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Full Length Research Paper

Survey of some heavy metals in Yemeni vegetables

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Abstract

The present study aims to determine the occurrence and concentrations of some heavy metals in 60 samples of Yemeni vegetables divided into three groups namely, (cabbage – lettuce – leek- watercress) as the first once, while the second including (eggplant cucumber – squash – tomato), finally the third group was (carrots – green onion – potatoes – radish) which were collected in 2011, from local markets in Ibb City, Yemen, and the results could be summarized as the following. The highest value for Cd was in sample of squash 0.36 ppm, and less value in sample of lettuce was 0.001 ppm. Meanwhile, Cu reached its highest value including 1.6 ppm in sample of cucumber, and the less value 0.0059 ppm in sample of eggplant. On the other hand, Fe reached the highest value 13.9 ppm in sample of leek, and the lowest value 0.072 ppm in sample of cabbage. Finally Pb reached its highest value 1.7 ppm in sample of lettuce and less value was 0.0076 ppm in sample of tomato.

Keywords: Yemeni vegetables, chemical contamination, heavy metals.

INTRODUCTION

Vegetables are the extremely important life-supporting materials for human beings and animals because vegetables contain essential components of protein, vitamin, iron, calcium and other nutrients (Bahemuka and Mubofu, 1999). However, nutritional value and consumer acceptance must be taken into consideration when vegetables are being considered as food, because vegetables can contain both essential and nonessential elements over a wide range of concentrations (Chien *et al.,* 2002 and Gupta *et al.,* 2008). The occurrence of high metals content in edible plants, is of considerable importance, since they might constitute a possible toxicological hazard. Heavy metals, when concentrated in living organisms should be regarded as toxins towards mammals and particularly humans.

Accumulation of specific elements results mainly from pollution, and might, in some cases, constitute useful environmental markers, (Michelot *et al.,* 1998). Human beings are encouraged to consume more vegetables and fruits, which are a good source of vitamins, minerals, fiber and are beneficial for health. However, these plants contain both essential and toxic metals over a wide range of concentrations. It is well known that plants take up metals by absorbing them from contaminated soil as well as from deposits on parts of the plants exposed to the air from polluted environments (Khairiah *et al*, 2004 and Chojnacka *et al*, 2005). Heavy metals can be classified as potentially toxic (arsenic, cadmium, lead, etc.), probably essential (vanadium, cobalt) and essential (copper, zinc, iron, manganese, etc.). Toxic elements can be very harmful even at low concentration when ingested over a long time period (Unak *et al.,* 2007). The essential metals can also produce toxic effects when the metal intake is excessively elevated (Gopalani *et al.,* 2007). It is necessary to assess the levels of heavy metals in edible vegetable and to report possible contamination that would represent a health hazard. Disposal of sewage water and industrial wastes is a great problem. Often it is drained to the agricultural lands where it is used for growing crops including vegetables. Vegetables, especially those of leafy vegetables grown in heavy metals contaminated soils, accumulate higher amounts of metals than those grown in uncontaminated soils because of the fact that they absorb these metals through their leaves (Jassir *et al*., 2005). Human exposure to heavy metals is a subject of public health concern that have attracted the attention of researchers, health and nutrition experts all over the world. The allowable Limit of Heavy Metals, as safe values for copper, lead, and cadmium in fruit and vegetables recommended by the WHO / FAO are 40, 0.3, and 0.2 mg/kg, respectively. The objective of these regulations are to protect human health and natural resources from toxicity of these heavy metals. So, our study aims to determine the occurrence and concentrations of some heavy metals such as, Cadmium (Cd), Copper (Cu), Iron (Fe) and Lead (Pb), in 60 samples of Yemeni vegetables divided into three groups (cabbage – lettuce – leek- watercress) was the first, while the second including (tomato - cucumber – eggplant –squash), finally the third group was (potatoes – radish – carrots – green onion) which were collected in 2011, from local markets in Ibb City, Yemen.

MATERIALS AND METHODS

Samples

A total of 60 samples of Yemeni vegetables, 5 samples of each vegetable types, divided into three groups (cabbage – leek – lettuce – watercress) was the first ones, while the second including (cucumber – eggplant – squash – tomato), finally the third group was (carrots – green onion – potatoes – radish) which were collected by the students of last year class in food science and technology department- faculty of agriculture – Ibb university ,Yemen, in 2011 from local markets in Ibb City, Yemen.

