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Survey of Heavy Metals Residue (Ni and Cr) in raw Tarom rice and evaluation of cooking methods effects on the concentrations of these metals

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Abstract:

Introduction: Consumption of food contaminated by heavy metals, especially nickel and chromium, cause adverse effects on human health, including impairment of renal function, met-hemoglobinemia, cirrhosis, and many other intoxication consequences. Since rice is one of the main meals of Iranian people, this project was conducted to determine the amount of contamination of nickel and chromium in rice, and to find how the cooking process may be effective on these elements.
Materials and Methods: Five samples were collected randomly from five geographic regions of Qaemshahr (i.e., North, South, East, West, and Center). Residues of nickel and chromium in raw and cooked rice were determined by the flame atomic absorption spectrophotometer (FAAS). Statistical analyses were done by SPSS V.18 software, and the mean values of groups were comprised by ANOVA software.
Results: The average values of nickel / chromium were 0.174 ±0.01 for raw rice and 0.036±000 for the rinsing water of cooked rice. The amount of these elements in the cooked rice by the "Virgo" cooking method was 0.12 ±0.0311 and for the "kateh" method (ordinary cooking of rice) was 0.142±0.035, respectively.
Conclusion: The results indicated that the cooking processes of Virgo and Kateh methods had positive impacts on reducing the amount of nickel / chromium compared to the raw rice.

Keywords: Raw Rice; Heavy Metals; Cooking process; Chromium / nickel; Atomic absorption flame spectrophotometer

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1. Introduction

Heavy metals are trace elements with harmful effects because of their toxicity. If they enter into the environment as a result of bioaccumulation , trace elements may be extremely toxic even in their trace amounts [1-3]. Heavy metals are extensively used in the industry. They are released to the environment from natural and anthropogenic sources. These metals can enter the food chain from aquatic and agricultural ecosystems, threatening human health and life indirectly. Heavy metals, such as chromium and nickel, have bioaccumulation characteristics in the tissues of living creatures, including human beings, animals, plants, and fish through water, air, and soil pollution. Hence, the risk of consuming even low amounts of contaminated food by these elements is high [1, 2].chromium and nickel are two of the most well-known environmental intoxicants to humans[4].

Toxic effects of chromium on plant growth is observed in the germination process, as well as the growth of roots, stems, and leaves. Germination is the first physiological stage that is affected by chromium. Reducing germination due to chromium stress is the result of reducing the activity of the amylase enzyme. Impeding cell division caused by the heavy metals in the plant roots can affect the growth of roots. Chromium has adverse effects on the growth of the aboveground parts of plants. The main reason for that is the reduction in the root growth and consequently transferring less water and nutrition to the aboveground parts of the plants. Moreover, transferring chromium to the aboveground parts has direct effects on the cellular metabolism. Also, chromium has adverse effects on the physiological processes such as photosynthesis, water relations, and mineral intakes. Effects of chromium in different stages of photosynthesis include stabilizing carbon dioxide, electron transfer, optical phosphorylation, and enzyme activities. Due to structural similarity with some of the essential elements, chromium can also be effective in plant mineral feedings. Metabolic changes are also made by chromium in plants. These changes are applied via direct effects of this metal on enzymes, metabolites, or its capability in producing reactive oxygen species and causing oxidative stress. Oxidative stress leads to cellular damages. Chromium also affects the activities of catalase, peroxidase, cytochrome oxidase, and nitrate reductase enzymes. Accumulation of metal ions by the plant affects the inner cells ionic hemostasis [5,6]. Other important toxic effects, apart from contacting, inhalation, or ingestion of hexavalent chromium compounds, are as follows: dermatitis, allergic and eczematous skin reactions, skin and mucous membrane ulcerations, perforation of the nasal septum, allergic asthmatic reactions, bronchial carcinomas, gastro-enteritis, hepatocellular deficiency, and renal oligoanuric deficiency [7].

Nickel-induced toxicity and carcinogenicity with an emphasis on the generation and role of reactive oxygen species is reviewed. Nickel is a known haematotoxic, immunotoxic, neurotoxic, genotoxic, reproductive toxic, pulmonary toxic, nephrotoxic, hepatotoxic and carcinogenic agent [8].

