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Analysis of mineral and heavy metals in some medicinal plants collected from local market

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ABSTRACT

Objective: To determine sodium (Na), iron (Fe), magnesium (Mg), manganese (Mn), lead (Pb), zinc (Zn), cadmium (Cd) and copper (Cu) in some medicinal plants regularly used in cooking in Indian curries. **Methods:** All the nutrients were determined by using atomic absorption spectrophotometer (AAS). **Results:** The average concentrations detected were ranged from 150.22 to 521.98, 782.42 to 813.84, 15.75 to 532.72, 85.72 to 101.50, 0.478 to 9.890, 0.684 to 2.751, and 11.51 to 94.05, 6.94 to 49.76 mg/kg for Na, Fe, Mg, Mn, Pb, Zn, Cd and Cu, respectively. **Conclusions:** The mineral and metal contents in the samples were found at different levels. Therefore, these medicinal plants are rich in some essential minerals, especially Fe and Mg which are essential for human health.

1. Introduction

Indian diet is primarily vegetarian and consists of various cereals and vegetables along with spices, often used in the preparation of curries[1]. Plant foods can contribute significantly to human nutrition and health, because they contain almost all essential human nutrients. However, nutrient composition varies among different plant foods. Improvement of nutritional quality of our food supply, especially with respect to essential nutrient minerals, such as magnesium, iron and zinc, could be an important goal of vegetable crops[2]. It shows that 70%-80% of the worlds′ population rely on non-conventional medicine, especially from herbal sources[3]. The role of inorganic elements in animal and plant metabolism has long been established, but the effect and influences of these elements on administration of medicinal plants have received relatively little attention. The administration of medicinal plant, traditionally has been largely indiscriminate without due regard to possible side effects. Diet has long been considered as the major source of human exposure to trace elements and consequently the levels in basic foodstuff, but medicinal uptakes are of greater interest from the toxicological and nutritional points of view[4]. The human body requires a number of minerals in order to maintain good health. A number of minerals essential to human nutrition are accumulated in different parts of plants as it accumulates minerals essential for growth from the environment[5]. Macro and microelements influence biochemical processes in the human organism[6]. Study of elements with respect to indigenous medicinal plant reveals that major and trace elements have significant roles in combating a variety of human ailments and disease[7].

The leaves of *Murraya koenigii* are used as an herb in Ayurvedic medicine. Their properties include much value as an anti-diabetic, antioxidant, antimicrobial, anti-inflammatory, hepatoprotective, anti-hypercholesterolemic. Curry leaves are also known to be good for hair, for keeping it healthy and long. They also contain iron. Although most commonly used in curries, leaves from the curry tree can be used in many other dishes to add spice[8]. Coriander contains antioxidants, which can delay or prevent the spoilage of food seasoned with this spice and the chemicals derived from coriander leaves were found to have antibacterial activity against *Salmonella choleraesuis* and it is used in folk medicine[9,10]. Leaves of these herbs are used to flavour a range of dishes and typically there are fried in oil until crisp to impart flavour to all types of curry preparations. These herbs have been used in traditional Indian medicine system for a variety of ailments[11]. *Phyllanthus niruri* extracts of this herb have shown promise in treating a wide range of human diseases. It has anti-hepatotoxic, anti-lithic, anti-hypertensive, anti-HIV and

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anti-hepatitis B[12]. *Solanum nigrum* has a long history of medicinal usage, dating back to ancient Greece. Leaves of this plant are used to treat mouth ulcers that happen during winter periods of Tamil Nadu, India. Chinese experiments confirm copper in particular has been associated with stomach and intestinal distress, as well as anemia in humans[13]. *Hibiscus cannabinus* leaves are highly nutritious, being a significant source of beta-carotene, vitamin C, protein, iron, and potassium[14]. *Trigonella foenumgraecum* may have potent antiviral properties, having relieved common cold symptoms in a group of volunteers. The United States Department of Agriculture states that, a 180 g serving of boiled spinach contains 6.43 mg of iro[15].

Essential, trace elements and minerals in Indian medicinal plants have been investigated by many researchers[16-19]. Several attempts have been made to determine of the macro and micro-nutrient contents of herbal, medicinal and aromatic plants from many countries all over the world. For example medicinal, aromatic and spice plants growing in Argentina[20], Syria[21], Australia[22], Egypt[23], Italy[24], Poland[25], France[26], Nigeria[27], Hawaii[28], China[29], Turkey[30], and the USA[31] have been analyzed. Leaves of *Mentha spicata, Murrya koenigii* and *Coriandrum sativam* are used as culinary spices. Leaves of the plants listed in Table 1 are used for the preparation of curries/sampar with the combination dals. Hence, the knowledge on minerals and heavy metals content is essential to evaluate quality. This study therefore presents data on the level of selected minerals and heavy metals in selected culinary herbs and greens (extensively used for preparation of curries).