Methods

The heavy metals in this investigation, such as Cadmium (Cd), Copper (Cu), Iron (Fe) and Lead (Pb) were determined according to the standard method of A.O.A.C. (2005), by using Atomic Absorption Spectroscopy (AAS), NOVA 300 made by NOVA Company (USA).

Statistical analysis

All the samples analyses in this study were carried out in triplicate and the results were reported as mean values. The obtained data were subjected to statistical analysis and the average, compared by Microsoft Excel statistical software (Microsoft Office Excel 2003, Microsoft Corp., Redmond, WA, USA).

RESULTS AND DISCUSSIONS

Vegetables are rich sources of vitamins, minerals, and fibers, and also have beneficial anti-oxidative effects. Meanwhile, chemical contamination from sources such as industries, vehicles and pesticides can affect the safety of food. Heavy metals are one of a range of important types of contaminants that can be found on the surface and in the tissue of fresh vegetables. Prolonged human consumption of unsafe concentrations of heavy metals in foodstuffs may lead to the disruption of numerous biological and biochemical processes in the human body. Heavy metal accumulation gives rise to toxic concentrations in the body, while some elements (e.g. arsenic, cadmium, chromium) act as carcinogens and others (e.g. mercury and lead) are associated with developmental abnormalities in children. Some chronically consumed vegetables from markets in Chongqing, China, were contaminated with lead and cadmium according to the heavy metal sanitary standards for edible vegetables established by China and FAO / WHO, (Yang *et al.,* 2011).

Data in Table (1) represented the results of survey on some heavy metals such as Cadmium (Cd), Copper (Cu), Iron (Fe) and Lead (Pb) in 60 samples of Yemeni vegetables which were collected from local markets in IBB City, Yemen in 2011. These samples were three groups namely (cabbage - leek - lettuce - watercress) was the first ones, while the second including (cucumber - eggplant – squash - tomato), finally the third group was (carrots - green onion – potatoes - radish), and the levels of these heavy metals as: the highest value for Cd was in sample of squash 0.36 ppm, and less value in sample of lettuce was 0.001 ppm. Meanwhile, Cu reached its highest value including 1.6 ppm in sample of cucumber, and the less value 0.0059 ppm in sample of eggplant. On the other hand, Fe reached the highest value 13.9 ppm in sample of leek, and the lowest value 0.072 ppm in sample of cabbage. Finally Pb reached its highest value 1.7 ppm in sample of lettuce and less value was 0.0076 ppm in sample of tomato. Our results are demonstrated clearly that, Yemeni vegetable in ibb city under this investigation were within the limit of heavy metals in local and international standards, these results were in harmony with many studies in different countries such as Zhu, *et al.,* (2011) who analyzed eight heavy metals, namely Cu, Zn, Fe, Mn, Cd, Ni, Pb and As, in nine

Table 1. Concentrations of some heavy metals in Yemeni vegetables samples*:

