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Potential Health Risk Assessment of Cr, Cu, Fe and Zn for Human Population via Consumption of Commercial Spices; a Case Study of Hamedan City, Iran

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ABSTRACT

Aims Spices are sources of many bioactive compounds that can improve the taste of food as well as affecting the digestion and metabolism. Along with that, they may also contain some substances as heavy metals, which have harmful effects on the body. The aim of present study was to assess the potential health risk of Cr, Cu, Fe and Zn contents of cardamom, curry powder and turmeric in Hamedan City, Iran.
Instrument & Methods 18 industrially packaged and weighted spice samples (cardamom, curry powder and turmeric) belonging to 6 famous brands were bought from different supermarkets of Hamedan City, Iran, in 2015. The human health risks posed by chronic exposure to the heavy metals were assessed by computing the average daily intake of metal. The health risk index (HRI) for the local population through the consumption of spice was assessed using DIM/RfD formula. Data were analyzed using ANOVA, DMS post-hoc, Tukey HSD and Pearson's correlation coefficient tests.
Findings Cr was detected in spice samples in 0.08-1.67mg/kg, Cu 0.05-1.28mg/kg, Fe 1.04-6.89mg/kg and Zn 0.40-2.25mg/kg. The mean concentration of Cu, Fe and Zn were lower than MPL. The DIM values for the examined spice samples were below the recommended values.
Conclusion The levels of Cr, Cu, Fe and Zn are less than the MPL in cardamom, curry powder and turmeric in Hamedan City, Iran.

Keywords Metals, Heavy; Spices; Food Safety; Health Status Indicators; Adverse Effects

CITATION LINKS

[1] Mineral compositions of eight common ... [2] Mineral contents of some plants used as condiments in ... [3] Evaluation of heavy metals contents in spices and herbs available on ... [4] Heavy metals health risk assessment for population via ... [5] Total arsenic, lead, and cadmium levels in vegetables cultivated at the Andean villages of ... [6] Market basket survey for some heavy metals in ... [7] Heavy metals contamination of table salt consumed in ... [8] Mineral and heavy metal contents of the outer and inner tissues of ... [9] The determination of cadmium and six other heavy metals in ... [10] Concentrations of 21 metals in 18 species of mushrooms growing in ... [11] Assessing potential dietary intake of heavy metals in some selected fruits and vegetables from ... [12] Trace elements in soils and ... [13] Determination of some heavy metal levels in soft drinkson the Ghanaian market using atomic absorption ... [14] Selected heavy metals analysis of Persian sturgeon's (Acipenserpersicus) caviar from southern Caspian ... [15] Analysis of some herbal plants from India used in the control of diabetes mellitus by NAA and ... [16] Heavy metal content of potato and corn chips from ... [17] Variation in heavy metal concentrations of ... [18] Removal of phenol from petroleum refinery wastewater through adsorption on date-pit Determination of mineral content in Indian spices ... [19] Analysis of minerals and heavy metals in some spices collected from ... [20] Monitoring of metallic micronutrients and heavy metals in ... [21] Heavy metals in Egyptian spices and medicinal plants and the effect of ... [22] Risk assessment of heavy metals in honey consumed in Zhejiang province, southeastern ... [23] Health risks of heavy metals in contaminated soils and food crops irrigated with wastewater in ... [24] A comparative study of human health risks via consumption of food crops grown on wastewater irrigated soil (Peshawar) and relatively clean water ... [25] Heavy metal levels in kiwifruit orchard soils and trees and its potential health ... [26] Heavy metals health risk assessment for population via consumption of vegetables grown in old ... [27] Contamination and health risks from heavy metals in cultivated soil in Zhangjiakou City of ... [28] Evaluation of possible health risks of ... [29] Quality control methods for spices ... [30] Exposure and risk assessment for aluminium and heavy metals in ...

Introduction

Spices are dried parts of plants grown in various regions of the world, which have been often used as diet components to improve aroma, color, palatability and acceptability of food since ancient times. Most of spices are fragrant, aromatic and pungent and several uses of these plants are for culinary purposes [1-3].

Nowadays, contamination of foods by heavy metals has become an inevitable challenge [4]. Heavy metals have long been known as a major contamination problem, not only for working conditions but also for the environment. Heavy metals are important environmental pollutants, especially in area with high anthropogenic pressure. Their presence in the environment particularly atmosphere and water, even in trace amounts, can cause serious problems for all organisms. Heavy metal accumulation in soils and resulting in vegetables through irrigation with contaminated water, metal based fertilizers and pesticides, transportation, industrial emissions, harvesting process and storage is of concern due to the adverse effects on food quality. Therefore, heavy metals are among the major pollutants of food supply and may considered the most important problem to our environment. Generally, these metals are not biodegradable or destroyable and enter into human body via food, water and air. They can also make acute poisoning, as well as long-term health problems, through accumulation in human vital organs, especially liver and kidney, with different mechanisms, e.g. interference with essential metals, oxidative stress, interaction with cellular macromolecules and producing progressive toxic effects [5-8].

