MINERAL CONCENTRATION IN RICE STRAW AND SOIL IN KYONGBUK PROVINCE, KOREA

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Summary

A field survey was carried out in Korea to assess the mineral composition of rice straw since it is a cheap and available cattle feedstuff. Forage and soil samples were collected in 4 localities in the Kyongbuk province. Soil analysis were also carried out in order to establish the relationships between soil composition and mineral content in the rice straw. Based on NRC tables, the rice straw samples provided adequate amounts of Mg, Ca, K, S, Mo, Mn and Zn. Percentages of samples deficient in P, Na, Cu and Se were 83, 50, 67 and 83 respectively. Soil samples, whose mean pH was 5.8 and mean organic matter content was 3.99%, were comparatively acidic and had high organic matter content. They also had high amounts of extractable Fe and Mn. Correlation coefficients between mineral content in soil and rice straw were low, i.e., 0.42 for Mn ($p < 0.05$), and 0.37 for Mo ($p < 0.05$). The low or nonexistent correlation between soil and forage composition indicates the difficulty of establishing appropriate methods of mineral availability to the plants.

(Key Words : Rice Straw, Forage Mineral, Korea, Forage-Soil Interaction, Cattle Nutrition)

Introduction

One of important factors in efficient livestock production is to provide a balanced diet that covers the mineral requirement for animals as close as possible. In order to achieve this, it is necessary to know the composition of current feedstuffs commonly offered to animals. In the case of mineral nutrition, this allows to correct mineral deficiencies or excesses relatively with ease and with low cost, improving the nutrition and consequently the production of animals. There are many nutrition tables available that nutritionists can utilize to find requirements of animals and feed composition, but there is an increasing need to provide information on feed composition in a local basis since the composition of different feeds varies according to the area where they are grown. This is especially true for minerals. Besides, the composition of some common animal feeds are sometimes not included in the tables. In regard to this situation, mineral analysis of forages in Asian region has been done in a series of our study. In this study, mineral analysis was undertaken on Korean rice straw which is a common feedstuff for cattle production, and in which there is not enough information about the mineral composition. Through the study of soil characteristics, an insight of the soil-plant relation was sought after.

Materials and Methods

Twenty-nine samples of rice straw of Japonica breed were collected from 4 different regions chosen around Taegu City at random. Taegu City is located in Kyongbuk Province in Korea. At the time of sample collection the rice had been harvested, and hay had been made from the straw to be used as feed for livestock. All the samples were kept in identified polyethylene bags until the moment of preparation. Soil samples from the paddy soils, where the rice had been cultivated, were also collected. The paddy field had been treated by fertilizers such as N, P and K in a common way in Korea. In Korea, most of the

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harvest of rice is done in autumn. Therefore, it appears that there is little seasonal effect on quality of rice straw.

After the rice straw samples were ground, contents of Mg, Ca, Na, K, Fe, Zn, Cu, Mn and Mo in the samples were analyzed by atomic absorption spectrophotometry after wet digestion, with 4:1 of nitric to perchloric ratio. Selenium was analyzed by fluorometry with the use of diaminonaphthalene after wet digestion (Watkinson, 1966), and P was measured by colorimetry. Sulfur analysis was carried out by titrimetry. All the results were expressed in a dry matter basis.

Air dried soil samples were sieved through a 2 mm sieve and were extracted with water to measure Ca, Mg, Na and K. Phosphorous was measured by the method of Bray (1945). Available Fe, Zn, Cu and Mn were measured with HCl solution of 0.1 N, while Mo was measured as total Mo in soil digestion with nitric and perchloric mixture. Soil organic matter was analyzed as weight loss after 24 h at 430℃, discounting the loss of free water, while pH was measured in water suspensions. The data were statistically analyzed by GLM (General Linear Models) procedure of the SAS program (SAS, 1985).

In order to assess the adequacy of mineral contents per kg of dry matter, NRC tables for adult beef cattle requirements (NRC, 1984) were used with the exception of Ca and P. The minimum requirements of Ca and P were determined on the basis of heifers of which body weight is 272 kg and daily gain is 0.23 kg.

Results

Mineral concentrations of rice straw are presented in tables 1 and 2. Percentages of the samples of which concentrations of P and Na were below the requirements were 97 and 50 respectively. Magnesium, Ca, K and S of rice straw were all above the requirements.

