Variability in Ash, Crude Protein, Detergent Fiber and Mineral Content of Some Minor Plant Species Collected From Pastures Grazed by Goats

A. B. Serra[1], S. D. Serra, E. A. Orden[2], L. C. Cruz[2], K. Nakamura and T. Fujihara[3]
Faculty of Life and Environmental Science (*formerly Faculty of Agriculture*), Shimane University, Matsue-shi, Shimane, 690 Japan

ABSTRACT : This study was conducted to determine the protein content, cell wall fractions, and mineral concentrations of some minor plant species collected for one year in pastures grazed by goats in the Philippines. An assessment of nutrient variability and a comparison of forage protein and mineral concentrations to the critical value of protein and minerals based on animal needs were also studied. The plant species were the following: grasses (*Axonopus compressus, Eleusine indica, Rottboellia exaltata*); legumes (*Aeschynomene indica, Calopogonium muconoides, Desmodium tortousum)*; and herbs (*Corchorus olitorius, Ipomea aquatica, Sida acuta, Synedrella nodiflora*). The two seasons (dry and wet) were subdivided into Dry-1 (December to February, 132 mm total rainfall), Dry-2 (March to May, 25 mm total rainfall), Wet-1 (June to August, 1,138 mm total rainfall), and Wet-2 (September to November, 1,118 mm total rainfall).

Results showed that significant differences were obtained on various nutrient fractions including those mineral concentrations across species. Across season, acid detergent lignin (ADL) had higher ($p < 0.05$) value at Dry-1. Legumes and herbs were higher in crude protein (CP) especially *Sida acuta*. Grasses showed the highest neutral detergent fiber (NDF) and acid detergent fiber (ADF) with the addition of *Sida nodiflora* (herb) for it contained high NDF. *Aeschynomene indica* contained the highest amount of ADL and the herbs (*Ipomea aquatica and Sida acuta*) had exceptionally high concentration of minerals. Coefficient variation of the various nutrient values ranged from 27.3 to 136.7%. Some forage minerals appeared to be deficient (sodium, phosphorus and copper) or excess (molybdenum) for the whole or part of the year. This study shows that some minor plant species could extend the range of concentration of some nutrients (i.e., CP and minerals) beyond that normally found in conventional pasture species.

(**Key Words**: Tropical Forage, Nutrient Variability, Nutrient Content, Mineral Concentration, Herbs)

INTRODUCTION

The variabilities in nutrient composition of forages are affected by plant factors (genus, species, variety or stage of maturity of the herbage) and environmental factors (soil type, soil pH, water, or climatic changes accompanying the advancing season). The effects of forage species on nutrient characteristics need to determine especially that the diets of goat contain more browse, herbs and weeds. The nutrient contents of these plant species especially more to their mineral concentrations, their strengths and weaknesses are nevertheless important to know especially that the traditional feed sources (forage grasses and legumes) can be deficient in some elements for animal production purposes (Minson, 1990). Wilman and Derrick (1994) showed the potential of dicotyledonous species to extend the range of concentration of some major elements beyond that normally found in temperate grasses, and possibly holds true to some of the tropical plant species.

This study was conducted to determine the protein content, cell wall fractions, and mineral concentrations of some minor plant species collected in pastures grazed by goats. An assessment of nutrient variability and a comparison of forage protein and mineral contents to the critical value of protein and minerals based on animal needs were also done. The word "critical" was used to note a concentration in forage below or above with excesses what is considered the requirement of the animals. The nutrient variation of the dominant pasture species, paragrass (*Brachiaria mutica*) and stargrass (*Cynodon plectostachyum*) were reported earlier (Serra et al., 1996c). The present report is a part of our research

[1] On-leave from Central Luzon State University, Nueva Ecija, 3120 Philippines.
[2] Department of Animal Science, Central Luzon State University, Nueva Ecija, 3120 Philippines.
[3] Address reprint requests to T. Fujihara.
Received February 29, 1996; Accepted November 11, 1996

study in characterizing the nutrient contents of Philippine forages with emphasis on their mineral concentrations.

