RUMINAL SOLUBILIZATION OF MACROMINERALS IN SELECTED PHILIPPINE FORAGES

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Summary

The dry matter (DM) disappearance and ruminal solubility of calcium (Ca), phosphorus (P), magnesium (Mg), and potassium (K) in eight Philippine forages were studied. The forages were: paragrass (*Brachiaria mutica* (Forsk.) Stapf), stargrass (*Cynodon plectostachyum* Pilger), napiergrass (*Pennisetum purpureum* Schumach), calopo (*Calopogonium muconoides* Desv.), centrocema (*Centrocema pubescens* Benth.), gliricidia (*Gliricidia sepium* (Jacq.) Walp.), leucaena (*Leucaena leucocephala* (Lam.) de Wit.), and sesbania (*Sesbania grandiflora* (L.) Poir. Nylon bags with samples were incubated for 0, 3, 6, 12, 24, 48 and 72 h in rumen cannulated sheep. The 0-h bags were washed with deionized water. For the 0-h samples, 20.4, 17.2, 50.7, 52.2 and 80.1% of the DM, Ca, P, Mg, and K was solubilized, respectively. At 3-h incubation period, DM disappearance was 10 percentage units higher than that of 0-h incubation whereas mineral disappearance increased by 43, 21, 30 and 13% for Ca, P, Mg, and K, respectively. At 72-h incubation period, greater proportion of DM, Ca, especially in P, Mg, and K was solubilized with a value of 73.8, 71.5, 85.6, 91.4 and 98.2%, respectively. The average particulate passage rate obtained in the present study was 1.9%/h where as the range of disappearance rates of various mineral elements were: 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. The effective ruminal solubilization (ERS) of the macrominerals was calculated where particulate passage rate and disappearance rate of the various elements were included in the equation. The ERS of Ca, P, Mg, and K was 50.0, 72.6, 83.9 and 94.5%, respectively. Species differences ($p < 0.05$) on the various mineral solubilities were also observed. This study shows that ruminal solubility of macrominerals in selected Philippine forages is K > Mg > P > Ca.

(**Key Words** : Tropical Forage, Philippine Forage, Mineral Content, Solubilization, In Situ, Grass, Legume)

Introduction

The essential mineral elements are recognized based from experiments. They perform essential functions in the body and must be present in the food. In ruminants, the essential minerals are not only for the animal *per se* but also for the microbes in the rumen. Durand and Kawashima (1980) stated that essential minerals are needed by the ruminal microbes for cell functions, cellulytic activity and growth. Moreover, they contribute to the regulation of some physicochemical characteristics of the ruminal medium such as osmotic pressure, buffering capacity, redox potential and dilution rate, all of which affect ruminal fermentation.

In assessing mineral requirements of animals, both the quantity of minerals in the feeds and their bioavailability need to be considered. The former can be determined chemically while the latter is much more difficult to assess. One technique that can help in determining the mineral bioavailability is the use of nylon bags incubated in the rumen of surgically modified ruminants (in situ technique). This technique can measure the extent and rate of release of macrominerals in the rumen where most of the organic matter is digested.

The in situ technique has been used with varying success in the determination of DM, protein and fiber degradabilities but very few studies deal with ruminal solubility of minerals (Field, 1981). Only five papers dealing on this topic can be found in the literature: Playne et al., 1978; Rooke et al., 1983; Van Eys and Reid, 1987; Emanuele and Staples, 1990; Ledoux and Martz, 1991, None of them reported work on forages from the humid tropics. Playne et al. (1978) studied forages typically

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grown in Australia, Rooke et al. (1983) used silages in United Kingdom, and the rest studied American forages either grown in temperate or sub-tropical areas. Thus, information on the ruminal solubility of minerals from tropical forages is limited. Consequently, this study was conducted to determine DM disappearance and ruminal solubility of Ca, P, Mg and K from eight Philippine forages. The data could be of help in formulating a diet for the ruminants in the tropics where mineral deficiencies are common (McDowell, 1985) and mineral supplementations are either rare or none at all.

