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Arsenic Intake through Consumed Rice in Iran: Markets Role or Government Responsibility

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ABSTRACT

Background: the present study investigated arsenic content in Iranian, imported rice on sale in Tabriz (fourth most populous city of Iran) market, and assesses daily arsenic intake from rice.
Methods: A total of 33 locally available rice samples from different brands were collected and then wet and dry ashing digestion procedures were compared for decomposition of them before analyzing by graphite furnace atomic absorption spectrometry (GFAAS).
Results: The mean arsenic concentration in Iranian rice was 0.065 mg/kg versus 0.082 mg/kg in imported samples. There was no significant difference between arsenic concentrations between two groups of samples (P=0.061).
The average daily ingestion rate of total arsenic was 0.11 and 0.15 µg/kg body weight from consumption of 110g of Iranian and imported rice respectively.
Conclusion: Based on our estimation, daily dietary intake of arsenic from Iranian and imported rice was approximately 7 and 9 µg/day for local population, respectively.All of the rice grains that were sampled from Tabriz market were low in total arsenic compared to the standard. Nonetheless regular monitoring of all rice varieties should be continued.

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Introduction

Arsenic is one of the serious health threaten materials which it progressively enter in humans daily dietary. Arsenic can be mobilized naturally in water and soils through weathering reactions, microbiological activities, geochemical reactions, volcanic emissions and other anthropogenic activities.[1]

In the environment, arsenic exists in the form of both organic and inorganic compounds. Inorganic arsenic species including As (III) and As (V), the most toxic forms due to their high bioavailability and toxicological effects, are classified as non-threshold, Class I human carcinogens.[2] The toxicity of arsenic to human health ranges from skin lesions to cancer of the brain, liver, kidney, and stomach.[3]

Although it is assumed that water is the major exposure pathway of inorganic arsenic, recent studies have indicated the worldwide concern about dietary arsenic exposure and the associated health risks.[4-6] The major amount of ingested arsenic comes from sea foods; however, only a small proportion of their arsenic content is in inorganic forms and a great majority of them are fortunately non-toxic arsenobetaine (AB) or arseno-sugars.[7,8] Thus, consumption of fish and seafood provides a relatively small share of dietary inorganic arsenic.[9]

In contrast to seafood, the rice plant bio-accumulates more toxic inorganic arsenic species, arsenate and arsenite.[10] It is generally grown under flooded conditions where arsenic mobility is high so rice is more problematic than other cereals in the accumulation of arsenic.[11,12] Additionally, rice is the dominant staple food for more than half of the world's population[13] particularly in the Asian countries which daily rice consumption was estimated up to 0.5 kg (dry weight) per person in these countries.[14] Noticeably, many of the rice producing/exporting countries suffer from arsenic contamination in their groundwater or soil[15,16] and studies from some of these countries report high levels of arsenic in rice.[14,17-19] Zavala and Duxbu-ry[14] reported that "the global normal range of arsenic in rice grain is 0.08 - 0.20 mg kg^{-1}".

In Iran, rice is the second source for supplying food after wheat that has increasingly been consumed since 1950.[20] Iranian people eat an average of 40 kg of rice every year. Although Iran is eleventh producer of rice at the world with an annual production 2600000 tons in 2010, during the last years the demand for rice has considerably been increased in comparison with its production, as a result, currently Iran is known as one of the large-scale importer of rice countries.[21]

Institute of Standard and Industrial Research of Iran set limit of 0.15 mg kg^{-1} as the maximum level for arsenic in rice.[22] In spite of cultivating of rice in Iran and importing from Asian countries, there are fewer evidences about arsenic levels in rice grain, which is consumed as the most important foodstuff in Iran.

Hence, the aim of this study was to evaluate the level of arsenic in rice samples collected from Tabriz City market as fourth most populous city of Iran.

Materials and Methods

Sampling, preparation, analysis

A total of 33 rice samples including local grown rice (n=15) and various brands of imported rice (n=17) were collected from main market of Tabriz City, northwestern Iran. Each sample package contained 2 kg of selected rice grains and assigned individual identification numbers for them. Characteristics of each sample were recorded on the packages and after carrying to the laboratory, stored for a short time e.g. three days in cool and dry place until they were analyzed.

Generally, there are three digestion methods for rice samples preparation for total arsenic analysis including wet acid digestion method (Wet ashing), Dry ashing and microwave digestion. In this study, wet ashing and dry ashing methods were compared and the appropriate digestion procedure with analysis apparatus was selected. Next, two different rice samples from each group were digested with both of these methods in parallel.

