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Health Risk Assessment of Inorganic and Total Arsenic Content in Consumed Rice in Iran

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Abstract

Aim: Rice is one of the most important parts of human diet in the world, therefore it is necessary to determine its quality by measurements of hazard pollutants.

Materials and Methods: In this study, the health risk index and concentration of arsenic was calculated according to the per capita consumption of rice. Also, the risk of cancer was assessed using the risk assessment method for slope cancer.

Findings: the average concentration of iAs was 64, 80, 92, 99, 82 µg kg^{-1} and tAs was 370, 269, 214, 110, and 97 µg kg^{-1} for Argentina, Uruguay, USA, Iran, and India, respectively. The risk ratios for India are greater than one and indicate the potential health risk.

Conclusion: Carcinogenic risk values for total arsenic indicate that it is greater than $4X^{-10}$ in all countries and indicates a high risk of cancer for humans. On the other hand, the risk ratio index for rice imported from India, Uruguay, and Argentina is more than one and indicates the possibility of potential risk to the consumer. Carcinogenic risk values for total arsenic indicate that, imported rice is larger than $4X^{-10}$ and indicates a high risk of cancer in Iranian consumers. The risk ratio for rice imported from other countries is less than one and does not indicate the potential for risk to the consumer. Also, the carcinogenic risk values for the mineral arsenic show that, imported rice from other countries is less likely to indicate a risk of cancer in Iranian consumers.

Keywords: Inorganic and total arsenic • Rice • Hazard • Quotient • Cancer risk

Introduction

Rice is one of the most important agricultural products in the world [1]. Rice has been described as a natural arsenic accumulator. Diverse varieties of rice from all over the world grown on the same soil store up different amounts and species of arsenic [2]. The key to resolving arsenic accumulation in food plants lies in understanding the genes that control uptake from the soil and storage within the plant's edible portions. Due to the fact that rice is a plant in which the cumulative property of arsenic is more than other plants, thus arsenic in rice has become a health problem so that different communities have made the need to measure arsenic in rice mandatory [3]. The major source of arsenic in the environment back to its usage in arsenic-containing pesticides. Arsenic maintains in the soil for long periods of time like other metals and metalloids [4,5], where it can either absorb by plants or washed down into the groundwater, and leads to a threat to human health [6]. The baseline concentrations of As in rice are roughly 10-fold larger compared to other grains [7].

The previous studies show that two factors are account for concentrations of As in grain. First, As in paddy soils mostly occurs in arsenite form (its reduced form), which is more mobile than arsenate [8]. Second, recent evidence indicates that the uptake of arsenite by rice is mediated by the same transport system responsible for silicon (Si) absorption [9]. Chronic effects of exposure to inorganic arsenic through eating food and drinking water including skin injuries, mental disability, hypertension, peripheral vascular disease, cardiovascular disease, respiratory, and diabetes. Skin lesions are the most common chronic benign side effects associated with arsenic [10,11]. The toxicity of different species of arsenic is as follows: Monomethyl arsenite (III)> Dimethyl arsenite (III)> Arsenic (III)> Arsenic (V)> Monomethyl arsenite (V)> Dimethyl arsenite (V) [12]. Arsenic has mutagenic, teratogenic, genotoxic and neurotoxic effects that directly depends on the type of arsenic species and their oxidation states. Inorganic arsenic is classified as a carcinogen in group I, and trivalent arsenic (arsenite) is more toxic and mobile than pentavalent arsenic (arsenate) [13]. The type of arsenic in rice is mainly mineral arsenic (III & V), monomethyl arsenite (V) and dimethyl arsenite (V). The reference dose of mineral arsenic is 0.0003 mg/kg body weight per day. The toxicity of monomethyl arsenite (V) and dimethyl arsenite (V) is at least one hundred times lower than that of inorganic arsenic (III & V), so it seems reasonable to consider only the inorganic arsenic (III & V) to comment on the allowable limit of this element [14]. Therefore, it is suggested that the measurement of mineral arsenic replace the measurement of total arsenic. It should be noted that all reputable centers in the world use only mineral arsenic in rice as the basis for consumption decisions [15]. The only country that has set the permissible amount of mineral arsenic in rice is China with 150 micrograms per kilogram (ppb) and the codex has set the amount of 200 micrograms per kilogram (ppb)