*Vegetables	(Cd) ppm	(Cu) ppm	(Fe) ppm	(Pb) ppm
Cabbage (average ± SD)	**0.0029 ± 0.0020**	**0.03 ± 0.0139**	**1.0076 ± 0.7108**	**0.0666 ± 0.0137**
Sample 1	0.0015	0.029	0.072	0.066
Sample 2	0.0023	0.05	1.603	0.047
Sample 3	0.0069	0.041	0.57	0.064
Sample 4	0.0015	0.014	0.763	0.066
Sample 5	0.0025	0.016	2.03	0.09
Leek (average ± SD)	**0.018 ± 0.0084**	**0.0568 ± 0.0289**	**12.7706 ± 0.7014**	**0.1758 ± 0.0446**
Sample 1	0.004	0.081	12.06	0.18
Sample 2	0.018	0.028	13.98	0.14
Sample 3	0.015	0.032	12.102	0.26
Sample 4	0.027	0.042	12.979	0.159
Sample 5	0.026	0.101	12.732	0.14
Lettuce (average ± SD)	**0.0069 ± 0.0041**	**0.0544 ± 0.0286**	**2.267 ± 0.3142**	**0.7532 ± 0.7520**
Sample 1	0.0095	0.026	2.461	1.545
Sample 2	0.01	0.093	2.053	0.093
Sample 3	0.001	0.031	1.772	1.79
Sample 4	0.011	0.085	2.652	0.108
Sample 5	0.003	0.037	2.397	0.23
Watercress (average ± SD)	**0.0268 ± 0.0033**	**0.0334 ± 0.0229**	**6.0006 ± 0.2991**	**0.352 ± 0.0882**
Sample 1	0.025	0.011	5.63	0.43
Sample 2	0.026	0.022	5.837	0.37
Sample 3	0.022	0.073	5.982	0.19
Sample 4	0.03	0.045	6.532	0.43
Sample 5	0.031	0.016	6.022	0.34
Cucumber (average ± SD)	**0.0466 ± 0.0137**	**0.57 ± 0.5524**	**1.6672 ± 0.2788**	**0.058 ± 0.0258**
Sample 1	0.05	0.46	1.927	0.024
Sample 2	0.04	0.264	1.976	0.034
Sample 3	0.068	0.307	1.75	0.093
Sample 4	0.026	0.161	1.283	0.062
Sample 5	0.049	1.658	1.4	0.077
Eggplant (average ± SD)	**0.037 ± 0.0286**	**0.13002 ± 0.1796**	**1.4024 ± 0.2699**	**0.0488 ± 0.0160**
Sample 1	0.049	0.482	1.8	0.02
Sample 2	0.019	0.0102	1.509	0.045
Sample 3	0.088	0.106	1.195	0.067
Sample 4	0.011	0.0059	1.022	0.055
Sample 5	0.018	0.046	1.486	0.057
Squash (average ± SD)	**0.1164 ± 0.1218**	**0.308 ± 0.1831**	**2.1972 ± 0.1778**	**0.0526 ± 0.0233**
Sample 1	0.36	0.067	1.929	0.078
Sample 2	0.052	0.168	2.386	0.083
Sample 3	0.057	0.536	2.389	0.038
Sample 4	0.058	0.27	2.08	0.025
Sample 5	0.055	0.499	2.202	0.039
Tomato (average ± SD)	**0.0292 ± 0.0146**	**0.2348 ± 0.0272**	**1.8942 ± 0.1138**	**0.03667 ± 0.0226**
Sample 1	0.0025	0.196	1.944	0.0076
Sample 2	0.0266	0.247	1.969	0.0689
Sample 3	0.032	0.231	1.966	0.0143
Sample 4	0.0417	0.278	1.669	0.0459
Sample 5	0.043	0.222	1.923	0.0466
Carrots (average ± SD)	**0.0268 ± 0.0209**	**0.1789 ± 0.1488**	**2.9484 ± 0.5951**	**0.0712 ± 0.0259**
Sample 1	0.068	0.3686	2.86	0.11
Sample 2	0.012	0.016	2.585	0.046

Table 1. Continue

Sample 3	0.014	0.114	3.957	0.073
Sample 4	0.016	0.345	2.191	0.087
Sample 5	0.024	0.051	3.149	0.04
Green Onion (average ± SD)	**0.0308 ± 0.0269**	**0.354 ± 0.0823**	**2.0724 ± 0.1169**	**0.1584 ± 0.0857**
Sample 1	0.014	0.4	2.188	0.163
Sample 2	0.025	0.35	2.067	0.129
Sample 3	0.015	0.24	1.929	0.297
Sample 4	0.084	0.3	2.219	0.173
Sample 5	0.016	0.48	1.959	0.03
Potatoes (average ± SD)	**0.027 ± 0.0117**	**0.2186 ± 0.2066**	**1.7642 ± 0.1866**	**0.116 ± 0.0788**
Sample 1	0.028	0.25	1.938	0.218
Sample 2	0.027	0.58	1.894	0.195
Sample 3	0.022	0.23	1.916	0.103
Sample 4	0.047	0.02	1.523	0.023
Sample 5	0.011	0.013	1.55	0.041
Radish (average ± SD)	**0.0292 ± 0.0052**	**0.1328 ± 0.0432**	**4.5298 ± 0.3917**	**0.1115 ± 0.1040**
Sample 1	0.024	0.11	3.821	0.117
Sample 2	0.023	0.062	4.879	0.3067
Sample 3	0.034	0.172	4.907	0.082
Sample 4	0.029	0.18	4.504	0.042
Sample 5	0.036	0.14	4.538	0.01

*Samples were 5 for each type of vegetables results (average ± Stander Deviation).

