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Zinc Levels in Rice and in Soil According to the Soil Types of Japan, Indonesia, and China

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During the past a few years there is a growing interest concerned with human environmental health problems arising especially in reference to zinc contamination. However, little is known about the levels of zinc in the rice and soil in Japan, Indonesia and China even though rice is staple food of these countries and it has been considered to be a good indicator of daily intake of zinc. On the other hand, while abundant information on the cadmium content in the rice and soil of Japan is available, there are only a few reports about the zinc content in the rice of Indonesia (Suzuki *et al.*, 1980; Koyama *et al.*, 1988). Unfortunately, there is no research reported on zinc levels in rice and the rice field soil of China.

Zinc as one of the trace elements, serves a variety of functions, however the concentration of the metal must be maintained within certain limits if these functions are to remain unimpaired. The importance of zinc in human beings has been demonstrated by researchers. Most of the reports have been on the essensiality of zinc in human beings and the consequences of zinc deficiency. The daily intake of zinc from foods in many countries had been studied by some researchers to determine what an adequate intake is (Horiguchi *et al.*, 1978; Toro *et al.*, 1994). Unfortunately, there are no data from Indonesia and China. Therefore, it is necessary to determine accurately the zinc content in rice and paddy soil of Japan, Indonesia and China and its correlation to the soil types and the daily intake of zinc from rice. The present study attempts to do this by: 1) determination of zinc contents in the rice samples from Japan, Indonesia and China; 2) Estimation the daily zinc intake as an additional reference; and 3) an analysis of the correlation of zinc in rice and the soil types of those areas in each country.

MATERIALS AND METHODS

As many as 178 unpolished rice and soil samples have been collected. Samples from Japan (N=111) were taken from Hokkaido/Tohoku, Hokuriku, Kanto, Tokai, Chugoku, Shikoku and Kyushu; the east, the northeast, and the south parts of China (N=22); and Indonesia (N=45) were taken from Java, Sumatra, Kalimantan and Sulawesi. Soil samples were also collected from rice fields where rice plants were growing. Sample sites recorded were usually at the prefecture or city.

Approximately 0.1 gram of a rice sample was put into a test tube for pretreatment and weighed, dried in an oven at 105° C for 48 hr and weighed again to assess the water content. The completely dried rice sample was ashed on a hot plate with 1.0 ml of concentrated nitric acid (metal free) until dryness. 2.0 ml of 14% nictric acid

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were added to dissolve the residue. Two methods were used for pretreatment of a soil sample: 1) Extraction by HCl without ashing. Aproximately, 1 gram of a dried and filtered soil sample was put into a tube, weighed, added together with 50 ml of 0.1 N HCl , and shaken in a water bath at 30°C for 1 hr. The upper clear solution was separated and centrifuged at 3000 rpm for 5 min for zinc analysis, and 2) extraction by ashing with nitric acid. Approximately, 1 gram of dried and filtered soil sample was put into a test tube, weighed, added by 5.0 ml of concentrated nitric acid (metal free), and then ashed over a hot plate. Next, 10.0 ml of pure water was added and the clear supernatant was removed for zinc analysis. Each sample was analyzed two or three times by an autosampler AAS at wavelength 229 nm for rice samples and 326 nm for soil samples. Under the same conditions, standard materials provided by the US National Bureau of Standards were used for reference to confirm accuracy: 0.1 gram of powdered rice (No. 1568) and 0.5 gram of orchad leaves (No. 1571) for soil samples. Concentrations of zinc in the ashed rice solution was analyzed using the conventional AAS method after five-fold dilution with deionized water, under the conditions recommended.

Daily intake of zinc from rice (R) was calculated by multipling the content of zinc in rice with daily rice consumption from each country (CIC method). The values obtained were used to assess the total daily zinc intake by calculating: T=(Et/Er) x R, where, T= Total daily zinc intake (microgram); Et= Total daily energy intake (kcal); Er= Daily energy intake from rice (kcal); R= Daily zinc intake from rice (microgram), data from FAO (1991). Identification of soil type was based on the Soil Map of the World, Volume VIII (1978) and Volume IX (1979) by FAO (Food and Agricultural Organization). A few samples on the borderline between the two soil types were excluded.

RESULTS AND DISCUSSION

The estimated average of the zinc levels in rice and rice field soil of Japan, Indonesia and China are shown in Table 1. Since the frequency distribution of the data is mostly skewed, the geometric mean and geometric deviation were calculated. In this study, Japanese rice (23.38 µ g/g) seemed to have somewhat higher zinc levels than those reported by Ohmomo and Sumiya (1981), that is, 20.5 µ g/g and by Masironi *et al.* (1977), that is, 15.2 µ g/g in polished rice of Japan. Similar results were seen in Indonesian rice (23.51 µ g/g) which had higher zinc concentrations than that observed by Suzuki et al. (1980) in Java rice that is 19.02 µ g/g but a little lower than reported by Koyama *et al.* (1988) , 24.9 µ g/g, from Java rice. China had the lowest in zinc levels in rice among the three countries (21.47 µ g/g). Compared with Bangladesh (13.6 µ g/g), Philippines (18.6 µ g/g), and Taiwan (16.7 µ g/g) reported by (Masironi (1977); the levels of zinc in the rice of the three countries under study were higher. Moreover, compared with the zinc content in rice from Southern Catalonia, Spain (19.07 µ g/g) observed by Schuhmacher *et al.* (1994) the present data from the three countries was slightly higher, but practically identical with the zinc levels for unpolished rice from Houston, Texas, reported by Suzuki and Iwao (1981), 22.9 µ g/g.

