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Cadmium Content in Rice and Its Daily Intake in Various Countries

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Man ingests cadmium daily from foods and beverages. The major source of cadmium intake is rice for rice eating countries. Aproximately 50 % of the daily cadmium intake of Indonesian comes from rice (Suzuki et al. 1988a), and for the Japanese, about 40 to 60 % (Yamagata 1978). Cadmium in rice comes from soil via rice plant roots. Rice may thus be the best indicator for the environmental monitoring of cadmium especialy in rice eating countries. It is also easy to sample, transport and conserve (Suzuki et al. 1988b).

Several recent surveys on cadmium content in rice and daily cadmium intake have been reported for Bangladesh, Brazil, India, Indonesia, Japan, Korea, Malaysia, Philippines, Singapore, Thailand and USA (Moritsugu et al. 1964, Masironi et al. 1977, Nakatsuka et al. 1988, Suzuki et al. 1980 and 1982). Data for daily cadmium intake have been reported for England, Indonesia, Japan and USA (Ministry of AFF 1973, Suzuki et al. 1985, Suzuki and C-C Lu 1976, Kowal et al. 1976 and Johnson et al. 1975). However, little data are available on geographical differences in daily cadmium intake from rice. The tolerable weekly intake for cadmium as proposed by FAO/WHO (1972) is 400-500 micrograms/person or 57-71 micrograms/day/person weighing 70 kg.

Ninety two percent of world rice production is from the Asia-Pacific region, and from which samples were obtained for the present study. The following countries were included: India, China, Bangladesh, Thailand, Indonesia , Philippines, Japan, and Korea whose world production percentages of rice are 29.3, 23.4, 7.1, 6.5, 6.3, 2.3, 1.6 and 0.8 %, respectively (FAO 1985).

This study was conducted to determine cadmium content in rice from the above countries and based on the data obtained, daily cadmium intake from rice and the total daily cadmium intake were calculated.

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MATERIALS AND METHODS

From 1985 to 1988, rice samples were collected from the following countries: Bangladesh, Brazil, China, India, Indonesia, Japan, Malaysia, Philippines, Singapore, Korea, and Thailand. Some of the samples were collected from rice fields and some were obtained commercially. Most of the samples were in the unpollished condition.

0.1 gram of the rice sample was put into a test tube and weighed, dried in an oven at 105° C. for 48 hours and weighed again to determine water content. The dried sample was ashed on a hot plate with 1 ml of concentrated metal free nitric acid until dry. 2.0 ml of 14 % nitric acid were then added and the residue at the bottom of the test tube was dissolved. Cadmium in the solution was assessed by a flameless atomic absorption spectrophotometer (Hitachi 180-30), with automatic background correction. Each sample was analyzed two or three times by an autosampler at a wave length of 229 nm. Under the same conditions, 0.1 gram of standard material (powdered rice, No. 1568) provided by the US National Bureau of Standard was used as a reference to confirm accuracy. Reliablility of the cadmium determination was 18.7 %, expressed as the coeficient of variation of 10 repeated analyses of the same rice sample lot. Recovery was determined by adding 0.002 microgram of cadmium to each five 0.1 gram rice sample from a single lot. The recovery rate ranged from 74 % to 118 %, the average being 94 %.

Daily cadmium intake from rice was calculated by cadmium content in rice multiplied to daily rice consumption. The value obtained was used to assess total daily cadmium intake using for daily energy intake and rice consumption from Food Balance Sheets, 1979-1981 Average, by FAO (1984), as follows:

$$T = (Et/Er) \times R$$

where, T: Total daily cadmium intake (microgram), Et: Total daily energy intake (kcal), Er: Daily energy intake from rice (kcal), R: Daily cadmium intake from rice (microgram).

RESULTS AND DISCUSSION

The results of cadmium estimation for rice samples from each of the countries are shown in Table 1. Rice samples of Japan from 24 prefectures were divided for seven areas: Hokkaido/Tohoku, Hokuriku, Kanto, Tokai, Chugoku, Shikoku and Kyushu. The cadmium content in rice produced in Indonesia was divided for four main islands: Java, Sumatra, Borneo and Celebes. Such a division was not possible for Bangladesh, Brazil, Malaysia, Philippines and Singapore since sample location was not known. Due to the limited number of samples, the mean data for Malaysia was not used in this study.

