pISSN 1229-1153 / eISSN 2465-9223 *J. Food Hyg. Saf.*
Vol. 33, No. 4, pp. 240~247 (2018)
https://doi.org/10.13103/JFHS.2018.33.4.240

Journal of Food Hygiene and Safety
Available online at http://www.foodhygiene.or.kr

Monitoring and Risk Assessment of Lead and Cadmium in Various Agricultural Products Collected from the Korean Market

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(Received May 30, 2018/Revised July 17, 2018/Accepted July 13, 2018)

ABSTRACT - This study was carried out to determine the levels of lead and cadmium as found in nine agricultural products (n = 578) sold in Korea, and to estimate the risk to human health that is summarily associated with their intake. The concentrations of Pb and Cd were measured using an ICP-MS after microwave digestion in this study. The average contents of Pb and Cd were measured as 0.014 and 0.017 mg/kg for barley, 0.006 and 0.005 mg/kg for mung bean, 0.008 and 0.007 mg/kg for kidney bean, 0.010 and 0.004 mg/kg for green bean, 0.008 and 0.001 mg/kg for pineapple, 0.016 and 0.002 mg/kg for apricot, 0.015 and 0.002 mg/kg for Japanese apricot, 0.021 and 0.002 mg/kg for plum and 0.019 and 0.003 mg/kg for jujube, respectively. The levels of Pb and Cd in the study samples were less than the maximum residual levels established by the European Union (EU), CODEX, and the Korea Food Code. As we have seen, the daily dietary exposures of Pb and Cd from these agricultural products for the general population were noted as 0.067% of PTWI (25 μg/kg b.w./week) and 0.28% of PTMI (25 μg/kg b.w./month), respectively. In line with the study conclusions, these results suggest that the current dietary intakes of Pb and Cd from these agricultural products in Korea have no appreciable risk effects on health for humans as noted in this experiment.

Key words : Lead, Cadmium, Agricultural products, Risk assessment, ICP-MS

Heavy metals are not biodegradable, have long biological half-lives and have the potential for accumulation in the different body organs leading to unwanted side effects[1,2]. In particular, lead (Pb) and cadmium (Cd) are the heavy metals of most concern because of their potential for toxicity or accumulation in plant and animals[3]. In animals, Pb absorbed from foods or the environment is accumulated in the skeleton, especially in bone marrow. It is a neurotoxin and causes behavioral abnormalities, retarding intelligence and mental development. It interferes in the metabolism of calcium and vitamin D, affects hemoglobin formation and causes anemia. The entrance of Pb at levels > 0.8 μg/mL into blood causes various abnormalities[4-6]. Cadmium is a potent human carcinogen and has been classified as a category 1 carcinogen (human carcinogen) by the International Agency for Research on Cancer and the National Toxicology Program of the USA, because of its characteristics as a lung carcinogen. It can also cause Itai-Itai disease, osteoporosis, non-hypertrophic emphysema and irreversible renal tubular injury[7,8].

Lead and cadmium are significant environmental pollutants. Anthropogenic activities such as agriculture, industry and urban life increase the Cd and Pb content of soils and waters, thereby contributing to the contamination of raw materials[9,10]. It is well known that contamination of plants with heavy metals may occur due to irrigation with contaminated water, the addition of fertilizers and metal-based pesticides, industrial emissions, transportation, the harvesting process, and/or storage[11,12]. The Cd and Pb content in food can also increase significantly through manufacturing processes and through contact with the materials used in the packaging[13]. Therefore, exposure to Pb and Cd depends on dietary habits and geographical location[14]. In particular, food is a major source of both Pb and Cd for the general populations[15,16].