varieties of edible vegetable oils collected from China, were determined by inductively coupled plasma atomic emission spectrometry (ICPAES). The concentrations for copper, zinc, iron, manganese, nickel, lead and arsenic were observed in the range of 0.214–0.875, 0.742–2.56, 16.2–45.3, 0.113–0.556, 0.026–0.075, 0.009–0.018 and 0.009–0.019 (µg/g), respectively. On the other hand a systematic survey of As, Cd, Cr, Cu, Ni, Pb and Zn concentrations in vegetables from 416 samples in Beijing, China was carried out by Bo *et al.,* (2009). The results indicated that, the metal concentrations in vegetables ranged from < 0.001 to 0.479 µg/g fresh weight (fw) (As), < 0.001 to 0.101 µg/g fw (Cd), < 0.001 to 1.04 µg/g fw (Cr), 0.024 to 8.25 µg/g fw (Cu), 0.001 to 1.689 µg/g fw (Ni), < 0.001 to 0.655 µg/g fw (Pb) and 0.01 to 25.6 µg/g fw (Zn), with average concentrations of 0.013, 0.010, 0.023, 0.51, 0.053, 0.046 and 2.55 µg/g fw, respectively. The results showed that the concentrations of As, Cr, Cu, Cd, Pb and Ni in vegetables from open-fields were all significantly higher than those grown in greenhouses. Meanwhile, the levels of four different heavy metals [cadmium (Cd), lead (Pb), chromium (Cr) and copper (Cu)] were determined in various vegetables [leek (*Allium ampeloprasum*), sweet basil (*Ocimum basilicum*), parsley (*Petroselinum crispum*), garden cress (*Lepidium sativum*) and tarragon (*Artemisia dracunculus*)] cultivated around Sanandaj City, Iran by Maleki and Zarasvand, (2008). Atomic absorption spectrometry was used to determine the concentrations of these metals in the vegetables. The average concentrations of each heavy metal regardless of the kind of vegetable for Pb, Cu, Cr and Cd were 13.60 - 2.27, 11.50 - 2.16, 7.90 - 1.05 and 0.31 - 0.17 mg/kg, respectively.

Another study by Harmanescu *et al.,* (2011), carried out to measure the levels of heavy metals (Fe, Mn, Zn, Cu, Ni, Cd and Pb) found in common vegetables (parsley, carrot, onion, lettuce, cucumber and green beans) grown in contaminated mining areas compared with those grown in reference clear area and to determine their potential detrimental effects via calculation of the daily metal intake (DI metal) and Target Hazard Quotients (THQ) for normal daily consumption of these vegetables, for male and female gender. The results of this study regarding metal contents in soils, vegetables, DI metal and THQ suggest that the consumption of some vegetables (especially parsley, carrot and cabbage and less for lettuce, cucumber and green beans) is not free of risks in these areas. The complex THQ parameter use in health risk assessment of heavy metals provides a better image than using only a simple parameter (contents of metals in soils and vegetables). The target hazard quotient (THQ) was developed by US EPA, as one quantitative way to evaluate potential health risks associated with long-term exposure to chemical pollutants in food stuffs, and the THQ is a ratio between the measured concentration and the oral reference dose. On the other hand the heavy metal concentration of Cadmium (Cd), Cobalt (Co), Copper (Cu), Iron (Fe), Nickel (Ni), Lead (Pb) and Zinc (Zn) was analyzed by Kumar *et al.,* (2009) using Inductive Coupled Plasma Analyzer (ICPA) in 18 vegetable crop plants and their parts along with their soil, collected from various agricultural fields around Anand province, Gujarat, India. The vegetables crop plants were Anthem (*Anthum graveolens*), Beat (*Brassica oleracea*), Bitter Gourd (*Momordica charantia*), Brinjal (*Solanum melongena*), Cauliflower (*Brassica oleracea* var. *botrytis*), Chilli (*Capsicum annum*), Coriander (*Coriandrum sativum*), Fenugreek (*Trigonella foenum-graceum*), Garlic (*Alium sativum*), *Coccinia indica*, Lufa (*Luffa acutangula*), Lady's Finger (*Abelmoschus esculentus*), Mint (*Mentha piperata*), Radish (*Raphanus sativum*), Spinach (*Spinacia oleracea*), Tomato (*Lycopersicum esculentum*), Vetches (*Cyamopsis soralioides*) and White Gourd (*Lagernaria vulgaris*). The results showed concentration dependent variables of heavy metal levels among vegetable crop plants. The lower and higher concentration gradient along with their mobility gradient was also determined. A perusal of data reflects that accumulation gradient of each crop plant component vary according to their nature, properties and pod sol climate of a particular crop plant. The data on accumulation and mobility of heavy metals such as Cd, Co, Cu, Fe, Ni, Pb and Zn from soil to leaves through roots and stems, suggested that all the metals were highly mobile. The main cause for concern in terms of contamination of vegetables in Delhi by heavy metals relates to Lead (Pb). 72 % of 222 (quality controlled) samples of palak contained Pb concentrations that exceeded the Indian (Prevention of Food Adulteration act (PFA) permissible limit of 2.5 mg/kg. If the more stringent CODEX limit of 0.3 mg/kg is used, then 100% of the palak samples exceeded safe limits. On the other hand, the content of lead (Pb), copper (Cu), zinc (Zn), cobalt (Co), nickel (Ni), and cadmium (Cd) in some selected fruits and vegetables from the Misurata City Market, Libya, were measured by Elbagermi *et al.,* (2012), who used atomic absorption spectrophotometry. The results of this study showed that the average concentrations detected ranged from 0.02 to 1.824, 0.75 to 6.21, 0.042 to 11.4, 0.141 to 1.168, 0.19 to 5.143, and 0.01 to 0.362 mg/kg for Pb, Cu, Zn, Co, Ni, and Cd, respectively. The highest mean levels of Pb, Cu, Zn, Co, Ni and Cd were detected in mango, melon, spinach, banana, mango, and mango fruits, respectively. Meanwhile, Lettuce, spinach, celery and cabbage avidly accumulate cadmium while potato tubers, maize, french beans, and peas accumulate much less. Many studies show linear relationships between soil cadmium concentrations and wheat and barley grain, cabbage, and lettuce cadmium contents, (Arora *et al.,* 2008).

