Cadmium Concentration in Current Japanese Foods and Beverages

Yuriko KIKUCHI, Tetsuo NOMIYAMA, Nami KUMAGAI, Takamoto UEMURA and Kazuyuki OMAE

Department of Preventive Medicine and Public Health, School of Medicine, Keio University, Japan

Abstract: Cadmium Concentration in Current Japanese Foods and Beverages: Yuriko Kikuchi, *et al.* Department of Preventive Medicine and Public Health, School of Medicine, Keio University—

Aims—The present study was to determine the cadmium (Cd) concentrations in ordinarily consumed foods and beverages in Japan. **Methods—**Cd concentrations in 519 foods and beverages purchased from a local market were measured with the flame or flameless atomic absorption spectrophotometer (AAS). **Results—**The Cd concentration in each food group was as follows: cereals 0.004–0.380 µg/g, potatoes <0.01–0.08 µg/g, sugars and sweeteners <0.01 µg/g, pulses <0.010–0.220 µg/g, nuts and seeds <0.01–0.18 µg/g, vegetables (grown in soil) <0.001–0.128 µg/g, vegetable (grown by means of hydroponics) <0.001–0.002 µg/g, fruits <0.001–0.033 µg/g, mushrooms <0.01–0.19 µg/g, algae 0.040–2.380 µg/g, fish <0.01–0.02 µg/g, shellfish <0.010–5.050 µg/g, meats <0.001–0.100 µg/g, eggs <0.001 µg/g, milk <0.010 µg/g, fats and oils <0.001–0.001 µg/g, confectioneries <0.020–0.100 µg/g, beverages <0.01–0.13 µg/g, seasoning and spices <0.01–0.06 µg/g, and various supplement tablets <0.001–0.036 µg/g. **Conclusion—**A database of Cd content in foods was compiled. Cd in cereals varied from 0.004 to 0.380 µg/g. Algae, shellfish and pulses contained much higher concentrations of Cd. Vegetables grown by hydroponic cultivation contained only a very low or undetectable amount of Cd. Estimation of dietary Cd intake from the database could provide a reasonable method for estimating the relative contributions of different food groups to dietary Cd intake.

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Key words: Cadmium (Cd), Foods, Database, Japan

Food was the main source of cadmium (Cd) intake for non-occupationally exposed people. Most foods contain Cd, and concentrations in foodstuffs have been reported

to show an extremely wide range¹⁾. Although average dietary concentrations are usually below the provisional tolerable weekly intake (PTWI) of 7 µg/kg bw/d proposed by FAO/WHO, some people would take more Cd per day²⁾. The Codex Committee on Food Additives and Contaminants (CCFAC) held its 33rd session in March, 2001, and agreed to adopt the 0.1 mg/kg level for Cd in cereals, pulses and legumes, but this level would not apply to oilseeds (flax) or to wheat, rice, soybeans, peanuts and bran. It is essential to validate the daily Cd intake in Japan for accurate estimation of Cd in foods and beverages currently consumed.

To update the data on the Cd content in foods is necessary, because new foodstuffs appear in markets, for example vegetables grown by hydroponics. A new instrument has been developed for Cd analysis, that can detect Cd more accurately at ppt levels. Data made available data by Suzuki *et al.*³⁾ were at the ppb level.

The aim of the present study was to measure Cd concentrations in foods and beverages ordinarily consumed in Japan, and to make a Cd content table for the estimation of Cd intake by Japanese.

Methods

1) Sample collection

Five hundred and nineteen samples, collected from at least three separate lots, were prepared for analysis. Vegetables grown by different methods, such as hydroponics and soil culture, and different places of production were selected. Only one sample of each type of foodstuff without seasonal variation was taken. Foods and beverages were purchased at a local market in Tokyo, but their production areas varied from Hokkaido to Kyushu. The following foodstuffs and numbers of samples were prepared:

Cereals: 14 brown rice, 2 well-milled rice, 7 soft wheat flour, 1 medium wheat flour and 4 hard wheat flour, 4 breads, 10 Japanese noodles and 3 buck wheat noodles, potatoes and starches: 9 Konjac, 3 sweet potatoes and 3 potatoes, sugars and sweeteners: 2 brown lump sugar, 2 soft sugars and 3 honey, pulses: 3 Azuki beans, 4 soy beans, 3 Momen-Tofu, 3 Kinugoshi-Tofu, 3 Yaki-Tofu and

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Correspondence to: Y. Kikuchi, Department of Preventive Medicine and Public Health, School of Medicine, Keio University, 35 Shinanomachi, Shinjuku-ku Tokyo 160-8582, Japan