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for mineral arsenic in rice. In Iran, total arsenic is in the range of 120-150 micrograms per kilogram (ppb) [16]. So far, different types of arsenic in rice produced in different countries have been evaluated and it has been found that in many of these cases, rice consumption has been unrestricted according to international standards. On the other hand, by imaging an element of rice grain, it has been determined that the highest amount of arsenic is in rice husk and rice germ. Health risk assessment generally consists of four steps including identification, dose-response assessment, exposure assessment and risk description. Assessing the exposure and determining the dose to the body is one of the most important steps in risk assessment [17]. Risk assessment is the process by which the likelihood and severity of damage, loss, or injury resulting from a potential health hazard or threat is estimated [18]. The purpose of the risk assessment is to look at the contamination of food, soil, air, water or sediment, to examine all possible ways in which the studied organisms are exposed to contamination, to estimate the amount of contaminant entering the body of the living creatures and to examine the effects. The hazard of heavy metals is mainly divided into two types of carcinogenic and non-carcinogenic effects [19]. In evaluating the non-carcinogenic effects of heavy metals, a function called Hazard Potential (THQ) is used, which is the ratio of the desired pollutant concentration to a standard value (RfD, Oral Reference Dose). RfD The daily entry of a contaminant into a person's body during his or her lifetime is without significant risk. RfD can be calculated from the division (NOAEL, No Observable Adverse Effect Level) on the safety factor between 10 and 100 and for comparison between species, as well as for studies related to chronic, semi-chronic and acute exposure to a single variable [20]. This factor is related to the extrapolation of the transfer of data related to animal experiments to humans. According to the above explanations, the aim of present study is collecting different information such as amount and type of arsenic in rice and its per capita consumption as well as comparing them in different countries in order to health risk assessment.

Materials and Methods

Apparatus

An HG 70 continuous-flow vapor system (Varian, Australia) equipped with a gas-liquid separator was used for AsH_3 generation. Determination of inorganic arsenic performed with a 20 plus Varian atomic absorption spectrometer with a hollow cathode lamp at a wavelength of 193.7 nm and slit 0.5 nm using an air–acetylene flame [21]. A flame heated quartz cell was employed for atomizing arsenic hydride to arsenic. The Agilent 7900 ICP-MS (Agilent Technologies, USA) with the Octopole Reaction System (ORS) collision/reaction cell (CRC) was used for the analysis of tAs in rice samples at m/z of 75.

Reagents

All chemicals were of analytical reagent grade unless otherwise stated. The As (V) stock standard solution (1000 mg L^{-1}) was obtained from Merck (Germany). Potassium iodide was prepared from Merck (Germany). Sodium meta-arsenite (Merck), was prepared in deionized water. Sodium borohydride (Merck) solutions were prepared fresh daily and were supplemented with 0.6% sodium hydroxide. Nitric acid solution was prepared from 63% HNO_3 (Merck). Argon (purity 99.999%) was prepared from Pars Balloon (Iran).

Sample preparation

The polished rice samples were obtained from the local market with different origins including Iran (IR), United States of America (USA), Argentina (AR), Uruguay (UR), and India (IN). The 100 g each polished rice samples were crushed and sieved through a 30 mesh strainer to make rice flour and 1.00 g of the rice flour sample was weighed into a polypropylene centrifuge tube (50 mL), 25 mL of 2.0 M HNO_3 was added, and the sample was vortexed for 30 seconds. To avoid the possible interference on As signal of the double ion ^{40}Ar, ^{35}Cl on the signal at mass 75, HCl was not used in any steps involved the extraction of the samples under study. The tightly capped tube was placed in an oven at 95°C for 5 hours where it was agitated for 30 seconds, every 60 minutes. After the extraction had finished, the sample was cooled at room temperature. The cooled rice flour suspension was centrifuged at 8000 rpm for 15 minutes and then the supernatant was passed through a 0.45 μm PTFE membrane filter. The filtrate was stored at 4°C and analyzed within 24 hours to minimize any species inter-conversion.