Human beings are encouraged to consume more fruits, vegetables and cereals that are good sources of vitamins, minerals and dietary fibers which are beneficial to human health. These plants contain both essential and toxic heavy metals over a wide range of concentrations[12,17]. In general, the levels of heavy metals in fruits and vegetables are very low. However, due to their high dietary intake, fruits and

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vegetables are the main contributors to the dietary exposure of heavy metals. Keeping in the view of the potential toxicity cumulative behavior of heavy metals and the frequent consumption of fruits, vegetables and cereals, it is necessary to monitor the levels of heavy metals in these food items, to evaluate their contribution to the daily intake of the metals through risk assessment and to ensure that the levels of heavy metals meet the agreed international requirement. Human toxicity by consuming foods contaminated with Pb and Cd has been regularly assessed by food safety authorities[18,19]. The Joint FAO/WHO Expert Committee on Food Additives (JECFA) established provisional tolerable weekly intakes (PTWI) for Pb and Cd, the limits being 25 μg/kg body weight for Pb[4] and 7 μg/kg body weight for Cd[20]. In 2009, the toxicity of Cd was reassessed by the European Food Safety Authority (EFSA) and EFSA set a reduced tolerable weekly intake (TWI) of 2.5 μg/kg body weight for Cd in food[21]. Recently, JECFA decided to express the tolerable intake for Cd as a monthly value in the form of a provisional tolerable monthly intake (PTMI), owing to the exceptionally long half-life of Cd. Therefore, the PTWI for Cd of 7 μg/kg body weight was withdrawn and the PTMI for Cd of 25 μg/kg body weight, which corresponds to a daily intake of 0.8 μg/kg body weight was established by JECFA[22].

With a rather dramatic change in dietary patterns because of rapid economic development during the past three decades and the globalization of the food market, more Koreans have concerns about the safety of their diets. Ministry of Food and Drug Safety (MFDS) has been responsible for monitoring the levels of heavy metals in raw foods and establishing the safety guidelines for Pb and Cd in individual raw foods for the past decade[23,24]. This study is part of the monitoring program for heavy metals in agricultural products conducted by MFDS. In this study, we selected the nine items of agricultural products (barley, green bean, kidney bean, mung bean, pineapple, Japanese apricot, apricot, plum and jujube) which need further monitor in Korea, and investigated the levels of Pb and Cd in these agricultural products collected from the Korean market using an inductively coupled plasma mass spectrometry (ICP-MS). Finally, based on our monitoring data and the nationally representative dietary intake data of the population, we estimated the daily dietary exposure levels of Pb and Cd associated with their intake for the Korean population and assessed their risks compared with PTWI or PTMI of JECFA.

Materials and Methods

Reagents and standards

Nitric acid (65%, HNO_3) and hydrogen peroxide (H_2O_2) for sample digestion were purchased from Dongwoo Fine Chem Co. (Seoul, Korea) and Junsei Chemical Co. Ltd. (Tokyo, Japan), respectively. Purified water (18 MΩ cm) for sample preparation was produced by the Milli-Q system (Millipore Corp., Bedford, MA, USA). All chemicals and reagents used were analytical grade unless stated otherwise. Standard solutions of Pb and Cd were prepared daily from 1000 mg/L stock solution (Merck, Darmstadt, Germany) by serial dilution using 5% nitric acid (v/v, in water).

Sample collection

All the samples ($n = 578$) of barley, green bean, kidney bean, mung bean, pineapple, Japanese apricot, apricot, plum and jujube including domestic and imported agricultural products were collected from local markets in South Korea. Collected samples were rinsed with purified water and only the edible parts of the samples were homogenized, packed in polyethylene decontaminated containers and stored at −70°C until analysis.

Sample preparation and instrumental analysis

The concentrations of Pb and Cd in all samples were measured using ICP-MS after microwave. The sample amounts for Pb and Cd analysis were 1.0 g for barley and pulses and 2.0 g for fruits. The sample was weighed into a polytetrafluoroethylene (PTFE) digestion vessel, and then 65% nitric acid and hydrogen peroxide were added. The vessels were allowed to stand at room temperature for 2 h and were placed inside the microwave oven (ETHOS PLUS, Milestone S.r.l., Sorisole, Italy). The digestion was carried out according to the manufacturer's pre-set program. After that, the digested solutions were heated at 100°C until dryness to remove nitric acid, then re-dissolved with 20 mL of 5% nitric acid (v/v, in water) and filtered with 0.45 μm filters (Hydrophilic PVDF Millipore Millex-HV, Millipore, Billerica, MA, USA). The instrument used for Pb and Cd analysis in this study was an ICP-MS (Elan DRC II, PerkinElmer Inc., Waltham, MA, USA) and the instrumental