In soil extracted by hydrochloric acid (soil^{a}), the average zinc level from those of Japan, Indonesia and China were 2.54±2.11, 1.86±1.95, and 2.41±3.65 µ g/g, respectively, while those by the nitric acid ashing method (soil^{b}) were 105.59± 46.22, 72.48±36.97, and 98.84±93.16 µ g/g for Japan, Indonesia and China respectively. Statistical analysis showed that the zinc levels for rice from Japan, Indonesia and China were not different; however, the zinc concentration in soil^{a} and

Table 1. Estimation of zinc contents in rice and soil samples of Japan, Indonesia and China (μ g/g)

	Rice samples from:			Soil[a] samples from:			Soil[b] samples from:		
	Japan	Indonesia	China	Japan	Indonesia	China	Japan	Indonesia	China
N	111	45	22	111	45	22	111	45	22
Min	11.29	15.45	16.21	0.30	0.29	0.29	17.72	22.01	37.33
Max	38.47	35.25	28.54	12.86	11.56	18.05	352.45	194.53	491.95
Mean	23.38	23.51	21.47	2.54	1.86	2.41	105.59	72.48	98.84
SD	4.80	5.53	3.56	2.11	1.95	3.65	46.22	36.97	93.16
CV, %	20.50	23.50	16.60	82.90	105.10	151.40	43.80	51.00	94.30
GM	22.90	22.89	21.19	1.91	1.29	1.47	96.44	64.23	81.24
GD	1.23	1.26	1.18	2.13	2.31	2.55	1.55	1.65	1.73

Note: N, number of samples; Mean, arithmatic mean; SD, standard deviation; CV, coefficient of variation; GM, geometric mean; GD, geometric deviation; soil[a], metals extracted by hydrochloric acid, soil[b], metals ashed by nitric acid; p, level of significance; ANOVA, $F=1.32$, $p>0.05$, for rice samples from Japan, Indonesia and China; $F=4.26$ and 12.02, $p<0.01$, for soil[a] and soil[b], respectively.

soil[b] from the three countries was different at $p>0.05$ and $p>0.01$ for soil[a] and soil[b], respectively.

Table 2 shows number of soil samples collected from Japan, indonesia and China. Rice grown in *Histosols* soil type (Table 3), all samples from Indonesia, were observed to be high in zinc content, 27.37 μ g/g, while rice grown in *Acrisols* soil type, also all samples from Indonesia, had the lowest content, 21.04 μ g/g. On the other hand, zinc levels in soil were low in *Histosols* soil type when extracted both by the hydrochloric acid method and nitric acid ashing method. This may be because of parent materials in which *Histosols* soil type developed. *Histosols* soil

Table 2. Numbers of rice samples collected from Japan, Indonesia and China broken down into seven soil types

Soil type	Japan	Indonesia	China	Total
Andosols	81	4	0	85
Cambisols	8	0	0	8
Fluvisols	11	0	0	11
Gleysols	3	0	12	15
Histosols	0	14	0	14
Luvisols	0	10	0	10
Acrisols	0	17	0	17
Mixed soil*	8	0	10	18
Total	111	45	22	178

*, see footnote of Table 2.

type developed in organic materials and total zinc soil has been related to a greater degree to parent materials than to any pedological factors (Shuman, 1980). In addition, organic matter in soil can solubilize mineral zinc to make the element useful for plants. Therefore, even though *Histosols* soil type contains a lower level of zinc, it use for plants was high.

Mixed soils, 10 out of 18 samples from China, seemed to have the highest content of zinc both in the soil extracted by the hydrochloric acid method and ashed by the nitric acid method, 4.50 and 137.75 µ g/g, respectively. *Luvisols* (all samples from Indonesia) were the lowest or 1.23 µ g/g in the soil extracted by hydrochloric acid method and 61.99 µ g/g in soil ashed by the nitric acid method of all the soil types analyzed.

Table 3. Differences of zinc content in rice & soil samples by soil types (µ g/g)

Soil type	Zn in rice		Zn in soil[a]		Zn in soil[b]	
	GM	GD	GM	GD	GM	GD
Andosols	22.49	0.09	1.64	0.32	92.94	0.19
Cambisols	24.90	0.06	2.03	0.32	83.20	0.13
Fluvisols	22.90	0.09	1.42	0.29	96.08	0.12
Luvisols	21.20	0.13	0.93	0.34	52.36	0.27
Acrisols	20.63	0.09	1.46	0.29	78.20	0.19
Histosols	27.11	0.06	1.84	0.40	57.89	0.18
Gleysols	22.46	0.07	2.02	0.27	75.71	0.18
Mixed soils	22.39	0.08	2.39	0.55	112.29	0.26

Abbreviations and marks: see the footnote of Table 1; *, the mixed soils of *Andosols, Lithosols, Histosols,* and *Acrisols,* p, level of significance; ANOVA, F=2.50, p<0.05 for Zn in rice; F=1.65, p>0.05, for Zn in soil[a]; and F=4.54, p<0.01, for Zn in soil[b].