Sharma *et al.,* (2009) found that, vegetables (*Beta vulgaris* L., *Abelmoschus esculentus* L. and *Brassica oleracea* L.) from the production and market sites of India were tested for Cu, Cd, Zn and Pb, at market sites, the mean concentration of Cu in cauliflower, and of Zn and Cd in both palak and cauliflower had exceeded the Prevention of Food Adulteration (PFA) standard. Zn at the production sites also exceeded the PFA standard in cauliflower. Cd concentration in vegetables tested from both production and market sites was many folds higher than the European Union (EU) standard. In contrast, Pb in vegetables tested from both production and market sites was below the PFA limit, but was considerably higher than the current EU and WHO standards. Heavy metals accumulation in vegetables tested are higher at market sites than those at the crop production sites. The contributions of these vegetables to dietary intake of Cu, Zn, Cd and Pb were 13%, 1%, 47% and 9% of provisional tolerable daily intake, respectively. The study concludes that the transportation and marketing systems of vegetables play a significant role in elevating the contaminant levels of heavy metals which may pose a threat to the quality of the vegetables with consequences for the health of the consumers of locally produced foodstuffs. Observed concentrations of Cu, Zn, Cd and Pb in the vegetables were also compared with PFA act (30, 50, 1.5 and 2.5 µg/g, respectively) and EU (0.1 and 0.3 µg/g, respectively, for Cd and Pb) standards of food contamination. The contribution of the

heavy metal contamination through dietary intake of the vegetables tested is also assessed based on the average daily consumption of the vegetables. Dietary exposure to heavy metals, namely cadmium (Cd), lead (Pb), zinc (Zn) and copper (Cu), has been identified as a risk to human health through the consumption of vegetable crops by Kachenko and Singh, (2006). Cadmium, Pb and Zn contamination was greatest in vegetables from Boolaroo, and Cu concentrations were greatest in vegetables sampled from Port Kembla. At Boolaroo, nearly all the samples exceeded the Australian Food Standards maximum level (0.01 mg/kg fresh weight) of Cd and Pb in vegetables. Over 63% of samples exceeded international food standard guidelines set by the Commission of the European Communities and the Codex Alimentarius Commission. All vegetables sampled from Cowra, which is a relatively pristine site had Cd and Pb levels below the Australian and international food standards guideline values. Meanwhile, the heavy metal concentration of Cadmium (Cd), Cobalt (Co), Copper (Cu), Iron (Fe), Nickel (Ni), Lead (Pb) and Zinc (Zn) was analyzed using Inductive Coupled Plasma Analyzer (ICPA) by Kumar, *et al.,* (2007), in 21 vegetables collected from Vegetable Market of Anand town, Gujarat, India. The vegetables are Lady's Finger (*Abelmoschus esculentus*), Onion (*Alium sepa*), Cauliflower (*Brassica oleracea var. botrytis*), Beat (*Brassica oleracea*), Chilli (*Capsicum annum*), Tindora (*Coccinia indica*), Pattarveli (*Colocasia sp.*), Coriander (*Coriandrum sativum*), Cucumber (*Cucumis sativus*), Turmeric (*Curcuma longa*), Vetches/Gavar (*Cyamopsis soralioides*), Bean Pods (*Dolichos lablab*), Carrot (*Ductus carrotus*), Ginger (*Gingiber officinalis*), Sweet Potato (*Ipomoea batatas*), Bottle Gourd (*Lagernaria vulgaris*), Tomato (*Lycopersicum esculentum*), Bitter Gourd