Although some of the heavy metals, e.g. Cu, Fe, Mn, Ni and Zn, are essential nutrients for human growth at low contents, they become toxic at higher concentrations, but some, e.g. Cr, Pb, Cd, Co, and Cu, are toxic even in relatively small amounts, and therefore pose an adverse health effect in both humans and animals [9-11].

Chromium (VI) compounds are toxics and known as human carcinogens, whereas chromium (III) is an essential element [12]. Copper is a mineral, which is important to healthy hormone secretion, nerve conduction, and the growth of connective tissue and bones [13]. Iron is an essential and vital component for human health and the human body contains 60-70μg/g of Fe. Furthermore, the Fe compounds such as myoglobin and hemoglobin are essential for survival [14, 15]. Zinc is one of the important metals for normal growth and development in human beings [16, 17].

For the safe consumption of spices, the presence of heavy metals in these products and the associated health risks needed to be evaluated. In this regard, Kumaravel & Alagusundaram have analyzed mineral content in Indian spices and have reported the mean concentration of Cr, Cu, Fe and Zn as 0.05, 1.15, 6.91, and 1.20mg/kg, respectively [18]. Inam *et al.* have reported the mean concentration of Cu in some spices, collected from local markets of India, as 11.55mg/kg [19]. Krejpcio *et al.* have evaluated the heavy metals contents in spices, available on the Polish markets, and have reported the concentration of Cu, and Zn in the range of 0.38-23.52mg/kg and 2.76-38mg/kg, respectively [3]. Ozcan has analyzed the content of heavy metals in some plants used as condiments in Turkey and has reported the concentration of Cr, Cu, Fe and Zn in the range of 3.11-19.10, 2.82-14.40, 46.70-1229.2, and 5.54-49.70mg/kg, respectively [2]. After monitoring some metallic micronutrients and heavy metals content in spices from Austria, Chizzola *et al.* have reported the mean concentrations of Cu, Fe, and Zn as 10.58, 238.17, and 34.79mg/kg, respectively [20].

Due to that no studies about health risk assessment of heavy metals in spices has been reported in Iran, the aim of present study was to assess the potential health risk of Cr, Cu, Fe and Zn contents of cardamom, curry powder and turmeric in Hamedan City, Iran.

Instrument & Methods

According to the Cochran's sample size formula, 18 industrially packaged and weighted spice samples (cardamom, curry powder and turmeric) belonging to 6 famous brands were bought from different supermarkets of Hamedan City, Iran, in 2015.

About 50g of each spice samples were placed in quartz crucibles, dried at 105°C for 24h and subsequently ashed in the muffle furnace at 400°C. Ash was dissolved in 1mol/l diluted

HNO_3 and filled up in 50ml volumetric flasks to the mark by the nitric acid. The content of Cr, Cu, Fe and Zn in the mineralized sample was determined after extraction of the complexes with APDC (1-pyrrolidindithiocarbamate acid ammonium) to MIBK (methylisobuthylketon) phase (Merck; Germany) by ICP-OES (710-ES, Varian; Australia) with three replications. Distilled deionized water and ultra-high-purity commercial acids (Merck; Germany) were used to prepare all reagents, standards and spices samples. All the instrumental conditions applied for Cr, Cu, Fe and Zn content determinations were set in accordance with general recommendations (wave length for Cr, Cu, Fe and Zn; 359.3nm, 324.8nm, 248.3nm and 206.2nm, respectively) [3, 21].

The human health risks posed by chronic exposure to the heavy metals were assessed by computing the average daily intake of metal (DIM) using (C_{metal}×C_{factor}×$D_{food\ intake}$)/$B_{average\ weight}$ formula [22-25]; where C_{metal}, C_{factor}, $D_{food\ intake}$, and $B_{average\ weight}$ represent the heavy metal concentrations in spices (mg/kg), conversion factor, daily intake of spice, and average body weight, respectively. The conversion factor (0.085) is used to convert fresh weight into dry weight [24]. The average daily intake of spice for adult and children is considered 0.002kg per person per day. The average adult and children body weight are considered as 70.0 and 15.0kg, respectively, according to the data from the Iranian Ministry of Health and Medical Education.