MATERIALS AND METHODS

The study area was conducted at the small ruminant farm of Department of Animal Science, Central Luzon State University, Philippines (altitude of 76 m at 15° 43′ N, 120° 54′ E). The area had two distinct tropical seasons: the dry (December to May) and the wet (June to November). The two seasons were subdivided into Dry-1, from December to February with 132 mm total rainfall; Dry-2, from March to May with 25 mm total rainfall; Wet -1, from June to August with 1,138 mm total rainfall; and Wet-2, from September to November with 1,118 mm total rainfall.

The minor plant species were collected in the pastures where the goats grazed. These were the following: grasses (*Axonopus compressus, Eleusine indica, Rottboellia exaltata*); legumes (*Aeschynomene indica, Calopogonium muconoides, Desmodium tortousum*); and herbs (*Corchorus olitorius, Ipomea aquatica, Sida acuta, Synedrella nodiflora*). Hand plucking method, simulating the grazing animals as closely as possible, was used in collecting the plant samples. Monthly plant sampling for a duration of one year was done. It could be noted, however, that some species appeared for a particular time of the year. All the samples collected were dried and later ground to pass a 2-mm screen in a Wiley mill. Each sample was properly labeled, and stored in plastic container for later analyses.

The different samples collected were analyzed for dry matter (DM) and crude protein (CP) by the procedures of AOAC (1984). Neutral detergent fiber (NDF), acid detergent fiber (ADF), and acid detergent lignin (ADL) were assessed by the procedures of Goering and Van Soest (1970). The different samples were also prepared for mineral analysis by a wet ashing (nitric-perchloric acids) method. The mineral concentrations: calcium (Ca), potassium (K), magnesium (Mg), sodium (Na), phosphorus (P), cobalt (Co), copper (Cu), iron (Fe), manganese (Mn), molybdenum (Mo), and zinc (Zn) were measured by Inductively Coupled Plasma Emission Spectrometer (ICPS 2000, Shimadzu Co., Kyoto, Japan). All the glasswares used for mineral analysis were washed with acid before use to remove the contaminating minerals.

Data obtained for each specie were grouped into seasons, Wet-1, Wet-2, Dry-1 and Dry-2. Analysis of variance and comparison of means were statistically analyzed using Statistica for Macintosh™ Release 4.1 (Statsoft, Inc., Tulsa, OK). Mean and standard error of the mean (SEM) for each nutrient category were presented. Variability of nutrient was presented by range and coefficient of variation (CV).

RESULTS AND DISCUSSION

Ash, crude protein and detergent fibers

The ash, CP and detergent fibers of some minor plant species collected in pastures grazed by goats are shown in table 1 with significant difference (ADL at $p < 0.01$, and the rest at $p < 0.001$) across species. Ash content tended to be higher in *Ipomea aquatica* and the least was seen in *Corchorus capsularis*. Crude protein, as would be expected was higher in legumes and herbs than those grasses especially in *Synedrella nodiflora*. The herbs although not a common pasture species, they can contribute to the dietary protein requirements of the grazing goats. Unlike other domestic ruminants the diets of goats contain grasses, legumes, browse, herbs and weeds.

The total cell wall represented by NDF was found to be greater in grasses than those legumes and herbs with the exception of *Synedrella nodiflora*. Ligno-cellulose compound or ADF tended to be greater in all grasses including *Aeschynomene indica* (legume) and *Synedrella nodiflora* (herb). Acid detergent lignin of all legumes and grasses *Axonopus compressus* and *Eleusine indica* (during Dry-1) were either above or within the average content of all plant species. Generally, the whole leaves of monocotyledons (grasses) contain more total cell walls than those leaves of dicotyledons (legumes and herbs; Bailey, 1973).

Macrominerals

The true effects of species on mineral uptake are best seen when plants are grown in pure culture and under uniform soil conditions (Fleming, 1973). Nevertheless the data gathered in this study could be used in understanding the mineral variability among plant species in a given pasture lands. The macrominerals of the different plant species under consideration are shown in table 2 and differences across species (P at $p < 0.01$, and the rest at $p < 0.001$) were noted. Earlier report (Fujihara et al., 1992a) showed a differences on macromineral concentrations (Ca, P and Mg) of some Philippine forages.