3 *Nama-age*, nuts and seeds: 1 chestnuts and 6 sesame seed, vegetables: 2 pumpkin, 3 cabbage, 3 cucumber, 3 edible burdock, 3 *komatsuna* (grown in soil), 1 *komatsuna* (grown by hydroponics), 3 perrila, 3 garland chrysanthemum (grown in soil), 2 *komatsuna* (grown by hydroponics), 3 gingers, 3 *Daikon* (: Japanese radish), 3 onions, 3 Qing gin cai, 8 sweet corn, 3 tomatoes (fruits), 3 tomato canned products and 3 tomato juice, 3 egg plants, 3 Chinese chives, 3 carrot, 3 garlic, 3 welsh onions, 3 Chinese cabbage, 3 parsley, 3 sweet peppers, 3 broccoli, 3 spinach (grown in soil), 3 (grown by hydroponics), 3 *Mitsuba*, 3 bean sprouts, 3 crisp type, 3 butter type lettuce, fruit: 3 strawberries (juice sacs), 3 strawberry jam, 3 Satsuma mandarins (juice sacs), 3 mandarin canned products, 3 orange fruit juice, 3 orange marmalade, 1 Oroblanco, 3 Japanese persimmons, 2 grapefruit (juice sacs), 3 grapefruit juice, 2 water melon, 1 pineapple, 4 banana, 1 grapes, 3 melon, 2 peaches, and 3 apples (raw), 3 apple juice, mushrooms: 3 winter mushrooms, 3 *Shiitake* and 3 *Shimeji*, algae: 3 purple laver, 3 Kombu, 3 *Tengusa*, 3 *Hijiki*, 3 *Wakame*, fish and shellfish: 3 sardines, 3 salmon, 3 salmon (canned products), 3 mackerel, 3 pacific saury, 3 *Tarako*, 3 tuna (raw), 3 tuna (canned products), 3 short necked clams, 3 short necked clams (canned products), 3 oysters, 3 freshwater clams, 3 scallops, 3 scallops (adductor muscle), 3 shrimps, 3 spear squid, 3 octopus and 6 fish paste products, meat: 3 beef, 3 pork, 3 chicken, 3 cattle liver, 3 swine liver, 3 chicken liver, 3 ham, 3 bacon, 3 sausages, eggs: Hen eggs (3), milk and dairy products: 3 liquid milk, 3 yorgurt, 3 lactic acid bacteria beverages, 3 cheese, 5 ice cream, fats and oils: 9 vegetable oil, 4 butter, and 3 margarine, confectioneries: 3 rice crackers, 1 custard pudding, 1 orange jelly, 1 coffee jelly, 3 potato chip, 4 chocolate, beverages: alcoholic beverages (3 sake, 4 beer, 3 white wine, 3 red wine, 3 Shochu, 3 whisky, 2 umeshu, 4 synthetic sake), teas and leaves (6 green tea, 6 oolong tea, 6 black tea), 3 coffee (infusion), 3 instant coffee, 1 carbonated beverages, 3 mugicha, seasoning and spices: 3 worceter sauce, 10 soy sauce, 3 edible salt, 4 vinegar, 20 soup stock, 3 ketchup, 2 mayonnaise, 4 miso, 3 curry roux, 6 pepper, 1 baker's yeast dried, 2 kind of supplement of tablet.

Cooking methods, such as infusion of tea or coffee and cutting, were based on the Standard Tables of Food Composition in Japan, 4th and 5th Editions^{4, 5)}.

2) Measurement

Analytical methods were modified from the Koizumi *et al.* method⁶⁻⁸⁾ conducted by the Japan Food Research Laboratories.

2-1) Preparation of sample solution:

All samples were processed for analysis on the day of purchase. To measure the Cd in the edible portion of foods, the samples were mashed, and 10 to 20 g of a sample was put into a 500 ml Kjeldahl flask. Twenty ml

of nitric acid (HNO_3) and 5 ml of sulfuric acid (H_2SO_4) were added to the flask, and then thermolysis was carried out. One ml of perchloric acid (HClO_4) was added to the flask and heated until discoloration to make a sample solution for the next step.

2-2) Measurement with flame atomic absorption spectrophotometer

The sample solution was moved funnel, and a 10 ml solution composed of 50% ammonium citrate II and TB (Thymol blue) indicator was added. After neutralization with 25% ammonium solution, the sample was mess up to 100 ml with distilled water. Five ml of 3% ADPC solution and 5 ml of 10% ammonium sulfate were then added to the sample. After the addition of 10 ml butyl acetate and vigorous shaking for 5 min, the butyl acetate layer was evaporated on a water bath, and further dried on a hot plate after the addition of 1 ml acetic acid. The remnant was resolved with 1% HNO_3 solution, and used for analysis with a flame atomic absorption spectrometry (AAS). Standard Cd solutions of 0.2, 0.4 and 0.8 $\mu\text{g/g}$ were made from the standard Cd solution (100 ppm, proved by JCSS). Water was added to 10 ml of standard Cd solution, and the same procedure as for the samples was employed to get a standard volume of Cd concentration by AAS. The detection limit for Cd in foodstuffs was 0.01 $\mu\text{g/g}$ by means of a flame atomic absorption spectrometer (AA-890, Nippon Jarrell-Ash Co. Ltd., Tokyo, Japan) equipped a Cd anion lamp (Hamamatsu Photonics Co. Ltd., Shizuoka, Japan) at 228.8 nm wavelength. Air-acetylene gas was for the flame.

2-3) Measurement by flameless AAS

After evaporation of the butyl acetate layer at the same extraction fraction as previously described, thermolysis was preformed by the addition of 1 ml acetic acid, and dried slowly. The remnant was resolved with 5 ml of 1% HNO_3 solution, and subjected to analysis with a flameless atomic absorption spectrometer (AAS).