Table 1. ICP-MS operating conditions

Instrument parameter	Elan DRC II (PerkinElmer)
Nebulizer	Meinhard type
Spray chamber	Cyclonic type
RF generator	Frequency: 10 MHz, power output 1300 W
Ar flow rate (L/min)	Plasma: 19, auxiliary: 1.3, nebulizer: 0.93
Analytical masses	^{208}Pb, ^{111}Cd
Measurement mode	Standard mode

operating conditions are summarized in Table 1.

Analytical quality assurance (AQA) and method validation

Appropriate analytical quality assurance procedures and precautions were taken to ensure the reliability of the results. To avoid contamination of the samples, all materials used for sample digestion and dilution were immersed in freshly prepared 15% nitric acid (v/v, in water) for 24 h, then rinsed in thoroughly purified water, and dried before use. All determinations were made in triplicate and reagent blank determinations to correct the instrument readings were performed for every batch of nine samples measured.

For validation of the analytical procedure, the accuracy and precision of the method were tested by determining two certified reference materials (CRM) of rice flour (KRISS 108-01-001, Korean Research Institute Standard and Science, Deajeon, Korea) and spinach flour (NIST 1570a, National Institute of Standard & Technology, Gaithersburg, MD, USA). A recovery test was also performed using samples spiked with Pb and Cd for accuracy and precision assessment. The limit of detection (LOD) and the limit of quantification (LOQ) were calculated as the concentration equivalent to three times and ten times of the standard deviation of the signal of the blank solution, respectively. The linearity was calculated using Pb and Cd standard solutions at levels of 0.0005, 0.001, 0.0025, 0.005, 0.0075 and 0.010 mg/L (zero included).

Dietary exposure estimates and risk assessment

The daily dietary exposures of Pb and Cd through the nine agricultural food items were estimated with the concentrations of Pb and Cd investigated in this study and the amount of consumption of each food item. The food consumption data was obtained from the Korean Nutrition Survey[25] which provides food consumption data for 8,641 individuals as determined during 2008 in face-to-face interviews using the 24h recall method. Body weight data were also obtained from the Korean Nutrition Survey (KHIDI[25], 2008). The typical body weight (55 kg) for the general adult population of 20 years and older in South Korea was used for the estimates of dietary Pb and Cd exposures. We calculated daily dietary exposure of Pb or Cd as:

$$\textit{Daily dietary exposure} = \frac{\textit{Daily food consumption} \times \textit{Pb or Cd concentration}}{\textit{Body weight}}$$

For the calculation, contaminant levels below LOD were considered to be at the level of LOD/2.

For the purpose of risk assessment, the mean and 95% percentile of daily exposure level were compared with the PTWI of 25 μg/kg body weight/week for Pb and the PTMI of 25 μg/kg body weight/month for Cd as proposed by the JECFA[22].

Results and Discussion

Analytical method validation

The recoveries of Pb and Cd, LOD and LOQ in the individual matrix were analyzed, and the linearity of the calibration curve was calculated (Table 2). The recovery test was carried out by spiking 0.01 and 0.1 mg/kg of Pb or Cd into samples and the recoveries ranged from 84.2% to 105.7% for Pb and 83.5% to 105.2% for Cd. The LOD and LOQ of Pb in barley and pulses were 0.0001 and 0.0004 mg/kg and those in fruits were 0.0001 and 0.0002 mg/kg. The LOD and LOQ of Cd were 0.00003 and 0.0001 mg/kg, regardless of sample matrix. The linearity (r^2) of the calibration curve was above 0.9999 in both Pb and Cd.

