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Evaluation of the Quality and Potential Risks of Imported Rice in Khuzestan Province

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KEYWORDS

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ABSTRACT: Rice is one of the most staple foods in the diet of people all over the world and the second most consumed food among the people in Iran. Therefore, it is expected this product be offered in suitable quality to the household food basket. In this study, microbial contamination, as well as concentrations of mycotoxins and heavy metals in imported rice samples available in the market of Ahvaz, were evaluated and the health risk of exposure to heavy metals was assessed in three groups of children, women, and men. According to the results, the contamination of rice with *Bacillus cereus* in all the samples was within the acceptable level set by Iran National Standards Organisation, but mold and yeast contamination in 14.28% of the samples was more than the acceptable level. Examination of mycotoxins showed that 71.42% of the samples contained aflatoxin B1 and total. Aflatoxin G1 and ochratoxin A were observed in 50% and 35.71% of the samples, respectively; the amount of these toxins in all the samples was less than the limit set by International NGO Safety Organization (INSO). Concentrations of cadmium, lead, and arsenic in the rice samples were 0.042±0.01, 0.14±0.03, and 0.13±0.03 (mg kg^{-1}), respectively. Estimation of daily intake (EDI) of the elements through rice was less than the provisional tolerable weekly intake (PTWI) recommended by Codex. Hazard quotient (HQ) and hazard index (HI) values were less than 1 in all three groups of women, men, and children. However, the cumulative risk of cancer for children, women, and men were 2.14×10^{3}, 7.40×10^{-4}, and 6.86×10^{-4}, respectively. Therefore, the imported rice was safe in terms of the amount of mycotoxins, but it can be a potential source for exposure to heavy metals.

INTRODUCTION

After wheat, rice (*Oryza sativa*) is the second most important food for many people in the world [1, 2]. It is estimated that more than 50% of the world's population consumes rice and two-thirds of the daily calories needed for the population of Asian countries are provided by rice [2–4]. According to the FAO reports, world rice production in 2014, was about 741.47 million tons. According to the reports of Iran's Ministry of Agriculture Jihad, in the 93-92 crop year, the area under cultivation of rice varieties in Iran was estimated at 539000 hectares, and among these, Mazandaran province with 37% (199366 hectares) of rice cultivation area, had the highest amount in the country [5,6]. The annual production of rice in Iran was estimated at about 2.5 million tons [7]. Considering the position of rice in providing food and calories needed by the people and the important role of this strategic product in the food basket of the people of

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the world, determining its quality and health is of great importance.

Today, food safety is an important issue around the world and contamination of agricultural products with mycotoxins and heavy metals is recognized as an important challenge for food safety [8,9]. Due to its nutritional value and high moisture absorption power, rice can be an ideal environment for the growth and development of fungal species, especially mycotoxin-producing fungi. Mycotoxins are secondary metabolites produced by certain types of molds such as *Aspergillus*, *Penicillium*, *Fusarium*, etc., which are produced in suitable conditions in agricultural products and food, and cause contamination [10]. Aflatoxins are the most well-known toxins among mycotoxins [11]. Mycotoxin production is affected by factors such as moisture content, water activity, temperature, storage time, ecological conditions, the initial level of contamination, ability to produce toxins of fungal species, and nature of the substance [8]. The presence of high levels of mycotoxins in the diet causes chronic and acute adverse effects in animals and humans. Therefore, reducing mycotoxins in food should be used as a part of programs to increase food security [10,12].

Furthermore, controlling the amount of heavy metals in rice is one of the other factors that should be considered to maintain the health of consumers. In general, all the elements in the environment come from two natural sources (Earth's crust) and human resources. For example, chemical fertilizers, animal manures, pesticides containing toxic elements, and agriculture with contaminated water are among the human factors for accumulating heavy metals in agricultural products [2,9,13]. In 2010, World Health Organization listed four elements (Hg, As, Cd, Pb) in the priority list of the ten most important chemicals related to the public health [14]. Heavy metals can enter the human body through the three main pathways: swallowing, inhalation, and skin contact. But food consumption has been identified as the main pathway (>90%) which exposes humans to toxic elements (arsenic, cadmium, lead, and mercury) and could cause major effects on general health such as renal and hepatic dysfunction, anemia, increased cardiovascular diseases, as well as neurological and skeletal problems [2]. Therefore, due to the high rate of rice consumption and its significant share in people's daily food basket, it is very important to study the content of mycotoxins and heavy metals in rice to ensure its health and safety; thus, it has been studied in various studies [10,15–18]. For example, the amount of heavy metals in Pakistani and Iranian rice was examined, and based on the results, the amount of these metals in Pakistani imported rice was higher compared to Iranian rice [18]. Also, the arsenic and cadmium contamination in Mazandaran province rice in 75% and 15% of the samples, respectively, were higher than the permitted range [5]. In another study, the aflatoxin B_1 contamination in about 20% of Kohgiluyeh and Boyer Ahmad and Khuzestan rice was higher than the permitted range [7].