Most samples were measured by flameless AAS. The standard Cd solution for flameless AAS was prepared from Cd standard solution for AAS (100 ppm, proved by JCSS) at 0.005, 0.001, 0.0015 $\mu\text{g/g}$. The detection limits was 0.001 $\mu\text{g/g}$. A flameless atomic absorption spectrometer (AA-11 with FLA-100, Nippon Jarrell-Ash Co. Ltd., Tokyo, Japan) equipped with a Cd anion lamp (Hamamatsu Photonics Co. Ltd., Shizuoka, Japan) at 228.8 nm wavelength was used. The deuterium lamp technique was used for background correction. The carbon furnace was a tubetype graphite cuvette. The dry condition was for 30 s at 170°C, the ash condition was 15 s heating at 400°C, 15 s, and the atomizing condition was 3 s at 1700°C. Perging gas flow was 2.0 l/min argon gas.

Results

Table 1 shows the data on Cd content in various foods. Item numbers in the table corresponded to the numbers

Table 1. Cadmium concentration in foods and beverages

Item No. (4th)	Item No. (5th)	Food & description	n	Mean (ug/g)	Min	Max	Analysis	Note
Cereals								
1-10-a	01015	Wheat flour, soft	7	0.016	0.010	0.023	FL	
1-11-a	01018	Wheat flour, medium	1	0.048	—	—	FL	
1-12-a	01020	Wheat flour, hard	4	0.021	0.011	0.026	FL	
1-13-a	01026	Bread, white table bread (commercial products)	4	0.018	0.01	0.02	F	
1-21-a	01041	Japanese noodles, <i>Hoshi-udon</i> dry	10	0.016	0.012	0.020	FL	
1-41-a	01080	Rice, Paddy rice, brown, raw	7	0.004	0.004	0.005	FL	Place A
			7	0.354	0.34	0.38	F	Place B
1-41-b	01083	Paddy rice, well-milled, raw	1	0.004	—	—	FL	Place A
			1	0.32	—	—	F	Place B
1-62-a	01129	Buckwheat, dried buckwheat noodles	3	0.023	0.02	0.03	F	
Potatoes & starches								
2-3	02003	Konjac, block, made from fine powder	6	<0.01	—	—	F	
—	02004	Konjac, block, made from corn	3	<0.01	—	—	F	
2-5-a	02006	Sweet potatoes, tuberous root, raw	3	<0.01	—	—	F	
2-11-a	02017	Potatoes, tubers, raw	3	0.035*	<0.01	0.08	F	
Sugars & Sweeteners								
3-1	03001	Sugar, brown, lumpy	2	<0.01	—	—	F	
3-4-a	0303	Sugar, soft, white	1	<0.01	—	—	F	
3-4-c	03004	Sugar, soft, yellow	1	<0.01	—	—	F	
3-16	03022	Honey	3	<0.01	—	—	F	
Pulses								
7-2	04003	Azuki beans, boiled, canned in syrup	3	<0.01	—	—	F	
7-15-a	04023	Soy beans, whole, domestic dried, raw	4	0.128	0.03	0.22	F	
7-21-a	04032	<i>Momen-Tofu</i>	3	0.015*	<0.01	0.03	F	
7-21-b	04033	<i>Kinugoshi-Tofu</i>	3	0.013*	<0.01	0.03	F	
7-23	04038	<i>Yaki-Tofu</i>	3	0.027	0.01	0.03	F	
7-24	04039	<i>Nama-age</i>	3	0.012*	<0.01	0.03	F	
Nuts & Seeds								
6-8-a	05010	Chestnuts, Japanese chestnuts, raw	1	<0.01	—	—	F	
6-12-a	05018	Sesame seeds, roasted, white	3	0.022	0.01	0.03	F	
		Sesame seeds, roasted, black	3	0.127	0.03	0.18	F	
Vegetables								
12-18-a	06048	Pumpkin, fruit, raw	2	<0.01	—	—	F	
12-24-a	06061	Cabbage, head, raw	3	<0.01	—	—	F	
12-25-a	06065	Cucumber, fruit, raw	3	<0.001	—	—	FL	
12-31-a	06084	Edible burdock root, raw	3	0.027	0.02	0.03	F	
12-32-a	06086	<i>Komatsuna</i> , leaves, raw, soil	3	0.027	0.014	0.053	FL	
		<i>Komatsuna</i> , leaves, raw, hydroponics	1	<0.001	—	—	FL	
12-36	06095	Perrila, leaves, raw	3	0.0013**	<0.001	0.003	FL	
12-39-a	06099	Garland chrysanthemum, leaves, raw, soil	3	0.028	0.018	0.042	FL	
		Garland chrysanthemum, leaves, raw, hydroponics	2	0.001**	<0.001	0.001	FL	
12-41-a	06103	Ginger, rhizome, raw	3	0.017	0.01	0.02	F	
12-56-a	06134	<i>Daikon</i> : Japanese radishes, roots without skin, raw	3	<0.01	—	—	F	
12-70-a	06153	Onions, bulb, raw	3	0.020	0.01	0.03	F	
12-74-a	06160	Qing gin cai, leaves, raw	3	0.015	0.009	0.025	FL	
12-83-a	06175	Sweet corn, immature kernels, raw	1	<0.01	—	—	F	
12-83-b	06176	Sweet corn, immature kernels, boiled	1	<0.01	—	—	F	
—	06178	Sweet corn, immature kernels, frozen	3	<0.01	—	—	F	
12-84-b	06180	Sweet corn, canned products, whole kernel style	3	<0.01	—	—	F	
12-85	06182	Tomatoes, fruit, raw, soil	3	0.004	0.001	0.009	FL	soil
		Tomatoes, fruit, raw, hydroponics	3	<0.001	—	—	FL	hydroponics
12-86-a	06184	Tomatoes, canned products, whole	3	0.008*	<0.01	0.01	F	
12-86-b	06185	Tomatoes, canned products, juice	3	<0.01	—	—	F	
12-87-a	06191	Eggplant, fruit, raw	3	0.015	0.005	0.023	FL	
12-93-a	06207	Chinese chives, leaves, raw	3	0.017*	<0.01	0.04	F	
12-94-a	06214	Carrots, regular, root, without skin, raw	3	0.012*	<0.01	0.02	F	
12-95	06223	Garlic, bulbs, raw	3	0.050	0.01	0.11	F	
21-96	06226	Welsh onions; <i>Nebuka-negi</i>	3	0.006	0.003	0.009	FL	
12-101-9	06233	Chinese cabbage, head, raw	3	<0.01	—	—	F	
12-104	06239	Parsley, leaves, raw	3	0.052	0.012	0.091	FL	
12-108	06245	Sweet peppers, green, fruit, raw	3	0.005	0.002	0.008	FL	
12-114-a	06263	Broccoli, inflorescence, raw	3	0.010*	<0.01	0.02	F	
12-117-a	16267	Spinach, leaves, raw, soil	3	0.065	0.021	0.128	FL	
		Spinach, leaves, raw, hydroponics	3	0.004	0.002	0.008	FL	
12-123-a	06278	<i>Mitsuba</i> : <i>Ito-mitsuba</i>	3	0.001**	<0.001	0.002	FL	hydroponics
12-28-a	06289	Bean sprouts, raw	3	<0.01	—	—	F	
12-73	06312	Lettuce, head, crisp type, raw	3	0.017	0.01	0.03	F	
12-72	06313	Lettuce, butter type, raw	3	0.041	0.002	0.092	FL	