Determination of total As (tAs) and inorganic As (iAs)

For tAs determination in the samples, inductively coupled plasma mass spectrometry (ICP-MS) was used. For calibration, the external calibration curve using acidic solutions of As (V) in the range of 0.01-10 μg kg^{-1} was used for all determinations. For iAs determination in the samples, calibration curves were carried out using acidic solutions of As (V) in the range of 1-10 μg kg^{-1}. The curves were employed to determine the concentration of As (III) in sample solutions by using the absorbance measurement found in the presence of potassium iodide. The method involves the continuous generation of arsenic hydride from aqueous samples acidified with HCl to final concentration of 2 M, which were mixed with reducing agent and HCl. An arsenic hallow cathode lamp was used as a light source at 193.7 nm (band bass 1 nm) using an air-acetylene flame. The arsine was purged from the sample using argon to the heated quartz cell and after one minute, the absorbance of arsenic was determined.

The relationship between different speciation of As is given by:

$$tAs = iAs + oAs$$

Results

As shown in Table 1 the average concentration of iAs was 64, 80, 92, 99, 82 μg kg^{-1} and tAs were 370, 269, 214, 110, and 97 μg kg-1 for Argentina, Uruguay, USA, Iran, and India, respectively. Our results of arsenic level for Iranian rice were close to the Sharafi et al. (2019) findings, who revealed that average national concentration of arsenic 83 μg kg^{-1}, but Indian samples had higher concentration than this study.

Rice consumption per capita

China, the world's largest producer of rice, is also one of the largest consumers of rice. The country consumes about 160 million tons of rice annually. After the Asians, it is the South Americans and then the Africans who have taken the next positions in terms of per capita consumption. World rice consumption statistics also show that Iranians consume 7 times more rice than Europeans. The per capita consumption of rice in Iran is 39 kg per year, while the people of the European Union consume only 5 kg of rice per year. The average consumption of rice in the world is 57.2 kg, which is higher than in Iran. This figure is 68 kg in developing countries and 12 kg per year in developed countries. The per capita consumption of rice in some other countries is in kilograms per year: China 76, India 73, Japan 58, Egypt 42, USA 11, Russia 5. Thailand, India, China and Bangladesh with per capita consumption of more than 70 kg of rice in They are ranked first in the year, and Australia and Europe have the lowest rice consumption in the world with a per capita consumption of less than 10 kg.

Discussion

Due to the fact that the chemical form of arsenic is crucial for risk assessment, recently published scientific studies on the measurement methods

Table 1. Concentration ± SD of inorganic and total arsenic species in rice sample determined by HG-AAS and ICPMS.

Origin	Concentration (μg kg^{-1})	
	iAs ± SD by HGAAS	tAs ± SD by ICPMS
Argentina	64 ± 5	370 ± 14
Uruguay	80 ± 4	269 ± 7
USA	92 ± 5	214 ± 8
Iran	99 ± 25	110 ± 25
India	82 ± 4	97 ± 7

iAs = Inorganic arsenic, tAs = total arsenic, SD= standard deviation.

of different species have expanded significantly. The best way to measure element species is to ensure that there are generally no changes in the species, including the use of techniques that are able to make measurements in the sample tissue. However, few techniques are selective and sensitive enough to be able to quantify elements in small quantities. In practice, the measurement of different species of an element consists of two main stages of extraction and measurement, and these steps need to be properly optimized to ensure a minimum of changes in the species of elements, especially in complex matrices such as food (Such as measuring arsenic and total arsenic in rice). Some methods of measuring different types of arsenic in rice are:

The World Health Organization (WHO) and China have enacted legislation that sets the maximum levels of mineral arsenic in rice at 200 micrograms per kilogram and 150 micrograms per kilogram, respectively. The United States has not set a limit for the mineral arsenic in rice, but the US Food and Drug Administration (FDA) has begun projects to establish standard methods for determining mineral arsenic in food, and because rice is an important ingredient in a variety of materials. Food for infants and young children, the maximum amount of arsenic should be specified for rice and rice [16].