Carcinogenic effects of chromium and nickel depend on the rate and method of their absorption, and their risks are increased in the long-term occupations involving respiration. According to some reports by Yuan TH, nickel and chromium are effective in causing gastric cancer [5,10,11].

Enzyme prohibition in producing the morphologic changes and even death is reported due to toxic effects of heavy metals such as nickel and chromium in subcellular levels. Chromium and nickel affect the hematopoiesis system by reducing the volume of blood production. Moreover, they cause neural toxicity as well as chronic renal toxicity, causing fertility disorders in men. They have also been reported in carcinogenic disorders [12].

The risk of heavy metal contamination exists in every agricultural product, and the gradual accumulation of these toxicities cause adverse effects on different organs in the body . The important point to be noticed is that the prominent property of these metals is their stability, and they do not dissolve like most of the organic materials during biological and chemical processes. Thus, they cause irrevocable damages by the concentration and accumulation of these metals in the foods and environment.

Rice, especially white rice, is a cereal foodstuff that forms an important part of the diet of various people, including the Chinese, Japanese, Korean, Iranian people, and other Asian nations. It is to note that people, especially those who take rice as their staple food for daily energy, are unavoidably exposed to significant amounts of heavy metals because the fertilizers that are used in the farms have extensive amounts of heavy metals [5] . Rice is one of the major agricultural products in the international markets [13]. Variety of rice, its treatment, and diversity of cooking techniques may affect elemental content and intake of heavy metals [13].Thus, the detection of heavy metal concentrations in food products and their dietary intake is very important for assessing their risk to public health [14]. The main sources of heavy metal contamination in agricultural crops are irrigation with contaminated water, fertilizers, metal based pesticides, industrial emissions, transportation, harvesting process, and storage of crops [15, 16, 17].

There are various studies in the world on the heavy metal contents in rice, but no comprehensive studies are available about providing approaches in minimizing the contents of the metals in rice in Iran. With the cultivation area of about 400 thousand hectares out of a total of 650 thousand hectares, Gilan and Mazandaran provinces are the main lands in the country in cultivating rice. Regarding dangerous effects in the human body in consuming contaminated rice to heavy metals, and also extensive consumption of this agricultural product as a popular food in Iran, this study is done to analyze the residues of heavy metals (nickel and chromium) in Tarom rice and assess the effect of cooking process on reducing the rate of this contamination. This study also aims to present an optimized method for cooking rice.

2. Materials & Methods

2.1. Used Substance:

All the prepared substances and solutions are from Merck Co. (Germany). The substances include standard nickel/chromium solution with a density of (1000 mg/l), perchloric acid, sulfuric acid and nitric acid. The electric conductivity of deionized distilled water used in this test was less than 0.05µs. All the relevant laboratory vessels were washed with nitric acid (5%) to eliminate any possible contaminations and rinsed then with deionized water.

2.2. Equipment:

The level of absorption was measured by Zeiss Flame Atomic Absorption Spectrophotometer (FAAS) (Rayleigh Co. – China). Deionized distilled water used in the analysis was prepared by Direct Q Deionizer (Millipore Co.).

2.3. Sampling:

The city of Qaemshahr was first categorized into 5 geographic regions (North, South, East, West, and the Center). 5 mixed compound samples (1 Kg) were randomly selected from each region. Thus, a total of 25 samples were collected and transferred to the laboratory.

2.4. Samples preparation:

Preparation of samples for measuring heavy metals was done according to the acidic digestion method.
All the vessels were acid washed, then rinsed by deionized water, and dried in an oven to eliminate possible contaminations. To prepare the samples, 2 + 0.0001g of rice was weighed from each sample and left in a place with the temperature of 105˚C for 48 hours. Then, 10ml of perchloric acid (70%), 5ml of sulfuric acid (70%), and 30ml of nitric acid (70%) were added to each sample and kept for half an hour in the laboratory temperature. Then, each sample was placed in a heater to boil slowly to obtain a transparent solution with a volume of 3ml. After that, the samples were reached 25ml volume by adding deionized distilled water. After proper calibration of different parts of the apparatus and being assured from stabilization and unchanged conditions, the values were read from the apparatus.