Given that in Iran, accurate statistics on the prevalence of diseases caused by food and water as well as related risk factors have not been recorded, it seems necessary to identify various risk factors and their adverse effects on health. Since the Khuzestan province is one of the important points of import of imported rice, therefore, the general evaluation of the quality of imported rice in this province is a kind of indicator for measuring the safety of this product in the country. Therefore, due to the increasing consumption of imported rice, this study aimed to investigate the microbial contamination (*B.cereus*, mold, and yeast) as well as concentrations of mycotoxins (aflatoxin (AF), B_1, G_1, AF_{total}, ochratoxin A (OTA), zearalenone (ZEN), and deoxynivalenol (DON) and heavy metals (cadmium, lead, and arsenic) in imported raw rice samples available in the market of Ahvaz in 2020.

MATERIALS AND METHODS

Materials

To conduct this research, 14 samples of the imported rice were randomly purchased from the Ahvaz market (Khuzestan Province) in fall 2020. All samples of rice were imported from Pakistan and were marketed in 10 kg bags and their production date was not more than one year. All the chemicals were of laboratory grade and purchased from Merck Company (Merck, Germany).

Investigating microbial contamination

Mold and yeast

In this study, the number of mold and yeast in the rice samples was evaluated according to the guidelines set by Iran National Standards Organization (no. 10899). For this purpose, the surface culture of different dilutions (10^{-1}-10^{-4}) of the rice sample in Dichloran glycerol agar (DG18) culture medium was prepared and kept in an incubator for 5 to 7 days at 25 °C and, then, evaluated [19].

Bacillus cereus

Contamination of *B. cereus* in the samples was evaluated according to the guidelines set by Iran National Standards Organizations (no. 2324). After diluting the rice samples, the culture was performed in Mannitol egg yolk polymyxin agar (MYP agar). *B. cereus* was counted after 24-48 h of incubation at 30°C [20].

Measurement of mycotoxins

After grinding, the rice samples were homogenized using a 2 mm mesh sieve. Then, AF B_1, AF G_1, AF $_{total}$, OTA, ZEN, and DON tests were performed according to the guidelines set by Iran National Standards Organizations (nos. 6872, 9238, 9239, and 10215) by high performance liquid chromatography (HPLC, Shimadzu LC-20AD, Japan) and purification. Mycotoxins were extracted from the tested samples using methanol: water solvent (grade 3) with the ratio of 2: 8. Injection, isolation, and detection of mycotoxins were performed by the reverse phase method with high-performance liquid chromatography using reverse phase column, derivative, and fluorescence detector, respectively. The amount of mycotoxin was calculated by comparing the area under the standard curve with the unknown sample by calculating the dilution coefficient in μg kg^{-1} [8,21–24].

Measuring the concentration of heavy metals

Heavy metal concentrations were evaluated according to previously described method [15]. Briefly, the rice samples were washed with deionized water and dried in an oven at 105°C for 72 h. In the next step, the samples were ground and the resulting powder was homogenized by sieving by a 1 mm mesh. Then, 0.5 g of the powdered sample was digested in 4 ml of nitric acid and 1 ml of hydrogen peroxide. The samples were heated in a water bath for 2 h at 90°C. The digested samples were made up to 25 ml with deionized water and filtered on the Whatman paper. Finally, the samples were analyzed using an inductively coupled plasma optical emission spectrometer (ICP-OES, Arcos EOP, Spectro Corporation,Germany).

Potential health risks of heavy metals through rice consumption

Estimation of daily intake (EDI)

The amount of daily absorption of metals depends on the concentration of metal in the food and the amount of food consumed daily. In addition, a person's body weight can affect the tolerance of pollutants. EDI is a concept that has been proposed to consider these factors and is calculated by the following formula [25]:

$$EDI = E_F \times E_D \times F_{IR} \times C_m / W_{AB} \times T_a \qquad (1)$$

where EDI is equal to the estimation of daily intake of metals (μg kg^{-1} BW d^{-1}), C_m is concentration of heavy metals in rice consumed in mg/kg, E_D is duration of exposure, E_F is the frequency of exposure (365 days per year), F_{IR} is the rate of ingestion (g $person^{-1}$ per day), W_{AB} is average body weight (Kg), and Ta is the mean exposure time (70 years) calculated by multiplying E_F by E_D.

