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Research Paper

Assessment of Heavy Metals in Potato and Onion Supplies in Rasht

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ABSTRACT

Background: The entry of heavy metals into the food chain is an important environmental challenge for humans. Due to their potential for accumulating in the body, the different aspects of the hazard posed by heavy metals should be carefully examined.

Objectives: The present study was conducted to determine the concentrations of heavy metals such as Arsenic (As), Cadmium (Cd), Chromium (Cr), Lead (Pb), and Nickel (Ni) in tuber crops i.e. potatoes and onions in Rasht, north of Iran.

Materials & Methods: A total of 140 potatoes and onions that were planted in difference cities of Iran were randomly procured from the city's fresh market in the spring during ten-day intervals. The acid digestion method was used for the preparation of the samples and the heavy metals were measured using an inductively coupled plasma optical emission spectrometer (ICP-OES).

Results: The mean concentration of Pb, Cd, Cr, and Ni found in the potato samples were 0.057, 0.079, 0.299, and 0.190 mg/kg of dry weight, respectively. The mean concentration of Pb, Cd, Cr, and Ni found in the onion samples were 0.067, 0.020, 0.275, and 0.235 mg/kg of dry weight, respectively. In both products, the amount of As was less than the device's detection limit (1.187 ppb). The mean concentration of heavy metals in the products received from the northern region was higher than the central and southern parts of Iran.

Conclusion: The results of this study showed that the mean concentration of Pb in both potatoes and onions were in the normal range. Similarly, the mean concentration of Cd, in onions was under the standard limit, but it was higher than the standard limit in some potato samples. Also, the mean concentration of Cr was higher than the standard limit.

Keywords: Heavy metals, Tuber crops, ICP-OES

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1. Introduction

Through different activities performed by humans, such as industrial activities, the use of fossil fuels, the disposal of municipal solid wastes and sewage, the use of pesticides, and so on, large amounts of heavy metals enter the environment [1, 2]. Heavy metals like lead, chromium, cadmium, arsenic, etc., which are contained in human food sources, play a critical role in their life because of their harmful effects. Heavy metals are accumulated in plants and human tissues over a long time, are toxic, and may cause different illnesses and disorders because the body cannot metabolize them [3, 4]. Extensive studies have been conducted to investigate the heavy metal contamination of food products. In addition, tubers crops including onion and potato can be polluted by heavy metals [5]. As tuber crops are essential ingredients in diets all over the world, monitoring of heavy metals is taken into consideration by researchers [6]. According to previous studies, direct relation has been shown between heavy metal amounts in water, soil, and the elements accumulated in tuber crops. It seems cultivation of these plants in polluted soil or irrigation of them with polluted water may cause hazardous elements to enter the food chain [7]. Significant data obtained from various studies have shown direct relevance between heavy metals amount in water or soil and metals amount in tuber crops. It seems cultivation of these plants in polluted soil or irrigation with polluted water may cause hazardous elements to enter the food chain [6-8]. Tubers, including potatoes and onions, have a share in people's food baskets, so study of food safety in terms of the presence of heavy metals is an important issue. Therefore, this study was aimed to investigate the concentration of Arsenic (As), Cadmium (Cd), Chromium (Cr), Lead (Pb), and Nickel (Ni) in the potatoes and onions consumed by the residents of Rasht.

2. Materials and Methods

Study type and study sample

The present descriptive study involved collecting random samples of potatoes and onions of various varieties from trucks during the unloading process at the central fresh market in Rasht. Specifically, samples were collected on March 30th, April 9th, 19th, and 30th, May 10th, 20th, and 31st, and June 10th and 20th of 2014. In each sampling stage, 1kg of the samples harvested in different cities of Iran was purchased. Agria potatoes and yellow onions are the most popular varieties brought to the central fresh market in Rasht. The onions with the highest production and distribution on the central fresh market of Rasht were harvested in Zanjan, Bandar Abbas, Isfahan, Tarom, Dezful, and the potatoes with the highest production and distribution in Ardabil, Jiroft, Dezful, Zanjan, Kermanshah and Kazeroon.

Sample preparation

To ensure the absence of contamination, all the glass and containers were rinsed and soaked in nitric acid 10% for 24 hours and were then rinsed clean with distilled water and dried. The samples were cut into pieces and dried at 80 °C for 24 hours. The dried samples were then milled into a powder. Acid digestion was performed for the samples according to the standard method [9]. The acid digestion of the samples was performed using the standard H3030 and F3030 methods. For this purpose, 1gr of the produced powder of samples were weighed, and 15 ml of Nitric acid to Hydrochloric acid at a 3:1 ratio were then prepared and added to the weighed powder in three 5 ml stages. The mixture was kept at 105 °C until a clear solution was obtained, which was then filtered and increased to a volume of 25 ml with distilled water [10].