2.4.1. Raw rice

In this method, 2 $\pm$ 0.0001g of raw rice was primarily weighed with Analytical Precision Scale and placed at 105˚C temperature for 48 hours. Then, 10ml of perchloric acid (70%), 5ml of sulfuric acid (70%), and 30ml of nitric acid (70%) were added to each sample and kept for half an hour in the laboratory temperature. The solutions were then placed in a heater to boil slowly to obtain a transparent solution with a volume of 3ml. After that, the samples were reached 25ml volume by adding deionized distilled water. After proper calibration of different parts of the apparatus and being assured from the stabilization and unchanged conditions, the values were read from the apparatus.

2.4.2. Cooked rice with rinsed method (pilaw)

According to this method, 25g of raw rice was weighed by an analytical precision scale and washed 3 times with 20ml of deionized water. Then, 100ml of deionized distilled water was added to the rice, left for some time. After that, the rice was cooked by the rinsed method, and then the cooked rice was placed at 105˚C temperature to completely dry. The amount of 2g cooked and dried rice was weighed with an analytical precision scale. 10ml of perchloric acid (70%), 5ml of sulfuric acid, and 30ml of nitric acid (65%) were then added and kept then for half an hour at the laboratory temperature. The solutions were then placed in a heater to boil slowly to obtain a transparent solution with a volume of 3ml. After that, the samples were reached 25ml volume by adding deionized distilled water. After proper calibration of different parts of the apparatus and assuring from stabilizing and unchanged conditions, the values were read from the apparatus.

2.4.3. Rice water (Rinsing water)

In this method, 25g of raw rice was weighed by an analytical precision scale and washed 3 times with 20ml of deionized water. After that, 100ml of deionized distilled water was added to the rice and left for some time. The rice was cooked and then rinsed. The cooked rice water was added to a boiling Bain Marie (boiling water bath) as some of the excess water evaporates and the minerals remain. Then, for more assurance regarding the evaporation of the existing water, it will be kept in an oven at 105˚C. 10ml of perchloric acid (70%), 5ml of sulfuric acid, 30ml of nitric acid (65%) were added to the remaining dried part and kept for half an hour at the laboratory temperature. Then, it was placed in a heater for the solution to boil slowly, and a transparent solution with the volume of 3ml was obtained. Deionized distilled water was then added to the solution for its volume to become 25mL. After proper calibration of different parts of the apparatus and assuring from stabilizing and unchanged conditions, the values were read from the apparatus.

2.4.4. Cooked rice by “Kateh” method (stewed)

In “Kateh” method, 25g of raw rice was weighed by an analytical precision scale and washed 3 times with 20ml of deionized water. After that, 100ml of deionized distilled water was added to the rice and left for some time. Then, the rice was cooked by “kateh” method and the cooked rice was placed at 105˚C temperature, for the existing humidity of the rice to be completely removed. 2g of the cooked rice was weighed by an analytical precision scale , 10ml of perchloric acid (70%), 5ml of sulfuric acid, and 30ml of nitric acid (65%) were added and left for half an hour at the laboratory temperature. Then, the rice was placed in a heater to boil slowly, and obtain a transparent solution with a volume of 3ml. Deionized distilled water was then added to the solution for its volume to reach 25ml. After proper calibration of different parts of the apparatus and assuring from stabilizing and unchanged conditions, the values were read from the apparatus [18,19].

2.5. Kateh method:

The difference between kateh and pilaw methods:
In cooking "kateh" rice, 25 grams of each sample were taken and washed in deionized water. Then, 200cc of deionized water was added to rice grains in a beaker, brought to boil and heated for 40mins. After 40 minutes, the temperature was reduced until all the water evaporated.
However, for "pilaw rice", the heat was turned off after 40 minutes, and the rice was separated from water by a drainer.

2.6. Measuring the rate of absorption:

The standard solutions for nickel and chromium were prepared in densities o.5mg/l, 1mg/l, 1.5mg/l, 2mg/l, and 2.5mg/l using 1000mg/l (1000mg/l) of principle standard solution. The level of absorption of standard solutions was determined by the aid of a relevant metal hollow cathode lamp, using Flame Atomic Absorption Spectrophotometer (FAAS) in the measuring wavelengths and calibration curves, respectively.
In this study, the LOD (limit of detection) of the device, i.e., the minimum amount to be detected, is estimated to be 0.001. Also, LOQ (limit of quantitation) for heavy metals, i.e., the minimum amount to be measured was 0.118ppm for chromium and 0.02 ppm for nickel. The percentages of recovery for the two metals were 98.85% and 99.735% for chromium and nickel, respectively.
In order to validate the data, the optical density (light absorption) of each sample was measured three times.
LOD[1], LOQ[2], and Recovery:
The minimum measurable value (limit of quantitation-LOQW) of the apparatus, i.e., the limit of detection (LOD), was equal to 0.001. Also, the LODs in this study for the heavy metals were as follows:

Cr	0.118ppm	Qaemshahr
Ni	0.02 ppm	Qaemshahr

The rate of recovery for the two studied metals is as follows:

Cr	98.85%
Ni	99.735%

2.7. Working conditions with atomic abruption apparatus

Calibration curves were drawn for both cadmium and chromium.

[1] -limit of detection
[2]-limit of quantitation

Chromium calibration curve:

After complete calibration of different parts of the apparatus and assuring from stabilizing and the unchanged apparatus conditions during the measurement, the calibration curve with the rate of optical absorption was drawn for the wavelength of 719 nanometer and standard solutions of 0.5,1, 1.5, 2 , 2.5,3,3.5,4,4.5, and 5 µg/ml.
Chromium calibration curve is shown in Fig. 1.

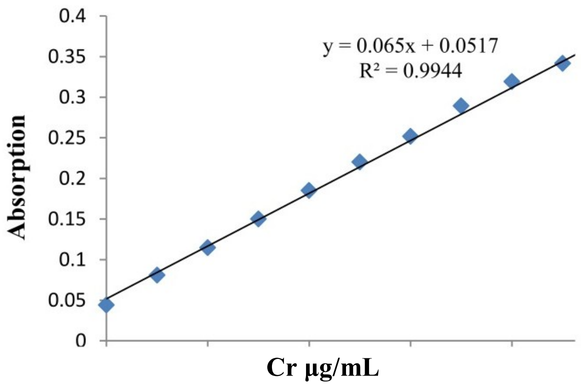

Figure 1: Chromium calibration curve

Nickel calibration curve:

Drawing nickel calibration curve is shown in Fig. 2.
After complete calibration of different parts of the apparatus and assuring from stabilizing and the unchanged apparatus conditions during the measurement, the calibration curve with the rate of optical absorption was drawn for the wavelength of 752 nanometer and standard solutions of 0.5,1, 1.5, 2 , 2.5,3,3.5,4,4.5, and 5 µg/ml.

(ppm: (parts per million) is equivalent to mg / kg or ηg / ml)

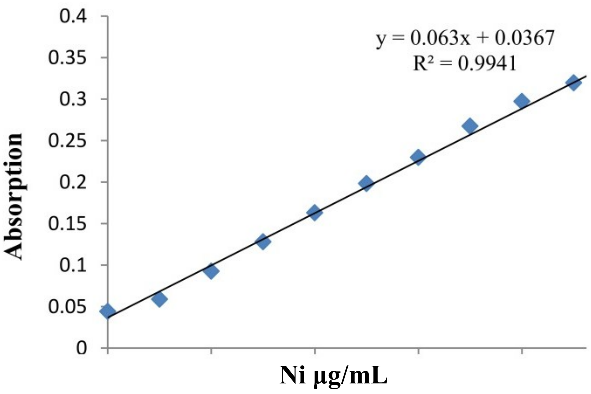

Figure 2. Nickel calibration curve

2.8. Statistical analysis:

All the data were analyzed by SPSS.17 software, both descriptively and inferentially, after the tests and recording the results. The mean and standard deviation indices were calculated for the descriptive analysis of each sample, with regards to the variables indicating the amounts of chromium and nickel in raw rice, rinsing and washing water, cooked rice by both "kateh" and "pilaw" cooking procedures. Moreover, the graphs regarding the amounts of chromium and nickel for the mean values of each variable were drawn by using Excel 2007 software. ANOVA test (variance analysis) was used for the inferential analysis to determine the differences in the densities of chromium and nickel in raw rice. Furthermore, a t-test was applied to compare the contamination in different regions, and P<0.05 was considered significant.

