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Data Report

A survey on the cadmium contamination in brown rice sold in Tokyo

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ABSTRACT — Heavy metals are ubiquitous in the environment and nature, and even in trace amounts, chronic exposure to them can have negative health effects on humans. It is known that rice, in particular, easily accumulate cadmium (Cd). Cd can accumulate in the human body and affect human health. In Japan, rice is a staple food and a main leading source of Cd poisoning. The Tokyo Metropolitan Government has been investigating the Cd content in brown rice sold in Tokyo since 1973 in order to prevent Cd poisoning in humans. A survey result from 2010 to 2018 stated that there was no sample that exceeded the maximum limit (0.4 ppm). Moreover, compared with past survey reports in Tokyo, the Cd content in brown rice has obviously decreased. In this survey, cadmium intake from brown rice was not particularly problematic in terms of food hygiene.

Key words: Cadmium, Brown rice, Food hygiene

INTRODUCTION

Cadmium (Cd) is widely present in the environment, including soil, water, and various foods due to natural sources and industries (Bradl *et al*., 2005). Heavy metals, such as Cd, accumulate in the body when ingested over a long period of time. Even in trace amounts, it may affect human health. Cd causes diseases such as pneumonia, kidney damage, and osteomalacia (World Health Organization, 1992a, 1992b; Waalkes, 2003; Agency for Toxic Substance and Disease Registry, 2012). In Japan, the Itai-itai disease was caused by Cd contamination in the water and soil via the drainage of the mine in the Jinzu River basin in Toyama Prefecture (Tsuchiya, 1976; Aoshima, 2012, 2016). The inhabitants of this watershed ingested water and rice containing Cd and developed osteomalacia.

Rice is the largest source of dietary intake of Cd and it is estimated that about 40% of Cd dietary intake is taken from rice in Japan. Furthermore, it has been shown that rice absorbs Cd easily (Uraguchi *et al*., 2009). The Codex Alimentarius Commission of Food and Agriculture Organization/World Health Organization (FAO/WHO) has proposed the maximum limit of Cd concentration of 0.4 ppm (mg/kg) in polished rice grains (Codex Alimentarius, 2008). Following this, a safety criterion of 0.4 ppm has been set by the Ministry of Health, Labor, and Welfare for Cd concentration in polished grains of rice based on the Food Sanitation Law in Japan.

The Tokyo Metropolitan Government has been investigating the content of Cd contained in brown rice sold in Tokyo since 1973 with the aim of preventing human

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Table 1. Cadmium concentration in brown rice by year (2010-2018).

year	Number of samples	Number of positive (%)	Level (ppm)		Average value (ppm)
			Minimum	Maximum	
2010	185	91.4	n.d.	0.29	0.05
2011	181	96.2	n.d.	0.38	0.05
2012	186	90.3	n.d.	0.27	0.05
2013	183	80.3	n.d.	0.19	0.04
2014	180	81.7	n.d.	0.21	0.05
2015	180	71.1	n.d.	0.22	0.04
2016	180	72.2	n.d.	0.25	0.04
2017	169	77.1	n.d.	0.33	0.05
2018	186	80.1	n.d.	0.26	0.05

* n.d.: < 0.01 ppm *Cd concentrations less than the lowest LOD in samples was evaluated as a half of LOD.

intake of Cd-contaminated rice in the city. In this study, we report the survey results of Cd content in brown rice during the nine years from 2010 to 2018 in Tokyo.

MATERIALS AND METHODS

Samples

From 2010 to 2018, brown rice samples produced in various Japanese regions were collected from warehouses in Tokyo.

Apparatus

A microwave digestion system, Microwave (MultiWave3000, PerkinElmer, Inc., Waltham, MA, USA), was used for acid digestion. Determination of elemental concentration was carried out with graphite furnace atomic absorption spectrometry (GF-AAS, AA7000, Shimadzu Corporation, Kyoto, Japan).

Reagents

The reagents of analytical grade quality were used for all analyses. Water was purified using a Milli-Q system (Merck Millipore, Tokyo, Japan). The standard solution of 100 mg/L for Cd (chemical analysis grade) was obtained from Kanto Chemical (Tokyo, Japan). In the digestion and extraction procedures, the concentrated nitric acid (61%) and hydrogen peroxide (35%) were used that were obtained from Kanto Chemical. For GF-AAS analysis, ammonium phosphate dibasic and ascorbic acid were used as the matrix modifier.

Method

The samples were homogenized using a food processor. About 0.5 g of each sample was accurately weighed, added with 8 mL of HNO_3, and then left overnight. Next, 2 mL of hydrogen peroxide was added just before the samples were microwave-digested. After being digested, the sample solution was made to cool down to room temperature, and it was made up to 50 mL with ultrapure water. Then, the Cd concentrations were determined by GF-AAS. The wavelength for Cd was set to 228.8 nm and the spectral bandpass to 0.5 nm. Then, for the matrix modifier, ammonium phosphate dibasic and ascorbic acid were used. In this method, the limit of quantitation (LOQ) for cadmium was 0.01 ppm.