Instrument specifications & calibration

The samples were analyzed using inductively coupled plasma optical emission spectrometer (ICP-OES) (ICP-OES made by Spectro Ametek in Germany) [9-11] The specifications of the ICP system used in this study are presented in Table 1.

The reliability and sensitivity of the device was evaluated by recovery method and calibration curve parameter. Calibration curve parameters are used to evaluate the accuracy and precision of analytical instruments. The calibration curve parameters include the slope, intercept, correlation coefficient (r), limit of detection (LOD), and limit of quantification (LOQ). The Emission line of elements and calibration curve parameters are presented in Table 2.

The recovery obtained in this work was in the range of 96–102%, providing good method accuracy. The recovery study was performed as follows: eight analyzed samples were spiked with standard solutions of Pb, Ni, Cd, As, and Cr. The average recovery percentages obtained were 96.0±2.3%, 96.7±1.7%, 98.3±1.1%, 97.3±0.8%, and 102.2±0.9% for Pb, Ni, Cd, As and Cr, respectively.

Table 1. Specifications of the ICP-OES system used in this study

Specifications	Values
System Power (Watts)	1400
Pump Speed (RPM)	30
Auxiliary Gas Flow Rate (L/min)	1
Nebulizer Flow Rate (L/min)	1
Coolant Flow Rate (L/min)	12

Statistical analysis

Descriptive statistics, including Median & Mean±SD or frequency and percentage, were used to present the data. The normality of the data was assessed using the Kolmogorov-Smirnov test. As the data was found to be normally distributed, analysis of variance (ANOVA) was employed to compare the mean values of heavy metals with a significance level set at 0.05. Two references were used to compare the average results with standard limits: the Iranian Institute of Standards and Industrial Research, which establishes the maximum acceptable levels of heavy metals in animal and human feed; and the Codex Alimentarius Commission's general standard for contaminants and toxins in food and feed (GSCTFF) [12, 13]. The statistical analysis was performed using SPSS software, version 22.

3. Results

A total of 140 potato and onion were analyzed. Tables 3 and 4 show descriptive statistics and standard concentrations (ppm) of minerals in onions and potatoes, respectively. The mean concentrations of the most common heavy metals (mg/kg) detected in the onions and potatoes by harvest location showed in Tables 5 and 6, respectively.

The mean concentration of Pb and Cd in both potatoes and onions were in the normal range but the mean concentration of Cr was higher than the standard limit.

As shown in Table 5, the average concentration of Pb in Mashhad and Zanjan was significantly higher than in other cities. Except for onions produced in Bandar Abbas, the mean concentration of Cr was higher than the standard limit, while in Loshan and Karaj, the average concentration of Cr was higher than the others harvested locations ($P<0.05$). The average concentration of Cd in Zanjan and Isfahan was significantly higher than in other locations ($P<0.05$). It seems that the concentration of all heavy metals studied in Zanjan is high.

According to the results in Table 6, the average concentration of Pb in potatoes in Ardabil and Hamedan was significantly higher than in other cities ($P<0.05$) and the mean concentration of Pb in other harvested locations were below the standard limit. In addition, the average concentration of Cd in potatoes except for Tarom, Gorgan, and Isfahan was significantly higher than the standard limit ($P<0.05$). Also, the average concentration of Cr in potatoes of all origins was more than the standard limit. The average amount of As in both products was lower than the detection limit (1.187 ppb) and was not

Table 2. Emission line of elements and calibration curve parameters

Elements	Emission Lines (nm)	LOD (ppb)	LOQ (ppb)	R^2	Slope	Intercept
As	189.042	1.187	1.844	0.9907	643963	52.007
Cd	214.438	0.048	2.4	0.9986	200000	15630
Ni	221.648	0.335	4.972	0.9998	673763	3626.2
Pb	220.353	0.38	2.946	0.9996	128957	1562.3
Cr	205.618	0.095	1.504	0.9999	631566	699.04

Table 3. Mean, median, minimum, maximum and standard deviation of concentrations of heavy metals (mg/kg of dry weight) in the onions

Metal	Median	Mean±SD	Min	Max	Standard
Lead (Pb)	0.053	0.067±0.061	ND	0.280	0.15
Chromium (Cr)	0.227	0.275±0.228	ND	1.15	0.1
Nickel (Ni)	0.205	0.235±0.195	ND	1.264	-
Cadmium (Cd)	0.001	0.020±0.070	ND	0.584	0.06
Arsenic (As)	ND	ND	ND	ND	0.15

ND: Not detected

detected by the device. Based on the geographic location of potato and onion cultivation areas, it is clear that the concentration of heavy metals in the northern region of the country is higher than the heavy metals concentration in the central and southern regions of the country.