Materials and Methods

Forage samples

Forage samples were collected at the experimental farms of the Department of Animal Science, College of Agriculture, Central Luzon State University, Philippines (15° 43′ N, 120° 54′ E) during wet season. The samples were categorized into three groups, i.e.: 1) grasses: paragrass (*Brachiaria mutica* (Forsk.) Stapf), stargrass (*Cynodon plectostachyum* Pilger), and napiergrass (*Pennisetum purpureum* Schumach.); 2) creeping legumes: calopogonium or calopo (*Calopogonium muconoides* Desv.) and centrocema (*Centrocema pubescens* Benth.); 3) tree legumes: gliricidia or kakawate (*Gliricidia sepium* (Jacq.) Walp.), leucaena or ipil-ipil (*Leucaena leucocephala* (Lam.) de Wit.), and sesbania or katuray (*Sesbania grandiflora* (L.) Poir. All the samples were air dried and later oven dried at 60℃ for 2 d and ground to pass in a 2-mm screen Wiley mill. They were stored in plastic containers for later analysis.

Experimental procedures

Three ruminally cannulated Japanese Corriedale wethers, average body weight of 45 kg, were fed timothy hay (*Phleum pratense* L.) at 2% body weight (DM basis). Water and mineralized salt blocks were available ad libitum throughout the duration of experiment.

After a 7-d adaptation period to the diet, nylon bags containing forage sample (5 g) were placed into the rumen of each animal following the procedure of Ørskov, Hovell and Mould (1980). The time of incubation (3, 6, 12, 24, 48 and 72 h) was similar to those previously published by Rooke et al. (1983), Van Eys and Reid (1987), Emanuele and Staples (1990), Ledoux and Martz (1991). The bags were placed into the rumen at time 08:30. Only six bags (representing the various time) per incubation period were placed in the rumen of each animal. This was replicated twice such that there were six bags (three animals × two sets of incubations) for each incubation time in every forage specie.

After retreival, the bags were washed individually with deionized water until the rinsing water cleared. The 0 bags were not placed in the rumen. Disappearance at 0 h was determined from DM and mineral loss after washing. All bags and contents were dried at 60℃ for 2 d. The residues were stored in a plastic container for later analysis.

After the in situ experiment, the wethers were given a pulse dose of ytterbium (Yb) labelled small particles to determine the passage rate of small particles. The immersion method of Mader et al. (1984) was used in labelling the hay particles with Yb. The hay was immersed in a 1% w/v acqueous solution of $YbCl_3 \cdot 6H_2O$ for 24 h, after which the supernatant liquid was descanted and rinsed in distilled water for 3 h and dried to the approximate original DM content. The wethers were intraruminally dosed with 15 g of the Yb-labelled hay particles. Following the intraruminally dosing of the Yb-labelled particles, fecal grab samples were collected at 0, 12, 24, 36, 48, 60, 72, 84, 120, 144 and 168 h. Fecal samples were dried at 60℃ for 2 d and kept for later analysis.

Laboratory analysis

The DM content of all forages and residues collected in the in situ experiment were determined. Then, they were digested with nitric and perchloric acids for the determination of macrominerals. The prepared solutions were analyzed for Ca, P, Mg, and K using an Inductively Coupled Plasma Emission Spectrometer (ICPS-2000, Shimadzu Co., Kyoto, Japan). Fecal samples were also ground and wet ashed. Ytterbium concentration of feces was also determined in the same spectrometer.

Calculations and statistical analysis

The quantity of a mineral remaining in each bag after each incubation time was expressed as a proportion of that mineral originally present in the bag prior to rumen incubation. The fractional disappearance rate of each mineral from nylon bags (Kd) was calculated from the slope of the linear regression (Rooke et al., 1983) of the natural logarithm of the proportion of each mineral remaining in the bag (y) on the length of incubation in hours (X):

$$\log_n y = k_d x + c, \qquad \text{[Equation 1]}$$

From the intercept value (c) of the above equation the proportion of each mineral rapidly released from the forage (a) was determined. These values then were used in the following formula used by Rooke et al. (1983) to calculate effective ruminal solubilization (ERS):

$$ERS = a + (1 - a) \times k_d / (k_p + k_d), \qquad \text{[Equation 2]}$$

where a is the proportion of minerals rapidly solubilized, k_d is the fractional rate of mineral disappearance from nylon bags and k_p is the rate of passage of particulate material.

The concentrations of Yb in the feces were used to determine the particulate passage rate constant (k_p). The passage rate constant was estimated using the procedures of Grovum and Williams (1973).

