Original Article

Potential health concerns of trace elements and mineral content in commonly consumed greenhouse vegetables in Isfahan, Iran

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Abstract

Background: This study aimed to investigate the potential health concerns of trace elements and mineral content of commonly consumed greenhouse vegetables in Isfahan, Iran.

Materials and Methods: Six kinds of greenhouse vegetables namely; *Raphanus sativus* (Radish), *Cucumis sativus* (Cucumber), *Solanum lycopersicum* (Tomato), green *Capsicum annuum* (Green bell pepper), yellow *C. annuum* (Yellow bell pepper), and red *C. annuum* (Red bell pepper) were collected from Isfahan greenhouses, between December 2012 and March 2013. The vegetables were analyzed in order to determine the concentrations of trace elements and trace minerals using instrumental neutron activation analysis (INAA).

Results: The results of INAA showed that the concentrations of aluminum, bromine, cobalt, rubidium and strontium of these vegetables were varied from 7.2 to 28.4 mg/kg, 0.6–11.7 mg/kg, 0.1–0.5 mg/kg, 4.2–8.4 mg/kg, and 12.0–141.0 mg/kg, respectively. The trace mineral concentrations of As, Cr, Cs, Sc, Th, and U in all of the samples were less than the defined tolerable upper intake level.

Conclusion: The results of this study revealed that considering the measured trace elements and mineral content levels, Isfahan greenhouse vegetables do not impose any serious health harmful effects for individuals in the studied area due to their meal consumptions.

Key Words: Greenhouse vegetables, instrumental neutron activation analysis, trace elements, trace minerals

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INTRODUCTION

Nowadays, greenhouse vegetables and fruits production have attracted considerable attentions, particularly as alternative crops of healthy eating.[1] The issue is based on the perception that greenhouse vegetables and fruits may be more profitable than the conventional agronomic or horticultural crops.

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Moreover, this may also be due to their growth and use capability in different seasons of the year.[2] However, the use of chemical pesticides and fertilizers, as a way of increasing greenhouse vegetables and fruits crops, could endanger the human health and impose harmful effects.[3]

In Iran, about 87% of agriculture fertilizers is in the form of phosphorus.[4] It should be noted that, such amount of fertilizers is considered to be carcinogenic.[5] In addition to phosphorus, fertilizers contain some other elements such as chromium, iron, manganese, and zinc that are needed for the human body and are vital to our health and wellness, in definite amounts.[6-8] However, large amounts of these elements can be toxic for certain individuals. "In general, these elements are presented in vegetables and fruits in trace and ultra-trace quantities.[3]"

In this regard, many studies have been done to quantify the trace elements and mineral contents of various vegetables and fruits.[3,8-11] However, according to the best of our knowledge, there is no report on greenhouses crops in Isfahan, Iran, with the methodology and analysis described here.

This study aimed to investigate the concentrations of trace elements and minerals in some greenhouse crops of Isfahan, Iran, using Instrumental Neutron Activation Analysis (INAA). INAA is a highly sensitive and nondestructive analytical technique used to determine the concentrations of trace and major elements in a variety of materials.[12] This method is based on the measurement of characteristic radiation from radionuclides formed directly or indirectly by neutron irradiation of the material of interest.[12]

MATERIAL AND METHODS

Six types of vegetables namely; *C. sativus* (Cucumber), green *C. annuum* (green bell pepper), *R. sativus* (Radish), red *C. annuum* (red bell pepper), *S. lycopersicum* (Tomato), and yellow *C. annuum* (yellow bell pepper) were collected from local Isfahan greenhouses between December 2012 to March 2013. The total number of samples was about 90, and there were 18 samples per each greenhouse vegetables. The study was performed based on the basic protocol on the determination of trace elements and minerals concentrations using INAA.[12] "Samples were transported to the laboratory within 1-day. They were individually brushed to remove adhering soil, washed with tap water, cut into small pieces with a scalpel and transferred to clean, dry vials. After 24 h freezing, to remove the samples water, they were dried in an oven at 60°C for at least 2 days, until a constant dry weight was obtained. The dried samples were homogenized with a pestle and mortar, and then, they were reduced to a powder. For quantity control, four biological standard references of peach leaves NIST-1547, bovine liver NIST-1577b, rice flour NBS-1568a and apple leaves NIST-1515 were considered.[3]"

Then, the samples were transferred to laboratory of Activation Analysis, Isfahan Research and Fuel Production Center, Isfahan, Iran, for determination of trace elements (aluminum [Al], bromine [Br], cobalt [Co], rubidium [Rb], and strontium [Sr]) and trace minerals (As, Cr, Cs, Sc, Th, and U) concentrations using INAA. The samples were irradiated with thermal neutrons from a miniature neutron source reactor. Table 1 gives the irradiation setup of the used neutron activation analysis (NAA).