Among the grass species, *Rottboellia exaltata* had the lowest Ca, Mg, and Na. Whereas, *Aeshnomene indica* showed the lowest Ca and P contents among the legume species. Between grass and legume, the former had higher Ca content than the latter. Other plant species (herbs)

Table 1. Ash, crude protein and detergent fibers of plant species collected in areas grazed by goats

Item[1]	Ash	CP	NDF	ADF	ADL
	% DM				
Grasses					
Axonopus compressus					
Dry-1	11.8	11.2	74.3	42.0	9.7
Dry-2	15.6	9.0	75.7	44.6	10.3
Wet-2	10.8	13.6	70.8	37.9	8.6
Eleusine indica					
Dry-1	16.0	7.8	75.2	50.6	8.2
Dry-2	12.4	9.6	69.7	36.5	3.9
Wet-1	10.8	9.1	73.1	36.8	3.4
Wet-2	11.9	9.2	75.5	41.1	5.0
Rottboellia exaltata					
Wet-2	17.8	16.3	72.0	42.3	3.4
Legumes					
Aeschynomene indica					
Dry-1	8.0	15.2	52.2	41.2	12.7
Wet-2	7.8	19.6	48.4	31.8	8.6
Calopogonium muconoides					
Dry-1	9.6	21.8	37.6	29.1	8.1
Dry-2	6.6	23.5	37.1	23.7	5.5
Wet-1	10.2	28.4	45.9	29.2	6.2
Wet-2	7.7	24.6	42.4	25.6	6.1
Desmodium tortousum					
Wet-2	10.0	22.2	35.4	26.7	6.1
Other plants (herbs)					
Corchorus olitorius					
Wet-2	7.3	20.2	32.9	20.4	4.5
Ipomea aquatica					
Wet-1	18.8	23.7	36.8	21.2	3.6
Wet-2	18.8	24.2	33.5	23.2	3.5
Sida acuta					
Dry-2	14.5	27.6	34.1	19.7	5.1
Wet-1	14.2	29.0	32.8	19.5	4.6
Synedrella nodiflora					
Wet-1	12.0	18.7	70.2	31.3	3.6
Wet-2	11.5	18.8	75.0	33.1	4.0
Mean	12.0	18.3	54.6	32.2	6.1
SEM (22)	0.8	1.5	3.8	1.9	0.6
p-level	0.0003	0.0000	0.0000	0.0004	0.0033

[1] Dry-1 (December to February), Dry-2 (March to May), Wet-1 (June to August), Wet-2 (September to November).

Table 2. Macrominerals of plant species collected in areas grazed by goats

Item[1]	Ca	K	Mg	Na	P
	% DM				
Grasses					
Axonopus compressus					
Dry-1	0.64	0.57	0.34	0.033	0.17
Dry-2	0.65	0.68	0.29	0.009	0.18
Wet-2	0.45	0.55	0.35	0.010	0.28
Eleusine indica					
Dry-1	0.40	0.86	0.27	0.020	0.17
Dry-2	0.52	1.04	0.39	0.011	0.24
Wet-1	0.40	1.18	0.38	0.022	0.35
Wet-2	0.37	0.87	0.30	0.011	0.29
Rottboellia exaltata					
Wet-2	0.30	0.86	0.19	0.003	0.22
Legumes					
Aeschynomene indica					
Dry-1	0.74	0.47	0.32	0.016	0.11
Wet-2	0.66	0.57	0.37	0.031	0.20
Calopogonium muconoides					
Dry-1	1.25	0.63	0.36	0.014	0.18
Dry-2	1.03	0.93	0.37	0.012	0.26
Wet-1	1.12	1.12	0.35	0.013	0.29
Wet-2	1.01	1.00	0.38	0.018	0.23
Desmodium tortousum					
Wet-2	2.10	0.67	0.41	0.026	0.25
Other plants (herbs)					
Corchorus olitorius					
Wet-2	1.06	0.94	0.39	0.006	0.36
Ipomea aquatica					
Wet-1	2.37	2.25	0.47	1.26	0.52
Wet-2	2.55	2.36	0.49	1.52	0.39
Sida acuta					
Dry-2	1.81	1.68	0.61	0.024	0.49
Wet-1	1.85	1.67	0.61	0.141	0.80
Synedrella nodiflora					
Wet-1	0.60	2.10	0.34	0.041	0.44
Wet-2	0.59	1.94	0.29	0.028	0.38
Mean	1.02	1.13	0.38	0.149	0.31
SEM (22)	0.14	0.13	0.02	0.02	0.03
p-level	0.0000	0.0000	0.0000	0.0000	0.0032