RESULTS AND DISCUSSION

According to the result of 1630 samples from 2010 to 2018, no sample exceeded the maximum limit (0.4 ppm) that was mandated by the Food Sanitation Law in Japan. Over the 9 years, the average Cd concentration ranged from 0.04 to 0.05 ppm (Table 1). It should be noted that Cd concentrations that were less than the lowest LOQ in samples were evaluated as a half of the LOQ.

According to previous reports (Hagiwara *et al*., 2010), between 1973 and 2009, the average of Cd content has been 0.04 to 0.09 ppm, and in some cases, brown rice that contained more than 0.4 ppm Cd were found every year from 1973 to 1981. However, since 1982, the number of brown rices containing more than 0.4 ppm of Cd has decreased significantly, and in the survey from 2002 to the present, no brown rice containing more than 0.4 ppm of Cd was found.

The distribution of cadmium concentration in rice from 2010 to 2018 is shown in Fig. 1. Over the nine years, from 2010 to 2018, the ratio of Cd content below the limit of quantification (0.01 ppm) was 17.6%; between 0.01 ppm and 0.05 ppm, 42.4%; between 0.05 ppm and 0.1 ppm, 26.6%; between 0.1 ppm and 0.2 ppm, 11.9%; and between 0.2 and 0.4 ppm, 1.4%. Similar results were found in national surveys.

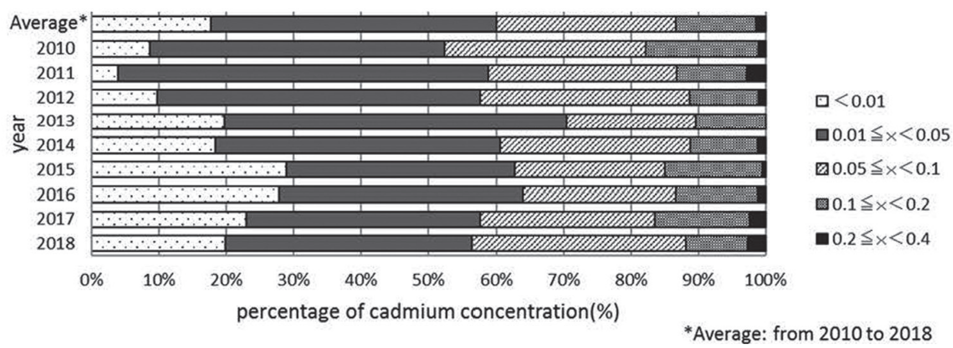

Fig. 1. Distribution of Cd concentration in brown rice from 2010 to 2018.

Table 2. Cadmium concentration in brown rice by production area.

	Hokkaido		Tohoku		Kanto		Chubu		Kansai		Chugoku		Kyusyu	
Number of samples	68		745		312		444		20		3		38	
Average value (ppm)	0.01		0.05		0.04		0.05		0.05		0.03		0.02	
Max value (ppm)	0.07		0.33		0.22		0.38		0.23		0.06		0.10	
	number	(%)	number	(%)	number	(%)	number	(%)	number	(%)	number	(%)	number	(%)
< 0.01	38	55.9	101	13.6	81	26.0	51	11.5	4	20.0	0	0	13	34.2
0.01 ≤ x < 0.05	28	41.2	311	41.7	141	45.2	178	40.1	11	55.0	2	66.7	24	63.2
0.05 ≤ x < 0.1	2	2.9	214	28.7	62	19.9	149	33.6	2	10.0	1	33.3	0	0
0.1 ≤ x < 0.2	0	0	102	13.7	25	8.0	64	14.4	2	10.0	0	0	1	2.6
0.2 ≤ x < 0.4	0	0	17	2.3	3	1.0	2	0.5	1	5.0	0	0	0	0
> 0.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0

In the same span of years, the average value of Cd content was extremely lower than before 2009 (Hagiwara *et al*., 2010). This is thought to be an effect of the measures taken by the government and Ministry of Agriculture, Forestry and Fisheries to reduce Cd, for example, phytoextraction, soil dressing, and water management (Murakami *et al*., 2007; Arao *et al*., 2009).

The Cd concentrations in brown rice are summarized in Table 2. They are classified into seven areas except for Okinawa and Shikoku. No significant difference was observed in the cadmium concentration between the areas. The average of cadmium concentration was ≤ 0.05 ppm in all regions, which is extremely low compared to the maximum limit. Samples with cadmium concentrations of 0.2-0.4 ppm were detected in four regions, namely Tohoku, Kanto, Chubu, and Kansai. The highest ratio of brown rice with low cadmium concentration was in Hokkaido. In conclusion, the cadmium concentration in brown rice was low in all regions and would unlikely to pose a risk to human health.

Conflict of interest---- The authors declare that there is no conflict of interest.

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