Gamma ray spectra of the irradiated samples were obtained with a well type high-purity Germanium detector. This type of detector is mainly used to minimize the geometry errors arising during gamma ray counting of the irradiated samples. The resolution of this detector was 2.0 keV for the energy peak of ^{60}Co. The NAA software (SPAN software, Multipurpose Gamma- Ray Spectrum Analysis Software, China Institute of Atomic Energy, Beijing, China) was used for the identification of the radionuclides and calculation of their activities.

RESULT

Figure 1 gives a comparison of mean concentrations of trace elements and trace minerals of the samples.

Table 2 shows concentrations of trace elements in the studied greenhouse vegetable samples.

From the tables, one can find that all kind of peppers are more nutritious than radish and cucumber.

The trace mineral concentrations of As, Cr, Cs, Sc, Th, and U in all of the samples were less than the defined tolerable upper intake level [Figure 1 and Table 2].

DISCUSSION

In this work, the concentrations of trace elements and trace minerals in vegetable samples of Isfahan

Table 1: Neutron activation analysis setup for greenhouse vegetable samples

Neutron flux $\times 10^{11}$ (n/cm^2/s)	Irradiation time	Decay time	Counting time	Elements determined
1	2 min	80 s	500 s	Al
5	7 h	4 days	1500 s	As, Br, Sr, U
5	7 h	10 days	5000 s	Co, Cr, Cs, Th

greenhouses were investigated. The precision and accuracy of the experiment were tested by analyzing standard reference materials, and a good agreement was found. Twelve elements in vegetable samples were divided into two groups of trace elements and trace minerals.

Aluminum

Environmental protection agency has not derived a reference dose or reference concentration for Al, however, the recommended dietary allowance (RDA) value of Al element is stated to be 7 mg/day.[3] The RDA represents the average daily nutrient intake level that meets the nutrient requirements of about 98% of healthy individuals in a particular life stage. Al concentrations of the analyzed samples in this study were between 7.2 mg/kg (for yellow bell pepper) to 28.4 mg/kg (for radish) [Figure 1]. It should be noted that in many of the analytical methods used by the scientists to determine the levels of Al in the environment and foods, a distinct toxic level for this element has not been determined and only a total amount in the samples presented.[10]

In the recent study by Shafaei, they have reported that the concentration of Al for Malaysian cucumber was 178 mg/kg, while for greenhouse cucumber it was 23.0 mg/kg.[12] Al Jobori *et al*. stated that the Al concentrations were 15.8, 6.9, 11.6, and 5.4 mg/kg, for Iraq pepper, radish, tomato, and cucumber, respectively.[3] The Al concentrations measured in this study was significantly lower than those reported in Iraq, opposed to Malaysia.

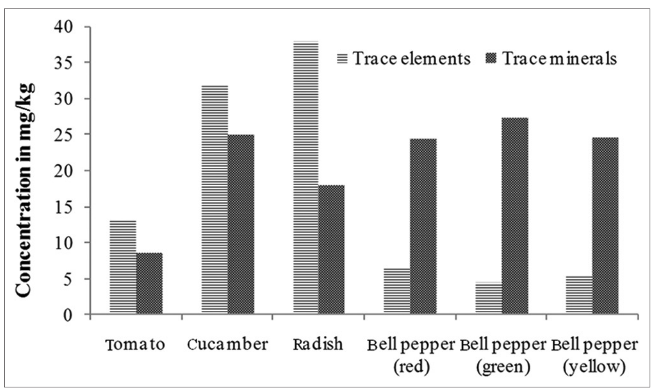

Figure 1: Comparison of mean concentrations of trace elements and trace minerals of the samples

Bromine

Bromine is one of the ubiquitous trace elements in the biosphere. The concentration of Br in vegetables depends on the type of soil which the vegetables are grown.[13] The RDA value of Br element is 25 mg/kg.[3] Br concentrations of the samples analyzed in this study were between 0.61 mg/kg (for green bell pepper) and 11.7 mg/kg (for radish).

