

Investigation of Cadmium and Lead Contents in Iranian Rice Cultivated in Babol Region

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This investigation surveyed cadmium and lead contents of Iranian rice (*Oryza sativa*) which is predominant rice culture in north of Iran. A total of 72 samples were collected from rice farms in Babol region of Mazandaran province. The samples were collected during harvesting of rice in farm. Two methods were used for cooking; Kateh and Pilaw. The grains of raw polished and cooked rice were digested by acid digestion method and then were analyzed for Cd and Pb by atomic absorption spectrometry. The results showed that average content of Pb in raw polished rice was $11.5 \pm 6.4 \mu\text{g/g}$ dry wt. The minimum and maximum Pb content in raw polished rice was 2.92 ± 0.8 and $20.26 \pm 7.8 \mu\text{g/g}$ for Tarom Hashemi from Boleh Kola and Fajer from Meson Abad, respectively. Analysis showed that cadmium was not detectable in all rice samples. The average content of Pb in Pilaw was lower than Kateh in all samples. It is noted that the average content of Pb was found to be upper the FAO/WHO guidelines. To assess the safety of dietary intake, weekly intake of Pb by rice was calculated based on daily consumption of rice and dietary intake compared with the Provisional Tolerable Weekly Intake (PTWI) established by the JECFA (WHO/FAO). The results indicated that weekly intake lead was less than the maximum weekly intake recommended by WHO/FAO.

Key Words: Rice, Lead, Cadmium, *Oryza sativa*, Food.

INTRODUCTION

Heavy metals species are trace elements, because of their toxicity can have a serious impact, if released into environment as a result of bioaccumulation and they may be extremely toxic even in trace quantities¹⁻³. Heavy metals are widely used in industry. They enter to the environment from natural and anthropogenic sources. The fate of heavy metals in soils would be controlled by a complex set of physical, chemical and biological reactions acting within the soil and also their mobility largely depend on the form of heavy metals and their sources⁴. Finally, heavy metals can enter the food chain from aquatic and agricultural ecosystems

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and threaten human health indirectly. These metals contaminate food source and accumulate in both agricultural products and seafood through water, air and soil pollution. Some of these elements are toxic to humans even at considerably low concentrations. Especially, toxic trace heavy metals like cadmium and lead are known to pose a variety of health risks such as cancer, mutations or miscarriages⁵. Cadmium and lead are two of the most well-known environmental intoxicants to humans⁶. Cadmium accumulates readily in living systems. In humans it has been implicated as the cause of renal disturbances, lung insufficiency, bone lesions, cancer and hypertension⁷.

Rice is a cereal foodstuff that forms an important part of the diet of many people worldwide and as such, it is a staple food for many. It is also known that people, especially those who take rice as staple food for daily energy, are inevitably exposed to significant amounts of heavy metals because fertilizers that are used in farm, had amounts of heavy metals⁶. Rice were identified as the major source of cadmium intake among the victims of Itai-itai disease endemic in the Jinzu river Basin in Japan in the mid 20th century⁸. *Oryza sativa* is a family native to Iran.

Many varieties of rice are cultivated in Iran. In Iran, rice was grown in some areas of the southern shores of the Caspian sea (north of Iran). In other word, the main outturns or agriculture products are rice in the north of Iran, especially Babol. Farmers used some chemical fertilizer on rice farms to make rice plant grow better. Chemical fertilizers such as super phosphate have Cd and Pb and they can be the major source of cadmium uptake in rice⁶. According to the Codex Committee for Food Additives and Contaminants, dietary intakes of heavy metals with high public concern need to be monitored on a regular basis and rapidly updated to identify recent dietary intakes of heavy metals in developing countries⁹. Iran, as one of those developing countries, definitely needs a monitoring system to ensure a safe food supply⁹.

There have not been many studies conducted to estimate the content of heavy metals in food such as rice in Iran, while many countries have evaluated the level of heavy metals and their intakes^{4,10-19}. Therefore, the present study attempted to determine Cd and Pb contents of polished and cooked rice that cultivated in Babol region (Mazandaran province, North of Iran) and to evaluate the safety of weekly intake from rice.

EXPERIMENTAL

Rice samples were collected in six agriculture areas in Babol of Mazandaran province. The first step, samples were collected in rice farms when farmers harvested their crops. Five types of raw rice that are the famous and best quality of cultivated in this region were chosen. Because these rice are more delicious than other types of rice. Collections were made by chance. Each sample was randomly handpicked, wrapped in a sampling bag and labeled with date and site. A total of 72 barn rice samples were sampled from six major rice production areas that six samples collected from any area.