3. Results

Table 1 shows that the maximum and minimum amounts of the mean and standard deviation for chromium in raw and processed Tarom rice in 5 different regions, related to raw rice sample with 0.174 + 0.009 ppm and cooked rice by rinsing method (pilaw), with 0.036 + 0.003ppm, respectively. Thus, regarding the statistical analysis of the data, a significant difference was found between the raw and the method of cooking rice with rinsing water (pilaw), i.e., P<0.05. However, since we removed the water from the cooked rice in the rinsing method (pilaw), 0.036 + 0.003 ppm of chromium was related to the removed water, and the remaining amount of chromium in the rice was 0.138 + 0.006ppm. Thus, the minimum rates of the mean and standard deviation for chromium regarding the cooked rice with the rinsing method were 0.12 + 0.002ppm.
According to the obtained data, the effect of regions on the remained chromium in raw rice became significant (P<0.05). Hence, there is a significant difference between the amounts of chromium in raw rice in different regions (charts 1 & 2), indicating the effect of different regions on the remaining chromium in raw rice. There are significant differences in other samples, i.e., the rinsing water and cooked rice "kateh" and the rinsing method "pilaw" in different regions (P<0.05), indicate the effect of different regions on the remaining chromium in the considered samples. Moreover, the cooking process largely reduces the density of metals in consumed rice in cooked form. Thus, in the case of greater care in the cooking process or more rinsing, the metal amounts in the rice would be reduced. Moreover, the reduced amount of metals could mainly be seen in the method of using rinsing water in cooking the rice (i.e., pilaw) compared to the ordinary cooked rice.

Table 1. The mean and standard deviation of total chromium amount in raw and processed Tarom rice produced in the city of Qaemshahr (in PPM)

Type of sample	Samples	Average + standard deviation
Raw rice	25	0.174±0.009
Rice water (Rinsing water)	25	0.036±0.0003
ordinary cooked Cooked rice by "kateh" method (stewed)	25	0.142±0.0018
Cooked rice with rinsed method (pilaw)	25	0.12±0.002
total	100	0.118±0.0033

*The unit is based on the dry-weight

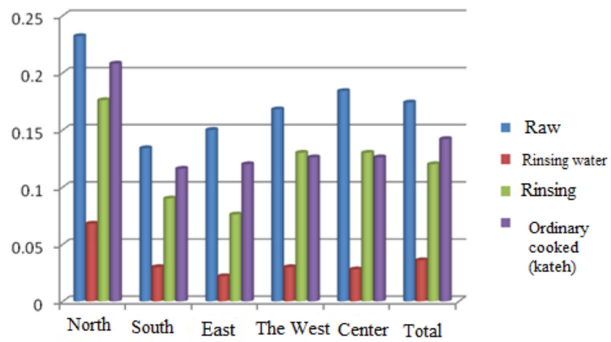

Chart 1. Average Chromium in raw rice, rinsing water, rinsing (pilaw) and ordinary cooked (kateh) for different regions.

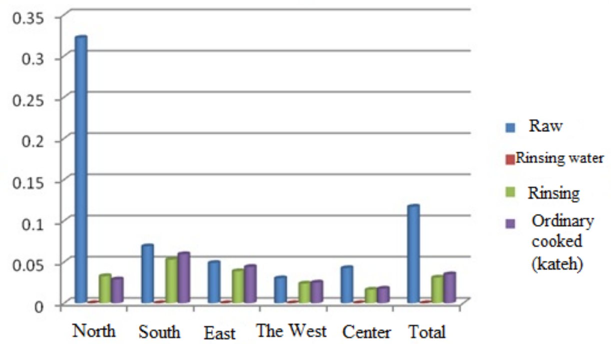

Chart 2. Average nickel in raw rice, rinsing water, rinsing (pilaw) and ordinary cooked (kateh) for different regions.

Table 2 shows that the maximum and minimum amounts of the mean and standard deviation for nickel in raw and processed Tarom rice in 5 different regions, relative to the raw rice sample with 0.117 ± 0.0003ppm and cooked rice by rinsing method (pilaw) with 0.000 ± 0.000ppm, respectively. Thus, regarding the statistical analysis of the data, a significant difference was found between the raw and the method of cooking rice with rinsing water, i.e., pilaw (P<0.05). However, since we removed the water from the cooked rice in the rinsing method (pilaw), 0.000 ± 0.000 ppm of nickel was related to the removed water, and the remaining rate of nickel in the rice was 0.117 ± 0.0003ppm. Thus, the minimum rates of the mean