Table 1. Cadmium concentration in foods and beverages (continued)

Item No. (4th)	Item No. (5th)	Food & description	n	Mean (ug/g)	Min	Max	Analysis	Note
Fruits								
13-6	07012	Strawberries, raw	3	0.008	0.002	0.014	FL	
13-7	07013	Strawberries, jam	3	0.007	0.006	0.010	FL	
13-18-b	07029	Satsuma mandarins, juice sacs, raw	3	<0.01			F	
13-20-a	07035	Satsuma mandarins, canned in light syrup, solid	3	<0.01			F	
13-24-a	07040	Oranges, Navel, juice sacs, raw	3	<0.01			F	
13-19-6	07043	Oranges, Navel, fruits juices, reconstituted fruit juice	3	<0.01			F	
13-25	07046	Oranges, marmalade, heavily sweetened	3	<0.001			FL	
-	07048	Oroblanco, juice sacs, raw	1	<0.01			F	
13-26	07049	Kaki: Japanese persimmons, nonastringent, raw	3	<0.01			F	
13-37	07062	Grapefruit, juice sacs, raw	2	<0.01			F	
13-38-b	07064	Grapefruit, fruit juices, reconstituted fruit juice	3	<0.01			F	
13-45	07077	Watermelon, raw	2	<0.01			F	
13-58	07097	Pineapple, raw	1	<0.01			F	
13-64	07107	Banana, raw	4	<0.01			F	
13-70	07116	Grapes, raw	1	<0.01			F	
13-80-a	07134	Melon, open culture, raw	3	0.016	0.001	0.033	FL	
13-22	07138	Peaches, canned in syrup, solids	3	<0.01			F	
13-88	07148	Apple, raw	3	<0.01			F	
13-89-b	07150	Apple, fruit juices, reconstituted fruit juice	3	<0.01			F	
Mushrooms								
14-1-a	08001	Winter mushrooms, raw	3	<0.01			F	
14-6-a	08011	Shiitake, nama (raw) shiitake	3	0.110	0.04	0.19	F	
14-9	08018	Shimeji, Honshimeji, raw	3	0.037	0.03	0.04	F	
Algae								
15-4	09004	Purple laver, toasted	3	0.180	0.07	0.36	F	
15-17	09019	Kombu, Rishiri-konbu, dried	3	0.343	0.15	0.68	F	
15-26	09025	Tengusa, agar jelly	3	0.247	0.04	0.48	F	
15-28	09031	Hijiki, boiled & dried	3	1.217	0.87	1.73	F	
15-35	09044	Wakame, Cut & dried	3	1.650	0.92	2.38	F	
Fish & Shellfish								
Fish								
8-26-a	10047	Sardines, Japanese pilchard, raw	3	<0.01			F	
8-77	10134	Salmon, Chum, raw	3	<0.01			F	
8-83	10143	Salmon, canned in brine	3	<0.01			F	
8-84-a	10154	Mackerel, raw	3	<0.01			F	
8-95-a	10173	Pacific saury, raw	3	<0.01			F	
8-118-a	10202	Cod fishes, Tarako, raw	3	<0.01			F	
8-265	10259	Tuna, big-eye, raw	3	0.020	0.02	0.02	F	
8-153-c	10263	Tuna, canned products, flaked light meat in oil	3	<0.01			F	
Shellfish								
8-171	10281	Short necked clams, raw	3	0.247	0.17	0.32	F	
8-173	10283	Short necked clams, canned products, in brine	3	0.213	0.17	0.26	F	
8-179	10292	Oysters, cultured, raw	3	0.487	0.29	0.81	F	
8-183	10297	Freshwater clams, raw	3	0.383	0.19	0.69	F	
8-195	10311	Scallops, raw	3	3.690	2.83	5.05	F	
8-196-9	10313	Scallops, adductor muscle	3	0.160	0.03	0.38	F	
8-219-a	10329	Shrimp, Giant tiger, cultured, raw	3	0.007*	<0.01	0.01	F	
8-206	10352	Squid, spear, raw	3	0.017	0.01	0.02	F	
8-238-a	10362	Octopus, common, raw	3	0.023*	<0.01	0.06	F	
8-246	10379	Fish paste products, Mushi-kamaboko	3	<0.01			F	
8-250	10381	Fish paste products, Yaki-chikuwa	3	<0.01			F	
Meats								
9-16-a	11020	Cattle, beef, without subcutaneous fat	1	<0.001			FL	
9-8-a	11065	Cattle, beef, Imported, chuck, without subcutaneous fat	2	<0.001			FL	
9-26	11092	Cattle, offal, liver, raw	3	0.060	0.04	0.10	F	
9-64-a	11116	Swine, pork, picnic shoulder, without subcutaneous fat	3	<0.001			FL	
9-80	11166	Swine, offal, liver, raw	3	0.020	0.01	0.03	F	
9-86	11176	Swine, ham, loin	3	<0.01			F	
9-85-a	11183	Swine, bacon	3	<0.01			F	
9-87-e	11186	Swine, sausages, Vienna	3	<0.01			F	
9-48-b	11220	Chicken, broiler meats, breast, without skin, raw	3	<0.001			FL	
9-50-b	11224	Chicken, broiler meats, thigh, without skin, raw	3	<0.001			FL	
9-55	11232	Chicken, offal, liver, raw	3	0.017	0.01	0.02	F	
Eggs								
10-5-a	12004	Hen eggs, whole, raw	3	<0.001			FL	