Preparation and cooking of samples: The seeds of the rice plant are first milled using a rice huller to remove the chaff (the outer husks of the grain). At this point in the process, the product is called brown rice. The milling was continued, removing the bran (*i.e.* the rest of the husk and the germ), thereby creating white rice. White rice often called polished rice. In the laboratory, each sample was washed with tap water and thereafter with distilled water and then dried in an oven at 80 °C.

Many methods used for rice cooking in Iran. Kateh and Pilaw cooking are the main cooking methods that were used in this research. Kateh is a simple Persian sticky-rice dish. For Kateh cooking, cook combines rice and salt. After that adds just enough water to rise above rice level to a depth of one inch. Over high heat, bring to a full rolling boil. Stir thoroughly with a fork, loosening grains of rice on the bottom of the pan. Reduce heat to a simmer, cover with a tight fitting lid, do not stir or peek for 20 min. After 20 min, turn off heat and let rice stand covered until ready to serve. Flake gently while transferring to serving dish. Kateh absorbs water during cooking. Pilaw method was made as following. The first, rice is mixed with more water than usual and enough salt. It place in a small saucepan or pot. Over high heat, bring to boil. When rice was parboiled, remaining water separated by a rice drainer. After that seived-parboiled rice is placed in a small pot or saucepan and is often heated in lower heat to steam remain water.

Sample analysis: To determine Cd and Pb contents in raw rice, a portion of rice grains cleaned and *ca.* 10 g were taken and weighed, dried at 105 °C for 48 h and weighed again to determine water content. Then, the sample was digested by a nitric-perchloric acid digestion method based on annual book of ASTM standards²⁰. Each rice sample was refluxes in a premixed solution of concentrated nitric acid and perchloric acid (70 %) (3+1) at the rate of 20 mL/g of sample. 2.5 mL of sulfuric acid (sp. gr. 1.84) was added per gram of sample. Then, the mixture was swirled and allowed it to stand for 0.5 h. Then, the beaker was covered with an acid washed watch glass, places it on a hot plate and gradually increased the temperature until the mixture is boiling. The boiling was continued until evaporation had occurred and perchloric acid fumes were evolved. The heating was terminated when about less than 3 mL of a clear liquid obtained. Afterwards, deionized water was added to bring the digest to 25 mL. The digested solution was analyzed for Cd and Pb contents by flame atomic absorption spectrometer (Perkin-Elmer pure atomic spectrometry). All samples were prepared and analyzed in triplicate. Concentrations were expressed in terms of µg/g on a dry weight basis. Analysis was done by SPSS program. Analysis of variance (ANOVA) followed by multiple comparison (Scheffe) were employed to detect significances between or among samples.

Estimation of Pb intake from rice: Weekly or daily Pb intake from rice was calculated by Cd and Pb contents in rice multiplied to weekly rice consumption⁸. Whenever possible, monitoring data from dietary intake studies are to be compared with acceptable or tolerable levels recommended by the Joint FAO/WHO Expert Committee on Food Additives. Hence, the total dietary exposure levels of Pb determined

in this study were compared with the provisional tolerable weekly intakes (PTWIs) by the JECFA to assess potential health risks faced by consumers²¹⁻²³. For toxicants that may accumulate in the body, such as lead, cadmium and mercury, the tolerable intakes are expressed on a weekly basis to allow for daily variations in intake levels because the real concern is prolonged exposure to the contaminants⁹.

RESULTS AND DISCUSSION

Lead and cadmium contents in raw polished rice: The results of lead and cadmium contents in 72 samples of raw polished rice from six areas are shown in Table-1 separately. These results indicated that the average content of Pb in rice was 11.5 ± 6.4 $\mu\text{g/g}$ dry wt. The minimum and maximum Pb content in raw rice was 2.92 ± 0.8 and 20.26 ± 7.8 $\mu\text{g/g}$ for Tarom Hashemi from Boleh Kola and Fajer from Meson Abad, respectively. ANOVA analysis showed that there was a significant difference in Pb contents in rice ($p < 0.05$). Fortunately, as shown in Table-1, analysis showed that cadmium was not detectable in all rice samples.