The data were analyzed as a randomized complete block design in which the variance components between forage species (main factor) and between animals (blocking factor) were estimated, and the residual variance was obtained by subtracting both from the total. Means were compared with protected least significant difference test (Snedecor and Cochran, 1980) at $p < 0.05$.

Results and Discussion

Macromineral concentrations of forages

Table 1 shows the macromineral concentrations of selected Philippine forages. The findings of the present study showed that differences ($p < 0.05$) existed in terms of various macromineral concentrations across species. As expected the trend on Ca and Mg contents of legumes both creeping legumes and tree legumes was higher than those grasses but the reverse was found on their P content with the exception of sesbania. The K content of the various forages was higher in grasses except in gliricidia.

TABLE 1. DRY MATTER AND MACROMINERAL CONTENTS OF SELECTED PHILIPPINE FORAGES

Forage	DM (%)	Ca	P	Mg	K
		········· % DM ·········			
Grasses					
Para	90.1	0.28	0.20	0.19	0.96
Star	92.4	0.39	0.28	0.17	0.89
Napier	89.0	0.35	0.20	0.17	0.80
Creeping legumes					
Calopo	88.3	0.77	0.19	0.22	0.70
Centrocema	88.3	0.89	0.17	0.20	0.56
Tree legumes					
Gliricidia	92.4	1.37	0.18	0.46	1.03
Leucaena	90.7	1.51	0.14	0.30	0.64
Sesbania	89.0	1.04	0.25	0.22	0.73
Mean		0.82	0.20	0.24	0.79
SEM		0.02	0.01	0.004	0.02
LSD[1] ($p < 0.05$)		0.07	0.02	0.02	0.05

[1] Least significant difference.

Dry matter and mineral disappearance at 0-h

The proportion of each mineral disappearing from nylon bags due to water rinsing gives an idea of the proportion of each mineral which is readily solubilized. This is presented in table 2, expressed as a percentage of the original concentration in the forage. The DM disappearance varied from 5.8 to 33.3%. Calopo and sesbania had the lowest and highest ($p < 0.05$) DM disappearance, respectively. Average DM disappearance was very closed to that reported for subtropical (Emanuele and Staples, 1990) and temperate (Ledoux and Martz, 1991) forages. Greater proportion of P, Mg and K disappeared from the forage compared with their DM but not in Ca.

TABLE 2. DRY MATTER AND MINERAL DISAPPEARANCE FROM NYLON BAGS WASHED WITH DEIONIZED WATER (0-H BAGS)

Forage	DM	Ca	P	Mg	K
	················· % ·················				
Grasses					
Para	17.8	3.6	82.2	55.4	92.0
Star	24.0	39.6	64.7	57.8	90.5
Napier	17.6	4.4	83.6	53.0	98.1
Creeping legumes					
Calopo	5.8	4.5	15.7	10.1	27.8
Centrocema	18.5	6.2	40.0	74.3	77.1
Tree legumes					
Gliricidia	22.7	24.3	39.9	64.3	74.0
Leucaena	23.9	30.3	46.4	61.9	88.2
Sesbania	33.3	24.5	33.3	41.0	93.3
Mean	20.4	17.2	50.7	52.2	80.1
SEM	0.2	0.3	0.5	0.9	0.3
LSD[1] ($p < 0.05$)	2.0	2.5	2.5	7.4	2.5

[1] Least significant difference.

Calcium disappearance varied from 4.5 to 39.6%. Stargrass had the highest ($p < 0.05$) Ca disappearance. Earlier report showed that bermuda grass which belongs to the same genus as stargrass had 52.9% solubility in water (Emanuele and Staples, 1990). Other grasses, however, like paragrass and napiergrass (elephantgrass) had very low Ca solubility of below 5%. In fact, Emanuele and Staples (1990) obtained a negative disappearance of Ca in dwarf elephantgrass. For the tree legumes, the data obtained in the present study give lower value than those obtained by Ibrahim et al. (1990) in gliricidia. In creeping legumes, the value for Ca solubility were also very low. Of the minerals studied by Collins (1985) on the effect of leaching, Ca was least affected. Calcium is not readily solubilized by water in most tropical and even temperate forages. This element is in bound form as calcium oxalates (Ward and Harbers, 1982) in legumes and either trapped or attached in the cell wall (McManus et al., 1979) of grasses and legumes.