Wet ashing digestion: For digestion with wet ashing, 5 g from each sample were grinded using a hand mill. Afterwards mixtures of different acids, namely $HClO_4$ (10ml), H_2SO_4 (5ml) and concentrated HNO_3 (30ml) were added to 2 g of each ground samples and kept for 30 min at room temperature. Then each mixture was heated on the hot plate. Gently boil unit 3ml clear, transparent digests were obtained. After cooling, the resulting solution was diluted to 25ml with distilled water. Digested rice samples were collected in polyethylene bottles and kept at 4°C till further analysis.[23] An analytical blank digestion (without sample) was carried out through the complete procedure.

Dry ashing digestion: Five gram of oven-dried, milled and homogenous samples was weighted and placed in special ashing dishes and then was dry-ashed in furnace at a temperature of 450-500°C until white ash was remained. After cooling, the residue was dissolved in 1ml of diluted HNO_3 and filtered through filter paper (Whatman No. 540). Finally, the samples were diluted to 25ml with distilled water and collected in polyethylene bottles.[24] All the glassware and polyethylene bottles were washed with dilute nitric acid, then rinsed with de-ionized water, and dried in a dust free environment. As concentration in digested samples was determined using graphite furnace atomic absorption spectrometer (GFAAS, Buck Scientific, Inc. 210VGP model, USA). Arsenic standards at concentrations of 0, 1.0, 5.0, 10.0, 30.0 and 50.0 µg/l were prepared from serial dilutions of a 0.05 mol/l certified arsenic stock solution (Merck Co, Germany) and the analysis was carried out using calibration curves with correlation coefficients (R^2) of 0.999. To validate the reproducibility of method duplicate rice samples were prepared (RSD=5%). Standards were re-measured during each set of experiments to assess accuracy in measurements. Arsenic concentrations were calculated according to the following formula:

$$As(\mu g/g) = \frac{C(\mu g/L) \times V(mL)}{W(g) \times 1000} \quad (1)$$

Where C presents concentration of arsenic in digested sample solution (µg/l), V is mL of sample solution and W is sample weight. All of the results were reported in mg kg^{-1} Dry Weight of rice grains. The detection Limit (DL) for arsenic in the samples was found to be 0.005 mg/kg.

Daily intake of arsenic from two groups of rice samples was calculated as

$$EDI = (C \times DI)/W_{AB} \quad (2)$$

Where EDI is estimation daily intake (µg $day^{-1}kg^{-1}bw$); C is arsenic concentration in rice samples (µg/g); DI: average daily intake rate of rice (g/person/day) and W_{AB} is average body weight set to 60 kg in this study. Estimated daily intake was compared to the Provisional Tolerable Daily Intake (PTDI) for arsenic.

Statistical analysis

The data analyses were performed using SPSS 16.0 for Windows (Chicago, IL, USA). The independent *t* tests, at *a* = 0.05 levels of significance was used to compare the arsenic contaminations between two different rice groups.

Ethical Considerations

The study was approved by the review board of Tabriz University of medicalsciences.

Results

Selection of optimum digestion method

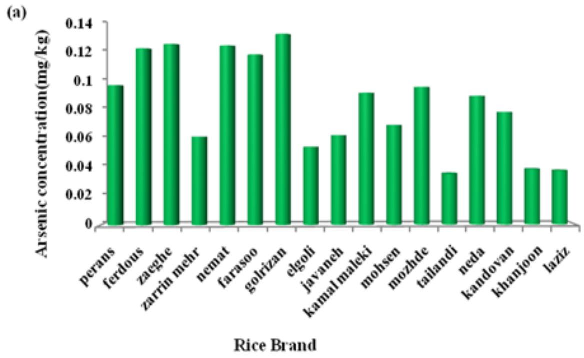
AAS technique has been accepted as the standard technique for metals determination since they offers satisfactory sensitivity and fairly low acquisition cost.[25] However when using wet ashing digestion method, because of mixing different type of concentrated acids in relatively high amounts, the result extraction solution was very acidic and damaged to graphite furnace. Therefore, the method was not appropriate for arsenic analyzing by graphite furnace atomic absorption technique. In contrast, dry digestion procedure had acceptable performance, provided better stability in analysis and was easier to use. Therefore was chosen as optimum method for the digestion of all the rice samples in this work, which was designed, for arsenic quantification in a general food chemistry laboratory. In the lack of microwave digestion system, dry digestion procedure can be compatible with analyzer system.

Arsenic contents in rice grain samples and potential health risk assessment

Arsenic contamination was detected in all 33 rice samples. Total arsenic concentrations ranged from 0.03-0.13 mg kg^{-1} among all analyzed samples. Because arsenic levels were low, only total arsenic concentration was determined in all 33 samples.