The maximum concentrations of total arsenic in different countries are given in Table 2. Studies show that the mineral arsenic is important in terms of toxicity. Although the average concentration of arsenic in brown rice is higher than in white rice, the risk of arsenic in white rice is higher because more white rice is eaten. In addition to skin cancer, mineral arsenic has been shown to cause lung and bladder cancer.

Health risk of consuming rice

Hazard quotient or Health Risk Index is calculated from the following equation:

$$HQ = \frac{CDI}{R_f DO}$$

$$CDI(mgkg^{-1}day^{-1}) = \frac{CF \times IR \times EF \times ED}{BW \times AT}$$

The rate of chronic arsenic consumption (CDI) is a function of its average concentration in rice, daily consumption dose of rice, and frequency of exposure (number of days), longevity and weight. However, since the average weight and average lifespan of maple in different communities is usually constant over a period of time, the two factors of arsenic concentration and daily consumption dose of rice play a decisive role in the amount of CDI. If the amount of HQ for each of the selected toxic elements is less than one, that element does not pose a significant risk of being toxic, and ratios greater than one for HQ indicates the potential for danger. The amount of oral reference dose (R_fDO) is determined by international institutions and its numerical value indicates the concentration of analyte that does not cause adverse effects during human life. For carcinogenic metals, the Cancer Slope Factor (CSF) risk assessment method is used, and for the formula for calculating the cancer slope factor (CSF) with 95% confidence in increasing the risk of cancer by contact with a potential cancer agent Gene that is consumed during human life is calculated from the following equation.

CR = Cancer Risk; CDI = Lifetime Average Daily Dose; CSF = Cancer Slope Factor;

$CR = CDI \times CFS$ The risk of cancer if the outcome (CR) is less than and equal to $6X^{-10}$ (less than one million people) is very low and the risk of carcinogenicity of the element can be neglected and if greater than $4X^{-10}$ indicates a high risk. On the other hand, ranges from $6X^{-10}$ to $4X^{-10}$, indicating a tolerable carcinogenic risk to humans. According to the information on rice consumption and total arsenic concentration in rice produced in that country, the risk ratio (HQ) for total arsenic was calculated [22,23]. As shown in Table 3, the risk ratios for Indian rice are higher than one and indicate the potential for danger. Carcinogenic risk values for total arsenic indicate that it is greater than $4X^{-10}$ in all countries and indicates a high risk of cancer in humans.

Table 2. Per capita consumption of rice, total arsenic concentration, inorganic and its allowable limit in different countries (14, 15).

Country	Micrograms per kilogram					
	Capita annual consumption (kg)	Classification of consumption	Maximum residue level of total arsenic	Maximum residue level of inorganic arsenic	Inorganic arsenic	Total arsenic
India	73	High	*	200	100	180
Iran	39	Medium	120	*	99	110
Uruguay	12	Low	300	200	80	269
Argentina	11	Low	300	200	64	370
U.S.A	11	Low	*	200	92	214

*No data was reported.

Table 3. Chronic intake, risk ratio and cancer risk index for total arsenic of rice in different countries

Country	mg kg^{-1} day^{-1}	mg kg^{-1}	Kg	HQ	Carcinogenic risk (CR)
	CDI	C (t-As)	IR		
India	0.0006	0.18	0.200	2.00	9.E-04
Iran	0.0002	0.11	0.107	0.65	3.E-04
Uruguay	0.0001	0.37	0.033	0.49	2.E-04
Argentina	0.0002	0.37	0.030	0.62	3.E-04
U.S.A	0.0001	0.214	0.030	0.36	2.E-04

Table 4. Chronic intake, risk ratio and cancer risk index for inorganic arsenic in rice in different countries.