The geometric mean of cadmium content in rice from the various countries in this study varied widely, ranging from 5.9 to 99.3 ppb wet wt. Mean cadmium content in rice of the seven areas in

Table 1. Estimation of cadmium content in rice (ppb wet wt.)

Country/Area		N	Geometric mean	G.D.	Min.	Max.
Bangladesh		6	17.0	1.4	5.3	25.6
Brazil		15	6.3	2.1	2.0	32.4
China:	East	11	6.6	1.8	1.8	12.3
	Northeast	7	8.0	2.6	3.8	66.4
	South	8	26.1	3.7	2.8	134.2
India:	North	8	12.5	1.9	3.0	31.0
	Southeast	9	11.4	3.3	1.3	82.3
	East	4	19.6	3.8	6.9	135.9
	Central	6	9.3	2.0	3.0	27.5
Indonesia:						
	Java Island	10	19.9	4.0	2.6	98.3
	Sumatra Island	29	28.7	4.2	2.3	520.5
	Borneo Island	7	21.6	3.1	4.5	92.5
	Celebes Island	5	71.1	3.9	23.4	564.4
Japan:						
	Hokkaido/Tohoku	69	23.1	3.1	3.4	309.2
	Hokuriku	74	99.3	2.5	5.1	468.8
	Kanto	64	49.0	3.3	2.1	321.5
	Tokai	16	47.5	3.2	2.7	228.8
	Chugoku	26	41.9	3.2	4.4	272.1
	Shikoku	26	20.5	5.0	1.1	256.8
	Kyushu	20	32.6	3.4	1.2	153.3
Korea:	Northwest	4	4.9	1.2	4.3	20.9
	Central west	18	17.3	2.4	4.0	49.6
	Southeast	3	(45.4,54.2,83.8)	-	-	-
Malaysia		3	(4.9,29.0,39.7)	-	-	-
Philippines		17	19.3	2.8	4.1	130.9
Singapore		7	5.9	2.1	1.9	26.6
Thailand:						
	East and Northeast	15	13.8	2.0	2.4	41.0
	North	13	19.1	5.9	1.1	584.4
	Central	20	11.2	2.3	2.3	34.4
	South	19	22.3	2.8	4.6	167.8

N, number of sample analyzed; G.D, geometric deviation.

Japan (20.5-99.3 ppb) exceeded that of the other countries. The cadmium content in the rice of Shikoku, Japan, was lowest, 20.5 ppb, followed by that of Hokkaido/Tohoku, 23.1 ppb. The highest value was for the Hokuriku area, 99.3 ppb.

Cadmium content in rice of the Celebes Island was highest among the islands, 71.0 ppb. For Java, Sumatra and Borneo, the value were essentially the same, being 19.9, 28.7 and 21.6 ppb, respectively or about 2.5 to 3 times less than that of Celebes.

Table 2. Mean total daily cadmium intake and the rice consumption data by country

Country/area	Range of total daily Cd intake 32%---68%	5%----95%	**Daily Cd intake from rice	**Total daily Cd intake
Bangladesh (578.2)*	9.1- 17.8	4.5- 35.6	9.8	12.7
Brazil (168.8)*	3.2- 14.3	1.6- 28.6	1.1	6.8
China: (350.8)*				
East	3.7- 12.1	1.9- 24.1	2.2	6.7
Northeast	3.0- 20.3	1.5- 40.6	2.8	7.8
South	6.9- 94.3	3.4-188.7	9.1	25.5
India: (283.0)*				
North	5.5- 19.9	2.8- 39.9	3.5	10.5
Southeast	2.9- 31.7	1.4- 63.4	3.2	9.6
East	4.3- 62.7	2.2-125.4	5.5	16.5
Central	3.9- 15.6	1.9- 31.2	2.6	7.8
Indonesia: (507.3)*				
Java Island	4.3- 68.8	2.1-137.6	10.1	17.2
Sumatra Island	5.9-104.2	2.9-208.3	14.6	24.8
Borneo Island	6.0- 58.0	3.0-115.9	11.0	18.7
Celebes Island	15.7-239.5	7.9-478.9	36.1	61.4
Japan: (300.2)*				
Hokkaido/Tohoku	8.0- 76.9	4.0-153.8	6.9	24.8
Hokuriku	42.9-268.2	21.5-536.5	29.8	107.3
Kanto	16.0-174.6	8.0-349.1	14.7	52.9
Tokai	16.1-164.8	8.0-329.6	14.3	51.5
Chugoku	14.2-145.3	7.1-290.6	12.6	45.4
Shikoku	4.5-111.5	2.2-223.0	6.2	22.3
Kyushu	10.4-120.0	5.2-240.0	9.8	35.3
Korea: (568.6)*				
Northwest	4.7- 6.7	2.3- 13.4	2.8	5.6
Central west	8.2- 47.0	4.1- 94.1	9.8	19.6
Philippines (371.7)*	6.7- 52.4	3.3-104.7	7.2	18.7
Singapore (293.1)*	3.6- 15.7	1.8- 31.5	1.7	7.5
Thailand: (612.1)*				
East and Northeast	6.7- 26.4	3.3- 53.6	8.4	13.4
North	3.2-110.3	1.6-220.7	11.7	18.7
Central	4.7- 25.1	2.4- 50.1	6.8	10.9
South	7.8- 61.0	3.9-122.1	13.6	21.8

