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Cadmium Contents in Foods and the Estimation of Cadmium Uptake from Foods¹⁾

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We analyzed Cd contents in more than 500 samples of foods purchased in Tokyo and the Osaka-Kobe area, and estimated the general contents in foods. The highest value was obtained in seaweeds (0.36 ppm) and high contents were found in shellfish, squid, "Tsukudani" of fish and wheat germ. Other foods contained less than 0.07 ppm.

The average uptake of Cd from foods was calculated to be about 40 $\mu\text{g/day/man}$, by multiplying the values estimated by averaging the general contents in similar foods by the amounts of daily uptake of the various food groups.

Keywords—cadmium content ; cadmium uptake ; foods ; heavy metal ; contamination

Introduction

Much attention has recently been paid to heavy metal contamination in foods, and the cadmium (Cd) contents in many foods have been analyzed, especially since the identification of the so-called "Itai-itai" disease as Cd-related. However, most studies were carried out on limited kinds of foods such as

rice and fish, or on foods in a limited geographical area.³⁾ Few reports deal with Cd contents in general foods.⁴⁾

It is important to determine the general contents in many kinds of foods in order to identify the background level, for use as a control value in assessing current pollution levels. Such values are also useful to esti-

- 1) A part of this work was presented at the 98th Annual Meeting of the Pharmaceutical Society of Japan, Okayama, Apr., 1978.
- 2) Location : a) 133, Yamadakami, Suita, Osaka, 565, Japan ; b) 5-1, Tsurumaki, Setagaya, Tokyo, 154, Japan ; c) Ikawadani, Tarumi, Kobe, Hyogo, 673, Japan ; d) 3-3, Sunayama-Minami, Wakayama, 640, Japan.
- 3) M. Moritsugi and J. Kobayashi, *Nohgaku Kenkyu*, **50**, 37 (1963) ; A. Ishizaki, K. Fukushima, and M. Sakamoto, *Jap. J. Hygien.*, **25**, 207 (1970) ; M. Fujii, "Kankyo Hoken Report," No. 4, Jap. Assoc. Public Health, Tokyo, 1971, pp. 9-34. ; K. Ikebe, Y. Tanaka, R. Tanaka, and N. Kunita, *Shokuhin Eiseigaku Zasshi*, **13**, 195 (1972) ; K. Saeki and T. Kumagai, *Ann. Report Yamaguchi Prefect. Inst. Public Health*, **15**, 115 (1972) ; T. Kumagai, *ibid.*, **15**, 122 (1972) ; Y. Tanaka, K. Ikebe, R. Tanaka, and N. Kunita, *Shokuhin Eiseigaku Zasshi*, **14**, 196 (1973) ; *idem*, *ibid.*, **15**, 313, 386, 390 (1974) ; S. Yamamoto, *Ann. Report Kumamoto Prefect. Inst. Public Health*, **1975**, 33 (1975).
- 4) a) N. Yamagata and I. Shigematsu, *Bull. Inst. Public Health*, **20**, 170 (1970) ; b) M. Fujii and M. Kondo, "Kougai : Taisaku To Gyosei," No. 6, Nippon Bohsai Shuppan, Tokyo, 1971, pp. 4-15 ; K. Fukushima, "Kankyo Hoken Report," No. 11, Jap. Assoc. Public Health, Tokyo, 1972, pp. 22-25.

mate the average uptake of Cd from foods. We analyzed the Cd contents in more than 500 samples purchased from markets in Tokyo and the Osaka-Kobe area.

Methods

Samples and Sampling—The kinds of foods were selected according to the list of foods in the National Nutrition Survey performed in 1973. Most of the samples were purchased from markets (mainly from the Nada-Kobe Co-op in Kobe and Daimaru Peacock Store in Tokyo) from February to May, 1977. We attempted to obtain similar kinds of foods in Tokyo and the Osaka-Kobe area.

Analysis—Cd was analyzed with atomic absorption spectrometers (Hitachi 208; Nippon Jarrell-Ash AA-1) after ashing the edible material (10–50 g) with $\text{H}_2\text{SO}_4\text{--HNO}_3$, or with plasma ashers (Yanagimoto FDA-158, LTA 4SN; Hitachi ASH-302). Some samples were analyzed after extraction of Cd with diethyl dithiocarbamate in methylisobutyl ketone, and D_2 correction was performed on the other samples. The content was expressed as ppm of wet weight.