[1] Dry-1 (December to February), Dry-2 (March to May), Wet-1 (June to August), Wet-2 (September to November).

showed a greater amount of macrominerals than those legumes and grasses, notably *Ipomea aquatica*. This species had exceptionally high in Na and above average in its concentrations of Ca, P, Mg and K. Also, *Sida acuta* contained Ca, P, Mg and K above the average concentration. *Corchorus capsularis* and *Synedrella nodiflora* had particularly high in Ca and P, respectively. If the macrominerals found in those herbs are readily released in the rumen, then they can provide a useful mineral supplement and so contribute to the dietary needs of animals. The findings of this study could be paralleled to those data gathered by Wilman and Derrick (1994) that some temperate dicotyledonous species (herbs) contained concentrations of macrominerals (P, K, Ca, Mg and Na) beyong that normally found in temperate grasses. Furthermore, the findings of Little et al. (1989) were that Indonesian herbs and weeds contained high amounts of P and Mg than those found in grasses and legumes.

Microminerals

The micromineral content of the different species are shown in table 3 with differences in Co at $p < 0.05$, Cu and Fe at $p < 0.01$, and the rest at $p < 0.001$. Among the three groups of plant species, the grass species tended to be lower in microminerals than those legumes and herbs which are both dicotyledonous species. This subject has been reviewed by Reid and Horvath (1980). They stated that temperate legumes usually contained higher concentrations of Co, Cu, Fe, Mo and Zn than those temperate grasses but lower in Mn. The trend on mineral differences of temperate forages might also be true to tropical forages (Fleming, 1973).

Calopogonium muconoides appeared to have high Mn content along with *Ipomea aquatica*. The latter species had the ability to absorb Co and Fe in large quantities than the other species. Moreover, it had also an appreciable amount of Mo. Another specie, *Sida acuta* found to accumulate large amount of Zn and also had appreciable amount of other microminerals. The findings of the present study could be supported by Little et al. (1989) when they observed that Indonesian herbs and weeds contained high amounts of microminerals (Cu, Zn, Co, Mn and Fe) than those in grasses and legumes.

The implications of the differences observed between plant species on their mineral content are of considerable interest in relation to animals health. Some species accumulated high amount of microminerals beyond what is normal for the ruminants. Grace (1991) reviewed and listed some elements with dietary concentrations that chronic toxicities might be expected, e.g. Fe, 500-6,000 mg/kg DM and the signs are weight loss, reduced milk

Table 3. Microminerals of plant species collected in areas grazed by goats

Item[1]	Co	Cu	Fe	Mn	Mo	Zn
	.....		mg/kg DM			.....
Grasses						
Axonopus compressus						
Dry-1	1.3	7.8	462	34.9	16.3	27.7
Dry-2	2.0	11.2	500	35.0	4.2	30.0
Wet-2	1.6	10.9	505	40.0	13.9	44.0
Eleusine indica						
Dry-1	1.5	6.0	634	22.6	26.4	34.6
Dry-2	2.2	8.0	559	61.1	31.2	42.0
Wet-1	1.3	8.0	339	65.6	21.3	83.4
Wet-2	3.0	7.4	234	49.8	25.7	57.9
Rottboellia exaltata						
Wet-2	2.2	9.7	283	26.2	18.7	26.8
Legumes						
Aeschynomene indica						
Dry-1	2.6	8.8	427	60.4	21.0	38.0
Wet-2	2.6	10.5	140	75.0	16.9	37.8
Calopogonium muconoides						
Dry-1	1.8	9.1	277	72.5	13.8	25.3
Dry-2	2.1	13.9	648	92.1	24.3	82.3
Wet-1	2.6	14.2	443	93.1	25.1	61.7
Wet-2	2.7	12.0	358	103.3	24.4	52.3
Desmodium tortousum						
Wet-2	1.8	7.9	347	60.6	23.6	40.4
Other plants (herbs)						
Corchorus olitorius						
Wet-2	1.7	10.7	160	56.1	20.5	36.2
Ipomea aquatica						
Wet-1	3.5	6.1	1,124	105.0	35.1	34.9
Wet-2	6.7	12.5	986	103.9	46.2	37.9
Sida acuta						
Dry-2	3.1	19.1	425	72.6	40.8	231.1
Wet-1	3.2	18.6	438	83.1	47.8	369.5
Synedrella nodiflora						
Wet-1	2.1	13.7	514	35.4	20.3	53.0
Wet-2	2.4	12.7	515	31.7	26.5	58.6
Mean	2.4	10.9	469	62.7	22.7	68.4
SEM (22)	0.2	0.7	50	5.6	2.2	17.0
p-level	0.0281	0.0028	0.0048	0.0001	0.0001	0.0001