4. Discussion

The results of the present study indicated the absence of As in potato and onion crops; however, mean concentrations of Cr was exceeded the standard limits in the potatoes and onions harvested in different cities of the country, except for onions produced in Bandar Abbas which was in the normal range. Similarly, the average concentration of Cd in potatoes was higher than the standard limit but the mean concentration of Cd in Tarom, Gorgan, and Isfahan was lower than the standard limit. Also, in the onion samples the average concentration of Cd was lower than the standard limit.

This study provides important insights into the levels of heavy metals in potato and onion samples from different regions of Iran. The results indicate that excessive levels of Cd, and Cr, were present in some samples, which is a cause for concern due to the potential negative health effects associated with long-term exposure to these heavy metals. It is essential to establish maximum permissible concentrations of other heavy metals in plants and food products to ensure public health and safety. Additionally, monitoring and regulating the levels of heavy metals in food and the environment are crucial to minimize exposure and prevent potential adverse health effects. Further research and collaboration between government agencies, researchers, and food producers are necessary to address this issue and establish appropriate regulations and standards.

The findings of this study are consistent with previous research that has highlighted the issue of heavy metal contamination in food products. Various studies have reported elevated levels of heavy metals in different food products including vegetables, fruits, grains, and seafood, in different regions of the world [14, 15]. The excessive levels of Cd, and Cr detected in the potato samples in this study are consistent with previous research that has reported these heavy metals to be prevalent in

Table 4. Mean, median, minimum, maximum and standard deviation of concentrations of heavy metals (mg/kg of dry weight) in the potatoes

Metal	Median	Mean±SD	Min	Max	Standard
Lead (Pb)	0.021	0.057±0.089	ND_1	0.593	0.15
Chromium (Cr)	0.227	0.299±0.274	ND_2	1.317	0.1
Nickel (Ni)	0.165	0.190±0.151	ND_3	0.712	-
Cadmium (Cd)	0.001	0.079±0.238	ND_4	1.684	0.06
Arsenic (As)	ND	ND	ND_5	ND	0.15

ND: Not detected; ND_1<DL(Pb)=0.38ppb; ND_2<DL(Cr)=0.095ppb; ND_3<DL(Ni)=1.187ppb; ND_4<DL(Cd)=0.048ppb; ND_5<DL(As)=1.187ppb

Table 5. The concentrations of the most common heavy metals (mg/kg) detected in the onions by harvest location

Harvest Location	Mean±SD				
	Lead (Pb)	Chromium (Cr)	Nickel (Ni)	Cadmium (Cd)	Arsenic (As)
Isfahan	0.068±0.071	0.251±0.173	0.187±0.089	0.035±0.130	ND
Arak	0.038±0.043	0.248±0.171	0.298±0.238	0.006±0.013	ND
Borujerd	0.068±0.036	0.241±0.015	0.197±0.089	0.001±0.001	ND
Bandar Abbas	0.058±0.068	0.021±0.026	0.052±0.045	0.001±0.001	ND
Tabriz	0.026±0.014	0.380±0.259	0.361±0.247	0.001±0.001	ND
Dezful	0.066±0.042	0.176±0.154	0.137±0.085	0.031±0.078	ND
Zanjan	0.101±0.024	0.311±0.113	0.255±0.047	0.058±0.090	ND
Shiraz	0.053±0.035	0.123±0.143	0.150±0.090	0.001±0.001	ND
Tarom	0.043±0.035	0.310±0.376	0.258±0.253	0.001±0.001	ND
Karaj	0.097±0.087	0.406±0.296	0.406±0.390	0.014±0.035	ND
Kermanshah	0.088±0.010	0.176±0.042	0.159±0.020	0.043±0.060	ND
Lushan	0.062±0.091	0.446±0.293	0.245±0.139	0.011±0.024	ND
Mashhad	0.145±0.067	0.299±0.037	0.214±0.012	0.001±0.001	ND

ND: Not detected (ND <DL=1.187 ppb)

various food products. For instance, a study conducted with Khan et al. (2008) found that the levels of Pb and Cd in vegetable samples were higher than the permissible limits set by the World Health Organization [16, 17]. Similarly, a study conducted in India with Githaiga et al. (2004) reported high levels of Pb and Cd in rice samples [18]. Pirsaheb et al. (2015) reported that the concentrations of Pb, Cd, Ni, Cr heavy metals In the surface and groundwater resources, was above medium level [19]. In a similar study, Saeed Nazemi and Ahmad Khosravi (2011) concluded that the concentrations of Pb, Cr, Cd, and As exceed the normal limits in a variety of herbs [20]. Mohajer et al. (2012) entitled "The concentration of Pb and Cd in lettuce, cabbage, onion and beet in Isfahan province", the concentrations of Pb and Cd were found to exceed the standard permissible limits [21, 22].

