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Risk Assessment for Heavy Metals in Korean Foods and Livestock Foodstuffs

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한국인의 대표식품 및 축산식품에 대한 중금속 위해도 평가

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Abstract

This study was conducted to evaluate exposure level and risk of heavy metals in livestock foodstuffs and Korean foods. Based on the "Food Intake Data," a part of the 2005 National Health & Nutrition Survey and the "2005 Seasonal Nutrition Survey", 113 Korean foods items were selected. 3 samples from different manufacturers of each 113 items of Korean foods were purchased on summer and fall, so total 678 samples were used. The food groups were classified into 15 categories. For the livestock foodstuffs category, meats and poultry (chicken, pork, pork belly, beef, beef feet soup), milks and dairy products (milk, ice cream, liquid yoghourt, sherbet), eggs (egg) were selected. It was found that the daily amount of heavy metals intake (mg/person/day) from livestock foodstuffs is 0.00020 arsenic, 0.00000 cadmium, 0.00020 lead, and 0.00006 mercury, and the daily amount of heavy metals intake (mg/person/day) from Korean foods is 0.0265 arsenic, 0.0083 cadmium, 0.0067 lead, and 0.0028 mercury. Daily amount of heavy metals intake from livestock foodstuffs was low among the food groups. For risk assessment, PDI (Probable Daily Intake) was calculated and compared with PTWI (Provisional Tolerable Weekly Intake) of JECFA (Joint FAO/WHO Expert Committee on Food Additive). Relative hazard of these livestock foodstuffs was 0.006% in arsenic, 0.000% in cadmium, 0.085% in lead, and 0.149% in mercury. Relative hazard of Korean foods was 0.941% in arsenic, 14.676% in cadmium, 3.319% in lead, and 6.860% in mercury. Thus, livestock foodstuffs and Korean foods were as safe as satisfied with the recommended standards of JECFA.

Key words : livestock foodstuffs, Korean foods, heavy metal, risk assessment, total diet study

Introduction

Human beings have caused the increase of environmental pollutions on the process of advanced industrialization. Among these pollutions, especially the spread of heavy metal pollution has been threatening the safety of foods such as farm products, fishes and livestock foodstuffs, causing the contaminations of soil, rivers, oceans and feeds. For typical examples of heavy metal contaminations, Minamata disease had been widely prevalent in Minamata, Japan by consuming fishes contaminated in methylmercury and the mercury poisoning had been widespread in Iraq by consuming breads made by wheat contaminated in seed disinfectants including methylmercury (Yorifuji *et al.*, 2008). Blackfoot disease had been prevalent in Taiwan for a couple of decades by consuming seashells of arsenic accumulated (Liu *et al.*, 2007)

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and Itai-itai disease had been spread in Toyama Prefecture, Japan by highly concentrated cadmium being exposed on foods and environment (Yamagami *et al.*, 2006). Heavy metals included in foods are known to be toxic to human body and accumulated chronically, causing the imbalance on the endocrine system (UNEP, 1992; FAO/WHO, 1997). The toxicity of arsenic, lead, mercury and cadmium are as very high as arsenic being ranked 1st, lead being ranked 2nd, mercury being ranked 3nd and cadmium being ranked 7th on the toxic contaminant lists announced by U. S Environmental Protection Agency (EPA) and U. S. Agency for Toxic Substances and Disease Registry (ATSDR) in 2005. The importance of heavy metals monitoring on foods was presented on a joint conference of FAO/WHO (Food and Agriculture Organization of the Untied Nations/World Health Organization) (WHO, 1974), and GEMS/Food (Global Environment Monitoring System/Food Contamination Monitoring and Assessment Programme) established in 1976 has been researching to evaluate a risk of contaminants included in foods with FAO, UNEP (United Nations Environment Programme) and WHO together (WHO, 2003; USFDA/WHO, 1999). Various advanced countries such as England, Denmark, United States, Spain, New Zealand and France are processing Total Diet Study (TDS) and reporting the risk of heavy metals to their citizens (Ysart *et al.*, 2000; Larsen *et al.*, 2002; Pennington *et al.*, 1986; Cuadrado *et al.*, 1995; Thomson *et al*,. 2008; Leblanc *et al.*, 2005). Since the first execution of TDS in 1966, England has been processing this research in every three years and based on this research, they are evaluating the amount of heavy metals, contaminants, remained pesticides and some nutrients being exposed on normal dietary patterns of citizen. United States has been processing TDS 4 times a year by dividing the whole country into 4 sections, and Australia has been processing this in every two years since 1990 (Egan *et al.*, 2002).

The first heavy metal research in our country was the measurement of mercury contained on rice, the principal food in our country, by Rural Development Administration in 1967 and after this, many examinations of heavy metals on major agricultural products being consumed a lot were followed (Lee and Lee, 2001). After that, the focus of researches was extended to seafoods known to contain high amount of heavy metals such as arsenic and mercury (Bang and Choi, 1993; Kang and Cho, 1996; Lee and Ko, 1997). Currently, many researches on agricultural products are being processed since problems of heavy metals from abandoned mines occurred a lot (KFDA, 2006), but reports of heavy metals on livestock products are very limited. There hasn't been any big collective damage from heavy metals reported yet in our country, but high concentrations of heavy metals were detected in the blood test project of Koreans presented by the Ministry of Environment in 2006, so cautions on heavy metals are being required now.

The amount of annual consumption on livestock products per one person has increased 3 times in Meats and Poultry and 6 times in Milks from 1980 to 2006 because of industrial development on last 27 years as well as income increase and the improved dietary life (Major Statistics in Agriculture, 2007). The concern of citizens on the promotion of health and the safety of foods are being increased rapidly as the income level of citizen increases, and the consumption of protein are being increased from livestock products than agricultural products. Therefore, continuous observation on the safety of livestock foodstuffs is being required but there are still not enough data on contaminants contained on livestock products. Recently, concerns and interests of citizens on the safety of livestock foodstuffs has been raised drastically in our country due to the import of U.S beef, FTA (Free Trade Agreement) negotiations, UR (Uruguay Round) and GR (Green Round). Our country established the standards on heavy metal contamination such as lead and cadmium to assure the safety on aquatic products such as Fishes and Crustacea in 2002 (Food code, 2002), and many researches has been conducted on aquatic products and monitoring on processed foods has been executed (Kim *et al.*, 2007; Kim *et al.*, 2004; Lee *et al.*, 2001) but still researches and data on heavy metals in livestock foodstuffs are insufficient, and the establishment of standards of heavy metals on livestock foodstuffs is needed. A lot of monitoring data are required in order to establish appropriate standards of heavy metals on livestock foodstuffs, and also the evaluation on the risk of various heavy metals on livestock foodstuffs being consumed by our citizens must be necessary.

As a governmental project, data from the evaluation on the amount of heavy metals being exposed through typical foods consumption by our citizens is being used as a very important data on risk assessment. Since Ministry for Health, Welfare and Family Affairs has newly completed the '2005 National Health & Nutrition Survey' and the '2005 Seasonal Nutrition Survey' recently, the selection of Food list for Korean based on data above was needed (The third Korea National Health & Nutrition Survey 2005-Nutrition survey (I), 2006; Report on 2005 National Nutrition Survey by Season, 2006). Therefore, this research was conducted to evaluate exposure level and risk of heavy metals in livestock foodstuffs and Korean foods.