Country	mg kg^{-1} day^{-1}	mg kg^{-1}	kg	HQ	Carcinogenic risk (CR)
	CDI	C (i-As)	IR		
India	0.000333	0.1	0.200	1.11	5.E-04
Iran	0.000176	0.099	0.107	0.59	3.E-04
Uruguay	0.000044	0.08	0.033	0.15	7.E-05
Argentina	0.000032	0.064	0.030	0.11	5.E-05
U.S.A	0.000046	0.092	0.030	0.15	7.E-05

Table 5. Chronic intake, risk ratio and cancer risk index for imported rice consumption in Iran relative to total arsenic concentration according to per capita consumption in Iran.

Country	mg kg^{-1} day^{-1}	mg kg^{-1}	kg	HQ	Carcinogenic risk (CR)
	CDI	C (t-As)	IR		
India	0.0003	0.18	0.107	1.07	5.E-04
Iran	0.0002	0.11	0.107	0.65	3.E-04
Uruguay	0.0005	0.269	0.107	1.60	7.E-04
Argentina	0.0007	0.37	0.107	2.20	1.E-03
U.S.A	0.0004	0.214	0.107	1.27	6.E-04

Table 6. Chronic intake, risk ratio and cancer risk index for imported rice consumption in Iran relative to inorganic arsenic concentration according to per capita consumption in Iran.

Country	mg kg^{-1} day^{-1}	mg kg^{-1}	kg	HQ	Carcinogenic risk (CR)
	CDI	C (i-As)	IR		
India	0.000178	0.1	0.107	0.59	3.E-04
Iran	0.000176	0.099	0.107	0.59	3.E-04
Uruguay	0.000142	0.08	0.107	0.47	2.E-04
Argentina	0.000114	0.064	0.107	0.38	2.E-04
U.S.A	0.000164	0.092	0.107	0.55	2.E-04

According to the information of rice consumption and concentration of mineral arsenic in rice produced in that country, the risk ratio (HQ) on mineral arsenic for the consumer of the same country was calculated. As can be seen in Table 4, only in India the risk ratios greater than one, indicating the potential for risk. Carcinogenicity values for total arsenic show that in India, Iran, respectively, it is greater than $4X^{-10}$ and indicates a high risk of cancer in humans.

According to the information on per capita rice consumption in Iran and the concentration of total arsenic in imported rice, the risk ratio (HQ) to total arsenic was calculated. As shown in Table 5, the risk ratio index for rice imported from India, Uruguay, Argentina is more than one and indicates the possibility of potential risk to the consumer. Carcinogenic risk values for total arsenic indicate that, imported rice is larger than $4X^{-10}$ and indicates a high risk of cancer in Iranian consumers. Another study conducted in Iran indicated that carcinogenic risk 7.919E-05 and 8.28E-05 for Iranian and Indian rice respectively [24]. This hazard can be due to industrial activities, burning of fossil fuels and follow as water and air pollution [25].

According to the information on per capita rice consumption in Iran and the concentration of mineral arsenic in imported rice, the risk ratio (HQ) for mineral arsenic was calculated. As can be seen in Table 6, the risk ratio for rice imported from other countries is less than one and does not indicate the potential for risk to the consumer. Also, the carcinogenic risk values for the mineral arsenic show that, imported rice from other countries is slightly larger than $4X^{-10}$ and are close to each other and are less likely to indicate a risk of cancer in Iranian consumers. On the other side,, the carcinogenic risk was similar to another study conducted in Iran [26].

Conclusion

Due to the scientific evidence and the much higher toxicity of inorganic arsenic the determination of permissible level of arsenic for consumers is necessary. According to the results, per capita rice consumption in Iran and the concentration of total arsenic in imported rice, the risk ratio index for rice imported from India, Uruguay, Argentina is more than one. On the other hand, the concentration of mineral arsenic in imported rice was only greater than one for rice imported from India, which indicates the possibility of potential risk. Also, the carcinogenic risk values for inorganic and organic arsenic show that, imported rice is larger than $4X^{-10}$ and indicates a high risk of cancer in Iranian consumers. As a suggestion people can significantly reduce the total arsenic and mineral content by washing rice before cooking.

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