[1] Dry-1 (December to February), Dry-2 (March to May), Wet-1 (June to August), Wet-2 (September to November).

yield, diarrhea and decrease Cu absorption, induced Cu deficiency, poor growth rates and impaired reproduction in cattle. Iron content of *Ipomea aquatica* was found to be high and some species were in the borderline of the toxic level. In the case of Mo, all the plant species were within the toxic level. Mixed plant species available for grazing or browsing by the goats could prevent Fe toxicity because some of the species especially those dominant pasture species have low level of this element. Paragrass (*Brachiaria mutica*) and stargrass (*Cynodon plectostachyum*) contained 222 and 326 mg Fe/kg DM, respectively (Serra et al., 1996b). Whereas, Mo toxicity in goats could be prevented by Cu supplementation because of their reverse relationship. However, goats are more tolerant to high Mo doses than sheep and cattle without showing ill effects (Haenlein, 1992) but plasma Cu level might be affected as in the case of Philippine goats (Fujihara et al., 1992b).

Wet season versus dry season

Table 4 shows the mean of the various nutrients that were grouped into seasons having a significantly different ADL ($p < 0.05$). Crude protein was appreciably higher during wet season while ash content and various detergent fibers were the reverse, higher during dry season. These were expected because the plants were under the growing stage accompanied by the advancing season.

Most of the mineral elements were found to be higher during wet season. These could be explained by the presence of the herbs which contained high amounts of minerals and they disappeared during the dry season. Thus, these plant species are good accumulator of mineral elements than those traditional forage species.

When the CP and mineral concentrations compared to the needs of ruminants (table 4), it appeared that elements P, Na and Cu found to be lower or in the borderline of the critical levels in some parts of the year. Whereas, Mo was observed to be higher than the critical level through out the year. Thus, the grazing animals consuming the various plant species might suffer mineral deficiencies or excesses (as in Mo) in some parts or through out the year.

Aside from the low level of P in the forages, its ratio to Ca exceeded from the desirable Ca : P ratio (table 4), one lying between 2:1 to 1:1 (Maynard et al., 1979). If the ruminal solubilization of dietary Ca and P is 50 and 73%, respectively (Serra et al., 1996a), then the ratio of Ca:P become narrower and closer to the desired ratio. Nevertheless, the presence of vitamin D is necessary in proper metabolism of these two elements and no attempt was made in determining the status of this vitamin in various plant species that were studied.

Table 4. Mean ash, crude protein, detergent fibers and mineral concentrations of plant species collected in areas grazed by goats and their comparison to the nutrient needs of ruminants

Item	Dry[1]		Wet[2]		Critical level[3]
	1	2	1	2	
% DM					
Ash	11.2	12.3	13.2	11.5	
CP	14.0	17.4	21.8	18.8	<6[4]
NDF	59.8	54.2	51.8	54.0	
ADF	40.7	31.1	27.6	31.4	
ADL	9.7[a]	6.2[b]	4.3[b]	5.5[b]	
Ca	0.76	1.0	1.3	1.0	0.3
K	0.63	1.1	1.7	1.1	0.6-0.8
Mg	0.32	0.41	0.43	0.35	0.2
Na	0.021	0.014	0.29	0.18	0.06
P	0.16	0.29	0.48	0.29	0.25
mg/kg DM					
Co	1.8	2.4	2.5	2.7	0.1
Cu	8.1	13.0	12.1	10.5	10
Fe	450	533	572	392	30
Mn	47.6	65.2	76.2	60.7	30-40
Mo	19.4	25.1	29.9	24.0	>6
Zn	31.4	96.3	120.5	44.0	30
Ca/P (1:1 to 2:1)[5]	4.7:1	3.4:1	2.6:1	3.4:1	
Cu/Mo (2:1)[6]	1:2.4	1:1.9	1:2.5	1:2.3	