Table 1. Cadmium concentration in foods and beverages (continued)

Item No. (4th)	Item No. (5th)	Food & description	n	Mean (ug/g)	Min	Max	Analysis	Note
Milk								
11-2	13003	Milk, ordinary liquid milk	3	<0.01			F	
11-8-a	13025	Yogurt, whole milk, unsweetened	3	<0.01			F	
-	13027	Yogurt, liquid type	2	<0.01			F	
11-10-a	13028	Lactic acid bacteria beverages, ordinary milk solids, non-fat	1	<0.01			F	
11-23	13040	Cheese, processed cheese	3	<0.01			F	
11-11-b	13043	Ice-cream, regular	3	<0.01			F	
11-12	13044	Ice milk	3	<0.01			F	
Fats & Oils								
5-1	14006	Vegetable oil, blend	9	<0.001			FL	
11-28	14017	Butter, salted	4	0.001**	<0.001	0.001	FL	
5-7	14020	Margarines, soft type	3	<0.001			FL	
Confectioneries and snacks								
4-41-d	15060	Traditional dry rice crackers, <i>shio-senbei</i>	3	0.073	0.05	0.10	F	
4-43	15086	Desert, custard pudding	1	<0.01			F	
4-47	15087	Desert, jellies, orange	1	<0.01			F	
4-47	15088	Desert, jellies, coffee	1	<0.01			F	
4-63-b	15103	Snacks, potato chips, regular	3	0.063	0.03	0.10	F	
4-77-b	15116	Chocolates, milk chocolate	4	0.048	0.02	0.08	F	
Beverages								
Alcoholic beverages								
(Fermented alcoholic beverages)								
16-1-b	16001	Sake, <i>Josen</i>	3	<0.01			F	
16-2-a	16006	Beer, pale	4	<0.01			F	
16-3-a	16010	Wine, white	3	<0.01			F	
16-3-b	16011	Wine, red	3	<0.01			F	
(Distilled alcoholic beverages)								
16-14-b	16014	<i>Shochu, Ko-ru</i>	3	<0.01			F	
16-5-b	16016	Whiskey	3	<0.01			F	
Compound alcoholic beverages								
16-10	16022	<i>Umeshu (plum sake)</i>	2	<0.01			F	
16-1-c	16023	Synthetic sake	4	<0.01			F	
16-21-a	16036	Tea, green tea, <i>Sencha, tea leaf</i>	3	0.013	0.01	0.02	F	
16-21-b	16037	Tea, green tea, <i>Sencha</i> , infusion	3	<0.01			F	
16-26-a	-	Fermented tea, oolong tea, tea leaf	3	0.090	0.04	0.13	F	
16-26-b	16042	Fermented tea, oolong tea, infusion	3	<0.01			F	
16-27-a	16043	Fermented tea, black tea, tea leaf	3	0.013	0.01	0.02	F	
16-27-b	16044	Fermented tea, black tea, infusion	3	<0.01			F	
16-30-b	16045	Coffee, infusion	3	<0.01			F	
16-30-c	16046	Coffee, instant	3	<0.01			F	
16-33-c	16054	Carbonated beverages, clear soft drinks	1	<0.01			F	
16-34-b	16055	<i>Mugi-cha</i> (wheat tea), infusion	3	<0.01			F	
Seasonings and Spices								
17-5-b	17002	Worcestershire sauce, semi-thick type	3	0.013	0.01	0.02	F	
17-3-a	17007	<i>Shoyu</i> : soy sauce, <i>Koikuchi</i>	6	0.020	0.01	0.03	F	
		<i>Shoyu</i> : soy sauce, genen, reduced salt	2	0.008*	<0.01	0.01	F	
17-3-b	17008	<i>Shoyu</i> : soy sauce, <i>Usukuchi</i>	2	0.015	0.01	0.02	F	
17-3-b	17012	Edible salt, common, <i>shokuen</i>	2	<0.01			F	
17-3-a	17014	Edible salt, refined, <i>shokuen</i>	1	<0.01			F	
17-4-a	17015	Vinegar, grain	3	<0.01			F	
17-4-a	17016	Vinegar, rice	1	<0.01			F	
17-8	17028	Soup stock, seasoning mix, granules, <i>katsuo</i> (dried fish granules)	5	0.018*	<0.01	0.05	F	
		Soup stock, seasoning mix, granules, <i>Konbu</i> (seaweed)	3	0.013	0.01	0.02	F	
		Soup stock, seasoning mix, granules, <i>Iriko</i>	2	0.033*	<0.01	0.06	F	
9-59	17024	Soup stock, chicken bones	5	<0.01			F	
17-1	17027	Consomme, cubes	5	<0.01			F	
17-6-a	17036	Tomatoes, processed goods, ketchup	3	0.020	0.02	0.02	F	
17-10-b	17043	Dressings, mayonnaise, egg yolk type	2	<0.01			F	
17-32-c	17046	Miso (soybean paste), rice koji, dark yellow type	4	0.018	0.01	0.03	F	
17-16-b	17051	Roux, curry	3	0.013	0.01	0.02	F	
17-18-a	17063	Spices, pepper, black, ground	3	<0.01			F	
17-18-b	17064	Spices, pepper, white, ground	4	<0.01			F	
17-32-b	17083	Yeast, baker's yeast, dried	1	0.050			FL	
Others								
-	-	Supplemental tablet, dietary fiber	1	<0.001			FL	
-	-	Supplemental tablet, calcium	1	0.036			FL	
			Total	519				

