分の草種において燐、銅およびセレン含量は低く、幾つかの草種ではマグネシウムと亜鉛は放牧家畜の要求量の下限値を下回っていた。その結果そこでの放牧ヤギでのそれらの全血・血漿中濃度への影響も明らかに見られた。*L. leucocephala, G. sepium* や *S. sesban* のようなマメ科飼料木（茎葉）は餌としての無機物含量の様相は他の改良牧草よりも相対的に優れていた。確実な方法としての濃厚飼料の補助（添加）によって血漿中亜鉛の濃度は増加するが、銅やセレンの血中濃度は依然として限界値を下回っていた。放牧されていた交雑ヤギでは、SGB投与に対する効果的な反応が見られた。また、妊娠中の母ヤギへのSGB投与では血中セレンの明らかな上昇、更に生まれた子ヤギの血中セレン濃度の改善が見られた。同様に分娩後授乳中においても、SBG投与母親の乳中セレン濃度は高く、セレンの乳腺組織への効果的な動きが観察された。しかしながら、母ヤギへのSGB処理による、子ヤギの生時体重や成長速度に対する著しい効果は見られなかった。以上の結果から、極僅かな量の濃厚飼料添加やSGB投与による無機物摂取量の増加とは別に、マメ科飼料木茎葉を広く利用して行くことによって、それらの比較的高い無機物含量と第一胃内での高い溶解性によって、無機物栄養の改善が可能である事が示唆された.