(*Momordica charantia*), Drumstick (*Moringa oleifera*), Brinjal (*Solanum melongena*) and Parwar (*Trichosanthes dioicea*). The high concentration of Cd was found in Onion, Coriander and Cauliflower, while Co and Cu content was recorded high in Cauliflower and Bottle Gourd. On the other hand, high content of Fe was observed in Cauliflower and Cucumber. Vetches and Lady's Finger had shown high concentration of Ni. Cauliflower and Onion showed high amount of Pb. Meanwhile, Cucumber and Cauliflower registered maximum content of Zn. The heavy metal concentration in vegetables was within the prescribed safety limits except Fe owing to iron-rich soil of the area.

Another study by Farooq *et al.,* (2008) found that, the contents of lead (Pb), copper (Cu), chromium (Cr), zinc (Zn) and cadmium (Cd) in various leafy vegetables viz., spinach, coriander, lettuce, radish, cabbage and cauliflower grown in an effluent irrigated fields in the vicinity of an industrial area of Faisalabad, Pakistan were assessed using atomic absorption spectrophotometer. The concentrations of Pb, Cu, Cr, Zn and Cd in the leaves, stems and roots of spinach, coriander, lettuce, radish, cabbage and cauliflower were found to be 1.1331–2.652, 1.313-2.161, 1.121-2.254; 0.252-0.923, 0.161-0.855, 0.221-0.931; 0.217- 0.546, 0.376-0.495, 0.338-0.511; 0.461-1.893, 0.361-0.874, 0.442-1.637; 0.033-0.073, 0.017-0.061, 0.011-0.052 mg/kg on dry matter basis, respectively. The contents of Cu, Zn, Cr, Pb and Cd were below the recommended maximum acceptable levels proposed by the Joint FAO/WHO Expert Committee on Food Additives. The leaves of spinach, cabbage, cauliflower, radish and coriander contained higher concentrations of Cu (0.923 mg/kg), Cd (0.073 mg/kg), Cr (0.546 mg/kg), Zn (1.893 mg/kg) and Pb (2.652 mg/kg) as compared to other parts of each vegetable. High concentrations of heavy metals as analyzed in the present analysis of different parts of the vegetables might be related to their concentration in the soils irrigated with industrial waste water. Ingestion of vegetables containing heavy metals is one of the main ways in which these elements enter the human body. Once entered, heavy metals are deposited in bone and fat tissues, overlapping noble minerals. Slowly released into the body, heavy metals can cause an array of diseases. A study by Guerra *et al.,* (2012), aimed to investigate the concentrations of cadmium, nickel, lead, cobalt and chromium in the most frequently consumed foodstuff in the São Paulo State, Brazil and to compare the heavy metal contents with the permissible limits established by the Brazilian legislation. A value of intake of heavy metals in human diets was also calculated to estimate the risk to human health. Vegetable samples were collected at the São Paulo General Warehousing and Centers Company, and the heavy metal content was determined by atomic absorption spectrophotometry. All sampled vegetables presented average concentrations of Cd and Ni lower than the permissible limits established by the Brazilian legislation. Pb and Cr exceeded the limits in 44 % of the analyzed samples.

CONCLUSION

Through the above results it is clear that, the importance of some minerals which has benefits for human body like Fe in leafy vegetables as a natural and rich source of this mineral. On the other hand the most dangerous heavy metals such as Cu, Cd and Pb in Yemeni vegetables in Ibb City, were found in low concentrations they are still within the limits of local and international standards.

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