Distribution of total arsenic in the classified Iranian and imported rice grains has shown in Fig. 1. The mean arsenic content in the locally grown rice samples was 0.065 mg kg^{-1} (n=15, SD= 0.018 mg kg^{-1}, median 0.07 mg kg^{-1}, and range 0.03-0.09 mg kg^{-1}). However, in imported rice grains mean concentration was 0.082 mg kg^{-1} (n=17, SD=

0.03 mg kg^{-1}, median 0.09 mg kg^{-1}, and range 0.035-0.13 mg kg^{-1}).



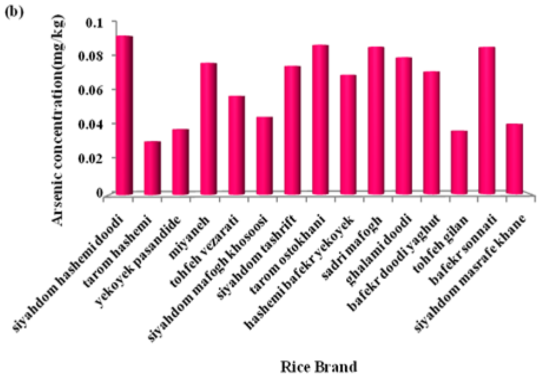


Fig. 1: The concentrations (mg kg^{-1}) of arsenic in imported (a) and Iranian (b) rice collected from Tabriz market

Almost 53% of imported rice samples had arsenic more than 0.082 mg kg^{-1} (average arsenic level in this group) while only 33% of Iranian grown samples containing more than average concentration.

Although the mean levels of arsenic in local produced rice was lower than the imported, there was no statistically significant difference between them (P=0.061).

In spite of arsenic presence in all samples, none has exceeded Iranian MCL for arsenic (i.e. 0.15 mg kg^{-1}).

To assess the potential health risks, Table 1 provides a comparison of estimated daily arsenic intake (EDI) from two groups of rice samples. We assume that a person (weighing 60 kg) consumes an average of 110 g per day of rice. The EDI for Iranian rice ranged from 0.055-0.165 (μg $day^{-1}kg^{-1}$bw), with a mean of 0.115 (μg $day^{-1}kg^{-1}$bw) and for imported samples ranged from 0.064-0.24 (μg $day^{-1}kg^{-1}$bw) with a mean of 0.151(μg $day^{-1}kg^{-1}$bw).

Table 1: Daily intake of Arsenic by consumption of 110 g of rice

Sample No	μg of As/kg	body weight/day
	Iranian rice	Imported rice
1	0.165	0.174
2	0.055	0.22
3	0.068	0.225
4	0.137	0.11
5	0.1	0.223
6	0.08	0.21
7	0.134	0.24
8	0.156	0.098
9	0.124	0.112
10	0.154	0.165
11	0.143	0.124
12	0.128	0.172
13	0.066	0.064
14	0.154	0.161
15	0.073	0.141
16	-	0.07
17	-	0.067

Discussion

Iranian people take rice as daily staple food and high amounts of rice must be supplied via local production and importing from other countries. Therefore, its safety is crucial issue and this study set out with the aim of assessing arsenic levels in rice samples of Tabriz market.

According to the obtained results, the average arsenic concentration in both Iranian cultivars and imported samples was less than the maximum concentration level for arsenic proposed by the Institute of Standards and Industrial Research of Iran (0.15 mg kg^{-1}). The highest total arsenic level (0.13 mg kg^{-1}) was observed for one of the Indian samples and the lowest value (0.03 mg kg^{-1}) was relevant to Iranian sample (Fig. 1). Similarly, average and maximum arsenic levels of 0.051 and 0.14 mg kg^{-1} were reported for different market available rice samples from Khorasan Province, in the Northeast of Iran.[26]

Rezaitabar et al. reported that the arsenic concentration in rice grains produced in Mazandaran Province on the Caspian Sea littoral, in the North of Iran was 0.39 mg kg^{-1} against 0.28 mg kg^{-1} of arsenic level in imported rice[27] which is noticeably higher than the results of present study. However, in consistent of our findings, the difference between the contents of arsenic in local and imported rice in their study was not significant.

One of the issues that emerge from these findings is need for further studies about the possible reasons for arsenic accumulation in Iranian rice grains and periodic monitoring of all rice varieties, which there are in people's food basket.

The average daily ingestion of total arsenic was 0.11 and 0.15 μg/kg body weight from consumption of 110g of Iranian and imported rice respectively.