The health risk index (HRI) for the local population through the consumption of spice was assessed using DIM/RfD formula [23-25]; where, DIM and RfD represent daily intake of metal and reference dose of metal obtained from ingestion, respectively. The oral reference doses for Cr, Cu, Fe and Zn were 0.003, 0.04, 0.70 and 0.30mg/kg/day, respectively. HRI of <1 means the exposed population is assumed to be safe [25-27]. The total HRI (THRI) of heavy metals for the fruit was calculated as the mathematical sum of each individual metal HRI value using HRI(toxicant 1)+HRI(toxicant 2)+ … + HRI(toxicant *n*) [28]. The maximum permissible limits (MPL) of heavy metal concentrations in studied spices were established by FAO/WHO (1.50mg/kg for Cr, 10.0mg/kg for Cu, 300.0mg/kg for Fe and 50.0mg/kg for Zn) [29].

The statistical analysis of the obtained data consisted in a first Shapiro-Wilk test for normality, followed by the study of the variance homogeneity using an ANOVA parametric test with a DMS post-hoc and Tukey HSD test. Finally, to study a correlation between the metals in the different spice samples, a Pearson's correlations study was performed [2, 21].

Findings

Chromium was detected in spice samples in 0.08-1.67mg/kg, Cu 0.05-1.28mg/kg, Fe 1.04-6.89mg/kg and Zn 0.40-2.25mg/kg. The mean concentration of Cu, Fe and Zn were lower than MPL (Figure 1).

Figure 1) Heavy metal concentrations of the spice samples (mg/kg of dry weight; nd: not detected)

Parameters	Cr	Cu	Fe	Zn
Cardamom				
Brand 1	nd	0.93	1.31	1.56
Brand 2	nd	0.98	1.42	1.25
Brand 3	nd	1.28	1.04	1.79
Brand 4	1.07	0.64	1.14	1.29
Brand 5	1.28	0.62	1.28	1.58
Brand 6	1.67	0.65	1.07	1.22
Mean	-	0.85±0.25	1.21±0.14	1.45±0.21
Curry Powder				
Brand 1	nd	0.31	6.41	2.25
Brand 2	nd	0.05	5.71	0.81
Brand 3	0.11	0.29	5.81	1.00
Brand 4	nd	0.09	5.96	0.78
Brand 5	nd	0.13	6.89	1.83
Brand 6	nd	0.12	6.42	1.24
Mean	-	0.17±0.10	6.20±0.44	1.32±0.56
Turmeric				
Brand 1	nd	0.10	1.75	0.40
Brand 2	0.15	0.09	2.09	0.44
Brand 3	0.45	0.07	1.49	0.50
Brand 4	0.08	0.11	1.47	0.44
Brand 5	nd	0.12	1.40	0.45
Brand 6	nd	0.14	1.34	0.66
Mean	-	0.10±0.03	1.59±0.27	0.48±0.09

The DIM values for the examined spice samples were below the recommended values, indicating that people (adult and children) might have no potential significant health risk through only consuming spice from the study area (Figure 2). Cu correlated significantly and positively with Zn ($r=0.572$; $p<0.05$).

Figure 2) Daily intakes of metals (DIM, mg) and health risk index (HRI) for individual heavy metal caused by the spices

Parameters	Cu	Fe	Zn
Adult			
DIM	8.99×10^{-7}	7.28×10^{-6}	2.62×10^{-6}
STD	9.23×10^{-7}	5.61×10^{-6}	1.36×10^{-6}
Min	1.21×10^{-7}	2.52×10^{-6}	9.71×10^{-7}
Max	3.11×10^{-6}	1.67×10^{-5}	5.46×10^{-6}
HRI	2.25×10^{-5}	1.04×10^{-5}	8.73×10^{-6}
STD	2.31×10^{-5}	8.01×10^{-6}	4.53×10^{-6}
Min	3.02×10^{-6}	3.60×10^{-6}	3.24×10^{-6}
Max	7.77×10^{-5}	2.38×10^{-5}	1.82×10^{-5}
Children			
DIM	4.19×10^{-6}	3.40×10^{-5}	1.22×10^{-5}
STD	4.31×10^{-7}	2.62×10^{-5}	6.35×10^{-6}
Min	5.67×10^{-7}	1.18×10^{-5}	4.53×10^{-6}
Max	1.45×10^{-5}	7.81×10^{-5}	2.55×10^{-5}
HRI	1.05×10^{-4}	4.86×10^{-5}	4.07×10^{-5}
STD	1.08×10^{-5}	3.74×10^{-5}	2.12×10^{-5}
Min	1.42×10^{-5}	1.68×10^{-5}	1.51×10^{-5}
Max	3.62×10^{-4}	1.11×10^{-4}	8.50×10^{-5}

Discussion

Breathing high levels of Cr(VI) can cause irritation to the lining of the nose, running nose, nose ulcers, and breathing problems, e.g. cough, asthma, shortness of breath, or wheezing. In addition, long-term exposure to Cr can cause damage to liver, kidney, circulatory and nerve disorders, as well as skin irritation [12]. The mean concentrations of Cr in our studied spice samples were much lower than the MPL, which revealed that the Cr level was much lower than what were reported in Turkey (8.75±2.39mg/kg) [2] and Egypt (33.75±5.37mg/kg) [21].