*: When the Cd concentrations were less than 0.01 ppm, they were taken as 0.005 for calculation. **: When the Cd concentrations were less than 0.001 ppm, they were taken as 0.0005 for calculation. F: analyzed by flame atomic absorption spectrometry (AAS). FL: analyzed by flameless atomic absorption spectrometry (AAS). Item No. based on Standard Tables of Food Composition in Japan 4th and 5th Editions.

in the Food Composition Tables in Japan, 4th and 5th Editions^{4, 5)}. The range (min-max) of cadmium concentrations were as follows: Cereals: rice (whole grain) 0.004–0.38 $\mu\text{g/g}$, wheat flour 0.01–0.048 $\mu\text{g/g}$, breads 0.01–0.02 $\mu\text{g/g}$, Japanese noodles 0.012–0.020 $\mu\text{g/g}$ and buck wheat 0.02–0.03 $\mu\text{g/g}$; potatoes and starches: Konjac <0.01 $\mu\text{g/g}$, sweet potatoes <0.01 $\mu\text{g/g}$, and potatoes <0.01–0.08 $\mu\text{g/g}$; sugars and sweeteners: brown sugar lump, soft sugars and honey are <0.01 $\mu\text{g/g}$; pulses: Azuki beans (canned in syrup) <0.01 $\mu\text{g/g}$, soy beans (whole) 0.03–0.22 $\mu\text{g/g}$, *Momen-Tofu* <0.01–0.03 $\mu\text{g/g}$, *Kinugoshi-tofu* 0.01–0.04 $\mu\text{g/g}$, *Nama-age* <0.01–0.02 $\mu\text{g/g}$; nuts and seeds: chestnuts <0.01 $\mu\text{g/g}$, sesame seed <0.01–0.18 $\mu\text{g/g}$; vegetables: pumpkin, cabbage, cucumber, perilla, *Daikon*, sweet corn, Chinese cabbage, tomatoe juice and bean sprouts were all <0.01 $\mu\text{g/g}$, edible burdock 0.02–0.03 $\mu\text{g/g}$, ginger 0.01–0.02 $\mu\text{g/g}$, onions 0.01–0.03 $\mu\text{g/g}$, Qing gin cai 0.009–0.025 $\mu\text{g/g}$, tomatoes (canned) <0.01–0.01 $\mu\text{g/g}$, egg plant 0.005–0.023 $\mu\text{g/g}$, Chinese chives <0.01–0.04 $\mu\text{g/g}$, carrots <0.01–0.02 $\mu\text{g/g}$, garlic 0.01–0.11 $\mu\text{g/g}$, Welsh onions 0.003–0.009 $\mu\text{g/g}$, parsley 0.012–0.091 $\mu\text{g/g}$, sweet peppers 0.002–0.008 $\mu\text{g/g}$, broccoli <0.01–0.02 $\mu\text{g/g}$, *Mitsuba* <0.001–0.002 $\mu\text{g/g}$ and lettuces 0.03–0.092 $\mu\text{g/g}$.