Insignificant Pearson's correlation coefficient (Table 4) was found between zinc in rice and soil extracted by hydrochloric acid (soil[a]) in Japan, Indonesia and China. Similar results could be seen between zinc in rice compared to that soil ashed by nitric acid (soil[b]) from Japan, Indonesia and China with a negative correlation being shown in Japan (r=-0.02, p>0.05). The correlation coefficient between zinc levels in soila to those in soil[b] was significant only for Japan and Indonesia (r=0.41; r=0.46, p>0.01, respective1y). A positive high significant correlation could be seen between zinc in soil[a] to soi1[b] (r=0.46, p<0.01). It can be said that the amounts of zinc in rice did not correlate with zinc in soil. Similar results also given by Rivai *et al.* (1990); Suzuki, and Iwao (1982); and Scuhmacher *et al.* (1994) indicated an insignificant relationship between metals in rice and metal concentrations in these types of soils. The same argument may occurr whether the organic matter or humus in soil, soil pH, oxydation or reduction electric potential, etc. give some influences on the absorbtion of metals by plants.

Daily zinc intake among the three countries is presented in Table 5. Total daily zinc intake from the rice of Indonesians was 21.9 mg/person higher than reported by Koyama *et al.* (1988) 13.26-16.56 mg/person. Chinese daily intake of zinc (22.7 mg/person) was higher than reported recently by Chen *et al.* (1992), 7.7-12.1 mg/person from data of Shanxi, China.

Table 4. Correlation coefficients between zinc in rice and soil samples by country

	N	Zn in rice	Zn in soil[a]	Zn in soil[b]
JAPAN	111			
Zn in rice		1.00	0.14	-0.02
Zn in soil[a]			1.00	0.41**
Zn in soil[b]				1.00
INDONESIA	45			
Zn in rice		1.00	0.08	0.08
Zn in soil[a]			1.00	0.46**
Zn in soil[b]				1.00
CHINA	22			
Zn in rice		1.00	0.28	0.24
Zn in soil[a]			1.00	0.40
Zn in soil[b]				1.00
Total	178			
Zn in rice		1.00	0.14	0.04
Zn in soil[a]			1.00	0.46**
Zn in soil[b]				1.00

Note: **, significant correlation at $p< 0.01$; Zn, zinc; [a] & [b] See Table 1 footnote

Table 5. Total daily zinc intake by country (mg/person)

Country	N	Zn in rice (μ g/g)	Daily Zn intake from rice (mg/person)	Total daily Zn intake
Japan (281.9)*	111	22.90	6.5	24.3
Indonesia (541.7)*	45	22.89	12.4	21.9
China (405.5)*	22	21.19	8.6	22.7

*, Average daily rice consumption (g/person) of 1984-1986 from the data of Food Balance Sheets by FAO (1991)

The total daily zinc intake by Japanese was the highest, 24.3 mg/person, not only among the three countries under study but also when compared to data of Ohmomo and Sumiya (1981), 4.8 mg/person and of Horiguchi (1978), 3.4 mg/person. The daily zinc intake from rice of the three countries was also higher when compared to the daily intake of zinc from rice for people in Southern Catalonia, Spain and from cereals (rice, noodles, sphagetti) consumed by people in Tarragona Province, Spain conducted by Schuhmacher *et al.* (1994; 1993), 2.6 and 1.2 mg/person, respectively. Furthermore, the zinc content of the household diet in Britain (Spring *et al.*, 1979), 9.1 mg/person, was lower than total zinc daily intake of the three countries under study. Zinc daily intake by people in Japan, Indonesia and China were higher than total zinc daily allowance from foods which is 1.5 mg/person based on the American diet (National Research Council, 1989).

SUMMARY

The means of zinc levels in rice of Japan, Indonesia and China were practically identical, 23.38, 23.51, and 21.47 µ g/g for Japan, Indonesia and China respectively. Regarding soil, Japan seemed to have an higher concentration of zinc. When samples were divided by soil type, *Histosols* (all samples from Indonesia) appeared to contain the highest (27.37 µ g/g) and *Acrisols* the lowest (21.04 µ g/g) zinc level among all the soil types. Mixed soils, 10 out of 18 samples from China, had the highest concentration of zinc both using hydrochloric extracting method and the nitric acid ashing method. The relationship of zinc in rice to the types of soils was insignificant. It appears that zinc contents in rice and soil are not influenced by soil type. Total dietary intakes of zinc of the people from Japan, Indonesia and China were 24.3, 21.9 and 22.7 mg/person, respectively, which was higher than the recommended dietary allowance of daily zinc intake from foods by the American standard diet (15 mg/person).

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