Non-carcinogenic risk

The hazard quotient (HQ) associated with rice consumption is defined as the ratio of EDI consumption of metals to the reference dose (RfD) for each metal. Reference doses for lead, cadmium, and arsenic were 0.0035, 0.001, and 0.003 μg kg^{-1} BW d^{-1}, respectively [26]. The HQ in this study was calculated by the following formula:

$$HQ = EDI / RfD \qquad (2)$$

where EDI is equal to the estimation of daily intake of metals (μg kg^{-1} BW per day); RfD is contaminant reference dose and indicates safety levels against oral administration for a lifetime (mg kg^{-1} per d).

In addition, the hazard index (HI) was measured by Equation 3. This index is the total risk for the sum of more than one HQ for a particular substance.

$$HI = \Sigma HQ \quad (3)$$

Incremental lifetime cancer risk (ILCR)

The risk of carcinogenicity indicates the possibility of an increase in cancer throughout a person's life due to exposure to a substance with carcinogenic potential. The carcinogenic risk was calculated using Equation 4:

$$ILCR = EDI \times CSF \quad (4)$$

where CSF is cancer slope factor for an average lifetime dose of 1 mg kg^{-1} body weight per day. CSFs for lead, cadmium, and arsenic were reported to be 0.0085, 6.3, and 1.5 μg kg^{-1} BW per day, respectively [25, 27].

In addition, cumulative carcinogenic risk (CCR) was measured by Equation 5.

$$CCR = ILCR_{Pb} + ILCR_{As} + ILCR_{Ca} \quad (5)$$

Statistical analysis

In this study, the experiments were performed in three replications. Statistical analyses were performed using SPSS 11.1 software. One-way analysis of variance (ANOVA) and Duncan's multiple test were used to evaluate the statistical differences between heavy metal concentrations. A sample t-test was used to compare the reference values with the obtained factors.

RESULTS AND DISCUSSION

Investigating microbial contamination

According to the results presented in Table 1, all the rice samples contained mold and yeast and *B. cereus*. As can be seen, the contamination of *B. cereus* infection in all the samples was less than the limit set by Iran National Standards Organization ($<10^2$). However, the amount of mold and yeast in 14.28% of the samples was more than the allowable limit. Lack of timely drying of rice and high final moisture content of rice caused microbial (fungal, bacterial) spoilage [18].

Table 1. Contamination of mold and yeast and *B. cereus* (cfu g^{-1}) of imported rice in Khuzestan province

#Sample	*Bacillus cereus*	Mold and yeast
1	$<10^2$	$<10^4$
2	$<10^2$	$<10^4$
3	$<10^2$	$<10^4$
4	$<10^2$	$>10^4$
5	$<10^2$	$<10^4$
6	$<10^2$	$<10^4$
7	$<10^2$	$<10^4$
8	$<10^2$	$<10^4$
9	$<10^2$	$<10^4$
10	$<10^2$	$<10^4$
11	$<10^2$	$>10^4$
12	$<10^2$	$<10^4$
13	$<10^2$	$<10^4$
14	$<10^2$	$<10^4$
Acceptable limit	$<10^2$	$<10^4$

Measurement of mycotoxins

The results of the evaluated mycotoxins in the rice samples are presented in Table 2. Based on the results, AFB_1 was observed in 71.42% of the rice samples with the highest value (1.27 μg kg^{-1}) in rice no. 7 and the lowest value (0.10 μg kg^{-1}) in rice no. 8. AFG_1 was also observed in 50% of the samples, with the highest (0.46 μg kg^{-1}) and lowest (0.07 μg kg^{-1}) levels in rice nos. 3 and 6, respectively. Rice contamination with AFB_1 and AFG_1 was within the allowable limit (5 μg kg^{-1}) set by International NGO Safety Organisation (INSO). Also, 71.42% of the rice samples contained AF total; in all the observations, it was less than the allowable limit set by the INSO (30 μg kg^{-1}). Ochratoxin was also observed in 35.71% of the samples in the range of 0.13 to 0.91, which was less than the allowable limit set by International Organization for Safety (5 μg kg^{-1}). The levels of ZEN and DON in all the samples were lower than the detection limit.