Of the total P in ground plant material, 60 to 83% is water-soluble and most of it, is inorganic (Bromfield and Jones, 1972). The present findings agreed to some extent with Bromfield and Jones (1972) as P disappearance due to water rinsing varied from 15.7 to 83.6%. The average P disappearance (50.7%) was lower than the previous reports. Emanuele and Staples (1990) had a mean of 65.5% on subtropical forages; Ibrahim et al. (1990) had a mean of 76% on tropical forages; Whitehead et al. (1985) and Ledoux and Martz (1991) had a mean of 85 and 66.8%, respectively on temperate forages. Possibly, the forages used in this study had more P attached or trapped or crysttallized in the cell wall. Across forages, napiergrass had the highest ($p < 0.05$) P disappearance of 83.6%. Previous reports showed that dwart elephantgrass and guineagrass had also high P disappearance of 83.3 and 89%, respectively (Emanuele and Staples, 1990; Ibrahim et al., 1990) Therefore, P in grass is more readily available in the rumen than those found in legumes.

The average Mg disappearance due to water rinsing was 52.2% and ranged from 10.1 to 74.3%. Across forages centrocema, a creeping legume, had the highest ($p < 0.05$) percentage of Mg disappearance. Earlier reports showed that guineagrass and bermudagrass had high Mg disappearance of 82 and 91.1%, respectively (Ibrahim et al., 1990; Emanuele and Staples, 1990), whereas, the grass species in the present study had a range of 53 to 57.8%. Ibrahim et al. (1990) obtained a Mg solubility of gliricidia, higher by 11 percentage units over the present study which was 64.3% due to differences in samples. They used young leaves and twigs of gliricidia.

Potassium, which had the highest solubility among the macro minerals measured, varied from 27.8 to 98.1% with a mean of 80.1%. The mean obtained in the present study was lower than those previous data published (Whitehead et al., 1985; Emanuele and Staples, 1990; Ibrahim et al., 1990; Ledoux and Martz, 1991). Almost all K was released or solubilized by water rinsing in various forages either tropical or temperate forages and K was the most leached element in the forages (Collins, 1985). Compared to the legumes, the grasses had the higher K solubility in water and the highest ($p < 0.05$) was observed in napiergrass.

The trend in the rate of mineral solubilities in water was, K > Mg > P > Ca. The same order was observed by Emanuele and Staples (1990). This partly agreed with the observation of Ibrahim et al. (1990) and Ledoux and Martz (1991) except in Mg and P although the former is less soluble than the latter. Thus, the proportion of minerals solubilized by water are associated to the soluble fraction of the forages and they are immediately available for the host animal and their ruminal microbes.

Ruminal DM and mineral disappearance at 3-h

Table 3 shows the DM and macrominerals disappearance after 3 h incubation in the rumen. This was expressed as a percentage of the original concentration in the forage. Differences ($p < 0.05$) among the forage species in DM, Ca, P, Mg, and K were observed. The average DM disappearance of forages at 3 h incubation was 10 units higher than that of 0 h incubation. Mineral disappearance increased by 43% for Ca, 21% for P 30% for Mg and 13% for K than that observed at 0 h incubation. With the exception of Ca, solubilization of P, Mg and K exceeded 50%. Most soluble was K, followed by Mg, P and Ca. This ranking agreed with that observed in temperate forages including silage (Ledoux and Martz, 1991) and partly agreed to Van Eys and Reid (1987), who found out that P was more soluble than Mg in fescue and

TABLE 3. DRY MATTER AND MINERAL DISAPPEARANCE FROM NYLON BAGS PLACED IN THE RUMEN FOR 3 H

Forage	DM	Ca	P	Mg	K
	....	....	%	....	....
Grasses					
Para	22.1	26.4	87.8	80.3	96.4
Star	38.4	47.9	85.0	82.2	97.8
Napier	23.4	20.5	76.2	78.5	98.3
Creeping legumes					
Calopo	19.7	16.6	45.5	56.2	86.2
Centrocema	16.4	14.5	51.8	92.9	82.5
Tree legumes					
Gliricidia	36.3	32.8	44.0	79.1	90.3
Leucaena	32.1	45.1	59.8	62.9	95.4
Sesbania	44.7	38.4	51.4	62.9	93.8
Mean	29.1	30.3	62.7	74.4	92.6
SEM	1.6	0.4	4.0	0.5	0.3
LSD[1] ($p < 0.05$)	13.5	3.5	NS[2]	4.0	2.5