* Average daily rice consumption (gram/person) of 1979-1981 from the data of Food Balance Sheets by FAO (1984).
** Data of geometric mean, microgram/person.

For southeast of Korea, the closest area to Japan, the amount of cadmium in rice was somewhat higher than those of northwest and central west. This content for three samples of southeast were 45.4, 54.2 and 83.8 ppb. In the northwest it was lowest among all the countries/areas investigated, being 4.9 ppb, and for the central west, 17.3 ppb.

The four areas of India and Thailand showed essentially the same cadmium content in rice. The value for India were 12.5, 11.4, 19.5 and 9.3 ppb for north, southeast, east and central areas, respectively. The east and northeast, north, central and south areas in Thailand showed values of 13.8, 19.1, 11.2 and 22.3 ppb, respectively.

Cadmium content for three samples from Malaysia were 4.9, 29.0 and 39.7 ppb and for Bangladesh and Philippines, 17.0 and 19.3 ppb, respectively. Singapore showed the lowest value (5.9 ppb) among the countries investigated, followed by Brazil (6.3 ppb).

Table 2 shows the range of total daily cadmium intake, and geometric mean of daily cadmium intake from rice and total daily cadmium intake from each country. The total daily cadmium intake in this study ranged from 5.6 - 107.3 micrograms. The highest total daily cadmium intake noted for the Hokuriku area of Japan, 107.3 micrograms and ranged from 21.5 - 536.5 micrograms. The total daily cadmium intake of Japan was higher than that of the other countries. The Celebes Island of Indonesia indicated the highest value, 36.1 micrograms of cadmium from rice.

Except for the Hokuriku area in Japan, mean total daily cadmium intake in this study was less than the tolerable weekly intake specified by FAO/WHO (1972) or 400 - 500 micrograms.

The mean cadmium content values in rice reported to date are: 66 ppb dry wt. for Japan (Moritsugu et al. 1964); 11, 2, 65, 13, and 41 ppb wet wt. respectively for Bangladesh, Brazil, Japan, Philippines, and Singapore (Masironi et al. 1977); 9, 20, 52, 5, 36, 24, 11, and 13 ppb dry wt. respectively for India, Indonesia, Japan, Korea, Malaysia, Philippines, Singapore, and Thailand (Nakatsuka et al. 1988); 40 ppb dry wt. for Indonesia (Suzuki et al. 1980); and 23.4 dry wt. for Texas, USA (Suzuki et al. 1982). Cadmium content in rice by soil type failed to indicate any definite relationship between them in the present investigation (Rivai et al. unpublished data).

Daily cadmium intake values were found to be the following: 15-30 micrograms for England (Ministry of AFF 1973); 17 micrograms for Indonesia (Suzuki et al. 1988a), 46.9 and 48.2 micrograms for Japan (Suzuki and C-C Lu 1976), and 13-16 and 10.5-34.5 micrograms for USA (Kowal et al. 1979 and Johnson et al. 1975). Daily cadmium intake in Java Island of Indonesia as estimated by Suzuki et al. (1988a) was 4 - 17 micrograms which is in agreement with 17.2 micrograms for the Java Island.

The geometric mean for cadmium in rice was highest in the Hokuriku area of Japan, followed by that for Celebes of Indonesia. Though the daily consumption of rice varies according to the country, the calculated mean daily cadmium intake was found highest for the Hokuriku area of Japan, followed by that for Celebes of Indonesia. Population survey should be conducted internationaly to know the existence of a risk group of higher cadmium intake.

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