Table 2. Content of mycotoxins (μg kg^{-1}) of imported rice in Khuzestan province

# Sample	AFB_1	AFG_1	AF_{total}	ZEN	OTA	DON
1	0.34	ND	0.41	ND	ND	ND
2	ND	ND	ND	ND	ND	ND
3	1.09	0.46	1.63	ND	0.24	ND
4	ND	ND	ND	ND	ND	ND
5	0.11	0.07	0.18	ND	0.91	ND
6	0.14	0.10	0.27	ND	ND	ND
7	1.27	0.14	1.56	ND	ND	ND
8	0.10	ND	0.10	ND	ND	ND
9	ND	ND	ND	ND	ND	ND
10	0.71	0.33	1.04	ND	0.17	ND
11	ND	ND	ND	ND	ND	ND
12	0.68	ND	0.7	ND	ND	ND
13	0.43	0.11	0.61	ND	0.13	ND
14	1.04	0.23	1.38	ND	0.46	ND
Acceptable Limit	5	5	30	0	5	0

Due to the toxicity and high carcinogenicity of mycotoxins, more than one hundred countries in the world, including Iran, have strictly set a limit for mycotoxins in various foods. Therefore, due to the importance of this subject in various studies, the amount of these compounds in different foods has been evaluated. For example, in the study conducted by Mosayebi and Mirzaee (2014), the levels of AFB_1, AFB_2, OTA, and total AF in the rice imported to Golestan Province were investigated in Iran [8] . In a research, the amounts of AFB_1, B_2, G_1, G_2, and AF_{total} in Indian, Pakistani, and Iranian rice samples were within the allowable range specified in Iran National Standards Organization [18]. It was also reported that the average concentrations of aflatoxin B1 and Ochratoxin in Kohgiluyeh and Boyer Ahmad and Khuzestan rice were 4.70 ng g^{-1} and 2.02 ng g^{-1}, respectively [7]. It was also reported in another study that the mycotoxins contamination (AFB1, AFtotal, ZEN, and DON) in rice of Mazandaran province were within the permitted range specified in Iran National Standards Organization. However, in their study, the ochratoxin A contamination in 25% of the samples was higher than permitted range [5]. Differences in the results of some of these studies with the present study in terms of mycotoxin contamination can be affected by environmental conditions such as temperature, humidity, water activity, and conditions of movement, transportation, and storage until consumption [8].

In general, according to previous studies, in order to minimize rice contamination with various mycotoxins, it is necessary to observe a health control cycle from the farm to the consumer table. More specifically in imported rice, observing suitable handling and transportation conditions and suitable storage conditions (GSP) such as controlling the temperature of its storage warehouses (20°C) and controlling humidity are of special importance in reducing fungal contamination in rice [8].

Heavy metals in rice

According to studies, activities from various industries lead to the accumulation of heavy metals in the soil. After heavy metals are released into the environment, they are accumulated in plants and animals, as the result of which human health can be threatened through the consumption of grains, fruits, vegetables, and meat of animals contaminated with heavy metals [28]. Crops have a high ability to absorb and accumulate heavy metals and rice is one of the main products of heavy metals which enter the body[13,26,29]. In this study, the concentrations of cadmium, lead, and arsenic in 14 samples of imported rice in Khuzestan Province was investigated. The results of mean concentrations and deviations of Cd, As, and Pb criteria are presented in Figure 1. Cadmium is one of the most toxic heavy metals that has been identified as a carcinogen by International Agency for Research on Cancer (IARC) [30]. In addition, the accumulation of cadmium in the human body leads to complications such as high blood pressure, kidney disorders, as well as lung and bone lesions [31]. The use of cadmium-contaminated fertilizers in agricultural lands is the main source of this element in rice [32]. As can be seen in Figure 1a, the cadmium concentration in all the samples was significantly lower than the standard value set by the codex (0.4 mg kg^{-1}) [33]. In this study, minimum (0.011±0.001 mg kg^{-1}) and maximum (0.071±0.004 mg kg^{-1}) cadmium concentrations were observed in samples 7 and 11, respectively. In this study, the average concentration of cadmium (0.042±0.01 mg kg^{-1}) was calculated, which was lower than the standard.

