Bioaccumulation of the Heavy Metals Contents in Green Leafy Vegetables

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Research Article

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Abstract

One of the major involvements of healthy soils in the environment is heavy metals which can be accumulated in vegetables and crops grown on due to the probability of food contamination through the soil-root interface. It should be considered that the preparation and processing of these materials could be provide the entrance of chemical hazardous materials and contaminants, such as heavy metals which nowadays are one of the most important contaminations in fruits and vegetables. Therefore, due to the lack of studies in packaged samples in Tehran Market, the main goals of current were to evaluate the levels of lead, cadmium, and nickel in 360 ready-to-eat vegetable, which were randomly collected from recognized sales centers in Tehran market level. In packaged vegetable samples, two groups of leafy and Tuber vegetables were investigated, which included scallion, mint, basil, cress, leek, parsley and radish. Inductively Coupled Plasma-Optical Emission Spectrometer (ICP-OES) method was used to analyze the concentration of these elements according to international protocols. Analy¬sis of Variance (ANOVA) test were used for analysis of the variances. Differences were considered significant at values of P< 0.05. The results of the present study showed that Lead content in mint and leek significantly higher than other leafy vegetables (p <0.003), while the highest nickel contents in cress samples in all 8 brands was on the top (p <0.001). Also, the lowest amount of lead and nickel observed in the parsley samples (p <0.03) and the least amount of cadmium was observed in basil (p <0.01). In the case of tuber vegetables, the highest concentrations of all studied heavy metals l were in scallion (p <0.01). The mean concentrations of lead, cadmium, and nickel in the investigated vegetables were much higher than the FAO/WHO and Codex standards. It is suggested that regular monitoring of heavy metals in vegetables and other food items should be done to prevent excessive production of these heavy metals in the human food chain. At the time of production, transportation and marketing of vegetables, the necessary precautions should be taken.