[1] Least significant difference.
[2] The F-test was not significant.

red clover herbage. Moreover, Playne et al. (1978) ranked mineral released from tropical hays after 12 h of ruminal incubation in the order of K > Mg > Na > P > Ca. On the contrary, Rooke et al. (1983) ranked rapid mineral released in lucerne silage and ryegrass silage: Na > Mg > K > Cu > Ca > Zn > P.

Across forages, stargrass had a very high solubility of all macro-minerals. On average, Ca disappearance was more prominent in tree legumes followed by grasses and the least in creeping legumes. Phosporus and K disappearances were higher in grasses. Magnesium disappearance was exceptionally high in centrocema. The trend on the solubility values observed at 0 and 3 h was consistent with previous reports (Whitehead et al., 1985; Van Eys and Reid, 1987; Ibrahim et al., 1990; Ledoux and Martz, 1991) and supported the conclusion of Van Eys and Reid (1987) which states that minerals disappearing after 3-h ruminal incubation probably are disassociated from the cell wall fraction.

Ruminal DM and mineral disappearance at 72-h

The DM and mineral disappearance after 72 h incubation in the rumen, expressed as percentage of the original concentration in the forage are presented in table 4. The DM disappearance ranged from 52.2 to 93.8% with a mean 73.8%. The low DM disappearance of calopo and centrocema was possibly due to the incorporation of vines in the smples which are more lignified. It was observed that DM disappearance of sesbania was exceptionally high, indicating that most of the nutrients within are soluble in the rumen. Earlier reports showed that the averaged DM disappearance of various forages incubated at 48 and 72 h in the rumen was 73.4 and 69.9, respectively. The former was temperate forage whereas the latter was temperate and subtropical forages (Ledoux and Martz, 1991 and Emanuele and Staples, 1990, respectively).

The extent of release of the four macrominerals at 72 h ruminal incubation varied from 53.2 to 84.9% for Ca, 70.6 to 95.9% for P, 81.1 to 98.0% for Mg, and 96.8 to 99.4% for K. The values observed were similar to those reported by Van Eys and Reid (1987) at 48 h and Emanuele and Staples (1990) at 72 h, but higher than those reported by Playne et al. (1978) at 72 h even at 168 h incubation period. The differences in values observed as mentioned by Emanuele and Staples (1990) were due to the differences in maturity of forages used (percent release of mineral decreases as plant maturity increases) or differences in washing procedures (hand washing vs mechanical washing, amount of water used in rinsing). The effects of forage specie, season and animal could not be ruled out as other major sources of variation.

Across forages, creeping legumes had low solubilities in Ca and P. These two elements were more attached or bound to cell wall fraction. As in the case of sesbania, it had a very high DM disappearance ($p < 0.05$) but low in Ca disappearance. Thus, the DM remained mostly lignified fiber and full of Ca attachement. From the different values observed in the present study, tropical forages could be grouped according to their mineral solubilities, i.e. for Ca disappearance: grasses > tree legumes > creeping legumes, for P disappearance: tree legumes > grasses > creeping legumes, for Mg disappearance: tree legumes and grasses > creeping legumes; for K disappearance: grasses and tree legumes > creeping legumes.

TABLE 4. DRY MATTER AND MINERAL DISAPPEARANCE FROM NYLON BAGS PLACED IN THE RUMEN FOR 72 H

Forage	DM	Ca	P	Mg	K
	....	....	%	....	....
Grasses					
Para	72.2	78.9	87.5	91.2	97.9
Star	79.5	84.9	92.1	92.5	99.4
Napier	75.7	83.7	85.7	91.5	98.3
Creeping legumes					
Calopo	59.8	53.2	76.1	81.1	96.8
Centrocema	52.2	55.5	70.6	91.5	98.3
Tree legumes					
Gliricidia	79.1	71.2	95.9	98.0	98.2
Leucaena	78.0	71.7	84.2	92.7	97.9
Sesbania	93.8	72.7	92.8	93.0	99.1
Mean	73.8	71.5	85.6	91.4	98.2
SEM	0.4	0.4	0.5	0.3	0.06
LSD[1] ($p < 0.05$)	3.2	3.3	3.8	2.4	0.5

[1] Least significant difference.