[1] Dry season : 1 (December to February); 2 (March to May).
[2] Wet season : 1 (June to August); 2 (September to November).
[3] Concentrations below which is deficient or above which, in the case of Mo, is excessive based on ruminant needs (McDowell, 1985).
[4] Minimum quantity required to meet the requirements of rumen bacteria (Minson, 1990).
[5] Desired ratio (Maynard et al., 1979).
[6] Desired ratio (Ward, 1978).
[a,b] Means in the same row without a common superscript differ ($p < 0.05$).

The observed Cu:Mo was outside the desired ratio of 2:1 (Ward, 1978) as shown in table 4. Low Cu:Mo will produce physiological Cu deficiency (Ward, 1978) and elevated Mo intakes depress Cu availability (Fleming, 1973; Ward, 1978; Mills, 1987; Keen and Graham, 1989). Fujihara et al. (1992b) showed that the Philippine grazing goats had low level of Cu plasma; possibly due to the low levels of forage Cu and high levels of forage Mo. The

Philippine goats responded to Cu supplementation as indicated in the significant rise of their plasma Cu level (Serra et al., 1994).

Nutrient variability

The sharp contrast in variation among the nutrient fractions including those mineral elements is pointed out in table 5. The spread between low and high values was mostly recognized for mineral elements than those ash, CP, NDF, ADF and ADL. Another measures of variability were the range and CV where most mineral elements showed greater variations especially of Na with 506.7 fold difference and 136.7% CV. Dietary mineral variations are due to the following (Fleming, 1973): 1) soil factors, 2) genus, species and variety, 3) stage of maturity of the plant, 4) seasonal and temperature effects, and 5) fertilization and sward management. The findings of the present study as supported by our previous report (Serra et al., 1996c) indicated that due to these mineral variations, the grazing goats have had at least subclinical deficiencies or excesses in some months of the year. Furthermore, it could be supported by the recent work of Ramires et al. (1991) that free-ranging Mexican goats had tremendous variations in the amounts of daily voluntary mineral consumption because their diets contained browse, ferbs and other plant species not common to large ruminants.

Table 5. Range and coefficient of variation of ash, crude protein, detergent fibers and mineral concentrations of plant species collected in areas grazed by goats during dry and wet seasons

Item	Range		Fold difference[1]	Coefficient of variation
	Minimum	Maximum		
	..... % DM			... % ...
Ash	6.6	18.8	2.8	31.2
CP	7.8	29.0	3.7	39.8
NDF	32.8	75.7	2.3	33.6
ADF	19.5	50.6	2.6	27.9
ADL	3.4	12.7	3.7	36.5
Ca	0.3	2.5	8.5	62.4
K	0.47	2.4	5.0	47.2
Mg	0.19	0.6	3.2	27.3
Na	0.003	1.5	506.7	136.7
P	0.11	0.8	7.3	48.2
	...mg/kg DM...			
Co	1.3	6.7	5.1	38.7
Cu	6.1	19.1	3.1	34.2
Fe	140	1,124	8.0	43.4
Mn	22.6	103.9	4.6	42.0
Mo	4.2	47.8	11.4	44.6
Zn	26.8	369.5	13.8	115.8

[1] Fold difference = Maximum / Minimum.

CONCLUSION

This study shows that nutrient variation was evident across plant species and the effect of season was pronounced. Some plant species could extent the range of concentration of some nutrients (i.e., CP and minerals) beyond that normally found in conventional pasture species. These plant species which indigenous to the country could be tapped as a good source of mineral elements to the animals. In conjunction to our previous reports, the present data could be used in planning nutrient supplementation to improve animal performance.

REFERENCES

AOAC. 1984. Official Methods of Analysis (14th Ed.). Association Official Analytical Chemist, Arlington, VA.

Bailey, R. W. 1973. Structural carbohydrates. In: G. W. Butler and R. W. Bailey (Ed.) Chemistry and Biochemistry of Herbage (Vol. I), pp. 1570-211.