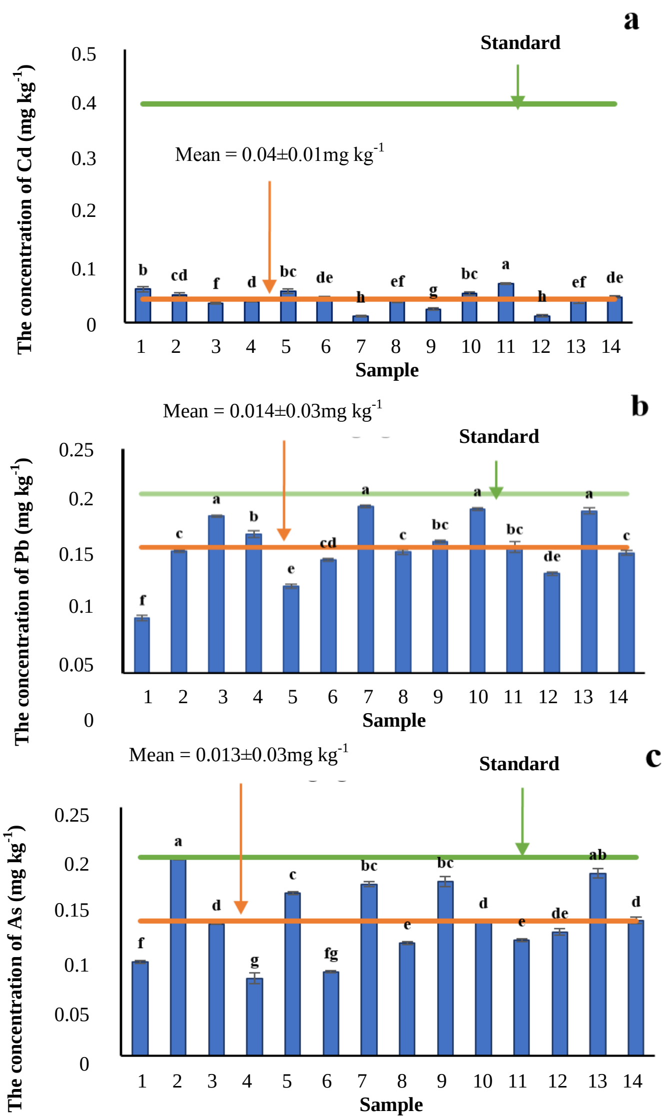

Figure 1. Content of heavy metal in imported rice samples. a) Cd; b) Pb and c) As.

Lead is an unnecessary element for the human body that is produced as the result of human activities such as gasoline production. Accumulation of this element in the body leads to kidney disorders, liver system disorders, delayed physical and mental development in children, hypertension in adults, cardiovascular damage, and inhibition of haemoglobin synthesis[32, 34] . As can be seen in Figure 1b, the lead concentration in all the samples was significantly lower than the standard value set by the codex (0.2 mg kg^{-1}) [33] . According to this study, the amount of lead concentration was significantly different between different samples of rice. The concentration of lead in the rice samples ranged from 0.061±0.002 mg kg^{-1} to 0.185±0.001 mg kg^{-1} and the average concentration of this element was 0.14±0.03 mg kg^{-1}, which was lower than the set standard [33] .

Arsenic is another important heavy metal in food products, the carcinogenic and non-carcinogenic effects of which have been reported by many researchers [9,32]. The use of fertilizers, fungicides, hormones, and irrigation by contaminated water has led to the release of large amounts of arsenic into the soil and accumulation of them in plant tissues [30, 32]. Due to anaerobic conditions in paddy soils, rice has a higher ability to absorb arsenic than other cereals [30]. As shown in Figure 1c, the concentration of arsenic in 92.85% of the samples was significantly lower than the allowable dose determined by the codex (0.2 mg kg^{-1}), but in 7.14% of the samples, it was not significantly different from the allowable dose. According to this study, the amount of arsenic concentration was significantly different between different rice samples. In this work, the concentration of arsenic in the rice samples was in the range of 0.077±0.001 to 0.197±0.005 mg kg^{-1} and the average concentration of this element was 0.13 ± 0.03 mg kg^{-1}, which was less than the allowable amount determined by the codex (0.2 mg kg^{-1}) [33].

Accumulation of heavy metals in rice is affected by various factors such as rice species, soil type, moisture, pH, and use of pesticides and chemical fertilizers [2,35,36] . White rice is one of the most basic foods in the diet of various people, especially in Asian countries, and the second most consumed food among the people of Iran. Moreover, heavy metal contamination is one of the food health concerns, so in recent years, extensive studies have been conducted to study these metals in rice. The amounts of cadmium and lead in rice in Iranshahr, southern east of Iran, were 0.0337±0.039 mg kg^{-1} and 0.123±0.14 mg kg^{-1}, respectively [32] . Based on the previous study, the concentrations of lead, cadmium, and arsenic in imported rice in Iran were reported as 0.56±0.56, 0.13±0.05, and 0.057±0.003 mg kg^{-1}, respectively [37]. Others also reported that the concentrations of Cd, Pb and As in imported rice (Indian and Pakistan cultivars) were higher than Iranian rice (Mazandaran, and Gilan cultivars) [18]. In another study, the amount of As and Cd in rice samples of Mazandaran province were in the range of (0.9-60 mg kg^{-1}), (2.6-5 mg kg^{-1}), respectively [5].