The accuracy and precision of the analytical method in this study have been checked by applying it to two CRMs. Table 3 shows the results of the determination of Pb and Cd in two CRMs. There were not significant differences ($P < 0.05$) between the certified value of the CRMs and our determined value for Pb and Cd concentrations. In addition, the relative standard deviation (RSD) as a statistical measure of the precision for a series of repetitive measurements was

Table 2. Results of analytical method validation for Pb and Cd

Parameters		Pb			Cd		
		Barley	Pulses	Fruits	Barley	Pulses	Fruits
LOD (mg/kg)		0.0001	0.0001	0.0001	0.00003	0.00003	0.00003
LOQ (mg/kg)		0.0004	0.0004	0.0002	0.0001	0.001	0.001
Linearity (r^2)			> 0.9999			> 0.9999	
Recovery (%)	Low conc.[a]	94.1	90.8-103.9	84.2-102.8	103.6	92.0-105.2	83.5-92.4
	High conc.[b]	86.1	89.7-91.6	87.1-105.7	94.6	90.3-97.2	84.8-94.9

[a]Low conc. means 0.01 mg/kg spiking
[b]High conc. means 0.10 mg/kg spiking

Table 3. Results of the determination of elements in the certified reference materials

Elements	Rice flour (natural) KRISS 108-01-001 (n = 5)			Spinach leaves NIST 1570a (n = 9)		
	Certified value (mg/kg)	Determined value (mg/kg)	RSD[a] (%)	Certified value (mg/kg)	Determined value (mg/kg)	RSD (%)
Pb	(0.027)[b]	0.026 ± 0.001[c]	2.6	(0.200)	0.207 ± 0.010	4.8
Cd	0.031 ± 0.002[d]	0.029 ± 0.001	2.1	2.89 ± 0.07	3.06 ± 0.14	4.6

[a]RSD means the relative standard deviation
[b]( ) means reference value
[c]Determined value is expressed as mean ± standard deviation (SD)
[d]Certified value is expressed as mean ± uncertainty

Table 4. Concentrations of Pb and Cd in various agricultural products

Agricultural products	Number of samples	Pb (mg/kg)			Cd (mg/kg)		
		Minimum	Maximum	Mean ± SD[a]	Minimum	Maximum	Mean ± SD
Barley	72	0.006	0.045	0.014 ± 0.007	0.004	0.042	0.017 ± 0.007
Pulses							
Green bean	80	0.003	0.033	0.010 ± 0.005	0.0003	0.021	0.004 ± 0.003
Kidney bean	80	0.001	0.058	0.008 ± 0.007	0.002	0.033	0.007 ± 0.005
Mung bean	53	0.001	0.024	0.006 ± 0.004	0.002	0.010	0.005 ± 0.002
Fruits							
Apricot	50	0.003	0.084	0.016 ± 0.012	0.0001	0.014	0.002 ± 0.002
Japanese apricot	90	0.004	0.054	0.015 ± 0.009	ND[b]	0.011	0.002 ± 0.002
Jujube	50	0.004	0.076	0.019 ± 0.014	0.0004	0.013	0.003 ± 0.002
Pineapple	50	0.0001	0.034	0.008 ± 0.008	ND	0.002	0.001 ± 0.001
Plum	53	0.003	0.090	0.021 ± 0.019	0.0001	0.005	0.002 ± 0.001

[a]SD indicates standard deviation
[b]ND means 'not detected'

below 5%. These results indicate that the method used in this study is suitable for Pb and Cd analysis in agricultural products.

Concentrations of Pb and Cd in agricultural products

The mean concentrations and ranges of Pb and Cd found in the nine items of agricultural products collected from the local markets in Korea are summarized in Table 4, and Fig. 1 and 2. The determined concentrations of Pb and Cd were expressed as mg/kg of wet weight.