Materials and Methods

Selection of Food list for Korean and Livestock Foodstuffs

In this research, 1) the 'Food Intake Data' obtained by 24 hours recall method from the '2005 National Health & Nutrition Survey', a survey in governmental unit being executed on approximately 40,000 families in 2005 by Ministry for Health, Welfare and Family Affairs and 2) data from the '2005 Season Nutrition Survey' were used as criteria to select Food list for Korean (The third Korea National Health & Nutrition Survey 2005-Nutrition survey (I), 2006; Report on 2005 National Nutrition Survey by Season, 2006). Method of Lee *et al.* (2005) mainly was used to select Food list. Taking a look at processes of selection, the amount of daily food intake per one person was analyzed from the data of average amount of annual food intake investigated by 24 hours recall method. 67 items of 'Highly consumed foods' included in 80% of accumulated food intake rate were selected first from total 553 items of foods (Table 1). And then, all items of foods were arranged in the order of frequency of each food being consumed per 1 day, then 21 items of foods, not included in 67 items of selected foods, from 'Frequent consumption foods' over 10% of daily frequency being consumed were added. And also, 9 items of 'Season foods' and 'Age foods', not included in previously selected 67 items and 21 items, from products with over 70% of accumulated rate from the analysis of the food intake per each season, area, sex and age and 2 items of foods, not included in previously selected items of foods, from 'Energy-supplying foods' with over 70% of accumulated rate of supplying energy were added, so total 99 items of foods were selected as the Basic food list. By listing foods not included in previously selected basic lists in the order of the amount of intake, top 14 kinds of foods from fish and shellfish consumed less but contained high heavy metals (Bang and Choi, 1993; Kang and Cho, 1996; Lee *et al.*, 2005; Lee and Ko, 1997) were added as High heavy metal foods. These fish and shellfish consumed less but contained high heavy metals should be added to prevent any side effect of underestimation on the amount of heave metal intake. So, total 113 items of foods for heavy metals analysis were selected as the final list in this research (Table 1).

Table 1. Flow chart for selection of Korean foods

Order	Criterion of Selection	Food list	
	2005 National Health and Nutrition Survey (NHNS) + 2005 Seasonal Nutrition Survey (SNS)		
1	Highly consumed food (67 foods)	Rice, Kimchi, Milk, Beer, Soju, Pork, Egg, Tofu, Onion, Radish, Bean sprouts, Beef, Instant noodle, Chicken, Orange, Cola, Potato, Beef feet soup, Apple, Tomato, Welsh, Noodles, Orange juice, Pork belly, Spinach, Yoghourt, Cider, Cucumber, Makgeolli, Young pumpkin, Siliced white-radish kimchi, Melon, Boiled fish paste, Soybean paste, Strawberry, Fruit soda, Soy sauce, Banana, Carrot, Young radish kimchi, Ice cream, Chinese cabbage, Garlic, Hot pepper paste, Soybean milk, Watery kimchi made of sliced radishes, Rice cake, Cabbage, Mackerel, Buckwheat noodles, Pickled radish, Green part of a radish, Lettuce, Suger, Unripe red pepper, Hygienic drink, Glutinous rice, Barley, Cereals, Bean oil, Wheat flour, Soybean, Squid, Uncleaned rice, Sweet drink made from fermented rice, Brown seaweed	
	Major Foods : 67 Foods (Food Intake Ratio 80.0%)		
2	Frequent consumption foods (21 foods)	Dropwort, Coffee mix, Salt, Sesame oil, Short-necked clam, Sesame leaf, Powered red pepper, Condiment soybean paste, Sesame, Coffee creamer, Sirup, Seaweed, Tomato ketchup, Vineger, Coffee powder, Ginger, Seasoning powder, Anchovy, Powdered sesame mixed with salt, Pepper, Flavoring matter	
3	Age foods (2 foods)	7~13	Sherbet
		20~29	Coffee extract
	Seasonal foods (7 foods)	Watermelon, Pear, Sweet potato, Mandarin, Grapes, Persimmon, Peach	
4	Energy-supplying foods (2 foods)	Confectionery, Snack	
	Basic food list : 99 foods (Food Intake Ratio 84.6%)		
5	High heavy metal foods (14 foods)	Alaska pollack, Scabbard fish, Crab, Flatfish, Canned tuna, Dried squid, Common octopus, Dried yellow corvina, Saury, Oyster, Shrimp, Yellow corvina, Spanish mackerel, Eel	
	Foods list for Heavy Metal : 113 foods (Food intake Ratio 86.4%)		

Purchasing of Foods

113 items of foods used in this research were purchased on August for fresh foods purchased in summer season and on October for fresh foods purchased in fall season from a large size marts and marketplaces. Processed foods were purchased from three different manufacturers and raw material foods were purchased from three different origins. Foods were purchased in the way of general foods from all over the country being selected evenly, not foods from one specific place being selected. That is, 3 samples from different manufacturers of each 113 items of foods from Food list for Korean were purchased on summer and fall, so total 678 samples were used on the measurement of the average heavy metal content on 113 items of selected foods. Since 3 samples of each items of selected foods were purchased on summer and fall from different manufacturers, so the heavy metal content of one item of selected food shall reflect the average heavy metal content of 6 samples. 3 samples on each 1 item of typical food from summer and autumn were analyzed for the amount of heavy metal but only each mean value of heavy metal from each item of food from summer and autumn were obtained by analyzing the amount of heavy metal after homogenizing and mixing 3 samples in one vessel per each season.

Based on meat production amount and imported amount data from 'Agricultural Outlook 2005' of Korea Rural Economic Institute (KREI), Korean Cattle beef and imported beef (Australian Holstein Beef) for beef were used in the ratio of 2 to 1, and domestic hybrid for three way cross produced by Landrace and Yokshire sow and Duroc boar was used for pork (Kim *et al.*, 2008). Domestic products (Broiler) of chicken and eggs were used (Ahn *et al.*, 1997), and also domestic products of milk and dairy products were used. Beef, pork, chicken and pork belly were purchased in plastic-wrapped packages as raw meat. Eggs, milks and dairy products were purchased in packages as end products.

Cooking of Foods

Selected foods were cooked according to a typical cooking method per each food, and distilled water was used for washing, cooking, and preparing foods. The amount of heavy metal at the time of food actually being consumed was tried to obtain by analyzing heavy metal after cooking foods. In case of food being consumed without being cooked, a sample was obtained by washing food, removing moisture and not consumable parts from it and homogenizing it with a mixer. For food requiring a simple cooking such as steaming, stir-frying, boiling, roasting, broiling, heating and grilling, the change of weight was recorded by measuring the weight of food both before cooking and after cooking. Detailed cooking methods of Korean foods were shown on Table 2. For any food necessary to select a specific part such as pork and chicken, parts usually being consumed except bones and internal organs were used. Shoulder-loin (pork), sirloin (beef) and ribs (beef) being used as preferred parts were selected (Kwack and Go, 2006). Body part and drumsticks of chicken were used as the ratio of 2 to 1. Since internal organs have higher concentrations of heavy metals than meat parts, so any place contacted with internal organs was not used. Data of the annual amount of food intake from the '2005 National Health & Nutrition Survey' and the '2005 Seasonal Nutrition Survey' show the amount of food intake by citizen in raw material form. Therefore, in case of cooked food, the change of food weight from cooking was reflected on the heavy metal content to combine with data of the annual amount of food intake from the '2005 National Health & Nutrition Survey' and the '2005 Seasonal Nutrition Survey'.

Pretreatment for Heavy Metal Analysis

Nitric acid of electronic grade (EP-S) was purchased from Dongwoo Finechem (Korea) and the standard solution (1000 ppm/100 mL) was purchased from SCP Science (Canada). A sample for heavy metal analysis was digested using microwave pretreatment equipment (Ethos, Milestone, Italy) (Sivaperumal *et al.*, 2007). 0.5 g of precisely measured homogenized sample was placed on a container of microwave pretreatment equipment and 12 mL of nitric acid was added. In case of difficult sample, 1-2 mL of 30% peroxide was added. Gas being generated was removed by opening the cap of container inside of hood for 12 hr and the sample was digested by using microwave pretreatment equipment. The sample was digested for 30 min in 200°C, and the temperature was configured to be dropped slowly to normal temperature for 50 min. After the sample was digested completely, the digested sample was filtered through a filter paper, placed on a flask and added with double distilled water to be diluted at the level of standard liquid. And, separately 12 mL of nitric acid was added on a container of microwave pretreatment equipment with the same method of making a testing liquid to be used as a solution for blank test.