Magnesium concentration of the rice straw had an areal distribution as shown in table 1. Area 4 had significantly high concentrations. Although area 3 did not show a high average,

TABLE 1. MACROMINERAL CONCENTRATION (%) IN RICE STRAW ON THE DRY MATTER BASIS

Area	P	Mg	Ca	Na	K	S
1(13)[1]	0.14(0.01)[2]	0.71^a(0.01)	0.37(0.00)	0.05(0.02)	1.38(0.14)	0.14(0.01)
2(5)	0.16(0.01)	0.14^b(0.01)	0.28(0.04)	0.06(0.04)	1.29(0.21)	0.14(0.01)
3(4)	0.11(0.01)	0.18^a(0.01)	0.33(0.04)	0.05(0.04)	1.66(0.24)	0.12(0.01)
4(7)	0.14(0.01)	0.22^c(0.01)	0.28(0.03)	0.20(0.03)	1.73(0.18)	0.14(0.01)
Total	0.14(0.01)	0.18 (0.01)	0.33(0.02)	0.09(0.02)	1.49(0.09)	0.13(0.00)

[1] Number of samples in parenthesis.
[2] Standard error in parenthesis.
[a,b,c] Values in the same column with different superscripts differ significantly ($p < 0.05$).

TABLE 2. MICROMINERAL CONCENTRATION (mg / kg) IN RICE STRAW ON THE DRY MATTER BASIS

Area	Fe	Zn	Cu	Mo	Mn	Se
1(13)[1]	598(45)[2]	34.3^a (2.2)	3.40(0.54)	1.13(0.12)	143(16)	0.07(0.01)
2(5)	556(72)	45.7^{bc}(3.5)	5.20(0.86)	1.45(0.20)	113(24)	0.07(0.01)
3(4)	472(81)	33.7^{ad}(3.9)	2.74(0.97)	1.50(0.22)	133(20)	0.06(0.01)
4(7)	624(61)	42.6^{cd}(3.0)	2.86(0.73)	1.39(0.17)	120(35)	0.06(0.01)
Total	537(31)	38.2 (1.7)	3.49(0.37)	1.30(0.08)	131(13)	0.07(0.01)

[1] Number of samples in parenthesis.
[2] Standard error in parenthesis.
[a,b,c,d] Values in the same column with different superscripts differ significantly ($p < 0.05$).

3 areas out of 4 had Na concentrations to meet the requirements. Percentages of the samples of which concentrations of Cu and Se were below the requirements were 67 and 83 respectively. Iron, Mo, Mn and Zn were all above requirements.

TABLE 3. SOIL EXTRACTABLE Ca, Mg, Na, K AND P OF FOUR DIFFERENT AREAS IN KOREA. VALUES OF P ARE IN PERCENT; OTHERS ARE IN (mg / kg)

Area	P	Mg	Ca	Na	K
1(13)[1]	0.75(0.62)[2]	2.48(0.33)	8.2(1.2)	10.3(1.9)	8.6(1.8)
2(5)	0.30(0.02)	2.54(0.84)	11.3(3.3)	11.0(1.9)	10.4(2.3)
3(4)	1.40(0.88)	4.23(0.96)	16.1(4.2)	13.8(1.4)	24.8(9.3)
4(7)	0.23(0.05)	2.99(0.71)	11.9(3.6)	12.1(1.5)	12.9(3.1)
Total	0.63(0.32)	2.86(0.32)	10.7(1.4)	11.3(1.1)	12.2(2.0)

[1] Number of samples in parenthesis.
[2] Standard error in parenthesis.

Extractable Fe and Mn were particularly high in paddy soils: 1,439 mg/kg and 199 mg/kg respectively (table 4). Mo contents were low in soil samples, but probably its availability was high since Mo in rice straw was 16 times higher than in soil. Statistically significant differences among regions were found for all the trace elements in soil but Zn. It is interesting to note that there were differences in soil extractable elements that was not reflected in the mineral composition of rice straw. Also the soil organic matter content showed differences among regions. Soil extractable macrominerals did not show any significant difference among areas.

TABLE 4. SOIL EXTRACTABLE Fe, Zn, Cu, Zn, TOTAL Mo, AND SOIL pH AND ORGANIC MATTER (OM) OF FOUR DIFFERENT AREAS IN KOREA. VALUES OF MINERALS ARE IN mg / kg AND ORGANIC MATTER IS IN PERCENT

Area	Fe	Zn	Cu	Mo	Mn	pH	OM
1(13)[1]	893(59)[2a]	4.27(1.21)	1.09(0.14)[a]	0.07(0.01)[a]	216(19)[a]	6.3(0.2)	3.90(0.28)[ac]
2(5)	1,298(35)[ab]	7.40(2.30)	5.81(1.11)[b]	0.08(0.02)[a]	101(24)[a]	5.5(0.2)	2.93(0.41)[a]
3(4)	2,394(221)[c]	9.49(2.31)	4.49(1.22)[b]	0.21(0.05)[b]	366(79)[b]	5.7(0.1)	5.43(0.22)[b]
4(7)	2,009(411)[bc]	8.95(2.92)	2.23(0.26)[a]	0.04(0.01)[a]	141(53)[a]	5.7(0.3)	4.11(0.27)[c]
Total	1,439(155)	6.66(1.13)	2.65(0.44)	0.08(0.01)	199(25)	5.8(0.1)	3.99(0.21)

[1] Number of samples in parenthesis.
[2] Standard error in parenthesis.
[a,b,c,d] Values in the same column with different superscripts differ significantly ($p < 0.05$).