The results showed that the mean levels of Pb in all samples were between 0.006 mg/kg in mung bean and 0.021 mg/kg in plum with ranges of 0.001-0.024 and 0.003-0.090 mg/kg, respectively. The levels of Pb observed in the samples covered a very wide range. In particular, the ranges of Pb levels in apricot (0.003-0.084 mg/kg), jujube (0.004-0.076 mg/kg) and plum (0.003-0.090 mg/kg) were greater compared with the ranges for barley, pulses, Japanese apricot and pineapple. The mean Pb level in barley was 0.014 mg/kg and the mean Pb levels in pulses were from 0.006 to 0.010 mg/kg. The levels are lower than those in China of 0.031 mg/kg for cereals and 0.026 mg/kg for pulses[3)], and similar to those in Australia (0.008-0.014 mg/kg for cereals; 0.005-0.012 mg/kg for legumes and pulses)[22)]. Within the selected fruits, the highest mean value of Pb was noticed in plum followed by jujube, apricot, Japanese apricot and pineapple. Heavy metals of Pb and Cd are persistent environmental contaminants, which may be deposited on the surfaces exposed to the air and then absorbed into the tissues of agricultural products[26,27)]. Therefore, the levels of Pb in fruits which need to be peeled for eating such as pineapples, bananas and oranges may be lower than in fruits which do not necessarily need to be peeled for eating. Our results also showed that the mean value and range of Pb in pineapple were 0.008 and 0.0001-0.034 mg/kg and were lower than in the other fruits which do not necessarily need to be peeled. These results were similar to those reported by other investigators[17,28)].

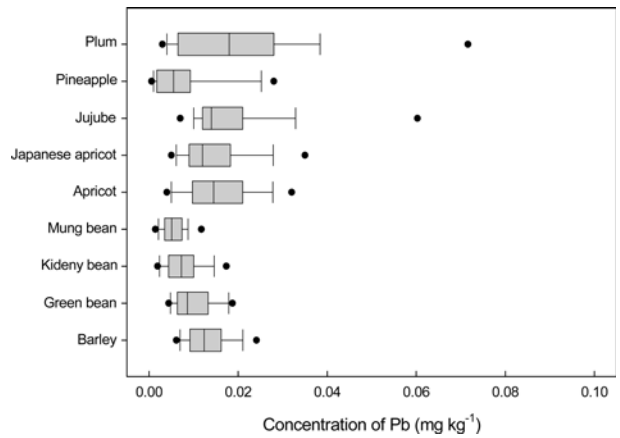

Fig. 1. Distribution of Pb concentration in agricultural products. The boundary of the box indicates the 25th and 75th percentiles, a line within the box marks the median, error bars indicate the 10th and 90th percentiles and outlying points indicate 5th and 95th percentiles.

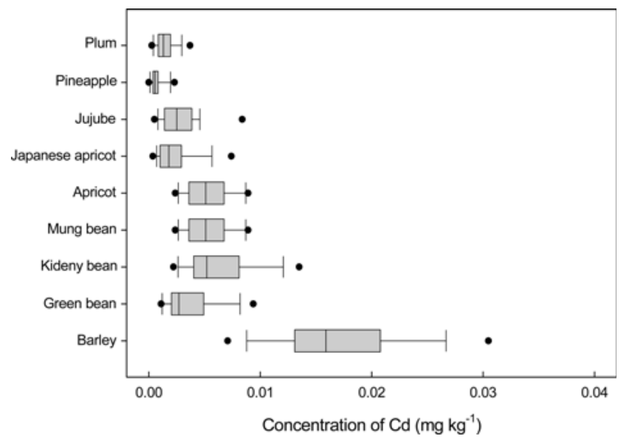

Fig. 2. Distribution of Cd concentration in agricultural products. The boundary of the box indicates the 25th and 75th percentiles, a line within the box marks the median, error bars indicate the 10th and 90th percentiles and outlying points indicate 5th and 95th percentiles.