Arsenic, Cadmium and Lead Analysis

Small quantity of heavy metals such as arsenic, cadmium and lead on food can be measured using Inductively Coupled Plasma Mass Spectrometry (ICP-MS) (Kim *et al.*, 2007). ICP-MS is composed of ICP, an ion-generating

Table 2. Food intake ranking and cooking methods of Korean foods

Ranking	Food name	Food intake (g)	Method	Detailed cooking method
1	Rice	205.7	Boiling	Add rice and water and boil them to make streamed rice
2	Kimchi	90.3	Without cooking	
			Boiling	Pour kimchi and water as much as kimchi sinks under water on a pot and boil them
3	Milk	66.5	Without cooking	
4	Beer	42.3	Without cooking	
5	Soju	28.9	Without cooking	
6	Pork	25.9	Boiling	After slicing pork into a certain size of chunk and adding these sliced pork with some amount of water into a pot, boil them
7	Egg	25.3	Boiling	After dissolving eggs and a little bit of water on a pot, boil them with low heat
			Panbroiling	After dissolving eggs, broil it on a skillet just like making a flat cake
8	Tofu	24.5	Boiling	After slicing tofu as a rectangular shape, boil them on a pot with a little bit of water just enough for these tofu chunks not being stuck on the pot
9	Onion	20.6	Boiling	After slicing onion in a certain thickness, boil them with a little bit of water just enough for these onion not being burned.
			Stir-frying	After heating a skillet, add sliced onion on the skillet and stir fry them by turning them over for the surface of these onion not to be burned
10	Radish	20.3	Without cooking	
			Boiling	After slicing radish in a certain size, boil sliced radish and a little bit of water just enough for these radish being sunk until radish will be fully cooked.
11	Bean sprouts	16.4	Boiling	After cleansing bean sprouts, boil them with a little bit of water just enough for these bean sprouts being sunk on a pot
			Blanching	After boiling water enough for bean sprouts being sunk on a pot, blanch bean sprouts on boiling water, soak them in cold water and squeeze them with a little bit of force
12	Beef	16.1	Boiling	After slicing beef into a certain size, add them with water and boil them enough for the color of beef being turned dark
			Roasting	After heating a skillet, roast sliced ribs on the skillet with low heat just enough for the surface of ribs not being burned
13	Instant noodle	15.8	Boiling	Add and boil the amount of water and instant noodle on a pot according to directions of the cover of noodle
14	Chicken	15.2	Boiling	After adding chunks of chicken on a pot and boil them with a little bit of water just enough for these chunks not being stuck on the pot
			Frying	After heating up an amount of oil on a preheated skillet, add chunks of chicken and fry them just enough for the inside of these chunks being fully cooked without the surface being burned
15	Orange	15.0	Without cooking	
16	Cola	14.6	Without cooking	
17	Potato	13.9	Boiling	After slicing potato into a certain size, boil them with a minimum amount of water on a pot
			Stir-frying	After slicing potato into a proper size, stir fry them on a preheated skillet by turning them over
18	Beef feet soup	13.7	Without cooking	
19	Apple	13.5	Without cooking	
20	Tomato	13.0	Without cooking	
21	Welsh	12.9	Without cooking	
			Boiling	After slicing welsh into a certain length, boil them with a minimum amount of water on a pot

Table 2. Continued

Ranking	Food name	Food intake (g)	Method	Detailed cooking method
22	Noodles	11.8	Boiling	After boiling water on a pot, add noddles on hot water and when noodles are cooked, soak them on cold water and remove moisture from noodles
23	Orange juice	11.8	Without cooking	
24	Pork belly	11.3	Roasting	After heating up a skillet, roast pork belly as much as usual by turning them over
25	Spinach	11.0	Blanching	After boiling water amount for spinach being sunk on a pot, blanch spinach on boiling water, soak them in cold water and squeeze them with a little bit of force
26	Liquid yoghourt	10.7	Without cooking	
27	Cider	10.6	Without cooking	
28	Cucumber	10.2	Without cooking	
29	Makgeolli	9.8	Without cooking	
30	Young pumpkin	9.7	Boiling	After cleansing young pumpkin and slicing it into a certain thickness, boil them with a minimum amount of water on a pot
			Stir-frying	After cleansing young pumpkin and slicing it into a proper thickness, stir fry them on a preheated skillet in low heat by turning them over just enough for the surface of young pumpkin not being burned
31	Siliced radish kimchi	9.2	Without cooking	
32	Melon	9.1	Without cooking	
33	Boiled fish paste	8.9	Boiling	After slicing boiled fish paste into a rectangular shape, boil them with a minimum amount of water on a pot
			Stir-frying	After slicing boiled fish paste into a rectangular shape, stir fry them on a skillet in low heat just enough for the surface of slices not being burned
34	Soybean paste	8.8	Without cooking	
35	Strawberry	8.8	Without cooking	
36	Fruit soda	8.0	Without cooking	
37	Soy sauce	7.6	Without cooking	
			Boiling	Pour soy sauce on a pot and boil it in a short time
38	Dried noodles	7.4	Boiling	After boiling water amount of 4 times of dried noodles' weight on a pot, add dried noddles on hot water and when noodles are cooked, soak them on cold water and remove moisture from noodles
39	Banana	7.4	Without cooking	
40	Carrot	7.0	Boiling	Slice carrot in a thin piece and boil them with a minimum amount of water on a pot
			Stir-frying	After cleansing Carrot and slicing it into a proper size, stir fry them on a preheated skillet in low heat
41	Young radish kimchi	7.0	Without cooking	
42	Ice cream	6.9	Without cooking	
43	Chinese cabbage	6.7	Without cooking	
			Boiling	After cleansing chinese cabbage and slicing it into a certain size, boil them with a minimum amount of water on a pot
44	Garlic	6.5	Without cooking	
			Boiling	After cutting garlic into thin slices, boil them with a minimum amount of water on a pot
45	Hot pepper paste	6.4	Without cooking	
46	Soybean milk	6.2	Without cooking	
47	Watery kimchi made of sliced	6.2	Without cooking	