Keywords: Packaged Vegetable, Heavy Metals, ICP, Contamination, Iran

Introduction

Consumption of vegetables as sources of vitamins, minerals, fiber and their beneficial antioxidants, especially among the urban community, is gradually increasing. Meanwhile, the consumption of heavy metal contaminated vegetables may harm human health [1-5]. Heavy metals cause serious health problems therefore accurately determining their residues are concerned seriously [6-10]. Heavy metals are widely distributed in the environment and released by natural and human activities into the air, water and soil through which plants can use it. The contamination of heavy metals in vegetables cannot be underestimated because fruits and vegetables are highly nutritious and are mostly consumed [11-16]. Contamination of vegetables with heavy metals may be due to irrigation with contaminated water, use of sewage water, soil contamination, excessive use of animal waste, irregular use of phosphate fertilizers by farmers, insecticides, fungicides, industrial emissions, transportation, the pollutants released from vehicles, the proximity of land to the road, the harvesting process, storage, or at sales sites [17-21]. The prolonged use of heavy metals in high concentrations through food such as fruits and vegetables may lead to accumulation over time, which can result in brain damage, damage to the heart, nervous system, liver, kidney, blood, lungs, bone and spleen, disturbance in breeding, mutagenicity and carcinogenesis [9]. Among all heavy metals, cadmium is one of the most moving elements that is easily absorbed by plants and transported to air organs and can accumulate up to high levels, so it can easily enter the food chain and is harmful to the health of humans and animals [5,15,22]. It is believed that cadmium causes damage even at lower concentrations and can easily be absorbed in many plants [23-25]. Nickel also plays an important role in plants as a heavy metal. This element does not have a toxic effect on the plant at the low concentrations but it is toxic to plants at high concentrations [26-27]. Some studies have shown that exposure to nickel is connected with cardiovascular disease; neurodegenerative deficiency; lung cancer and blood pressure [5, 28-30]. The toxicity of high concentrations of these elements on the one hand and its necessity for human growth on the other indicate the importance of recognizing the signs of poisoning of this element in the plant, as well as its rate of absorption by plants that grow under different concentrations. Previously, various studies have focused on vegetables. Typically, in 2018, researchers in a study have checked out the amount of cadmium, lead, copper, barium, cobalt, and tin by ICP-OES in dill, radish, radish leaf, parsley, spinach, onions, leeks, fenugreek and mint in Guilan province and estimated the daily absorbance of metals [31]. In another study in 2013, the levels of lead, cadmium and chromium contamination in vegetables collected from local markets in Tehran over a period of one year (at intervals of three months) were investigated [1]. . The results showed that in all samples of vegetables, lead, cadmium and chromium concentrations were higher than the limit. The highest amount of lead were reported in leafy vegetable samples were found in leafy cabbage, cauliflower, Chinese cabbage, broccoli, celery, spinach, salad lettuce, spinach lettuce; the highest amount of cadmium were reported, respectively, in Chinese cabbage, spinach lettuce, spinach, leaf cabbage, salad lettuce, broccoli, cauliflower and celery; and the highest amount of chromium were reported in Chinese cabbage, cauliflower, spinach, lettuce, cabbage, lettuce, celery and broccoli, respectively [1]. In the other study, the amount of lead measured by ICP-MS in leafy vegetables in terms of the highest level of lead was reported in celery, mint, spinach, dill, honeydew, coriander, cress, and the highest level of cadmium were reported respectively in honeydew leaf, cress, dill, spinach, coriander, mint and celery; it was reported that cadmium amount in mint and celery was lower than the WHO standards for cadmium in vegetables. Also, the amount of nickel was in accordance with existing standards [32-33]. In another study, the amount of heavy metals in leek, sweet basil, parsley, cress and tarragon was studied. The results indicated that lead, cadmium and chromium levels were higher than the limit [34]. In another study, lead and cadmium contamination in vegetables and water around the city of Gorgan were reported in Iran [35]. Despite this research, there is not much data on the evaluation of heavy metals in ready-to-eat vegetables, so that in the research on the concentration of heavy metals in Tehran supermarket vegetables in terms of health risk assessment for carcinogenesis and non-carcinogenicity was studied. In this study seven heavy metals of arsenic, cadmium, lead, chromium, copper, nickel and zinc in cucumber, tomatoes, lettuce, cabbage, potatoes and carrots in summer and autumn were investigated with potential health risk for consumers. The concentration of lead and chromium was higher than the codex limit, so that for lead, the highest amounts were respectively in cabbage, tomatoes, potatoes, carrots; and for chrome, in cabbage, potatoes and carrots, respectively; which were in excess of internationally permitted limits. The level of cancer risk was assessed safe in all metals, but the overall level of total cancer risk was unsafe [36]. In another study titled "Concentration and Heavy Risk Potential of Heavy Metals in Vegetables in Chongqing, China", the concentration and daily intake of heavy metals of lead, zinc, manganese, copper, cadmium and chromium in vegetable, have investigated and potential health risk was assessed for consumers. The results showed that the measured lead and cadmium concentrations exceeded the FAO / WHO rules and regulations of safety and health given by China which shows heavy contamination of the vegetable market by these elements [23]. In the other research, the level of nickel, zinc and copper in various vegetables randomly collected from supermarkets were investigated. The results of this study showed that the amount of heavy metals in the fruit is more than the leaves and leaves than the root [27]. The consumption of vegetables contaminated with cadmium and lead has a health hazard. Vegetables require two elements of water and soil for cultivation, so the assessment of the concentration of heavy metals in vegetables requires monitoring and continuous evaluation of these factors. Therefore, many studies have examined the factors affecting the formation or intensification of heavy metals in vegetables. Therefore, the study of the research records shows that various studies have been conducted on lead and cadmium in various types of crops in Iran. However, the studies related to these elements in ready-to-eat vegetables are very low and, given the high emphasis of nutritionists and health experts on daily receiving vegetables and increasing urban livelihoods and having little opportunity to prepare food, consumption of ready-made vegetables and consumer goods have become more widely used, nowadays. Therefore, since vegetables, especially in Iran, are considered to be the main human food, but little information is available on the amount of heavy metals in vegetables available in Iran. Considering the importance of the role of heavy metals in human health, the present study aimed to investigate the level of contamination with heavy metals of lead, cadmium and nickel in some parts of the edible parts of some ready-to-eat vegetables (mint, basil, parsley, leek, onion, radish, etc.) in commercial brands at the supply level and then determine the toxic effects associated with the concentration of heavy metals in agricultural products.