The Cd levels in most vegetables, including bulbs, roots and tubers, were usually below 0.05 $\mu\text{g/g}$, although leafy vegetables such as spinach and lettuce may have considerably higher levels. Some mushrooms have been found to contain high levels of Cd (1 $\mu\text{g/g}$).

Fruits: Cd was not detected except in strawberries and melons; strawberries (fruit) 0.002–0.014 $\mu\text{g/g}$, strawberry jam 0.006–0.010 $\mu\text{g/g}$ and melons 0.001–0.033 $\mu\text{g/g}$, mushrooms: all mushrooms contained low level of Cd: winter mushrooms <0.01–0.02 $\mu\text{g/g}$, *Shiitake* 0.04–0.19 $\mu\text{g/g}$, *Shimeji* 0.03–0.04 $\mu\text{g/g}$, algae: all algae contained a certain amount of Cd: purple laver 0.07–0.36 $\mu\text{g/g}$, Konbu 0.15–0.68 $\mu\text{g/g}$, *Tengusa* (Agar jerry) 0.04–0.48 $\mu\text{g/g}$, *Hijiki* 0.87–1.73 $\mu\text{g/g}$, and *Wakame* 0.92–2.38 $\mu\text{g/g}$.

Fish and shellfish: Cd was not detected (<0.01 $\mu\text{g/g}$) in sardines, salmon, mackerel, pacific saury, tuna (canned in products) or fish paste products. Other fish and shellfish contained a certain amount of Cd: Tuna (raw) 0.02 $\mu\text{g/g}$, codfish (*Tarako*) <0.01–0.03 $\mu\text{g/g}$, short necked clams 0.17–0.32 $\mu\text{g/g}$, oysters 0.29–0.81 $\mu\text{g/g}$, freshwater clams 0.19–0.69 $\mu\text{g/g}$. All scallops (raw) contained a relatively high level of Cd (2.83–5.05 $\mu\text{g/g}$). Scallops (adductor muscle) 0.03–0.38 $\mu\text{g/g}$, shrimps <0.01–0.01 $\mu\text{g/g}$, spear squid 0.01–0.02 $\mu\text{g/g}$ and octopus <0.01–0.06 $\mu\text{g/g}$.

Meats: Cd concentrations in the liver of beef, pork and chicken liver were 0.01–0.10 $\mu\text{g/g}$, but it was not detected in ham, bacon or sausages. Eggs: Cd was not detected in Hen eggs. Dairy products and milk: Cd was not detected in any liquid milk, yogurt, lactic acid bacteria beverages, cheese or ice cream.

Fats and oils: Cd was not detected in vegetable oil or margarine. The Cd concentration in butter was <0.001–0.001 $\mu\text{g/g}$. Confectioneries: Cd in rice crackers was 0.05–0.10 $\mu\text{g/g}$, potato chips 0.03–0.10 $\mu\text{g/g}$, chocolates 0.02–0.10 $\mu\text{g/g}$. Cd was not detected in custard pudding or jelly.

Beverages: Cd was not detected in any alcoholic beverage (sake, beer, wine, Shochu, whisky, umeshu, synthetic sake), tea (infusion), coffee, carbonated beverages or *mugi-cha*. Cd in tea leaves ranged from 0.01 to 0.13 $\mu\text{g/g}$. Cd was not detected in sake made from Japanese rice.

Seasoning and spices: Cd was not detected in worcestershire sauce, edible salt, vinegar or mayonnaise, but it was found in soy sauce (<0.01–0.03 $\mu\text{g/g}$), soup stock (<0.01–0.06 $\mu\text{g/g}$), ketchup (0.02 $\mu\text{g/g}$), miso (0.01–0.03 $\mu\text{g/g}$), curry roux (0.01–0.02 $\mu\text{g/g}$), pepper (<0.01–0.01 $\mu\text{g/g}$) and dried baker's yeast (0.05 $\mu\text{g/g}$). In half salt of soy sauce it was lower than in other kinds of soy sauce.

Supplements: Cd was not detected in dietary fiber tablets (<0.001) or calcium tablets (0.036 $\mu\text{g/g}$). Calcium tablets had been made of oyster shell.

Difference in cultivation soil or in hydroponics: Hydroponically grown *Komatsuna* contained <0.001 $\mu\text{g/g}$ Cd, compared to 0.014–0.053 for soil cultivation. Garland chrysanthemum, <0.001 compared to 0.018–0.024 in soil. Tomatoes, <0.001 compared to 0.001–0.009 in soil cultivation. Spinach, 0.002–0.008 $\mu\text{g/g}$ compared to 0.021–0.128 in soil cultivation.