Evaluating exposure to heavy metals

EDI consumption of rice

In this study, exposure to heavy metals including Pb, Cd, and As from rice consumption was evaluated. For this purpose, the population of Iran was divided into 3 main categories: women, men, and children. The average body weight of the women, men, and children was 65.5, 71.5, and 23 kg, respectively [38]. According to the guidelines by Iran National Standards Organization (no. 12968), the daily consumption of rice was considered 110 g per day for each Iranian [39]. The EDI for assessing heavy metal exposure through rice consumption was determined based on the average heavy metals. According to the results, the EDI of cadmium for men, women, and children was 0.061, 0.066, and 0.191 μg kg^{-1} BW per day, respectively. Also, the EDI of lead and arsenic for men, women, and children was estimated as 0.215, 0.231, and 0.669 μg kg^{-1} BW per day as well as 0.200, 0.215, and 0.621 μg kg^{-1} BW per day, respectively. Because of the potential for toxic elements to accumulate in the body, the provisional tolerable weekly intake (PTWI) for each heavy element has been set by FAO/WHO Expert Committee on Food Additives (JECFA). In this study, the amount of **e**stimation of weekly intake (EWI) to the heavy metals (cadmium, lead, and arsenic) was estimated based on the EDI value and compared with the PTWI values set by World Health Organization. According to the results presented in Table 3, the highest EWI was related to lead, arsenic, and cadmium, respectively, and the highest exposure was observed for children, women, and men, respectively, due to weight differences. Although in general the amount of EWI of the studied metals through rice in all the three groups was less than the amount of PTWI, the important point was that the tolerable amount was recommended for the total diet. It should be noted that consuming other foods containing heavy metals such as fish, wheat, and vegetables can make the situation worse and may exceed this limit.

Table 3. Calculated values of estimation of daily intake (EDI) and estimation of weekly intake (EWI) via eating rice and the published values of provisional tolerable weekly intake (PTWI) by FAO/WHO

Element	EDI (μg kg^{-1} BW per d)			EWI (μg kg^{-1} BW per week)			PTWI(μg kg^{-1} BW per week)
	Child	Female	Male	child	Female	Male	
As	0.62	0.21	0.20	4.35	1.50	1.40	14
Cd	0.19	0.06	0.06	1.33	0.46	0.43	7
Pb	0.66	0.23	0.21	4.68	1.62	1.50	25

In recent years, various studies have been conducted to examine the "EDI and PTWI" for heavy metals through food consumption [9,40]. The EDI of Pb, Cd, and As through rice was examined and their amounts were 8.6×10^{-5}, 2.8×10^{-4}, and 1.2×10^{-3} µg kg^{-1} BW per day, respectively [32] . In addition to, the EWI of arsenic in three age groups of children, adolescents, and adults through white rice was 2.04×10^{-4}, 1.48×10^{-4}, and 1.36×10^{-4} µg kg^{-1} BW per week, respectively. This study reported that the EWI of dietary arsenic was less than the allowable limit recommended by WHO/FAO. In this work, the rate of absorption in children was higher than that in other groups, which confirmed the results of the present study [17].

Non-carcinogenic risk

Estimating the health risks associated with consuming heavy metals in the diet by consumers is a vital and integral part of regulatory processes. Non-carcinogenic risk assessments of the studied elements were evaluated using the EDI and RfD values of each element. In general, the safe range for non-cancerous health risks from heavy metals is 1.00. If the HQ is less than 1, there is no obvious risk; if the HQ is greater than 1, there are potential non-carcinogenic effects on the human health [26,40]. The results of HQ and HI calculated for the elements studied in this study are shown in Figure 2. According to the results, the highest amount of HQ was observed in children and the lowest was in men. Therefore, special attention should be paid to rice consumption by children. However, in this study, the mean HQ values for all the elements studied in all the groups were lower than the HQ threshold. These potential risk assessment results showed that rice consumption posed no risk to non-cancerous health for the adult and children populations.