Materials and methods

Sample collecting

Samples of vegetable types were collected from January 2019 to June 2020 at the supply level of Tehran with three different brands. Edible samples of ready-to-eat vegetable packaging prepared from different recognized supermarkets included vegetables; cress, leek, mint, parsley, basil, scallion, and radish. The collected samples were transferred to the laboratory to measure the amount of lead, cadmium, and nickel in their edible parts under refrigerated temperature (4 ° C).

Sample preparation

At first, the purchased packaged vegetable samples were washed with deionized water and dried at a temperature of 50 ° C for 30 minutes in oven reaching the constant weight [37-40]. Samples an amount of 0.500g was weighted with 0.001g precision in specific containers for microwave digestion, after than 7 mL of 65% nitric acid and 0.5 mL of 30% hydrogen peroxide were added to it. Prepared samples were digested by the lab microwave as programmed, power 1000w for 15 minutes and 15 minutes hold, after that cooling for 15 minutes. The digested samples were filtered with a membrane filter (pore size 0.45 μm) and swelled with double distilled water to the volume of 100 ml. The amount of heavy metals in samples was then measured by ICP-OES system and standard solutions [41-42].

Determination of heavy metals, lead, cadmium and nickel

The amount of lead, cadmium, and nickel in prepared solutions was then measured with using inductively coupled plasma optical emission spectrometer (ICP-OES), IRIS Interpid II XSP Model and using five standard solutions(10, 50, 100, 500 and 1000 μg L^{-1}) for each heavy metals. The operational parameters for determining the elements by ICP-OES are presented in Table 1 [43].

Method	Parameters
RF power (W)	1400
Plasma generator	Argon
Plasma gas flow rate (L/min)	14.5
Auxiliary gas flow rate (L/min)	0.9
Nebulizer gas flow rate (L/min)	0.85
Sample uptake time(s)	240 total
Rinse time of (s)	45
Initial stabilization time (s)	Preflush:45
Pump rate (rpm)	15
Measurement Replicates	3
Frequency of RF generator (MHz)	resonance frequency:
Type of detector Solid state	27.12
Type of spray chamber Cyclonic	CCD Modified Lichte

Table 1: Performance parameters of determining the elements by ICP-OES

Risk assessment of Daily absorption of heavy elements in daily diet

Daily intake of heavy metals in vegetable

For this purpose, the estimated amount of each element consumed per product should be determined according to its consumption of EDI (Estimated Daily Intake) product. It should be noted that if this value is less than PTDI (Provisional Tolerable Daily Intake), there is no risk to consumers of that product. Otherwise, that product is dangerous to health. EDI is obtained from the following equation.

$$EDI = \frac{C \times Cons}{B_w}$$

In this equation, C is the concentration of each heavy metal in products in mg / kg, Cons is the daily consumption of that product by individuals in grams in Iran (this is reported according to the statistics of the standard institution) and Bw is the average body weight of an adult (60 kg) [44].

Statistical Analysis

Statistical analysis of data was performed using EXCEL software (Microsoft Corp., Redmond, WA, USA) to determine the amount and measurement of heavy metals in lead, cadmium and nickel in prepared vegetables. Using SPSS 20.0 statistical soft¬ware (SPSS Inc., Chicago, IL, USA), Analy¬sis of Variance (ANOVA) test were used for analysis of the variances. Differences were considered significant at values of $P < 0.05$.

Results and Discussion

The concentration of heavy elements studied in vegetable samples

The results of measuring lead, cadmium and nickel concentrations in the samples of different ready-to-eat vegetables by ICP-OES in three brands were reported as mean concentration in mg / kg in Table 2, respectively.