Discussion

The ratio of Ca to P in rice straw was appropriate (above 1:1) (Thornton, 1983), in only half of the samples. The ratio K/(Ca + Mg), which is used as a predictor of grass tetany (Mitchell, 1971) was above 2.2 in 25 of the samples (83%) as a consequence of high K levels. Although there were statistically significant differences among areas in Mg content in the samples, all but one sample had Mg contents above requirements. However, the ratio K/(Ca + Mg) did not show any difference among areas. Fe concentration in rice straw was above the requirement in all the samples, and it exceeded 500 mg/kg in 63% of the samples. This Fe level has a possibility to impair Cu absorption (Bremner et al., 1983). Percentage of the rice straw samples of which Cu concentration was below the recommended value was 67. On the other hand, although the Mo concentration was low, the Cu:Mo ratio was below the recommended value (Miltimore, 1971) of 2:1 in 37% of the samples, mainly due to the low Cu concentation in rice straw. Therefore, the high Fe content, the low Cu:Mo ratio and the low copper concentration indicates the necessity of Cu supplementation if this rice straw is used as an only feed source.

Selenium concentration was below the recommended value in most of the samples (83%), but according to ARC tables (1981), rice straw that had a value below requirements (>0.05 mg/kg) was only 10% of the samples.

When the mineral concentrations of Korean rice straw were compared with the reported values of Japanese rice straw (Secretariat of Agriculture, 1980), it was found that there were no substantial differences in Ca, P, Na and S (table 5). Potassium concentration was lower in Korean samples but it was still above the requirement and affected the ratio K/(Ca + Mg), in spite of the high concentration of Mg in Korean samples. The high K concentration seemed to be a characteristic of rice straw since reported values for U.S.A. (National Academy of Sciences, 1971) and Indonesia (Kumagai et al., 1990) were 1.32% and 1.74%, respectively.

Iron and Mn were two elements that were present with high amount in paddy soil, and the rice straw contents varied widely but always well above the requirements for domestic animals. Iron was present in rice straw with the amount up to 1,000 mg/kg or more. This may be due to the soil composition that influences Fe availability. Extractable Fe in soil samples ranged from 582 to 4,388 mg/kg, and Fe content in rice straw ranged from 375 to 1,032 mg/kg. However, there was no correlation between the extractable soil Fe and the Fe content in rice straw.

Soil pH was in accordance with reported values of Korean paddy soils, pH 5.4 (Kim, 1969), while organic matter was slightly higher than reported values of Malayan paddy soils, which were considered to be 3.36% in organic matter (Kawaguchi, 1969).

The total Mo content in soil was particularly low (0.08 mg/kg). It contrasts with the range of Mo in Asian tropical paddy soils (2.3 to 3.3 mg/kg) (Domingo, 1983). The fact that the rice straw concentrated Mo should mean that Mo existed in a highly available form. This is in accordance with the increase of Mo availability when the soil becomes waterlogged, and with the fact that Mo forms highly available complexes with organic matter (Mitchell, 1971). In contrast, low pH is sometimes associated with low Mo availability (Mitchell, 1971). The present state of knowledge points out that Mo availability is governed by many factors at the same time, and no general rule can be drawn for all soil (Thornton, 1983).

TABLE 5. MINERAL COMPOSITION OF JAPANESE AND KOREAN RICE STRAW. VALUES OF Ca, Mg, P, K, Na, AND S ARE IN PERCENT, AND Cu, Fe, Zn and Mn IN mg / kg.

	Ca	Mg	P	K	Na	S	Cu	Fe	Zn	Mn
Japanese[1]	.30	.10	.13	1.95	.07	.16	4.1	300	47	476
Korean	.33	.18	.14	1.49	.13	.13	3.5	537	38	131

[1] Reported values in standard tables of feed composition in Japan (12).

Large amount of extractable Fe and Mn were present in paddy soil. It is not uncommon since these two minerals tend to accumulated in soil as a consequence of the flooding. Domingo (1983) reported average Cu, Mn and Zn concentrations of 1.47, 75.13 and 2.37 mg/kg, respectively. The correlations that could exist between mineral concentration in soil and that in plant were investigated and it was found that most coefficients were extremely low. Only the correlation between Mn in rice straw and Mn in soil reached $r = 0.37$ ($p < 0.05$) and there was a low but significant correlation ($r = 0.40$, $p < 0.05$) between soil pH and Mn in rice straw. Molybdenum in rice straw was correlated to Mo in soil ($r = 0.39$, $p < 0.05$).

Rice straw is a useful feed for cattle. For the area studied in the present research, the results indicated that the rice straw had inadequate contents of P, Na, Cu and Se, while it had excessive level of K, that can strongly affect Mg absorption. Also Fe was present in high amount. High level of Fe has been reported as detrimental to Cu absorption (Bremner et al., 1983). This indicates the necessity of mineral supplementation or combination with other feedstuffs to supply nutrients that would become deficient in cattle when only rice straw is given.

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