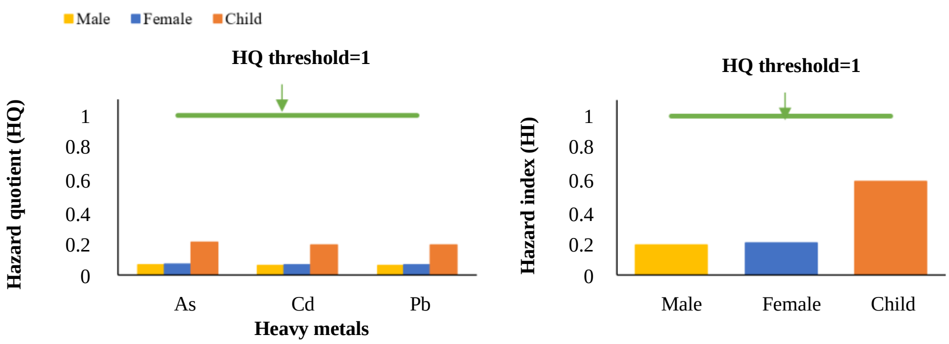

Figure 2. Non-carcinogenic risks due to intake of As, Pb, and Cd. A) HQ, B) HI

However, the non-carcinogenic health risks of exposure to individual heavy metals are not sufficient to describe the health risks of heavy metals, because according to previous studies, exposure to two or more contaminants may lead to additive effects and/or be interactive. Therefore, the cumulative health risk was assessed by collecting the HQ values of individual metals and reported as HI. In general, a HI value of higher than 1 indicates the potential for a negative impact of food on human health [31]. According to the results, the amount of HI was less than the acceptable range for all the three groups, which indicates no potential for non-carcinogenic health risks through exposure to heavy metals in this study.

Developmental effects, hard skin patches on the soles of the feet and palm of the hands, and cardiovascular diseases are examples of non-carcinogenic health risks [16]. Therefore, estimation of this index is very important and, in recent years, many studies have been conducted to assess the risk of non-carcinogenicity in various foods. For instant, the non-carcinogenic health risk of heavy metals in Iranshahr rice was investigated. Based on the results of their study, the HQ index was less than 1 [32], which is similar to the results of the present study. According to the other report, the amount of HQ for the individual studied metals was less than 1 in both children and adults. However, the HQ level of total elements in older adults was more than 1, which indicates the risk of non-cancerous health in this group [16].

Carcinogenic risk

The metals As, Cd, and Pb have been identified as carcinogenic heavy metals by the IARC[41], because chronic exposure of these metals, even to low doses, can lead to a variety of cancers in humans [25,42]. Based on the values set by Environmental Protection Agency (EPA), the ILCR range $<10^{-6}$, $>10^{-4}$, and $>10^{-3}$ is considered a safe limit, threshold risk, and considerable risk[25]. In general, the amount of ILCR in the range of 10^{-4} to 10^{-6} is acceptable [43,44]. The ILCR and CCR results calculated for the elements studied in this study are shown in Table 4. As can be seen, lead-induced ILCR was higher in children than in men and women; however, it was within the acceptable range (10^{-4}-10^{-6}). Therefore, in this study, there was no potential for cancer in women, men, and children through the lead. Examination of cadmium-induced ILCR showed that its value was above the threshold risk ($>10^{-4}$) for all the three groups. For children, this value exceeded the threshold and was in the considerable risk range ($>10^{-3}$). Therefore, there is a high potential for cancer in women, men, and especially children through cadmium. Arsenic-induced ILCR analysis showed that the value for all the three groups was above the threshold risk (10^{-4}) and its value was higher for children than other groups. Therefore, the arsenic metal in consumed rice had the potential to cause cancer in the long run.

Table 4. Carcinogenic risks due to intake of As, Pb and Cd in imported rice in Khuzestan province

Element	Incremental lifetime cancer risk (ILCR)			Cumulative carcinogenic risk (CCR)			Cancer Slope Factor (CSF)
	Child	Female	Male	child	Female	Male	
As	9.31×10^{-4}	3.22×10^{-4}	3.00×10^{-4}				1.50
Cd	1.20×10^{-3}	4.15×10^{-4}	3.84×10^{-4}	2.14×10^{-3}	7.40×10^{-4}	6.86×10^{-4}	6.30
Pb	5.69×10^{-6}	1.96×10^{-6}	1.83×10^{-6}				8.50×10^{-3}

In this study, CCR was also examined and the highest CCR rates were observed for children, women, and men, respectively. In this study, the CCR was higher than the threshold ($>10^{-4}$) for both men and women and was in the considerable risk range ($>10^{-3}$) for children, indicating the potential for carcinogenic risks through the exposure to heavy metals in imported rice of Khuzestan Province. Therefore, the health risk is high with the consumption of cadmium and lead through high-consumption imported rice in Khuzestan Province; this risk increases with the consumption of vegetables, fish, and other foods containing heavy metals.