Water content was determined as weight loss after heating at 105° for 4 hr or more.

Estimation of General Cd Contents and Cd Uptake from Foods—General Cd contents were obtained by averaging the values in a given group of foods: <0.01 was taken as 0.005.

Cd uptake from foods was calculated from the general Cd contents and the amount of food uptake as reported in the results of the National Nutrition Survey performed in 1973, by multiplying them together.

Results and Discussion

1. General Cd Contents

Cd is a naturally occurring material, and as expected, it was detected in all groups of foods tested. The analytical results are summarized in Tables I and II.

Of cereals we detected more than 0.2 ppm in wheat germ, but the average content

was from 0.005 to 0.097 ppm. The Cd content in rice was similar to the values reported by others,^{3,4)} although only a small number of samples was analyzed; the level was not decreased much by washing and steaming, as suggested by Akita *et al.*⁵⁾

The highest general content was obtained in seaweeds, most of which had been dried for the preparation of stock. On boiling 1 g of these in 100 ml of water for 3 min, 30 to 90 % of the Cd was released; Cd might occur with arginate in seaweeds because arginate can trap Cd effectively (T. Okano, T. Nishihara, and M. Kondo, unpublished results). In tea leaves, 0.04 ppm of Cd was detected and Cd was not recovered in the residue after soaking 5 g of leaves in 100 ml of hot water for 3 min, though Cd in the infusion was below the detectable level because of the dilution.

Other foods containing high contents of Cd were squid, shellfish, fish and “Tsukudani” of fish. As regards meat, the livers of cow, pig and chicken contained 0.058 ppm on average, being higher than the levels in other parts of the animals.

When the values were compared for foods in Tokyo and the Osaka-Kobe area using the Wilcoxon rank sum test, Cd contents in pulses and fish and total Cd were significantly higher in the latter area, while other foods showed non-significant differences.

2. Cd Uptake from Foods

The Cd uptake from foods was calculated to be about $40 \mu\text{g/day/man}$, by multiplying the general contents by the amount of daily uptake of foods (Table III). This comprised 40 % from cereals, 25 % from crops such as potatoes, pulses, fruits and vegetables, 25 %

5) Y. Akita, T. Takahashi, H. Yumoto, and S. Yamazoe, *Jap. J. Public Health*, **20** S, 469 (1973).

TABLE I. Cd Contents in Various Foods

Foods	Number of samples	Cd content (ppm)	
		Average	Range
Cereals			
Rice	3	0.067	0.05—0.09
Rice products	10	0.042	<0.01—0.13
Barley	3	0.005	<0.01
Wheat flour	4	0.016	<0.01—0.03
Bread	7	0.051	<0.01—0.10
Sweet bread	6	0.037	<0.01—0.06
Boiled noodles	4	0.011	<0.01—0.03
Dried noodles	13	0.037	<0.01—0.11
Others ^{a)}	7	0.097	<0.01—0.28
Seeds and nuts			
Seeds	4	0.025	<0.01—0.08
Nuts	10	0.042	<0.01—0.16
Potatoes			
Potatoes	3	0.007	<0.01—0.01
Others ^{b)}	5	0.024	<0.01—0.06
Products	8	0.013	<0.01—0.03
Sugars and jams			
Sugars	12	0.005	<0.01
Jams	6	0.012	<0.01—0.04
Confectionary			
Candy	6	0.011	<0.01—0.03
Sembei (rice cracker)	7	0.028	<0.01—0.08
Cake	4	0.009	<0.01—0.02
Biscuits	6	0.008	<0.01—0.02
Others ^{c)}	14	0.024	<0.01—0.06
Oils and fats			
Butter	2	0.005	<0.01
Margarine	4	0.005	<0.01
Vegetable oil	4	0.014	<0.01—0.04
Fats	3	0.005	<0.01
Others ^{d)}	4	0.012	<0.01—0.02
Pulses			
Miso (bean paste)	6	0.058	0.03—0.15
Soybean curd	6	0.019	<0.01—0.04
Soybean curd products	6	0.009	<0.01—0.03
Other soybean products ^{e)}	6	0.031	<0.01—0.08
Others ^{f)}	4	0.005	<0.01
Fruits			
Oranges	12	0.011	<0.01—0.04
Apples	3	0.005	<0.01
Bananas	2	0.005	<0.01
Strawberries	3	0.007	<0.01—0.01
Others ^{g)}	5	0.005	<0.01
Juice	12	0.006	<0.01—0.02
Vegetables (green and yellow)			
Carrots	3	0.028	<0.01—0.06
Spinach	3	0.022	<0.01—0.05
Sweet peppers	3	0.018	<0.01—0.04
Others ^{h)}	12	0.029	<0.01—0.08