Table 2. Continued

Ranking	Food name	Food intake (g)	Method	Detailed cooking method
48	Rice cake	5.9	Boiling	Boil rice cake with a minimum amount of water just enough for rice cake not being stuck on a pot
49	Cabbage	5.9	Without cooking	
			Stir-frying	Slice cabbage and stir fry them on a skillet in low heat
50	Mackerel	5.8	Broiling	Place mackerel on a preheated skillet and broil it in low heat by turning it over
			Boiling	After cleansing chunks of mackerel, boil them with a minimum amount of water on a pot
51	Buckwheat noodles	5.6	Boiling	After boiling water amount of 4 times of buckwheat noodles' weight on a pot, add buckwheat noodles on hot water and when noodles are cooked, soak them on cold water and remove moisture from noodles
52	Pickled radish	5.6	Without cooking	
53	Green part of a radish	5.2	Boiling	After cleansing green part of a radish and slicing them into a proper size, boil them with a minimum amount of water on a pot
54	Lettuce	5.1	Without cooking	
55	Suger	4.9	Without cooking	
56	Unripe red pepper	4.8	Without cooking	
			Boiling	After cleansing unripe red peppers and slicing them into a proper size, boil them with a minimum amount of water on a pot
			Stir-frying	After cleansing unripe red peppers and slicing them into a certain size, stir fry them on a skillet
57	Hygienic drink	4.8	Without cooking	
58	Glutinous rice	4.7	Boiling	Add water and barley corns on the inner bowl of electric rice cooker and boil them
59	Barley	4.6	Boiling	Add water and glutinous rice on the inner bowl of electric rice cooker and boil them
60	Cereals	4.6	Boiling	Add water and mixed rice & cereals on the inner bowl of electric rice cooker and boil them
61	Bean oil	4.6	Heating	Add bean oil on a skillet and heat them
62	Wheat flour	4.5	Baking	After mixing and kneading wheat flour and water and making chucks of 5~6cm diameter, bake them on a preheated skillet by tuning them over just enough for these chucks not being burned
63	Soybean	4.3	Boiling	After cleansing soybeans and soaking them a little bit, boil them with a minimum amount of water on a pot until soybeans will be fully cooked.
64	Squid	4.3	Boiling	After cleansing squid and slicing it into a certain size, boil them on a preheated skillet in low heat
65	Uncleaned rice	4.3	Boiling	Add water and uncleaned rice opn the inner bowl of electric rice cooker and boil them
66	Sweet drink made from fermented rice	4.3	Without cooking	
67	Brown seaweed	4.2	Broiling	After cleansing brown seaweed and slicing it into a certain size, broil them on a preheated skillet in low heat
68	Dropwort	4.1	Blanching	After cleansing dropwort and slicing it into a certain size, blanch them on a preheated skillet in low heat
69	Watermelon	3.8	Without cooking	
70	Confectionery	3.7	Without cooking	
71	Coffee mix	3.5	Without cooking	

Table 2. Continued

Ranking	Food name	Food intake (g)	Method	Detailed cooking method
72	Yellow corvina	3.5	Broiling	After cleansing yellow corvina and removing fins and scales from it, broil it on a preheated skillet by turning it over until it will be fully cooked.
			Boiling	After cleansing yellow corvina and removing fins and scales from it, boil it with a minimum amount of water on a pot until it will be fully cooked
73	Coffee extract	3.5	Without cooking	
74	Alaska pollack	3.3	Boiling	After cleansing alaska pollack, boil it with a minimum amount of water on a pot until it will be fully cooked
75	Salt	3.2	Without cooking	
76	Snack	3.1	Without cooking	
77	Pear	3.0	Without cooking	
78	Sesame oil Sesame oil	2.8	Without cooking	
			Heating	Pour sesame oil on a pan and heat it for a short time
79	Short-necked clam	2.3	Boiling	After cleansing short-necked clams, broil them with a minimum amount of water on a pot until they will be fully cooked
80	Sesame leaf	2.3	Without cooking	
81	Powered red pepper	2.3	Without cooking	
82	Sweet potato	2.3	Boiling with steam	Steam sweet potato until the inside of sweet potato will be fully cooked
83	Condiment soy-bean paste	2.2	Without cooking	
84	Scabbard fish	2.2	Broiling	After cleansing scabbard fish and removing fins and scales from it, broil it on a preheated skillet by turning it over until it will be fully cooked
			Boiling	After cleansing scabbard fish and removing fins and scales from it, broil it with a minimum amount of water on a pot until it will be fully cooked
85	Mandarin	2.2	Without cooking	
86	Sherbet	2.2	Without cooking	
87	Crab	2.1	Boiling	After cleansing crab and removing only crab meat, boil those crab meat on a pot until these being fully cooked
88	Flatfish	2.1	Without cooking	
			Boiling	Boil flatfish with a minimum amount of water on a pot until it will be fully cooked
89	Canned tuna	2.0	Without cooking	
			Boiling	After opening a can of tuna and removing fat, broil tuna with a little bit of water on a pot
90	Sesame	1.6	Without cooking	
91	Coffee creamer	1.5	Without cooking	
92	Sirup	1.4	Without cooking	
93	Dried squid	1.4	Without cooking	
			Stir-frying	After slicing dried squid in a certain size, stir fly them on a skillet by turning them over
94	Seaweed	1.4	Without cooking	
95	Common octopus	1.4	Boiling	After cleansing common octopus with salt and slicing it in a certain size, broil them with a minimum amount of water on a pot until these will be fully cooked.
			Stir-frying	After cleansing common octopus with salt and slicing it in a certain size, stir fry them on a preheated skillet until these will be fully cooked
96	Dried yellow corvina	1.3	Broiling	After cleansing dried yellow corvina and removing fins and scales from it, broil it on a preheated skillet by turning it over until it will be fully cooked.
97	Grapes	1.2	Without cooking	

Table 2. Continued

Ranking	Food name	Food intake (g)	Method	Detailed cooking method
98	Saury	1.2	Broiling	After cleansing saury and removing fins and scales from it, broil it on a preheated skillet by turning it over until it will be fully cooked.
			Boiling	After cleansing saury and removing fins and scales from it, boil it with a minimum amount of water on a pot until it will be fully cooked
99	Tomato ketchup	1.0	Without cooking	
100	Vineger	0.9	Without cooking	
101	Coffee powder	0.9	Without cooking	
102	Oyster	0.8	Without cooking	
103	Shrimp	0.8	Boiling	Boil shrimp and a minimum amount of water on a pot until it will be cooked
			Broiling	Broil shrimp on a preheated skillet by turning it over until it will be fully cooked
			Without cooking	
104	Persimmon	0.8	Without cooking	
105	Spanish mackerel	0.6	Broiling	After cleansing spanish mackerel and removing fins and scales from it, broil it on a preheated skillet by turning it over until it will be fully cooked.
			Boiling	After cleansing spanish mackerel and removing fins and scales from it, broil it with a minimum amount of water until it will be fully cooked
106	Eel	0.6	Broiling	Broil eel on a preheated skillet by turning it over until it will be fully cooked.
107	Ginger	0.4	Without cooking	
108	Peach	0.3	Without cooking	
109	Seasoning powder	0.2	Without cooking	
110	Anchovy	0.2	Boiling	Boil anchovies with a minimum amount of water on a pot until these will be fully cooked
			Stir-frying	After adding anchovies into a skillet, stir-fry it by stirring these with a scoop
111	Powdered sesame mixed with salt	0.2	Without cooking	
112	Pepper	0.1	Without cooking	
113	Flavoring matter	0.0	Without cooking	

device, and MS detecting generated ion, and it is an spectrometer to measure quality and quantity of 70 kinds of elements up to sub-ppb level (Jarvis *et al.*, 1992; Nageswara and Kumar, 2007). The analysis method using this ICP-MS is a technique of measuring with MS by extracting singly charged analyte ion generated in ICP. In this study, heavy metals such as arsenic, cadmium, and lead except mercury which doesn't need pretreatment were analyzed all with ICP-MS (7500 series, Agilent, USA). As conditions of analysis, 1200 W was used for RF power and acquisition time was configured as 25 seconds. The optimal operation condition was obtained by setting carrier gas flow as 1.24 L/min, sample uptake time as 100 seconds, sample uptake rate as 0.5 mL/min and pump speed as 17 rpm.