A steady diet of Cu, even at entirely allowable levels, breaks down the barrier that keeps unwanted toxins from entering the brain, and that it fuels an increase in the production of betaamyloid, but impedes the performance of problems that clear the stuff from the brain. Excess Cu can causes inflammation in the brain tissues, anorexia, fatigue, depression, premenstrual syndrome, migraines, anxiety, childhood hyperactivity, and learning disorders. Copper is found in a wide range of foods that we eat, including nuts, many fruits and vegetables, red meat, shellfish, as well as in many vitamin supplements [13]. The mean concentrations of Cu in our studied spice samples were 0.37±0.38mg/kg, which was much lower than the MPL. This average Cu concentration was lower than what were found in spice samples from Turkey (8.75±3.40mg/kg) [2], Poland (5.11±1.57mg/kg) [3], Egypt (11.40±3.68mg/kg) [21] and Austria (10.58±3.20mg/kg) [20].

Iron is a constituent of active site of various reproductive hydrogenases, most frequently associated with sulfur containing ligands. This element together with ferredoxin and heamoglobin plays an important and central role in metabolism. In addition, Fe facilitates the oxidation of proteins, fat and carbohydrates to control body weight which is an important factor in some diseases especially diabetes. It is necessary to mention that Fe deficiency causes anemia [14, 15]. The mean concentration of Fe in our studied spice samples was 3.0±2.31mg/kg and was much lower than the MPL. This average Fe concentration was lower than what was found in spice samples from Turkey (282.64±254.50mg/kg) [2], Egypt (1046.25±312.10mg/kg) [21] and Austria (238.17±136.81mg/kg) [20].

Zinc is an essential functional and structural element in biological systems often catalyzing reactions by binding to substrates by favoring various reactions, such as the mediation of redox reactions or oxidation–reduction reactions, through reversible changes in the oxidation state of the metal ions. Of course, Zn harms some physiological processes like breathing and others [16, 17]. The mean concentration of Zn in our studied spice samples was 1.08±0.56mg/kg and was much lower than the MPL. This average Zn concentration was lower than what was found in spice samples from Turkey (23.39±10.17mg/kg) [2], Poland (11.22±6.64mg/kg) [3], Egypt (68.80±11.19mg/kg) [21] and Austria (34.79±9.64mg/kg) [20].

According to the USEPA, if HRI is less than 1, there will not be obvious health risks for exposed population [27]. Therefore according to the results, all calculated HRI values of heavy metals were within the safe limits for children and adults (HRI<1). Furthermore, the THRI values, which varied from 9.86E-06 to 1.20E-04 for adult and from 4.61E-05 to 5.58E-04 for children, were also in the safe limit (THRI<1). Therefore, we can conclude that people might have no potential significant health risk through only consuming spices from the studied area.

It should be pointed out that heavy metals as well as many other chemical pollutants may accumulate over lifetimes of individuals. The cumulative effects, as a result, may be additive and/or interactive and the risk additively usually requires that all components act according to the same mechanism [30]. Despite the heavy metal contamination, level of spice species in Hamedan City is not critical, but that the exposure-risk estimate in this study was only for spices and did not account for any other alimentary source. Therefore, for more accurate estimate exposure from other sources should be added to estimate the total risk of each metal.

Although the research has reached its aims, there were some unavoidable limitations. The most important limitation of the current research was that there was not enough time for conducting the study. In addition, due to financial constraints, the study was under-powered, and thus, the size, convenience, and homogeneity of the sample limit the generalizability of this research. Although controlled consumption of spices has not adverse effect on the consumers' health, but due to the lack of adequate information about processing conditions, habitat adjacent to industrial areas and polluted with heavy metals, increased use of agricultural inputs, sewage sludge and wastewater by farmers, regular periodic monitoring of chemical pollutants content specially heavy metals in foodstuffs are recommended for food safety.

Conclusion

The levels of Cr, Cu, Fe and Zn are less than the MPL in cardamom, curry powder and turmeric in Hamedan City, Iran.

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