Brand	Heavy Metal	Vegetable						
		Leek	Cress	Parsley	Basil	Mint	Scallion	Radish
Brand 1	Lead	52.34ᵃ	38.94ᵇ	18.21ᵈ	-	-	39.14ᵇ	31.27ᶜ
	Cadmium	0.78ᵃ	0.66ᵇ	0.42ᶜ	-	-	0.59ᵇ	0.41ᶜ
	Nickel	48.17ᵃ	48.16ᵃ	17.66ᶜ	-	-	44.33ᵇ	40.75ᵇ
Brand 2	Lead	52.19ᵇ	30.45ᶜ	-	35.09ᶜ	68.63ᵃ	36.22ᶜ	24.45ᵈ
	Cadmium	0.41ᵇ	0.41ᵇ	-	0.38ᵇ	0.73ᵃ	0.41ᵇ	0.48ᵇ
	Nickel	25.63ᶜ	37.82ᵇ	-	21.33ᶜ	45.21ᵃ	40.72ᵇ	34.28ᵇ
Brand 3	Lead	41.78ᵃ	30.13ᵇ	13.21ᵈ	22.16ᶜ	42.18ᵃ	33.98ᵇ	22.53ᶜ
	Cadmium	0.32ᵇ	0.37ᵃ	0.35ᵃ	0.27ᶜ	0.43ᵃ	0.34ᵇ	0.39ᵃ
	Nickel	20.18ᶜ	35.98ᵃ	14.22ᵈ	18.72ᶜ	29.43ᵇ	37.18ᵃ	31.28ᵇ

*Mean scores with different small letters are significantly different in each row ($p<0.05$)

Table 2: The mean Content (mg/kg FW) of lead, cadmium and nickel in ready-to-eat vegetables

According to Table 2, the study of heavy metal contents of lead, cadmium, and nickel in studied vegetables shows showed that the highest contamination contents of lead, cadmium and nickel is in Brand 1 and among its vegetables the highest amounts of heavy metals (lead, cadmium and nickel) were found in leek. Brand 2 has the highest concentrations of heavy metals related to mint. However, in Brand 3, various amounts of heavy metals are different in vegetables and because accumulation and absorption of heavy metals in plants can have different reasons, the physical properties of the soil, temperature and humidity, the atmospheric abandonment of these metals, the amount of this metals in the soil and plant growth stage can be effective in harvesting (Sharma et al., 2008). Therefore, the observed changes in the concentration of heavy metals may be due to the variable capability and accumulation of heavy metals, changes in growth period and growth rate and climatic differences in production areas [45]. According to Table 2, there is a significant difference between lead concentrations in vegetable types (P> 0.05) and the highest and lowest levels of lead concentration are related to mint and parsley, which is consistent with the comparison of lead in Naghipour et al. study in 2018 regarding the level of lead contamination in mint [1,31]. In the case of cadmium, the highest amount of cadmium in Brand 1 is related to leek 0.78, in brand 2 of mint 0.73 and in mint brand 3, 0.43 in mg / kg. In the case of nickel content, the highest nickel content in Brand 1 was related to leek 48.17, in Brand 2 related to mint 45.21 and in Brand 3 related to scallion 37.18 and cress 35.98 in milligrams per kilogram, respectively. Also, the content of nickel in foods may be due to environmental contamination, the production and storage of food such as drying, cooking and packaging materials and one of the sources of nickel in food that can cause food contamination is the use of nickel in containers, food processing equipment and catalysts [43, 46].

Concentration of studied heavy metals based on the type of vegetable

Figure 1 shows the comparison of the average levels of lead and nickel concentrations based on the type of vegetable and figure 2 declare the cadmium contents on the studied samples. As it can be seen, lead content is higher than that of other vegetables. These results are consistent with the results of the 2007 study by Eslami et al. (2007) regarding the high levels of lead and cadmium in leek compared to basil and parsley [47]. In the case of cadmium, the highest amount was found in mint, and the scallion and cress had the highest amount of nickel. According to the data presented in Table 3, the rate of adsorption and accumulation of lead and cadmium in tuber vegetables such as radishes and scallops are more than leafy vegetables, which can be due to the soil for cultivating vegetables.