Yuita *et al*. found that the residual Br contents in vegetables grown in fumigated greenhouse are >10 times higher than those in elsewhere.[14] Average concentration of Br in a kind of Japanese radish (Kaiwar) is reported to be 10 mg/kg.[13] The concentrations of Br for Malaysian cucumber and greenhouse cucumber were 5 mg/kg and 3.9 mg/kg, respectively.[12] Al-Jobori *et al*. investigated that the Br concentrations were 16.1, 82.9, 31.9, and 9.9 mg/kg, for Iraq pepper, radish, tomato, and cucumber, respectively.[3]

Cobalt

Cobalt is mostly assimilated only by the intake of Vitamin B12, and not in its ionic or metallic form. Therefore, there is no clear recommended amounts of Co because there are just recommendations for Vitamin B12.[3] Moreover, there are currently no beneficial claims based upon Co as a single element.[3] Co concentrations of the analyzed samples in this study were between 0.05 mg/kg (for tomato) and 0.52 mg/kg (for cucumber) [Table 2].

Rubidium

Rubidium concentrations of the samples analyzed in this study were between 4.2 mg/kg for cucumber to 8.5 mg/kg for tomato [Figure 1]. The typical daily dietary intake of Rb is expected to be 1–5 mg. Foods with the highest content of Rb are coffee, black tea, fruits, and vegetables (especially asparagus). Rb is a relatively nontoxic element and has not shown

Table 2: Trace elements concentrations (mg/kg dray-weight) in greenhouses vegetables

Sample	Al (mg/kg)	Br (mg/kg)	Co (mg/kg)	Rb (mg/kg)	Sr (mg/kg)	Average (mg/kg)
Tomato	7.6±0.7	5.67±0.2	0.05±0.01	8.4±0.8	44.0±5.0	13.1
Cucumber	23.0±1.5	3.4±0.2	0.52±0.03	4.2±0.6	127.0±9.0	31.7
Radish	28.4±1.4	11.7±0.4	0.27±0.02	7.4±0.7	141.0±10.0	37.7
Bell pepper (red)	10.8±0.5	0.7±0.1	0.08±0.02	7.0±0.7	14.0±4.0	6.5
Bell pepper (green)	9.8±0.6	0.6±0.0	0.14±0.02	6.5±0.7	-	4.3
Bell pepper (yellow)	7.2±0.5	0.8±0.0	0.14±0.02	6.7±0.7	12.0±4.0	5.4
Minimum	7.2	0.6	0.05	4.2	12	
Maximum	28.4	11.7	0.52	8.4	141	

toxicological concern from the nutritional point of view.[15] However, there are some researches in the literature which have determined the concentrations of Rb in some of the foodstuffs.[3,12,15] In this regard, Anke *et al*. reported that the Rb concentrations in cucumber and tomato in Germany were 18.3 mg/kg and 8.45 mg/kg, respectively.[15] Shafaei found that the concentrations of Rb in a kind of Malaysian pepper, chili and chilli padi were 25.0 and 3.3 mg/kg, respectively.[12] Al-Jobori *et al*. determined the Rb for Iraq radish, tomato, and cucumber. The results of their study showed that the Rb concentrations were 63.6, 16.9, and 3.7 mg/kg, for Iraq radish, tomato, and cucumber, respectively.[3]

Strontium

Strontium concentrations of the samples analyzed in this study were between 12 mg/kg (for yellow bell pepper) and 141 mg/kg (for radish) [Figure 1]. The average concentration of stable Sr in soil is approximately 240 mg/kg.[12] However, in agricultural soils which are contained phosphate fertilizer or limestone, the concentration of Sr is approximately 610 mg/kg, significantly higher than soil without phosphate fertilizer.[12] Since Sr is chemically similar to calcium,[16] it is taken up from the soil by fruits and vegetables. The average concentrations of Sr in fruit ranged from 0.0416 to 2.232 μg/L.[12] Assuming a reference body weight of 70 kg, the typical daily Sr exposure is 0.046 mg/kg of body weight. Extremely high Sr uptake can cause disruption of bone development and cause lung cancer. But this effect can only occur when Sr uptake is in the thousands of mg/kg range.[12,16] Sr levels in our samples were not high enough to be able to cause these effects.

CONCLUSION

The concentrations of trace elements (Al, Br, Co, Rb, and Sr) and trace minerals (As, Cr, Cs, Sc, Th and U) in 6 types of vegetables namely; *R. sativus* (Radish), *C. sativus* (Cucamber), *S. lycopersicum* (Tomato), green *C. annuum* (Green bell pepper), yellow *C. annuum* (Yellow bell pepper), and red *C. annuum* (Red bell pepper) grown in Isfahan greenhouses were determined using INAA. The results of this study revealed that considering the measured trace elements and mineral content levels, Isfahan greenhouse vegetables do not impose any serious health harmful effects for individuals in the studied area due to their meal consumptions.

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Conflicts of interest

There are no conflicts of interest.

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