and standard deviation for nickel regarding the cooked rice with the rinsing method were 0311 ± 0.0002ppm.
Regarding nickel, the obtained data showed that the average amount of nickel in raw rice was 0.117 ± 0.0003ppm, 0.000 ± 0.000ppm in the rinsed water, 0.0311 ± 0.0002ppm in the rinsed rice, and 0.035 ± 0.0002ppm in cooked rice (kateh style), and a great difference was observed compared to the proposed FAO standards considering the rate of 0.1ppm. It indicated the healthy state of the rice in the region, and this metal provided no worries. However, the cooking process greatly reduced the density of metals in the rice consumed in cooked form. Thus, in the case of more care in the cooking process and the number of rinsing times, the rates of metals in the rice would be reduced. Furthermore, the rate of metal reduction could mainly be seen the rice cooked with rinsing method compared to the ordinary cooked rice.

Table 2. The mean and standard deviation of total amount of nickel in raw and processed Tarom rice produced in the city of Qaemshahr (in PPM)

Type of sample	Samples	Average + standard deviation
Raw rice	25	0.117±0.0003
Rice water (Rinsing water)	25	0.00± 0.00
ordinary cooked Cooked rice by "kateh" method (stewed)	25	0.035±0.0002
Cooked rice with rinsed method (pilaw)	25	0.0311±0.0002
total	100	0.046±0.0002

*The unit is based on the dry-weight

4. Discussion and Conclusion

Heavy metals find their ways into water ecosystems due to the airing of the stones and soils and also because of the human and volcanic activities. The toxic properties of some mineral compounds, especially heavy metals, are known for years. The most toxic elements in the environment include materials containing lead, mercury, cadmium, chromium, and nickel. These materials are collected in the human body and remain for a long time, acting as poisonous materials [6].
Toxic metals are harmful to human beings and other creatures, even in the small amounts. The metals accumulated in the human body (such as lead, chromium, etc.) are definitely dangerous. These metals are concentrated by the nutritional chain and are thus considered as important hazards for the existing organisms in the high levels of nutritional levels. Generally, toxic metals are not a lot inside most of the natural waters. Although all the toxic metals exist in natural resources, higher rates of them in water usually leads to the industrial, mineral, and agricultural extraction operations [6].
Contamination by heavy metals is one of the important environmental problems and is considered one of the important worries regarding food materials. Rice is among the highly consumable crops in the world, being extensively in people's diets. This study aimed to investigate the rates of chromium and nickel in rice [6, 20].
Many researchers reported heavy metal concentrations, especially for cadmium (Cd), lead (Pb), nickel (Ni), chromium (Cr), and the other elements in rice grains cultivated in various countries [20-24].
According to the fulfilled research, the contaminated rice causes the intake of cadmium in the countries whose main food is rice. A large rate (50%) of the cadmium intake in Indonesia comes from the rice that they consume [25].This rate is 40 to 60 percent in Japan [21]. Considering the individual consumption of rice in Iran, which is approximately 42.4 kg per year [20] and the area under rice cultivation in the Korbal region, which is approximately 15,000 hectares (equivalent to 25 percent of the rice cultivated area of Fars Province in 1999), the importance of this issue is clear [26].
The effects of different cooking processes on the remaining chromium and nickel metals in Tarom rice produced in Qaemshahr farms in the year 2011 are considered in our study. The results obtained from our study showed that the amount of chromium in the raw rice and the rinsed rice method had significant differences in comparison. Moreover, there is a significant difference for the chromium amount in the rinsing water of rice and in the cooked rice by rinsing method, i.e., pilaw. Moreover, a significant difference was observed in the rate of chromium in the raw rice and the rice cooked with the rinsing method (pilaw).

Table 3. The mean and standard deviation of total chromium and nickel amounts in the considered samples, and comparing them with FAO proposed standards (in PPM)

Metals	Samples	Total of Average and standard deviation	Average standard
Cr	100	0.118±0.0033	0.1
Ni	100	0.046±0.0002	0.1

Table 3 shows that the mean and standard deviation of 0.118 ± 0.0033ppm for chromium obtained from Tarom rice was a little higher than that proposed by FAO (0.1ppm), but the difference was not significant. However, although the difference seemed satisfactory, the slightly higher rate in the mean and standard deviation could still be worrying. The calculated data for nickel showed that the total mean and standard deviation for nickel is 0.046 ± 0.0002ppm, revealing a large difference compared to the standard rate proposed by FAO (0.1ppm). It indicated that the rice from the mentioned region was healthy based on the mentioned metal., thus providing no worries in that respect. Anyhow, the periodic analysis of the produced rice in the mentioned region seems to be essential [18, 27, 28].