Mercury Analysis

The amount of mercury in food was analyzed using Mercury analyzer (Nippon Instrument, Japan) (KFDA, 2002; Kim *et al.*, 2004). Mercury analyzer is an equipment of measuring a liquid or solid sample directly without any pretreatment. This is an equipment of capturing mercury discharged as gas on a gold amalgamation installed inside of the equipment by applying high heat to a sample and measuring the amount of captured mercury using atomic absorption spectroscopy, and it is used for measuring the total amount of mercury (Rigaku Industrial Corporation, 1979). Combustion gold amalgamation method applied on this equipment is a method of capturing mercury discharged as gas on a gold amalgamation by applying high heat to a sample. The combustion gold amalgamation method was applied on this equipment to analyze by loading a solid or liquid sample on equipment directly. As conditions of analysis, the first analysis step and the second analysis step for standard material were set as 1min and 2 min respectively, and the first analysis step and the second analysis step for food sample were set as 10min and 6min respectively. The content of mercury was measured by spreading M reagent for Mercury analysis on a loading boat, placing a food sample above it, covering

the food sample with M reagent, filling the loading boat using B reagent and M reagent in order and placing the loading boat on Mercury analyzer.

Risk Assessment of Heavy Metals

PDI (Probable Daily Intake) means the daily amount of intake per person and this is the actual amount of intake to the body when consuming through foods. The daily amount of heavy metal intake by one person (PDI, mg/person/day) on each livestock foodstuffs was obtained through multiplying the daily amount of each livestock foodstuffs intake by one person (kg/person/day) by the content of heavy metal (mg/kg) like the equation below. The daily amount of heavy metal intake by one person (PDI, mg/person/day) on each Korean foods was obtained through multiplying the daily amount of each Korean foods intake by one person (kg/person/day) by the content of heavy metal (mg/kg).

Daily amount of heavy metal intake (PDI, mg/person/day) on each livestock foodstuffs
= Daily amount of livestock foodstuffs intake by one person (kg/person/day) × Content of heavy metal (mg/kg).
Daily amount of heavy metal intake (PDI, mg/person/day) on each Korean foods
= Daily amount of livestock foodstuffs intake by one person (kg/person/day) × Content of heavy metal (mg/kg).

PTWI (Provisional Tolerable Weekly Intake) means the weekly permitted amount of intake and this is the weekly amount of intake to the body without inducing toxicity when consuming through foods. PTWI of arsenic, cadmium, lead and mercury established by JECFA (Joint FAO/WHO Expert Committee on Food Additive) are 0.350 mg/kg bw/week, 0.007 mg/kg bw/week, 0.025 mg/kg bw/week and 0.005 mg/kg bw/week respectively.

JECFA is the abbreviation of The Joint FAO/WHO Expert Committee on Food Additives, and this is a joint committee of food experts operated by United Nations Food and Agriculture Organization and World Health Organization. This committee is held twice a year in Rome and Geneva and this committee examines and supervises food additives. They have been reflecting the collected result of monitoring on the amount of contaminants such as heavy metals on foods from each country on the establishment of standards of contaminants.

For the risk assessment, the risk on heavy metals was evaluated by calculating PDI and then comparing it with PTWI value of JECFA. Since PDI uses mg/person/day as its unit and PTWI uses mg/kg bw/week as its unit, so in order to compare numerical values, the unit of person should be converted into kg and the unit of day should be converted into the unit of week.

Results and Discussion

In this research, Food list for Korean was newly selected based on recently revised data of the '2005 National Health & Nutrition Survey' and the '2005 Seasonal Nutrition Survey' from Ministry for Health, Welfare and Family Affairs and based on this list, the risk of heavy metal exposed through livestock foodstuffs and Korean foods were evaluated by analysing the amount of heavy metal on selected foods from Food list for Korean.

Selected types of foods were classified into food groups according to the standards of classification from 7th revision of 'Food Composition Table' (2007) and displayed on Table 3. Food is divided into 15 groups as Grains and Cereals, Potatoes and Starch, Sugars and Sweet, Pulses, Nuts and Seeds, Vegetables, Fruits, Meats and Poultry, Eggs, Fishes and Shellfishes, Seaweeds, Milks and Dairy products, Oils and Fats, Beverages and Seasonings. Livestock foodstuffs are classified into Meats and Poultry (chicken, pork, pork belly, beef, beef feet soup), Milks and Dairy products (milk, ice cream, liquid yogurt, sherbet) and Eggs (egg) according to the standards of classification from 7th revision of 'Food Composition Table' (2007) and displayed on Table 3. On food intake data from the '2005 National Health & Nutrition Survey' and the '2005 Seasonal Nutrition Survey', Grains and Cereals for 321.1 g, Vegetables for 327.0 g, Beverages and Alcohols for 145.7 g, Meats and Poultry for 95.1 g, Milks and Dairy products for 89.7 g were rated as food groups with a high rate of foods intake (Table 4). The result of this research showed that the intake of food on selected items of foods were 281.7 g of Grains and Cereals, 275.8 g of Vegetables, 131.2 g of Beverages and Alcohols, 82.2 g of Meats and Poultry and 86.3 g of Milks and Dairy products (Table 4).

Table 5 showed the daily amount of food intake by one person and the content of heavy metal on each livestock foodstuffs. As a result of analysis, the amount of arsenic was 0.0000-0.0099 mg/kg, the amount of cadmium was 0.0000 mg/kg, the amount of lead was 0-0.0108 mg/kg and the amount of mercury was 0.000011-0.001513 mg/kg on livestock foodstuffs. The daily amount of heavy metal intake by one person (PDI, mg/person/day) on each livestock foodstuffs was obtained through multiplying the daily amount of each livestock foodstuffs intake by one person (kg/person/day) by the content of heavy metal (mg/kg). The daily

Table 3. List of foods group in Korean foods

	Food group	Food name
1	Grains and Cereals	Rice cake, Confectionery, Snack, Died noodle, Noddle, Instant noodle, Buckwheat noodles, Wheat flour, Rice, Barley, Glutinous rice, Uncleaned rice, Cereals
2	Potatoes and Starch	Potato, Sweet potato
3	Sugars and Sweet	Sirup, Suger
4	Pulses	Soybean, Tofu, Soybean milk
5	Nuts and Seeds	Sesame
6	Vegetables	Siliced radish kimchi, Watery kimchi made of sliced radishes, Kimchi, Young radish kimchi, Sesame leaf, Pickled radish, Carrot, Dropwort, Garlic, Radish, Green part of a radish, Chinese cabbage, Lettuce, Ginger, Spinach, Young pumpkin, Cabbage, Onion, Cucumber, Bean sprouts, Tomato, Welsh, Unripe red pepper
7	Fruits	Persimmon, Mandarin, Strawberry, Banana, Pear, Peach, Apple, Watermelon, Orange, Orange juice, Melon, Grapes
8	**Meats and Poultry**	Chicken, Pork, Pork belly, Beef, Beef feet soup
9	**Eggs**	Egg
10	Fishes and shellfishes	Scabbard fish, Crab, Mackerel, Flatfish, Oyster, Dried yellow corvina, Saury, Common octopus, Anchovy, Alaska pollack, Eel, Short-necked clam, Spanish mackerel, Shrimp, Boiled fish paste, Squid, Dried squid, Yellow corvina, Canned tuna
11	Seaweeds	Seaweed, Brown seaweed
12	**Milks and Dairy products**	Sherbet, Ice cream, Liquid yoghourt, Milk
13	Oils and Fats	Sesame oil, Coffee creamer, Bean oil
14	Beverages	Fruit soda, Hygienic drink, Makgeolli, Beer, Cider, Soju, Sweet drink made from fermented rice, Coffee mix, Coffee powder, Coffee extract, Cola
15	Seasonings	Soy sauce, Hot pepper paste, Powered red pepper, Powdered sesame mixed with salt, Soybean paste, Seasoning powder, Salt, Vineger, Condiment soybean paste, Flavoring matter, Tomato ketchup, Pepper