TABLE-1
LEAD AND CADMIUM CONTENTS IN RAW POLISHED RICE FROM
DIFFERENT PRODUCTION AREAS ($\mu\text{g/g}$ dry wt)

Variety name	Area name	Lead*	Cadmium
Fajer	Meson abad	2.92 ± 0.8	ND**
Fajer	Barikheh	4.1 ± 1.2	ND
Fajer	Darvish khial	20.17 ± 7.5	ND
Fajer	Boleh Kola	18.14 ± 6.2	ND
Khazar	Barikheh	4.29 ± 0.9	ND
Khazar	Rahkola	14.82 ± 4.8	ND
Khazar	Hamzahn Kola	15.24 ± 3.6	ND
Tarom Hashemi	Boleh Kola	20.26 ± 7.8	ND
Tarom Hashemi	Dedashat	3.79 ± 1.2	ND
Tarom Hashemi	Dedashat	9.72 ± 3.3	ND
Tarom Hashemi	Hamzeh kola	6.19 ± 2.3	ND
Sang Tarom	Dedashat	18.79 ± 6.7	ND
	Min	2.92 ± 0.8	ND
	Max	20.26 ± 7.8	ND
	Average \pm SD	11.5 ± 6.4	ND

*Averages \pm Standard Deviation; **ND = No detectable.

Fig. 1 shows the distribution of Pb content in various raw polished rice and reveals that 9 % of rice samples had Pb content below 3 $\mu\text{g/g}$ (less than WHO guideline), while almost of 9 % containing more than 20 $\mu\text{g/g}$ of Pb. Moreover, almost of 42 and 42 % samples had 3-10 and 10-20 $\mu\text{g/g}$ of Pb, respectively.

Effect of cooking method on Pb content: Table-2 shows that the results of measurement of Pb content in raw polished, cooked rice (Kateh and Pilaw dishes) for four types rice. As shown this table, the average content of Pb raw polished rice

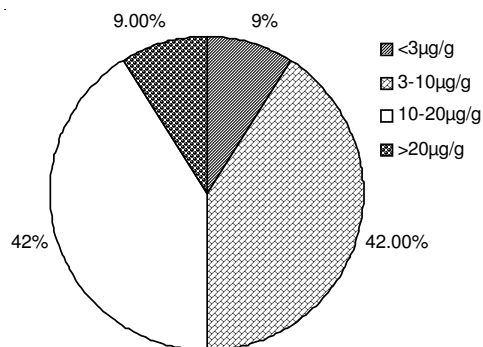


Fig. 1. Distribution of Pb contents in analyzed samples of rice

TABLE-2
EFFECT OF COOKING METHODS ON LEAD CONTENT COOKED RICE

Variety name	Area name	Pb (µg/g)			Remainder Pb in cooked rice (%)	
		Raw	Kateh	Pilaw	Kateh	Pilaw
Tarom Hashemi	Dedashat	9.72	5.5	2.7	56.58	27.78
Tarom Hashemi	Dedashat	3.79	2.2	1.09	58.05	28.76
Fajer	Darvishkhial	20.17	17.5	5.83	86.76	28.9
Fajer	Boleh Kola	18.14	16	4.17	88.2	22.99
Average ± SD		12.96±6.2	10.3±6.45	3.45±1.55	72.4±15.08	27.11±2.06

was higher than cooked rice (Kateh and Pilaw). In addition, the Pb content in Pilaw dishes was lower than Kateh dishes in all samples. Average per cent of remainder Pb in cooked rice was 72.4 ± 15.08 and 27.11 ± 2.06 for Kateh dish and Pilaw dish, respectively.

Evaluation of weekly intake of Pb: Table-3 shows weekly intake of Pb from rice. According to the published results⁸, daily consumption of rice in Asia countries ranges between 158-178 g/person-day and the average is 165 g/person-day and the average body weight is 60 kg/person. Table-3 reveals that mean weekly intake of Pb from rice at this study was 224.95, 200.85 and 67.23 µg/kg body weight/week for raw polished, Kateh and Pilaw rice, respectively.