The (PTDI) of 2.1 μg/kg body weight for inorganic arsenic had been established by Joint (FAO/WHO) Expert Committee on Food Additives (JECFA) which was withdrawn and replaced with a benchmark dose lower confidence limit for a 0.5% increased incidence of lung cancer in human (BMDL0.5) of 3 μg $day^{-1}kg^{-1}$bw (2-7 μg/kg bw per day based on the range of estimated total dietary exposure) in 2010.[28]

Inorganic arsenic in Asian and European rice is the dominate species.[14] Even if majority of the arsenic in analyzed rice samples being inorganic arsenic, contribution of these samples does not exceed 10% of the withdrawn PTDI even at the maximum exposure level.

Overall, for Iranian people who consumed about 100 g of rice per person per day, the estimated average daily intakes of arsenic from imported and local rice by adults were 9 and 7μgday^{-1} respectively. When 200g of rice with the same arsenic concentration was ingested, the exposure would be higher. Therefore, adaptation of appropriate control measures to ensure the safety of locally produced and specially imported rice is very important for consumer protection. As this issue requires cooperation between relevant agencies including the Ministry of Health-Medication & Medical Education, the Ministry of Industry, Mine and Trade, Agriculture Jihad Ministry, Institute of Standards and Industrial Research of Iran (ISIR) and Headquarters combat smuggling, the government has a key role in this regard.

One of the important elements to promote the quality and food safety is establishing and enforcing governmental rules, based on the standards and science and implementing health-promoting strategies to the extent possible.

Generation a system for registration and monitoring of activities about importation of foods by concerned authorities in collaboration with Ministry of Health as the lead agency for food safety can be used as a strategic plan in this regard. The identification of importers could be a first step. Then, the importer should notify and register the origin country, brand name, address of distributer, standard certification code and quantities of foods for brought it to the country.

This process followed by sampling and analysis of all rice consignments to the country by health inspectors and analysts of Food and Drug Organization, the Ministry of Health to certify them according to the latest Iranian National standards.

Apart from monitoring and surveillance program, the communication program could be in the form of regular meetings between responsible public agencies and private sectors such as importer's association to share information between stakeholders and introduce revised standards and governmental criteria for rice import into Iran.

Iran has already begun to implement the new standards and mandatory criteria for assurance of imported rice safety into Iran.

Conclusion

This study showed that arsenic intake from all analyzed rice was well below the lower limits on the benchmark dose for a 0.5% increased incidence of lung cancer (3-

μg $day^{-1}kg^{-1}$bw). Nevertheless, arsenic exposure from other dietary sources such as other cereals and vegetables should be survived and special attention should be paid to arsenic intake of children and high rice consumers.

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Competing interests

The authors declare that there is no conflict of interest.

References

1. Smedley PL, Nicolli HB, Macdonald DMJ, Barros AJ, Tullio JO. Hydrogeochemistry of arsenic and other inorganic constituents in groundwaters from La Pampa, Argentina. *Appl Geochem* 2002;17:259-284.
2. ATSDR (Agency for Toxic Substances and Disease Registry). Toxicological profile for arsenic.U.S.Department of Health and Human Services. Atlanta: Agency for Toxic Substances and Disease Registry;2007.
3. Thakur JK, Thakur RK, Ramanathan A, Kumar M, Kumar Singh S. Arsenic Contamination of Groundwater in Nepal-An Overview. *Water* 2011;3:1-20.
4. Das HK, Mitra AK, Sengupta PK, Hossain A, Islame F, Rabbani GH. Arsenic concentrations in rice, vegetables, and fish in Bangladesh: a preliminary study. *Environ Int* 2004;30:383-387.
5. Halder D, Bhowmick S, Biswas A, Mandal U, Nriagu J, Mazumdar DNG, et al. Consumption of brown rice:a potential pathway for arsenic exposure in rural Bengal. *Environ Sci Technol* 2012;46:4142-4148.
6. Wu X, Gao M, Wang L, Luo Y, Bi R, Li L, et al. The arsenic content in marketed seafood and associated health risks for the residents of Shandong, China. *Ecotoxicol Environ Saf* 2014;102:168-173.
7. Vahter M, Marafante E, Dencker L. Metabolism of arsenobetaine in mice, rats and rabbits. *Sci Total Environ* 1983;30:197-211.
8. Sakurai T, Kaise T, Ochi T, Saitoh T, Matsubara C. Study of in vitro cytotoxicity of a water soluble organic arsenic compound, arsenosugar, in seaweed. *Toxicology* 1997;122:205-212.
9. Borak J, Hosgood HD. Seafood arsenic: Implications for human risk assessment. *Regul Toxicol Pharmacol* 2007;47:204-212.
10. Williams PN, Price AH, Raab A, Hossain SA, Feldmann J, Meharg AA. Variation in arsenic speciation and concentration in paddy rice related to dietary exposure. *Environ Sci Technol* 2005;39:5531-5540.
11. Zhu YG, Williams PN, Meharg AA. Exposure to inorganic arsenic from rice: A global health issue? *Environ Pollut* 2008;154:169-171.
12. Williams PN, Villada A, Deacon C, Raab A, Figuerola J, Green AJ, et al. Greatly enhanced arsenic shoot assimilation in rice leads to elevated grain levels compared to wheat and barley. *Environ Sci Technol* 2007;41:6854-6859.
13. Lu Y, Dong F, Deacon C, Chen HJ, Raab A, Meharg AA. Arsenic accumulation and phosphorus status in two rice (Oryza sativa L.) cultivars surveyed from fields in South China. *Environ Pollut* 2010;158:1536-1541.
14. Zavala YJ, Duxbury JM. Arsenic in rice:I. Estimating normal levels of total arsenic in rice grain. *Environ Sci Technol* 2008;42:3856-3860.
15. Shraim AM. Rice is a potential dietary source of not only arsenic but also other toxic elements like lead and chromium. *Arabian Journal of Chemistry* 2014(In press).
16. Rahman MA, Hasegawa H. High levels of inorganic arsenic in rice in areas where arsenic-contaminated water is used for irrigation and cooking. *Sci Total Environ* 2011;409:4645-4655.
17. Williams PN, Islam MR, Adomako EE, Raab A, Hossain SA, Zhu YG, et al. Increase in rice grain arsenic for regions of Bangladesh irrigating paddies with ele-