Table 4. Food intake and number of foods in each food group

	Food group	2005 National Health and Nutrition Survey (NHNS)		Selected Korean foods in this study	
		Food intake (g)	Food number	Food intake (g)	Food number
1	Grains and Cereals	321.1	54	281.7	13
2	Potatoes and Starch	20.2	12	16.2	2
3	Sugars and Sweet	7.5	9	6.3	2
4	Pulses	39.3	20	35	3
5	Nuts and Seeds	4.8	16	1.6	1
6	Vegetables	327.0	121	275.8	23
7	Mushrooms	4.4	10		
8	Fruits	87.4	54	76.9	12
9	Meats and Poultry	95.1	22	82.2	5
10	Eggs	25.8	3	25.3	1
11	Fishes and Shellfishes	67.7	111	48.4	19
12	Seaweeds	8.5	14	5.6	2
13	Milks and Dairy products	89.7	9	86.3	4
14	Oils and Fats	9.5	14	8.9	3
15	Beverages	145.7	55	131.2	11
16	Seasonings	37.5	29	32.9	12
	Total	1,291.2	553	1,114.3	113

amount of heavy metal intake by one person (PDI, mg/person/day) on each Korean foods was obtained through multiplying the daily amount of each Korean foods intake by one person (kg/person/day) by the content of heavy metal (mg/kg). For risk assessment, PDI was calculated and compared with PTWI of JECFA.

Intake and Risk Assessment of Arsenic being consumed on Livestock Foodstuffs and Korean Foods

Table 5 shows the daily amount of each livestock foodstuffs intake by one person and the content of arsenic. The daily amount of arsenic intake by one person through each livestock foodstuffs was able to be obtained from the daily amount of each livestock foodstuffs intake by one person and the content of arsenic. Among livestock foodstuffs, the daily intake of arsenic by a person through beef was the highest as 0.0002 mg/person/day. The total daily intake of arsenic by a person through each livestock foodstuffs was 0.0002 mg/person/day for Meats and Poultry and 0.0000 mg/person/day for Eggs and Milk and Dairy products (Table 5). The daily intake of arsenic from livestock foodstuffs in our country was 0.0002 mg/person/day and it was lower than 0.0018 mg/person/day for France and 0.0005 mg/person/day for England (Leblanc *et al.*, 2005; Ysart *et al.*, 2000). In this research, the daily amount of arsenic intake by one person through each livestock foodstuffs is 0.0002 mg/person/day and the weakly consumption can be calculated as 0.0011 mg/person/week, and the weekly intake of arsenic per kg is 0.00002 mg/kg bw/week (Table 6). The level of arsenic intake through livestock foodstuffs is 0.00002 mg/kg bw/week corresponding 0.006% of PTWI value (0.3500 mg/kg bw/week) which is the safety standards of JECFA, so it was proved to be in a low level under the recommendation of JECFA (Table 6).

As a result of comparing total food groups contributing the arsenic intake of our citizen, Seaweeds and Fishes and Shellfishes were found to have a high impact as 63.2% and 30.3% respectively, and Meats and Poultry, Eggs and Milks and Dairy products were 0.6%, 0.0% and 0.0% respectively so that the amount of arsenic intake through livestock foodstuffs was insignificant (Table 7). Analyzing TDS results of France and England, the amount of arsenic intake through livestock foodstuffs was reported as 0.00306 mg/persom/day and 0.000534 mg/persom/day respectively, and in case of Fishes and Shellfishes, the amount of arsenic intake was 0.03859 mg/person/day and 0.06100 mg/person/day respectively, so just like our country, the amount of arsenic intake from livestock foodstuffs was measured lower than the amount of arsenic intake from aquatic products (Leblanc *et al.*, 2005; Ysart *et al.*, 2000).

In this research, the daily amount of arsenic intake by one person through each selected food from Food list for Korean purchased in 2007 was 0.0265 mg/person/day (Table 7).

Table 5. Food daily intakes, heavy metal contents and heavy metal daily intake in each livestock foodstuffs

	Food group	Food list	Arsenic			Cadmium			Lead			Mercury		
			Food intake (kg)	contents (mg/kg)	daily intake (mg/person/day)	Food intake (kg)	contents (mg/kg)	daily intake (mg/person/day)	Food intake (kg)	contents (mg/kg)	daily intake (mg/person/day)	Food intake (kg)	contents (mg/kg)	daily intake (mg/person/day)
1	Meats and Poultry	Chicken	0.0152	0.0000	0.0000	0.0152	0.0000	0.0000	0.0152	0.0108	0.0002	0.0152	0.000039	0.000001
		Pork	0.0259	0.0000	0.0000	0.0259	0.0000	0.0000	0.0259	0.0000	0.0000	0.0259	0.001513	0.000039
		Pork belly	0.0113	0.0000	0.0000	0.0113	0.0000	0.0000	0.0113	0.0000	0.0000	0.0113	0.000136	0.000002
		Beef	0.0161	0.0099	0.0002	0.0161	0.0000	0.0000	0.0161	0.0000	0.0000	0.0161	0.000127	0.000002
		Beef feet soup	0.0137	0.0000	0.0000	0.0137	0.0000	0.0000	0.0137	0.0000	0.0000	0.0137	0.000127	0.000002
		Sum			**0.0002**			**0.0000**			**0.0002**			**0.000045**
2	Eggs	Egg	0.0253	0.0000	0.0000	0.0253	0.0000	0.0000	0.0253	0.0000	0.0000	0.0253	0.000217	0.000006
	Sum				**0.0000**			**0.0000**			**0.0000**			**0.000006**
3	Milks and Dairy products	Sherbet	0.0022	0.0000	0.0000	0.0022	0.0000	0.0000	0.0022	0.0000	0.0000	0.0022	0.000092	0.000000
		Ice cream	0.0069	0.0000	0.0000	0.0069	0.0000	0.0000	0.0069	0.0000	0.0000	0.0069	0.000384	0.000003
		Liquid yoghourt	0.0107	0.0000	0.0000	0.0107	0.0000	0.0000	0.0107	0.0000	0.0000	0.0107	0.000545	0.000006
		Milk	0.0665	0.0000	0.0000	0.0665	0.0000	0.0000	0.0665	0.0000	0.0000	0.0665	0.000011	0.000001
		Sum			**0.0000**			**0.0000**			**0.0000**			**0.000009**
		Total			**0.0002**			**0.0000**			**0.0002**			**0.000060**

Table 6. Total Dietary Intake amount and PTWI on heavy metals in livestock foodstuffs

	Daily intake per person (mg/person/day)	Weekly intake per person (mg/person/week)	Weight (kg)	Weekly intake per kg (mg/kg bw/week)	PTWI (mg/kg bw/week)	Ratio (%)
Arsenic (As)	0.00020	0.0011	56.35	0.000020	0.3500	0.0060
Cadmium (Cd)	0.00000	0.0000	56.35	0.000000	0.0070	0.0000
Lead (Pb)	0.00020	0.0011	56.35	0.000020	0.0250	0.0852
Mercury (Hg)	0.00006	0.0004	56.35	0.000007	0.0050	0.1491

This shows the level of arsenic intake lower than 0.206985 mg/person/day of Spain, 0.0621 mg/person/day of France, 0.0650 mg/person/day of England, 0.0380 mg/person/day of U.S and 0.1820 mg/person/day of Japan (Llobet *et al.*, 2003; Leblanc *et al.*, 2005; Ysart *et al.*, 2000; US FDA 2004; Mohri *et al.*, 1990). The weekly amount of arsenic intake through selected food from Food list for Korean are 0.1855 ß²/person/week and 0.0033 mg/kg bw/week respectively (Table 8). The level of arsenic intake through selected food from Food list for Korean is 0.0033 mg/kg bw/week corresponding 0.940% of PTWI value (0.3500 mg/kg bw/week) which is the safety standards of JECFA, so it was proved to be in a low level under the recommendation of JECFA (Table 8).