The mean levels of Cd varied from 0.001 mg/kg in pineapple to 0.017 mg/kg in barley. In particular, the mean value of Cd in barley was the highest among the nine items of agricultural products and also had the widest range (0.004-0.042 mg/kg). A similar result has been reported in a Swedish study[29]. They reported that the mean value of cereal products for Cd (0.024 mg/kg) was the highest among various food groups. The mean levels of Cd estimated in pulses were 0.004-0.007 mg/kg and these values are similar to those observed by Kim et al.[30] (0.007 mg/kg in pulses). The mean values of Cd in fruits ranged from 0.001 mg/kg to 0.003 mg/kg and are lower than those in barley and pulses. According to a report by JECFA[22], the mean level of Cd in fruits was 0.006 mg/kg for Australia, 0.006 mg/kg for China, 0.004 mg/kg for EFSA (covering 19 European countries), 0.005 mg/kg for France and 0.003 mg/kg for USA. These results for various countries were similar to our results. The distribution of Cd levels in various Korean foods has been previously reported by Kim and Wolt[31]. They reported that the average Cd concentration in shellfish (0.46 mg/kg) was the highest results and those in other foods including rice, cereals, potatoes, vegetables and fruits were about 0.02 mg/kg. Their average Cd concentrations were slightly higher than our results. This difference can be explained by the differences of species in cereals and fruits selected for monitoring[32] and a variation in Cd concentrations in soils[33].

The levels of Pb and Cd found in 578 samples of agricultural products in this study were less than the maximum residual levels (MRLs) proposed by EU legislation and the CODEX Alimentarius. The MRLs for Pb by the EU and the CODEX in cereals, pulses and fruits excluding berries and other small fruits are 0.2, 0.2 and 0.1 mg/kg, respectively. In the CODEX Alimentarius, the MRLs of Cd in pulses and cereals except buckwheat, cañihua and quinoa are 0.1 mg/kg, and the MRLs in fruits are not established. In EU legislation, the MRLs of Cd in fruits and cereals excluding germ, wheat and rice, are 0.05 and 0.1 mg/kg, and the MRL in pulses is not established[34-36].

Evaluation of dietary exposure and risk assessment

For most people, the main route of exposure to toxic heavy metals is through the diet[37]. Consequently, information about dietary intake is necessary in order to evaluate the potential health risks for the individual. In this study we calculated the daily intake of Pb and Cd deriving from the consumption of nine items of agricultural products and compared these with the PTWI or PTMI set by international organizations, to assess the potential health hazards for Korean people. It should be state that the purpose here is not to evaluate the total diet exposure, but rather to study the intakes of Pb and Cd from some agricultural products.

Table 5 and 6 show the daily dietary exposure and risks of Pb and Cd to the general population through the nine items of agricultural products selected in this study. The daily dietary exposure of Pb through these agricultural products was 2.4×10^{-3} μg/kg body weight on average, which corresponds to 0.067% of PTWI. The extreme dietary exposure of Pb (95th percentile) was 8.1×10^{-3} μg/kg body weight/day which is equal to 0.23% of PTWI. In the case of Cd, the mean and 95th percentiles of daily dietary exposure were 2.2×10^{-3} and 9.8×10^{-3} μg/kg body weight, which correspond to 0.28 and 1.2% of PTMI. The dietary exposure of Cd through agricultural products selected in this

Table 5. Estimated daily dietary exposure to Pb and Cd through the consumption of agricultural products

Agricultural products	Food intake (g)		Daily dietary exposure of Pb (μg/kg bw[a])		Daily dietary exposure of Cd (μg/kg bw)	
	Mean	95th percentile	Mean	95th percentile	Mean	95th percentile
Barley	6.71	31.65	1.7×10^{-3}	8.1×10^{-3}	2.1×10^{-3}	9.8×10^{-3}
Pulses						
Green bean	0.39	0	7.1×10^{-5}	0	2.8×10^{-5}	0
Kidney bean	0.32	0	4.7×10^{-5}	0	4.1×10^{-5}	0
Mung bean	0.07	0	7.6×10^{-6}	0	6.4×10^{-6}	0
Fruits						
Apricot	0.08	0	2.3×10^{-5}	0	2.9×10^{-6}	0
Japanese apricot	0.001	0	2.7×10^{-7}	0	3.6×10^{-8}	0
Jujube	0.08	0	2.8×10^{-5}	0	4.4×10^{-6}	0
Pineapple	0.72	0	1.1×10^{-4}	0	1.3×10^{-5}	0
Plum	1.06	0	4.1×10^{-4}	0	3.9×10^{-5}	0
Sum			2.4×10^{-3}	8.1×10^{-3}	2.2×10^{-3}	9.8×10^{-3}

[a]bw indicates body weight.