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

Fujihara, T., T. Matsui, S. Hayashi, A. Y. Robles, A. B. Serra, L. C. Cruz and H. Shimizu. 1992a. Mineral status of grazing Philippine goats. I. The nutrition of calcium, magnesium and phosphorus of goats in Luzon island. Asian-Australasian J. Anim. Sci. 5:383-388.

Fujihara, T., T. Matsui, S. Hayashi, A. Y. Robles, A. B. Serra, L. C. Cruz and H. Shimizu. 1992b. Mineral status of grazing Philippine goats. II. The nutrition of selenium, copper and zinc of goats in Luzon island. Asian-Australasian J. Anim. Sci. 5:389-395.

Goering, H. K. and P. J. Van Soest. 1970. Forage fiber analyses (apparatus, reagents, procedures, and some application). Agric. Handbook No. 379. ARS, USDA, Washington, DC.

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

Haenlein, G. F. W. 1992. Advances in the nutrition of macro- and micro-elements in goats. In: R. R. Lokeshwar and A. T. Kumer (Ed.) Recent Advances in Goat Production, pp. 933-950. Proc. V Int. Conference on Goats, 2-8 March, New Delhi.

Keen, C. L. and T. W. Graham. 1989. Trace elements. In: J. J. Kaneko (Ed.) Clinical Biochemistry of Domestic Animals (4th Ed.), pp. 753-795. Academic Press, Inc., San Diego.

Little, D. A., S. Kompiang and R. J. Petheram. 1989. Mineral composition of Indonesian forages. Trop. Agric. (Trinidad). 66:33-37.

Maynard, L. A., J. K. Loosli, H. F. Hintz and R. G. Warner.

1979. Animal Nutrition (7th Ed.). McGraw-Hill Book Company, New York.

McDowell, L. R. 1985. Nutrition of Grazing Ruminants in Warm Climates. Academic Press, Inc., San Diego.

Mills, C. F. 1987. Biochemical and physiological indicators of mineral status in animals: copper, cobalt and zinc. J. Anim. Sci. 65:1702-1711.

Minson, D. J. 1990. Forage in Ruminant Nutrition. Academic Press, Inc., San Diego.

Ramires, R. G., A. Loyo, R. Mora, E. M. Sanchez and A. Chaire. 1991. Forage intake and nutrition of range goats in a shrubland in Northeastern Mexico. J. Anim. Sci. 69:879-885.

Reid, R. L. and D. J. Horvath. 1980. Soil chemistry and mineral problems in farm livestock. Anim. Feed Sci. Tech. 5:95-167.

Serra, A. B., S. D. Serra, E. A. Orden, L. C. Cruz and T. Fujihara. 1994. Sustained-release mineral bolus for Philippine grazing goats. Proc. VIII Int. Symp. Ruminant Physiol., 25-30 Sept., Willingen, Germany. Proc. Soc. Nutr. Physiol. 3:86.

Serra, S. D., A. B. Serra, T. Ichinohe and T. Fujihara. 1996a. Ruminal solubilization of macrominerals in selected Philippine forages. Asian-Australasian J. Anim. Sci. 9:75-81.

Serra, S. D., A. B. Serra, T. Ichinohe, T. Harumoto and T. Fujihara. 1996b. Amount and distribution of dietary minerals in selected Philippine forages. Asian-Australasian J. Anim. Sci. 9:139-147.

Serra, A. B., S. D. Serra, M. Fujihara, E. A. Orden, L. C. Cruz, T. Ichinohe and T. Fujihara. 1996c. Monthly nutrient variation of paragrass (*Brachiaria mutica*) and stargrass (*Cynodon plectostachyum*) collected from pastures grazed by goats. Asian-Australasian J. Anim. Sci. 9:203-210.

Ward, G. M. 1978. Molybdenum toxicity and hypocuprosis in ruminants: a review. J. Anim. Sci. 46:1078-1085.

Wilman, D. and R. W. Derrick. 1994. Concentration and availability to sheep of N, P, K, Ca, Mg and Na in chickweed, dandelion, dock, ribwort and spurrey, compared with perennial ryegrass. J. Agric. Sci. (Camb.) 122:217-223.