Effective ruminal solubilization (ERS) of minerals

The ERS of some macrominerals in selected Philippine forages are presented in table 5. The different values of ERS were calculated based on Equation 2 where particulate passage rate and disappearance rates of various mineral elements were included in the equation. The average particulate passage rate obtained in the present study was 1.9%/h whereas the range of disappearance rates of various mineral elements were: 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.

TABLE 5. EFFECTIVE RUMINAL SOLUBILIZATION OF SOME MACROMINERALS IN SELECTED PHILIPPINE FORAGES[1]

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	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.

The ERS of Ca varied from 32.9 to 67.7% and with a mean 50%. Centrocema and stargrass had the lowest and highest ($p < 0.05$) ERS of Ca, respectively. The mean ERS value of Ca obtained in the present study agreed with the mean ERS of Ca as observed by Van Eys and Reid (1987) but lower than the ERS value obtained by Ledoux and Martz (1991). Both previous workers, however, used temperate forages. Moreover, mean ERS of Ca of the present study showed good agreement with the percentage digestibility assumed in NRC (1984). The ERS of Ca varied by types of plant as could be seen in this study. Creeping legumes with vines in the samples gave low ERS of Ca. Low apparent digestibility of Ca (below 40%) in guineagrass and stargrass was also reported elsewhere (Perdomo et al., 1977).

The mean ERS of P was 72.6% and varied from 57.1 to 85.7%. Lowest and highest ($p < 0.05$) were observed in calopo and stargrass, respectively. The mean ERS of P in the present study was in good agreement to the mean ERS of P in forages used by Ledoux and Martz (1991) but this was lower than that observed by Van Eys and Reid (1987). Ledoux and Martz (1991) stated that the lower values observed in the ERS of P were due to contamination from ruminal fluid or ruminal microbes. As estimated by Rooke et al. (1983), temperate silage digested at 48 h had all residual P of bacterial origin. The lower ERS value of P of the present study might be due to the bacterial contamination. It may also be that the ERS or digestibility of P in tropical forages is really low. The latter assumption could be supported by the work of Perdomo et al. (1977) which obtained a low apparent P digestibility of guineagrass and stargrass, 35 and 37%, respectively against the 85% true digestibility of dietary P in temperate forages (NRC, 1984).

The ERS of Mg varied from 71.9 to 95.1% with a mean83.9%.No specie differences were found on ERS of Mg of various forages. However, calopo and centrocema had the lowest and highest ERS value. Previous works (Van Eys and Reid, 1987; Ledoux and Martz, 1991) obtained a mean ERS of Mg with a value of 88 and 86%, respectively, on temperate forages. Apparent Mg digestibilities of guineagrass and stargrass were found low by Perdomo et al. (1977), at 42 and 47%, respectively.

In contrast to other macrominerals, the ERS of K in various forages were the highest. It varied from 87.5 to 98.2% with a mean 94.5%. Across forages, it was lowest ($p < 0.05$) in calopo but highest ($p < 0.05$) in stargrass and paragrass. The findings of the present study were consistent and agreed to the previous findings (Rooke et al., 1983; Van Eys and Ried, 1987); Ledoux and Martz, 1991) which showed that ERS of K was above 90%. It was also in K that had the highest apparent digestibility among the minerals in tropical forages (Perdomo et al., 1977). They observed 88 and 87% apparent digestibility in guineagrass and stargrass, respectively. Thus, K is associated more in the cell soluble fraction of any forages.

Conclusion

This study concludes that species differences exist on the solubilities of macrominerals (Ca, P, Mg and K) in Philippine forages. Creeping legumes tended to have lower ruminal solubilities of macrominerals than those grasses and tree legumes. Combining particulate passage rate and macromineral disappearance rates, this study and previous studies indicate that the trend of ERS in K > Mg > P > Ca. Therefore, those minerals with high ERS are associated to the soluble fraction and those with low ERS are associated to the fiber or structural fraction of the forage.

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