Table 6. Risk of dietary exposure to Pb and Cd through the consumption of agricultural products

Agricultural products	Risk of dietary exposure to Pb (% of PTWI)		Risk of dietary exposure to Cd (% of PTMI)	
	Mean	95th percentile	Mean	95th percentile
Barley	4.8×10^{-2}	2.3×10^{-1}	2.6×10^{-1}	1.2×10^{-0}
Pulses				
Green bean	2.0×10^{-3}	0	3.5×10^{-3}	0
Kidney bean	1.3×10^{-3}	0	5.1×10^{-3}	0
Mung bean	2.1×10^{-4}	0	8.0×10^{-4}	0
Fruits				
Apricot	6.5×10^{-4}	0	3.6×10^{-4}	0
Japanese apricot	7.6×10^{-6}	0	4.5×10^{-6}	0
Jujube	7.7×10^{-4}	0	5.5×10^{-4}	0
Pineapple	2.9×10^{-3}	0	1.6×10^{-3}	0
Plum	1.1×10^{-2}	0	4.8×10^{-3}	0
Sum	0.067	0.23	0.28	1.2

study was similar to that of Pb. However, the risk of dietary exposure to Cd was about four times higher than that of Pb. This can be explained by the difference of PTWI for Pb (25 μg/kg body weight/week) and PTMI for Cd (25 μg/kg body weight/month) used in the estimation of the risk.

The main contribution to the daily exposure of Pb and Cd comes from barley. This is similar to results reported by Satarug et al.[38)] and Muller et al.[39)]. They reported that in non-occupationally exposed individuals, vegetables and cereals in foods are major sources of Cd. Kim and Wolt[24)] also reported that because rice is commonly and highly consumed by Koreans, it was the dominant contributor to Cd in the diet, representing on average 25% of the total dietary exposure for the general population. Sun et al.[40)] analyzed the contribution of food commodities to the Pb intake for the total population of Jiangsu Province, China and found that rice followed by wheat flour and bean products contributed most to the total Pb intake for both children and the general population.

Acknowledgments

The authors thank the Ministry of Food and Drug Safety (R&D Project No. 10231-Food Safety-021) for financial support.

국문요약

본 연구에서는 국내 유통 중인 농산물 9품목(n = 578)에 대한 납과 카드뮴 함량을 조사하고 이들의 섭취로 인한 위해성을 평가하고자 하였다. 납과 카드뮴의 함량은 마이크로웨이브 분해 후 ICP-MS로 분석하였다. 조사대상 농산물의 납 평균 함량은 각각 보리 0.014 mg/kg, 완두콩 0.010 mg/kg, 강낭콩 0.008 mg/kg, 녹두 0.006 mg/kg, 파인애플 0.008 mg/kg, 살구 0.016 mg/kg, 매실 0.015 mg/kg, 자두 0.021 mg/kg, 대추 0.019 mg/kg이었고, 카드뮴 평균함량은 보리 0.017 mg/kg, 완두콩 0.004 mg/kg, 강낭콩 0.007 mg/kg, 녹두 0.005 mg/kg, 파인애플 0.001 mg/kg, 살구 0.002 mg/kg, 매실 0.002 mg/kg, 자두 0.002 mg/kg, 대추 0.003 mg/kg이었다. 모든 시료의 납, 카드뮴 함량은 EU, CODEX 및 국내 기준보다 낮은 수준이었다. 조사 대상 농산물에 대한 납, 카드뮴의 인체노출량을 산출한 결과, 납은 잠정주간섭취허용량(PTWI, 25 μg/kg b.w./week)의 0.067%, 카드뮴은 월간잠정섭취허용량(PTMI, 25 μg/kg b.w./month)의 0.28%이었다. 이상의 결과는 조사 대상 농산물의 납, 카드뮴 오염도와 이들의 섭취에 의한 위해성이 모두 낮은 수준이라는 것을 보여준다.

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