TABLE-3
WEEKLY DIETARY INTAKE OF LEAD BY EATING RICE

Item	Min	Max	Average
Daily rice consumption (g/day)	158	178	165
Provisional tolerable weekly intake (µg/ week for an average 60 kg adult)	-	-	1500
Weekly Pb intake (µg/week for an average 60 kg adult) by			
Raw polished	53.82	441.10	224.95
Kateh	40.55	380.98	200.85
Pilaw	20.10	126.92	67.23

Lead and cadmium contents in raw polished rice: As shown in Table-1, the average content of Pb in raw polished was 11.5 ± 6.4 $\mu\text{g/g}$ dry weight and Cd content was not detectable. Although Cd content was not detectable but the mean value of Pb concentration in raw polished was more than the FAO/WHO guideline level. Therefore, the average content of Pb, in this study is over the maximum permitted level for rice compared with FAO/WHO Codex. According to the Joint FAO/WHO Expert Committee on Food Additives (JCEFA) that a maximum level of Cd has proposed 0.2 mg/kg in rice but the community warned that people who eat a lot of rice from regions containing the higher levels of cadmium could be significantly exposed. Joint FAO/WHO Expert Standards Program Codex Alimentation Commission (JCEFA)²² has proposed a maximum level of 0.3 mg/kg lead in rice.

As shown in Table-1, Pb contents are very different in the same varieties that have grown in the different farms because of heavy metals contents in rice depend on soil (moisture, pH), redox potential, weather conditions, using of fertilizer, water and contamination rate. Solubility of metals is known to increase with a decrease in soil pH and hence plant metal uptake is higher in acidic soils than in calcareous soils. Metal uptake due to soil pH under the present state is limited in both soils, but any reduction in pH soil in these farms could raise metal availability and metal uptake by plants, also which could increase health risk. It is also known that there is a linear relationship between metal availability and organic matter content²⁴. Study in other region of north Iran showed that average concentrations of Cd and Pb in rice were 0.41 ± 0.17 and 2.23 ± 18 $\mu\text{g/g}$ dry weight, respectively. In that study, the Cd and Pb content in the rice samples was found to be upper the FAO/WHO guidelines⁶.

Comparing the results in Table-1 with Cd and Pb contents of rice from other countries. The mean cadmium content values in rice reported to data are 50 ng/g dry weight for Japan⁸ in 1998-2000, 0.01 $\mu\text{g/g}$ dry weight to Taiwan¹³ in 2004. Whereas, Pb content was 2-3 and 10 ng/g in Japan⁸ and Taiwan¹³, respectively. It appears that the Cd content in Japanese rice were upper than Iranian rice. However, lead content was less than Iranian rice. The Pb content in rice samples from various countries¹³ ranged from 1.6 to 58.3 ng/g and the average content was 15.7 ng/g.

Effect of cooking method on Pb content: As shown Table-2, the average content of Pb raw polished rice was higher than cooked rice (Kateh and Pilaw) and the Pb content in Pilaw dishes was lower than Kateh dishes in all samples. It was expected that all Pb content remain in kateh rice because water is not drainage from rice and all water steam until rice change to sticky. However, water was drained in Pilaw method, so that a portion of Pb content transfer to boiled water by rice drainer. In addition, the mean value of Pb concentration in Kateh dishes was more than the FAO/WHO guideline level. However, in Pilaw dishes was approximately equal to the FAO/WHO guideline level.

Evaluation of weekly intake of Pb: The intake of Cd and Pb was estimated by multiplication of daily consumption with Cd and Pb contents in rice^{8,19}. The Codex committee on food additives and contaminants of the joint FAO/WHO food standards program has proposed draft levels for typical daily exposure and theoretical tolerable weekly intake (PTWI) for some of heavy metals in cereals such as rice. JECFA has set the Provisional Tolerable Weekly Intake (PTWI) for the Cd and Pb equal to 7 and 25 µg/kg of body weight, respectively²². As Cd content was not detectable in rice. Thus, there is not health risk of Cd due to rice consumption in this study. However, it is cleared in Table-3, the weekly intake of Pb *via* rice was less than the PTWI recommended by WHO/FAO in raw and cooked rice. The weekly intake of Pb from raw polished, Katch and Pilaw in this study was about 15, 13 and 4.5 % of PTWI, respectively.

Then, Pb intake may have health risk in future in Iran and this risk will increase with consumption of vegetable, fish, *etc.* Therefore, periodical monitoring of rate of contamination and consumption is necessary to assess the overall exposure level in community. In addition, it is been recommended to treat and remediate the polluted soils and environment by preventing of using more fertilizer for reduction in health risks. In conclusion, though Pb content in rice was upper than the WHO guidelines in this study, but the weekly intakes of Pb from rice was below the provisional tolerable weekly intakes recommended by WHO/FAO.

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