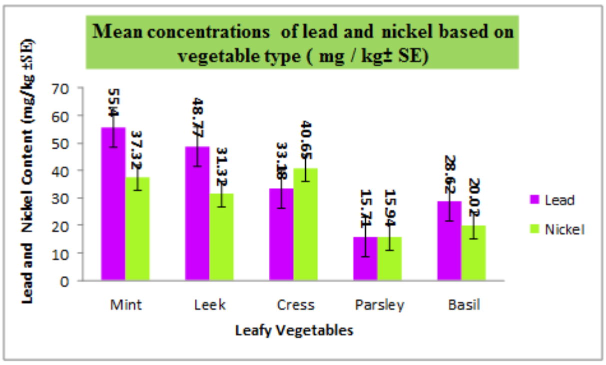

Figure 1 : Comparison of average concentrations of lead and nickel based on vegetable type (mg / kg± SE)

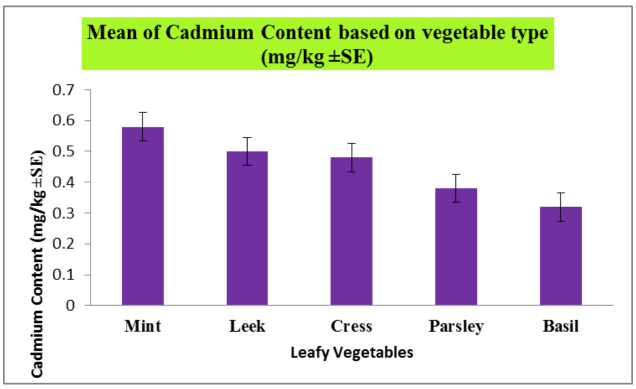

Figure 2 : Comparison of average concentrations of cadmium based on vegetable type (mg / kg± SE)

Comparison of the concentration of studied heavy metals with limits of national and international standards

The content of lead, cadmium and nickel in terms of mg / kg of monitoring standards in vegetables are given in table 3.

By comparing the average values of the elements studied in current study, it is observed that the lead and cadmium levels in all samples are much higher than those reported by regulatory agencies. The study of Nazemi and colleagues about the levels of arsenic, chromium, cadmium, lead and zinc in vegetables grown in the suburbs of Shahrood in Semnan province showed that the mean concentration of lead and cadmium in vegetables were higher than the standard provided by FAO and WHO for plants and it matches and confirms; this reason can be generalized to the results of this research, given that the cause of irrigation with wastewater has been discussed. Also, other reasons such as the transportation and marketing system should be important, which plays an important role in increasing the amount of heavy metals and endangering the quality of vegetables and the consequences for consumer health [48-52].

Element	FAO/ WHO*	Codex	Average
Lead	0.3	0.3	34.88
Cadmium	0.1	0.2	0.43
Nickel	67.00	-	31.63

*FAO: Food and Agriculture Organization
*WHO: World Health Organization

Table 3: Comparison the total average of heavy metal concentration in vegetable samples with the global standard limits (mg / g) [36, 44-48].

Conclusion

The results of current study due to determination of heavy metals of lead and cadmium in green samples in Tehran-Iran and their comparison with the amount of these metals in international standards indicate the high rate of contamination of prepared vegetables. Also, according to the results of this study, the high lead content of the examined vegetables with the maximum average concentration of cadmium, which has a more serious risk than lead, can be contaminated due to its proximity to the road or exposure to vegetables exposed to contamination, because most vegetables are cultivated in polluted environmental conditions in the margins of cities. The results of the present study showed that Lead content in mint and leek significantly higher than other leafy vegetables ($p < 0.003$), while the highest nickel contents in cress samples in all 8 brands was on the top ($p < 0.001$). Also, the lowest amount of lead and nickel observed in the parsley samples ($p < 0.03$) and the least amount of cadmium was observed in basil ($p < 0.01$). In the case of tuber vegetables, the highest concentrations of all studied heavy metals l were in scallion ($p < 0.01$). The mean concentrations of lead, cadmium, and nickel in the investigated vegetables were much higher than the FAO/WHO and Codex standards. It is suggested that regular monitoring of heavy metals in vegetables and other food items should be done to prevent excessive production of these heavy metals in the human food chain. At the time of production, transportation and marketing of vegetables, the necessary precautions should be taken. Also, human activities in the area, irrigation with sewage or sewage with runoff to agricultural land, excessive use of fertilizers or transport of metals through transportation or processing of vegetables in contact with contaminated water of washing of the vegetables or equipment in ready-to-eat vegetables. Therefore, serious monitoring of heavy metal contamination in vegetables, especially ready-to-eat vegetables, is very important and further studies are needed to identify the exact sources of metals in vegetables.

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