Intake and Risk Assessment of Cadmium being consumed on Livestock Foodstuffs and Korean Foods

Table 5 shows the daily amount of each livestock foodstuffs intake by one person and the content of cadmium. Cadmium was not detected from all livestock foodstuffs, so the total daily amount of cadmium intake by a person through each livestock foodstuffs was 0.0000 mg/person/day (Table 5). In this research, the daily amount of cadmium intake by a person through livestock foodstuffs was none and in case of France, Spain and England, the value were 0.00042 mg/person/day, 0.00225 mg/person/day and 0.00075 mg/person/day respectively (Leblanc *et al.*, 2005; Llobet *et al.*, 2003; Ysart *et al.*, 2000). The level of cadmium intake through livestock foodstuffs is 0.0000 mg/kg bw/week corresponding 0.0000% of PTWI value (0.0070 mg/kg bw/week) which is the safety standards of JECFA, so it was proved to be in a low level under the recommendation of JECFA (Table 6).

As a result of comparing total food groups contributing the cadmium intake of our citizen, Fishes and Shellfishes, Seaweeds and Vegetables were found to have a high impact as 49.1%, 21.0% and 11.4% respectively, and Meats and Poultry, Eggs and Milks and Dairy products were all 0.0% so that the amount of cadmium intake through livestock foodstuffs was insignificant (Table 7).

In this research, the daily amount of cadmium intake by one person through each selected food from Food list for

Table 7. Daily intake of heavy metal and relative ratio of daily intake of heavy metal in each food group

Food group	Arsenic		Cadmium		Lead		Mercury	
	Daily intake (mg/person/day)	Ratio (%)	Daily intake (mg/person/day)	Ratio (%)	Daily intake (mg/person/day)	Ratio (%)	Daily intake (mg/person/day)	Ratio (%)
1 Grains and Cereals	**0.0001**	0.51	**0.0004**	5.26	**0.0006**	8.85	**0.000194**	7.01
2 Potatoes and Starch	**0.0004**	1.43	**0.0003**	3.38	**0.0006**	8.29	**0.000001**	0.05
3 Sugars and Sweet	**0.0000**	0.00	**0.0000**	0.00	**0.0000**	0.42	**0.000001**	0.04
4 Pulses	**0.0000**	0.00	**0.0000**	0.00	**0.0000**	0.00	**0.000001**	0.04
5 Nuts and Seeds	**0.0000**	0.09	**0.0001**	0.91	**0.0000**	0.00	**0.000006**	0.21
6 Vegetables	**0.0002**	0.67	**0.0009**	11.41	**0.0013**	20.18	**0.000090**	3.24
7 Fruits	**0.0000**	0.01	**0.0003**	3.11	**0.0004**	5.63	**0.000008**	0.30
8 **Meats and Poultry**	**0.0002**	0.60	**0.0000**	0.00	**0.0002**	2.46	**0.000045**	1.63
9 **Eggs**	**0.0000**	0.00	**0.0000**	0.00	**0.0000**	0.00	**0.000006**	0.20
10 Fishes and shellfishes	**0.0080**	30.32	**0.0041**	49.12	**0.0021**	31.15	**0.002333**	84.49
11 Seaweeds	**0.0167**	63.24	**0.0017**	21.02	**0.0000**	0.21	**0.000011**	0.41
12 **Milks and Dairy products**	**0.0000**	0.00	**0.0000**	0.00	**0.0000**	0.00	**0.000009**	0.34
13 Oils and Fats	**0.0000**	0.00	**0.0000**	0.35	**0.0004**	6.68	**0.000012**	0.45
14 Beverages	**0.0000**	0.00	**0.0002**	1.87	**0.0010**	15.21	**0.000031**	1.11
15 Seasonings	**0.0008**	3.13	**0.0003**	3.57	**0.0001**	0.92	**0.000013**	0.48
Total	**0.0265**	100.00	**0.0083**	100.00	**0.0067**	100.00	**0.002761**	100.00

Table 8. Total Dietary Intake amount and PTWI on heavy metals in Korean foods

	Daily intake per person (mg/person/day)	Weekly intake per person (mg/person/week)	Weight (kg)	Weekly intake per kg (mg/kg bw/week)	PTWI (mg/kg bw/week)	Ratio (%)
Arsenic (As)	0.0265	0.1855	56.35	0.0033	0.3500	0.9406
Cadmium (Cd)	0.0083	0.0579	56.35	0.0010	0.0070	14.6761
Lead (Pb)	0.0067	0.0468	56.35	0.0008	0.0250	3.3193
Mercury (Hg)	0.0028	0.0196	56.35	0.0003	0.0050	6.8604

Korean purchased in 2007 was 0.0083 mg/person/day (Table 7). This shows the level of arsenic intake lower than 0.024 mg/person/day of Canada, 0.015 mg/person/day of U.S. and 0.012 mg/person/day of England (Canadian Total Diet Study 1999; US Total Diet Study, 2004; Ysart *et al.*, 2000). The level of cadmium intake through selected food from Food list for Korean is 0.0010 mg/kg bw/week corresponding 14.6761% of PTWI value (0.0070 mg/kg bw/week) which is the safety standards of JECFA, so it was proved to be in a low level under the recommendation of JECFA (Table 8).

Intake and Risk Assessment of Lead being consumed on Livestock Foodstuffs and Korean Foods

Table 5 shows the daily amount of each livestock foodstuffs intake by one person and the content of lead. Among livestock foodstuffs, the daily amount of lead intake by a person through chicken was the highest as 0.0002 mg/person/day. The total daily intake of lead by a person through each livestock foodstuffs was 0.0002 mg/person/day for Meats and Poultry, 0.0000 mg/person/day for Eggs and 0.0000 mg/person/day for Milk and Dairy products (Table 5). The daily amount of lead intake through livestock foodstuffs in France and England are 0.0025 mg/person/day and 0.0021 mg/person/day respectively, and 0.0002 mg/person/day of the daily amount of lead intake in our country was lower than values of France and England (Leblanc *et al.*, 2005; Ysart *et al.*, 2000). The level of lead intake through livestock foodstuffs is 0.00002 mg/kg bw/week corresponding 0.0852% of PTWI value (0.0250 mg/kg bw/week) which is the safety standards of JECFA, so it was proved to be in a low level under the recommendation of JECFA (Table 6).

As a result of comparing total food groups contributing the lead intake of our citizen, Fishes and Shellfishes and Vegetables were found to have a high impact as 31.1% and 20.1% respectively, and Meats and Poultry, Eggs and Milks and dairy products were 2.5%, 0.0%, 0.0% respectively so that the amount of lead intake through livestock foodstuffs was insignificant (Table 7).

In this research, the daily amount of lead intake by one person through each selected food from Food list for Korean purchased in 2007 was 0.0067 mg/person/day (Table 7). This shows the level of lead intake lower than 0.0184 mg/person/day of France, 0.0260 mg/person/day of England, and 0.0150 mg/person/day of U.S. (Leblanc *et al.*, 2005, Ysart *et al.*, 2000; US Total Diet Study, 2004). The level of lead intake through selected food from Food list for Korean is 0.0008 mg/kg bw/week corresponding 3.3193% of PTWI value (0.0250 mg/kg bw/week) which is the safety standards of JECFA, so it was proved to be in a low level under the recommendation of JECFA (Table 8).