vated arsenic in groundwaters. *Environ Sci Technol* 2006;40:4903-4908.

18. Roychowdhury T, Tokunaga H, Ando M. Survey of arsenic and other heavy metals in food composites and drinking water and estimation of dietary intake by the villagers from an arsenic-affected area of West Bengal, India. *Sci Total Environ* 2003;308:15-35.
19. Adomako EE, Williams PN, Deacon C, Meharg AA. Inorganic arsenic and trace elements in Ghanaian grain staples. *Environ Pollut* 2011;159:2435-2442.
20. Peykani GR, Kelashemi MK, Barikani SHS, Sasouli MR. Comparison of production productivity of 3 rice varietiesincluding long grain good quality, long grain high yielding and hybrid rice in Iran (Case study: Gilan province). *Am Eurasian J Agric Environ Sci* 2008;4:625-632.
21. Feizabadi Y. Study of rice marketing system in Iran. 85th Annual Conference of the Agricultural Economics Society Warwick University; 2011 April 18-20.
22. Pourgheysari H, Moazeni M, Ebrahimi A. Heavy metal content in edible salts in Isfahan and estimation of their daily intake via salt consumption. *Int J Env Health Eng* 2012;1(1):41-45.
23. Hodgson E. Bunyakiat K, Makmee S, Sawangkeaw R, Ngamprasertsith, S. Continuous production of biodiesel via transesterification from vegetable oils in supercritical methanol. *Energy & Fuels* 2006;20(2): 812-817.
24. Es'haghi Z, Khalili M, Khazaeifara A, Rounaghib GH. Simultaneous extraction and determination of lead, cadmium and copper in rice samples by a new pre-concentration technique: Hollow fiber solid phase microextraction combined with differential pulse anodic stripping voltammetry. *Electrochim Acta* 2011;56:3139-3146.
25. Janati SSF, Beheshti HR, Feizy J, Fahim NK. Determinations of cadmium, lead, arsenic and mercury in rice from Iran. *Int J Ind Chem* 2011;2:196-200.
26. Rezaitabar S, Esmaili-Sari A, Bahramifar N. Potential health risk of total arsenic from consumption of farm rice (Oryza sativa) from the Southern Caspian Sea littoral and from imported rice in Iran. *Bull Environ Contam Toxicol* 2012;88:614-616.
27. Rintala EM, Ekholm P, Koivisto P, Peltonen K, Venalainen ER. The intake of inorganic arsenic from long grain rice and rice-based baby food in Finland - Low safety margin warrants follow up. *Food Chem* 2014;150:199-205.
28. Qian Y, Chen C, Zhang Q, Li Y, Chen Z, Li M. Concentrations of cadmium, lead, mercury and arsenic in Chinese market milled rice and associated population health risk. *Food Control* 2010;21:1757-1763.