Foods	Number of samples	Cd content (ppm)	
		Average	Range
Vegetables (other)			
Japanese radish, roots	3	0.013	<0.01—0.03
Onions	4	0.043	0.02—0.09
Tomatos	4	0.005	<0.01
Cabbages	4	0.005	<0.01
Cucumbers	3	0.005	<0.01
Chinese cabbages	2	0.005	<0.01
Others ^{d)}	19	0.022	<0.01—0.10
Tsukemono (pickled vegetable)	8	0.019	<0.01—0.05
Fungi			
Mushrooms	8	0.033	<0.01—0.12
Seaweeds			
Seaweeds	12	0.358	0.19—0.55
Jelly	2	0.005	<0.01
Tsukudani (seaweed boiled down in soy)	4	0.034	<0.01—0.07
Seasonings			
Soy sauce	4	0.046	<0.01—0.09
Worcester sauce	2	0.018	<0.01—0.03
Salt	2	0.005	<0.01
Others ^{d)}	4	0.019	<0.01—0.04
Beverages			
Sake (rice wine)	4	0.010	<0.01—0.02
Beer	4	0.006	<0.01—0.01
Other alcoholic beverages	7	0.006	<0.01—0.01
Tea, coffee, and Cola	7	0.005	<0.01
Fish (fresh)			
Tuna, bonito and swordfish	10	0.063	<0.01—0.19
Sea-bream and flatfish	5	0.022	0.01—0.04
Jack mackerel and mackerel	6	0.042	0.01—0.07
Others ^{k)}	15	0.037	<0.01—0.11
Squid and octopus	4	0.094	<0.01—0.32
Crab and shrimp	5	0.070	0.01—0.14
Shellfish	11	0.185	<0.01—0.57
Fish (other)			
Salted fish	5	0.067	<0.01—0.22
Dried fish	8	0.095	0.02—0.41
Canned fish	8	0.028	<0.01—0.09
Tsukudani (fish boiled down in soy)	3	0.137	0.02—0.28
Kamaboko (fish paste)	16	0.022	<0.01—0.08
Fish ham and sausage	4	0.043	0.01—0.08
Meats			
Beef	6	0.018	<0.01—0.04
Pork	7	0.021	<0.01—0.09
Chicken	4	0.046	<0.01—0.09
Whale meat	3	0.053	0.01—0.11
Other meats	4	0.020	0.01—0.04
Ham and sausage	6	0.015	<0.01—0.05
Eggs			
Eggs	4	0.033	0.03—0.04

Foods	Number of samples	Cd content (ppm)	
		Average	Range
Milk			
Milk	5	0.006	<0.01—0.01
Cheese	5	0.017	<0.01—0.05
Others ^{d)}	12	0.005	<0.01—0.01
Processed foods			
Kiao-tsu	4	0.035	0.02—0.06
Shao-mai	4	0.040	0.01—0.08
Croquettes	3	0.025	<0.01—0.05
Salad	2	0.005	<0.01

a) Wheat germ, buckwheat flour, cornflake, cornstarch, etc.

b) Sweet potato, Dasheen (Taro), Yam.

c) Yokan (fine sweet paste), monaka (bean-jam wafer), manju (bean-jam bun), ama-natto (sugared bean), etc.

d) Dressing, spread, mayonnaise.

e) Fried soybean curd (abura-age; nama-age, ganmodoki).

f) Natto (fermented soybean), roasted flour of soybean, azuki bean, pea, etc.

g) Watermelon, muskmelon, pear.

h) Italian broccoli, garland chrysanthemum, paseley, etc.

i) Green pea, immature pea with pod, kidney pea with pod, soybean sprout, Welsh onion, great edible burdock, eggplant, etc.

j) Tomato catsup, Tonkatsu sauce.

k) Eel, whitebait, Japanese sea-bass, puffer, etc.

l) Milk powder, condensed milk, raw cream, yogurt, ice cream, etc.