Intake and Risk Assessment of Mercury being consumed on Livestock Foodstuffs and Korean Foods

Table 5 shows the daily amount of each livestock foodstuffs intake by one person and the content of mercury. Among livestock foodstuffs, the daily amount of mercury intake by a person through chicken was the highest as 0.000039 mg/person/day. The total daily amount of mercury intake by a person through each livestock foodstuffs was 0.000045 mg/person/day for Meats and Poultry, 0.000006 mg/person/day for Eggs and 0.000009 mg/person/day for Milk and Dairy products (Table 5). The daily amount of mercury intake from livestock foodstuffs in our country was 0.00006 mg/person/day and it was lower than 0.00114 mg/person/day for France and 0.00046 mg/person/day for England (Leblanc *et al.*, 2005; Ysart *et al.*, 2000). The level of mercury intake through livestock products is 0.000007 mg/kg bw/week corresponding 0.1491% of PTWI value (0.0050 mg/kg bw/week) which is the safety standards of JECFA, so it was proved to be in a low level under the recommendation of JECFA (Table 6).

As a result of comparing total food groups contributing the mercury intake of our citizen, Fishes and shellfishes was found to have a high impact as 84.49%, and Meats and Poultry, Eggs and Milks and Dairy products were 1.63%, 0.20% and 0.34% respectively so that the amount of mercury intake through livestock foodstuffs was insignificant (Table 7). Taking a look at English TDS result, the amount of mercury intake through livestock foodstuffs was 0.00046 mg/person/day and the amount of mercury intake through Fishes and shellfishes was 0.00100 mg/person/day. Similar with case of our country, the amount of mercury intake through livestock foodstuffs was lower than the amount of mercury intake through Fishes and shellfishes (Ysart *et al.*, 2000).

In this research, the daily amount of mercury intake by one person through each selected food from Food list for Korean purchased in 2007 was 0.0028 mg/person/day (Table 7). This shows the level of mercury intake lower than 0.0097 mg/person/day of France, 0.0030 mg/person/day of England and 0.0080 mg/person/day of England (Leblanc *et al.*, 2005; Ysart *et al.*, 2000; US Total Diet Study, 2004). The level of mercury intake through selected food from Food list for Korean is 0.0003 mg/kg bw/week corresponding 6.8604% of PTWI value (0.0050 mg/kg bw/week) which is the safety standards of JECFA, so it was proved to be in a low level under the recommendation of JECFA (Table 8).

Risk Assessment for Heavy Metals in Livestock Foodstuffs and Korean Foods

The amount of heavy metal being consumed through livestock foodstuffs was relatively lower than the amount of heavy metal being consumed through other food groups from Food list for Korean. The amount of heavy metal being consumed by citizen through livestock foodstuffs was found to be in a relatively safe level. The amount of heavy metal being consumed by citizen through Korean foods was found to be in a relatively safe level, as it was proved to be in a lower level than the recommendation of JECFA. Livestock foodstuffs in France and England are occupying a bigger proportion in typical food groups than livestock foodstuffs in our country, and also items and the intake amount of livestock foodstuffs in France and England are also more than a case of livestock foodstuffs in our country. Typical livestock foodstuffs of England were carcase meat, offal, meat products, poultry, eggs, milk and dairy produce, and typical livestock products of France were milk, ultra-fresh dairy products, cheeses, eggs and egg products, butter, meat, poultry and game, offals, delicatessen and ices cream (Leblanc *et al.*, 2005; Ysart *et al.*, 2000). The intake amount of heavy metals from typical livestock foodstuffs in our countries seems to be low because number of items and intake amount of typical livestock foodstuffs in Europe are bigger.

As a result of this research, more heavy metals were found to be consumed from fishes and shellfishes group than any other food groups of Koreans foods. Therefore, the risk of heavy metals should be more paid attention in cases of consuming a large quantity of fishes and shellfishes. Since the ratio of imported foods consumed by Korean has been increasing, more strict establishment of standards of heavy metals on imported foods should be applied. The safety of imported foods being consumed by our citizens should be improved by continuously inspecting heavy metals on imported foods and in order to achieve this, many researches on the risk assessment for heavy metals in imported foods should be executed later on.

Taking a look at a global trend of research on the intake of food contaminants, still many countries don't process researches on contaminants from foods actively. But, researches on the content, the intake amount and physiological effects of contaminants on foods are being actively processed and contaminations on various foods are being monitored well in advanced countries such as England, Denmark, United States, and France, so the total intake of foods is well evaluated there (Ysart *et al.*, 2000; Larsen *et al.*, 2002; Egan *et al.*, 2002; Leblanc *et al.*, 2005). Any insufficiency on this field shall be complemented and researches on evaluations of the intake level and risk of contaminants such as heavy metals shall be processed continuously in our country. And also, we shall make an effort to make people all over the world being able to consume food without any worries by setting the standard limit and regulations of various heavy metals intake through more researches and efforts with the international cooperation.

As a basic data for risk assessment of livestock foodstuffs for Korean, the result of this research can be used for (1) establishing the standards, (2) establishing the newest database for risk assessment of each heavy metal, (3) complementing international standards using this result as scientific data, (4) delivering scientific information of risk through the evaluation of the amount of contaminants being exposed from livestock foodstuffs, and (5) evaluation of risk from imported livestock foodstuffs.

Conclusion

As a national project, the information on the amount of heavy metals being exposed through the food intake of citizen is known as a very important basic data on risk assessments. Since Ministry for Health, Welfare and Family Affairs has newly completed the '2005 National Health & Nutrition Survey' and the '2005 Seasonal Nutrition Survey' recently, the selection of Food list for Korean based on data above was needed. This study was conducted to evaluate exposure level and risk of heavy metals in livestock foodstuffs and Korean foods. Based on the 'Food Intake Data', a part of the '2005 National Health & Nutrition Survey' and the '2005 Seasonal Nutrition Survey', 113 Korean foods items were selected. For the selection, 'Highly consumed foods', 'Frequent consumption foods', 'Energy-supplying foods', 'Seasonal foods' and 'Age foods' were considered. 3 samples from different manufacturers of each 113 items of Korean foods were purchased on summer and fall, so total 678 samples were used. Food is divided into 15 groups as Grains and Cereals, Potatoes and Starch, Sugars and Sweet, Pulses, Nuts and Seeds, Vegetables, Fruits, Meats and Poultry, Eggs, Fishes and Shellfishes, Seaweeds, Milks and Dairy products, Oils and Fats, Beverages and Seasonings. For the livestock foodstuffs category, Meats and Poultry (chicken, pork, pork belly, beef, beef feet soup), Milks and Dairy products (milk, ice cream, liquid yoghourt, sherbet), Eggs (egg) were selected. It was found that the daily amount of heavy metals intake (mg/person/day) from livestock foodstuffs is 0.00020 arsenic, 0.00000 cadmium, 0.00020 lead, and 0.00006 mercury, and the daily amount of heavy metals intake (mg/person/day) from Korean foods is 0.0265 arsenic,

0.0083 cadmium, 0.0067 lead, and 0.0028 mercury. For risk assessment, PDI (Probable Daily Intake) was calculated and compared with PTWI (Provisional Tolerable Weekly Intake) of JECFA (Joint FAO/WHO Expert Committee on Food Additive). Relative hazard of these livestock foodstuffs was 0.006% in arsenic, 0.000% in cadmium, 0.085% in lead, and 0.149% in mercury. Thus, these foods are as safe as satisfied with the recommended standards of JECFA. Relative hazard of Korean foods was 0.941% in arsenic, 14.676% in cadmium, 3.319% in lead, and 6.860% in mercury. Thus, Korean foods are also as safe as satisfied with the recommended standards of JECFA. The amount of heavy metal being consumed through livestock foodstuffs was relatively lower than the amount of heavy metal being consumed through other food groups from Food list for Korean. The amount of heavy metal being consumed by citizen through livestock foodstuffs and Korean foods was found to be in relatively safe level. The result of this research can be used for establishing the standards of livestock foodstuffs and the basic toxicity database for Korean foods.

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