According to studies, the prevalence of cancer has increased in recent years in the population of Iran [45] . Although the progression of cancer is influenced by various factors such as age, race, gender, etc., several studies have shown that exposure to environmental pollutants such as heavy metals like As, Pb, and Cd can increase the risk of cancer [42,46]. Therefore, estimating the ILCR index is very important and, in recent years, many studies have been conducted to assess the risk of carcinogenicity in various foods. According to previous report, the cumulative ILCR of arsenic and lead metals was higher than acceptable ($>10^{-4}$) for both adult and children groups [16]. In another study in Iran, the ILCR through rice consumption was estimated (2.37E-3), which was higher than the estimated ILCR in the present study. This means that consuming rice from Iranshahr market causes cancer risk for lifelong consumption. In their investigation, it was found that rice consumption in Iranshahr was a potential source for exposure to the considered elements [32]. Such local data are needed to increase global information and inform management agencies to facilitate decision-making and improve management strategies for these metals.

Carcinogenic effects usually occur over a long period of time and, according to the evidence, the increase in cancer among adults may occur as the result of exposure in childhood and, thus, lead to the increased risk of cancer in old age [47]. According to Food and Drug Administration, U.S. Department of Health and Human Services, exposure to heavy metals at an early age increases the risk of developing cancer more than exposure at older age [48]. Therefore, a risk reduction program should be considered to reduce the potential risk to children and adults; for this purpose, comprehensive environmental health programs and agricultural health policies can be used to reduce the use of pesticides and fertilizers, especially in the recommended major rice producers and exporters.

CONCLUSIONS

Khuzestan Province is one of the entry points for imported rice. This province with its numerous wharves is considered a place for the import of various types of rice into the country. Therefore, measuring the concentration of heavy metals and mycotoxins as well as studying microbial contamination in imported rice in Khuzestan Province is a kind of indicator for measuring the safety of this product in the country. Because contamination with heavy metals and mycotoxins is an important environmental problem and considered a food health concern in the world, this study aims to determine the content of heavy metals (lead, arsenic, and cadmium), mycotoxins (AFB_1, AFG_1, AF_{total}, OTA, ZEN, and DON), and microbial contamination (mold, yeast, and *B. cereus*) in imported rice of Khuzestan Province.

The results of this study showed that the *B. cereus* contamination of rice imported to Khuzestan Province was in accordance with the acceptable limit of Iran National Standards Organization. The contamination of mold and yeast in 14.28% of the samples was determined to be more than the allowable limit, which may be due to factors such as untimely drying of rice paddy, high final moisture content of rice, or poor storage conditions of these samples. Examination of mycotoxins also showed that the amounts of AFB_1, AFG_1, AF_{total}, and OTA were acceptable according to Iran National Standards Organization and the European Union. In addition, in this study, ZEN and DON were not identified in any of the samples. The concentrations of cadmium and lead in all the rice samples were lower than the limit set by Codex, but the amount of arsenic in 7.14% of the samples was close to the allowable level. Also, the average concentrations of cadmium, lead, and arsenic in the rice samples were 0.042±0.01 mg kg^{-1}, 0.14±0.03 mg kg^{-1}, and 0.13±0.03 mg kg^{-1}, respectively, which was lower than the limit set by Codex. From the perspective of human health, the EWI of each element through rice for men, women, and children in this study (taking into account the consumption of 110 g of rice per day in accordance with Iran National Standards Organization and weights 71.5, 66.5, and 23 kg for women, men and children, respectively) were 0.430, 0.462, and 1.337 μg kg^{-1} BW $week^1$, 1.507, 1.620, and 4.686 μg kg^{-1} BW $week^1$, and 1.400, 1.505, and 4.351 μg kg^{-1} BW $week^1$, which was less than the PTWI recommended by the WHO/FAO.

The HQ values for the individual elements and the HI values for the combined elements were less than 1 in all the three groups of women, men, and children, so it can be stated that rice consumption through the consumption of individual elements or combined elements posed no risk to non-carcinogenic health of consumers. However, the risk of cancer due to arsenic and cadmium exposure in all the three groups, especially children, was worrying because the ILCR values were too high at 10^{-4}. In addition, CCR for women and men was estimated to be 7.40×10^{-4} and 6.86×10^{-4}, respectively, which was higher than acceptable. The CCR for children was about 2.14 $\times10^{-3}$, which was in the high-risk range. The results of this study showed that although the concentration of the studied elements in the rice samples was less than the allowable level, the people of Khuzestan, especially those who consume rice as the main source of daily energy, are inevitably exposed to significant amounts of heavy metals (cadmium, arsenic, and lead) through rice consumption. Therefore, the consumption of imported rice in Khuzestan is a health risk according to the CCR, determined especially for children, and should be more important as a public health concern. This can also be exacerbated by using other contaminated foods, so it needs more careful consideration.

CONFLICT OF INTERESTS

No conflict of interest is declared.

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