TABLE II. Distribution of Cd in Various Foods

Foods	Cd content in food (ppm)													Total
	≤0.01	≤0.05	≤0.10	≤0.15	≤0.20	≤0.25	≤0.30	≤0.35	≤0.40	≤0.45	≤0.50	≤0.55	≤0.60	
Cereals	12/9	12/6	6/8	2/0	0/0	0/1	1/0							33/24
Seeds and nuts	4/5	1/0	2/0	0/1	0/1									7/7
Potatoes	6/5	2/2	1/0											9/7
Sugars and jams	10/7	0/1												10/8
Confectionary	13/10	6/4	3/1											22/15
Oils and fats	11/4	1/1												12/5
Pulses	5/10	10/0	1/1	0/1										16/12
Fruits	16/17	4/0												20/17
Vegetables (green)	6/3	5/4	2/1											13/8
Vegetables (other)	14/18	8/2	2/3											24/23
Fungi	3/0	2/2	0/0	0/1										5/3
Seaweeds	2/2	1/0	0/1	0/0	1/0	2/2	0/0	0/1	0/2	1/0	1/0	2/0		10/8
Seasonings	2/4	3/1	2/0											7/5
Beverages	12/9	0/1												12/10
Fish (fresh)	7/7	18/5	9/0	3/0	1/1	0/0	0/0	3/1	0/0	0/0	0/0	0/0	1/0	42/14
Fish (other)	7/7	9/9	4/2	2/0	0/0	1/1	0/1	0/0	0/0	0/1				23/21
Meats	7/8	8/5	0/1	1/0										16/14
Eggs	0/0	2/2												2/2
Milk	12/8	1/1												13/9
Processed foods	3/1	4/3	0/2											7/6
Total	152/134	97/49	32/20	8/3	2/2	3/4	1/1	3/2	0/2	1/1	1/0	2/0	1/0	303/218

The numbers show the numbers of samples in the Osaka-Kobe area (upper) and in the Tokyo area (lower) in which Cd was detected in the indicated range.

TABLE III. Estimation of Cd Uptake from Foods

Foods	Cd content (ppm)	Uptake of foods (g/day/man)	Uptake of Cd (μ g/day/man)
Cereals			
Rice	0.048	269.5	12.9
Wheat	0.034	90.0	3.1
Others	0.069	1.8	0.1
Seeds and nuts	0.037	1.5	0.1
Potatoes	0.015	50.7	0.8
Sugars and jams	0.007	12.4	0.1
Confectionary	0.018	13.1	0.2
Oils and fats	0.009	14.0	0.1
Pulses	0.026	63.6	1.7
Fruits	0.007	184.0	1.3
Vegetables			
Green and yellow	0.025	81.3	2.0
Others	0.018	202.5	3.6
Fungi	0.033	7.7	0.3
Seaweeds	0.247	4.5	1.1
Seasonings	0.026	27.3	0.7
Beverages	0.006	88.4	0.5
Fish			
Fresh	0.043	41.6	1.8
Squid, octopus and crab	0.081	14.1	1.1
Shellfish	0.185	2.7	0.5
Salted or/and dried	0.084	18.1	1.5
Products	0.037	19.5	0.7
Meats	0.026	73.9	1.9
Eggs	0.033	41.3	1.4
Milk	0.008	94.3	0.8
Processed foods	0.030	5.4	0.2
Total	—	1423.2	38.5

from seafood, 10 % from livestock products, and 10 % from others. This value is almost in agreement with those estimated by others in Japan^{4,6)} and in other countries,⁷⁾ and it

corresponds to about 1/10 of the amount which was estimated to be present in areas where "Itai-itai" disease occurred.^{4a)}

6) N. Yamagata and K. Iwashima, *Jap. J. Public Health*, **20 S**, 466 (1973).

7) L. Friberg, M. Piscator, G.F. Nordberg, and T. Kjellström, "Cd in the Environment," 2nd ed. CRC Press, Ohio, 1974 (translated by M. Kimura, Ishiyaku Shuppan, Tokyo, 1975, pp. 34—37).