Table 6. The concentrations (mean±SD) of the most common heavy metals (mg/kg) detected in the potatoes by harvest location

Harvest Location	Lead (Pb)	Chromium (Cr)	Nickel (Ni)	Cadmium (Cd)	Arsenic (As)
Isfahan	0.032±0.034	0.343±0.202	0.247±0.167	0.011±0.020	ND
Gorgan	0.048±0.019	0.173±0.046	0.124±0.909	0.018±0.027	ND
Azarshahr	0.074±0.056	0.475±0.241	0.259±0.146	0.136±0.113	ND
Tarom	0.043±0.054	0.208±0.168	0.124±0.091	0.018±0.027	ND
Ardabil	0.101±0.167	0.271±0.213	0.179±0.115	0.163±0.482	ND
Ajab Shir	0.023±0.027	0.527±0.542	0.274±0.279	0.099±0.198	ND
Dezful	0.009±0.001	0.124±0.100	0.069±0.047	0.090±0.080	ND
Hamadan	0.112±0.051	0.291±0.373	0.208±0.183	0.075±0.147	ND

Heavy metal contamination in food products can occur due to various factors, including soil contamination, the use of contaminated water for irrigation, and the use of fertilizers and pesticides that contain heavy metals. There is a growing concern about the accumulation of heavy metals in soils and plants due to human activities involving mining, smelting and refining, power generation, industrial waste, car smoke, steel industries, agriculture, sewage discharge, waste management, chemical fertilizers, pesticides, herbicides, insecticides, industrial and domestic waste, and sewage sludge added to soils to increase agricultural productivity [23, 24]. The results of this study also show that heavy metal levels vary across different regions of the country, with higher concentrations observed in the northern region compared to the central and southern regions. The variation in heavy metal contamination across different regions can be attributed to various factors, including differences in soil quality, water sources, and agricultural practices. For instance, a study conducted with Liu et al. (2013), in China, found that the levels of lead and cadmium in vegetables were higher in areas with a history of mining activities [25]. To achieve proper food safety conditions, it is recommended that we should change the cultivation patterns, remove contaminated lands from the production cycle, and identify the source of pollution. In addition, it is suitable that untreated industrial and domestic wastewater be prevented entry into the agricultural waters, and training farmers about the various pesticides and chemical fertilizers and their proper use [26].

The present study is suitable to inform relevant organizations of the heavy metal concentrations in crops, to enable their closer monitoring of the crops, and to demonstrate the necessity of imposing restrictions to reduce heavy metal concentrations in the food chain. It is important to identify the sources of these heavy metals in the environment and take measures to reduce their levels in food and water. Additionally, it is important for individuals to be aware of the potential risks associated with consuming food that may be contaminated with heavy metals and take appropriate precautions to minimize their exposure.

5. Conclusion

This study provides valuable insights into the levels of heavy metals in potato and onion samples from different regions of Iran. The results show that while the levels of As in the samples were below the detection limit. Also, the mean concentration of Pb in both onion and potatoes was in the normal range, but the levels of Cd in some potatoes and Cr onion and potatoes were higher than the standard limits. The study highlights the need for monitoring and regulating the levels of heavy metals in food products, developing updated standards and regulations for permissible concentrations of heavy metals in plants and food products, and implementing targeted interventions to reduce heavy metal exposure in high-risk areas.

Ethical Considerations

Compliance with ethical guidelines

The research protocol has been approved by Research Deputy of Guilan University of Medical Sciences (Approval Code: 93011801). This article has no human or animal sample.

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Authors' contributions

Conceptualization, Methodology: Mehdi Shirzad-Siboni and Azita Mohagheghian; Sampling & preparation: Elham Zolelmeyn; Data analysis: Saeed Omidi; Preparation & writing of original draft: Azita Mohagheghian; Laboratory analysis, preparation, review & editing of the manuscript: Mohammad Naimi-Joubani.

Conflict of interest

The authors declared no conflict of interest.

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