Discussion

Environmental pollution with cadmium and its effect on human health have been important issues in Japan⁹⁾. Itai-Itai disease, which is characterized by osteomalacia due to renal tubular dysfunction, was identified in the Jinzu River basin of Toyama Prefecture, Japan¹⁰⁾. Tsuchiya *et al.*¹¹⁾ reported high cadmium content in rice grown along the Jintsu river (with a mining plant up river) and generally higher levels throughout Japan in comparison with other countries. Thirteen samples of brown rice, grown with water from the Jintsu river showed Cd content between 0.44 $\mu\text{g/g}$ and 3.36 $\mu\text{g/g}$ in the middle of the rice paddy and between 0.37 and 0.72 at the irrigation water exit. Rice grown in other irrigation systems (other rivers) had Cd content from 0.05 to 0.07 $\mu\text{g/g}$ at the entrance, from 0.08 to 0.11 $\mu\text{g/g}$ in the middle of the rice paddy and from 0.03 to 0.1 $\mu\text{g/g}$ at the exit.

In the present study, we confirmed the different Cd concentrations in rice samples, probably due to different Cd content in soil in different geographical areas. Cd was present mainly in the outer parts of grain which was removed in the milling process¹²⁾, but the levels of Cd not found in flour, bread and rice were lower than the levels found in grain. An analysis of cadmium content

in 207 samples of common rice and glutinous rice collected in various parts of Asia showed no difference in the geometric mean Cd concentration which was about 20 ng/g dry weight¹³⁾, although Kawada *et al.*¹⁴⁾ and Shimbo *et al.*¹⁵⁾ found different Cd content in rice from different areas. The Cd concentration in rice was surveyed in about 37,000 places in Japan from 1997 to 1998 by The Food Agency of Japan¹⁶⁾, and the mean (min-max) of the cadmium concentration was 0.06 $\mu\text{g/g}$ (n.d.–1.2) in rice.

Available data on cadmium content in fish and in other vegetables were rather scanty. Soisungwan S *et al.*¹⁷⁾ reported Cd levels in foodstuffs and estimated the dietary Cd exposure. The maximum Cd level ($\mu\text{g/g}$) was found in vegetables, potatoes (0.1), cereals (including rice) and pulses (0.2), fruit (0.05), oilseed and cocoa beans (1), beef, poultry, pork and mutton (0.1), cattle, poultry, pig and sheep liver (0.5), kidney (2.0), fish (0.05), crustaceans and mollusks (2.0). In Finland, Tahvonon and Kumpulainen¹⁸⁾ found Cd concentrations in foodstuffs in Finland. The ranges of mean Cd content were lower than those in Japan.

In the present study, algae and shellfish showed high Cd concentrations. Even higher concentrations had been detected in oysters (up to 8 $\mu\text{g/g}$) and salmon flesh (3 $\mu\text{g/g}$)¹⁹⁾. In previous Japanese data²⁰⁾, the Cd concentration in oysters was 0.023–0.81 $\mu\text{g/g}$, scallops 1.53–2.25 $\mu\text{g/g}$, hepatopancreas of scallop 10.36–23.81 $\mu\text{g/g}$, konbu 0.33–1.14 $\mu\text{g/g}$, agar jelly <0.01–0.21 $\mu\text{g/g}$ and wakame 0.39–1.04 $\mu\text{g/g}$. A mollusc was known to accumulate Cd in the body, independent of environmental pollution, and usually had a Cd concentration of 0.2 $\mu\text{g/g}$. This concentration is considerably higher compared to those in the contaminated waters^{21, 22)}. Brown crab meat sometimes contained Cd at levels above 10 $\mu\text{g/g}$ ²¹⁾. Prawns captured in unpolluted or relatively-unpolluted Australian water sometimes showed Cd concentration above 0.2 $\mu\text{g/g}$. The content in bluff oysters (*Ostrea lutaria*) has been reported to contain Cd at 27 $\mu\text{g/g}$ dry weight²³⁾. Cereals and vegetables, however, appeared to account for more than 80% of the estimated total Cd intake due to the large amount of intake. Meat, especially internal organs, accounted for most of the remainder. Molluscs (clams) and crustaceans (aquatic arthropods) only constituted a small part of the diet, and are considered to contribute little to the Cd intake. Fish contained only small quantities of Cd, so it was not a major source of dietary Cd. For the extreme consumer of fish and clams, Cd intake could be estimated either by multiplying the typical exposure by 3 or by using the highest Cd levels found in all relevant foods. Such estimates gave Cd intakes of 90 and 93.5 $\mu\text{g/d}$, respectively.

Database estimation of dietary Cd intake probably provides a reasonable method for estimating the relative contributions of different food groups to dietary Cd intake^{24–26)}. Its use in exposure assessment needs to be

validated by analysis of duplicate diets. In a study on a sample of the US population, the database calculation gave an estimate of a Cd intake of about 24 $\mu\text{g/d}$; whereas an actual analysis of duplicate diets estimated the intake to be 56 $\mu\text{g/d}$ ²⁷⁾ so that in this instance, database estimations underestimated dietary Cd intake levels by 50%. A more accurate Cd content table should therefore be necessary. In this study, we made a satisfactory database to estimate Cd intake from ordinary foods. We also showed the variation in Cd content among various foods by place of production or method of cultivation. As expected, vegetables grown by hydroponic cultivation showed a very low or undetectable amount of Cd.

On the basis of these data we plan to arrange meals containing the least amount of Cd and with the maximum amount of Cd from ordinary foodstuffs for a human metabolic study (in preparation).

Cd in ten typical Japanese menus for the study were estimated to range from 11.9 to 184.14 $\mu\text{g/d}$.

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