Regarding the raw rice, the cooked rice with rinsing method (pilaw), and the ordinary cooked rice (kateh), the results of our study in the Qaemshahr city showed that the highest amount of chromium in the raw rice produced in the region belonged to the rice from the northern region of Qaemshahr and the lowest amount of it belonged to the southern region of that city. The highest amount of nickel in the produced raw rice in the region belonged to the northern region of that city, while the lowest amount was from the central and eastern regions of Qaemshahr. The highest amount of chromium in the cooked rice with the rinsing method (pilaw) belonged to the rice produced in the northern region of the mentioned city and its lowest amount was from the eastern regions of that area. Furthermore, the results indicated that the highest amount of nickel in cooked rice with the rinsing method (pilaw) belonged to the produced rice in the southern region of the area, and its lowest amount was from the central region of the area. The highest amount of chromium in the ordinary cooked rice (kateh) was from the northern region and its lowest amount was from the southern region of Qhaemshahr, while the highest rate of nickel in the ordinary cooked rice (kateh) belonged to the produced rice in the southern region and its lowest amount was related to the rice produced in the central region of the city.

Domingo et al. (2008) evaluated the heavy metals in different cooking styles and nutritional materials, including meat, beans, fish, vegetables, and rice. The densities of heavy metals in the nutritional materials were measured in this study. The rates of heavy metals, including cadmium and lead, were quite negligible in the raw rice samples in this study.

The imported rice from India was analyzed in a study by Mohammad Malakoutian. Twenty types of highly popular Indian rice were collected from the Iranian market, and three samples of each brand were assessed. After the acidic digestion, the amounts of chromium and nickel were determined by Flame Atomic Absorption Spectrophotometer (FAAS). The amounts of chromium and nickel in this study were obtained 0.653mg/kg and 0.019mg/kg, respectively. In our study, the amount of chromium was 0.118ppm, and the amount of nickel was 0.046ppm, which were lower than the results obtained by Malakoutian (chromium = 0.653ppm and nickel = 0.019ppm). Thus, a significant difference existed between the studies [19].

The amount of chromium in our study was 0.118ppm, and that for nickel was 0.046ppm, which were lower than the calculated amounts in the research by Zezouli. Hence, there was a significant difference observed between the studies [29].

The amounts for chromium and nickel in our study were lower than the calculated amounts in the research by Lim, in which the amount of nickel was 0.29ppm[30].

The amounts for chromium and nickel in our study were lower than the amounts calculated in the research by Shokrzadeh and Rokni , in which the amount of chromium was 0.305ppm [31].

In our study, chromium was 0.118ppm, and that for nickel was 0.046ppm, which were lower than the calculated amounts in the research by Karlovski (chromium =25-47ppm, nickel =10-80), and hence there was a significant difference between the studies [32].

Naseri et al. indicated that the cooking rice grains reduced the heavy metals contents. The minimum cooking efficiency was from chromium. The effect of the cooking methods was not significantly different in this study [33].

Zazouli and colleagues (2010) used three treatments (raw, Kateh and Pilaw) for the Iranian rice cultivated in the Babol region to detect Pb. They found that the average Pb concentration in the samples of raw rice was higher than that in the cooked rice (Kateh and Pilaw). Moreover, they detected a lower Pb content in Pilaw than in Kateh in all the samples, which was similar to our study.[34].

According to the results of our study analyzing the amounts of two heavy metals (chromium and nickel) in the Tarom raw and cooked rice of Qaemshahr, it can be concluded that the cooking process reduces the amounts of metals extensively in the cooked form. Thus, by paying attention to the cooking process or increasing the number of rinsing times, the amounts of metals will be reduced. Also, the reduction of the metals is more in the rice cooked with the rinsing method (pilaw) than the ordinary cooked rice (kateh). Hence, both methods are described in this study.

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Conflict of interest

None.

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