2. Materials and Methods

2.1. Sample collection

Fifteen medicinal plants (Table 1) were collected from local market in Salem, Tamil Nadu, India. After washing, the plants were dried at shade and powdered. The powdered materials were directly subjected to analysis.

2.2. Reagents and standards

Analytical grade nitric acid, hydrochloric acid and hydrogen peroxide (Merck, India) were used as received. Standard sample solutions of Cd, Cu, Fe, Zn, and Na (1 000 mg/mL) were obtained from Merck (Germany). All the solutions were prepared from triply distilled water.

2.3. Sample preparation

The glassware and polyethylene containers used for analysis were washed with tap water, then soaked over night in 6N HNO_3 solution and rinsed several times with ultra pure water to eliminate absorbance due to detergent. Accurately weighed (2.0 g) plant samples were transferred into a silica crucible and kept in a muffle furnace for ashing at 450o C for 3 hours and then 5 mL of 6M HCl was added to the crucible. Then, the crucible containing acid solution was kept on a hot plate and digested to obtain a clean solution. The final residue was dissolved in 0.1 M HNO_3 solution and made up to 50 mL. Working standard solutions were prepared by diluting the stock solution with 0.1 M nitric acid for checking the linearity[31].

2.4. Analytical procedure

Na, Fe, Mg, Mn, Pb, Zn, Cd and Cu in plant samples were analyzed using atomic absorption spectrophotometer (AA 6300, Shimadzo, Japan) equipped with flame and graphite furnace. Air-acetylene flame was used for determination of metal content. The instrument was operated with the following conditions in flame mode: acetylene 1.8 L/min, air 15 L/min, the inert argon gas flow and the temperature parameters were followed as recommended by manufacturer. The absorption wavelength for the determination of each metal together with its linear working range and correlation coefficient of calibration graphs are given in Table 2. Data were rounded off suitably according to the value of standard deviation from measurements in triplicate.

2.5. Statistical analysis

Results of the research were analysed for statistical significance by ANOVA. This research was performed by three duplicates with a replicate.

3. Results

Table 1.
Plants used in experiment.

Code	Local name	Botanical name	Parts used for cooking(Parts analyzed)
MS	*Pudina*	*Mentha spicata*. L	Leaves
HC	*Pulichai keerai*	*Hibiscus cannabinus*. L	Leaves
AP	*Seru keerai*	*Amaranthus polygonoides*. L	Leaves
MK	*Karivappillai*	*Murrya koenigii*. L	Leaves
CS	*Kothamallai*	*Coriandrum sativam*. L	Leaves
SG	*Agathik keerai*	*Sesbania grandiflora*.L	Leaves
AT	*Arai keerai*	*Amaranthus tristis*.L	Leaves
AC	*Mulai keerai*	*Amaranthus cruenttus*.L	Leaves
PN	*Kelianelli keerai*	*Phyllanthus nirui*. L	Leaves
MO	*Murungai keerai*	*Moringa oleifera*. L	Leaves
SN	*Manathakkali keerai*	*Solanum nigrum*. L	Leaves
TF	*Vanthiyak keerai*	*Trigonella foenumgraecum*.L	Leaves
SO	*Palak keerai*	*Spinacia oleracea*. L	Leaves
BR	*Pasalai keerai*	*Basella rubra*. L	Leaves
AD	*Arai keerai*	*Amaranthus dubius*. L	Leaves

Table 2.
Operating parameter for working element.

Elements	Wave length(nm)	Lamp intensity(mA)	Slit width(nm)	Correlation coefficient (*r*)
Pb	283.3	10	0.7	0.999 3
Cd	228.8	8	0.7	0.9996
Zn	213.8	8	0.7	0.993 1
Cu	324.8	6	0.7	0.999 1
Fe	248.3	12	0.2	0.999 4
Na	589.0	12	0.2	1.000 0
Mg	285.2	2	0.7	0.999 5
Mn	279.5	5	0.5	0.999 0

Table 3.
Mineral contents in herbs and greens (mg/kg dry wt).

Samples	Fe	Na	Mg	Mn
MS	395.74±4.09	808.09±1.64	532.72±0.93	85.72±1.13
HC	248.29±2.09	782.42±18.20	410.00±3.61	ND
AP	264.52±7.69	794.99±5.62	135.92±5.16	98.42±1.95
MK	154.85±3.12	797.99±3.07	15.75±2.83	97.36±0.67
CS	223.79±4.04	799.95±8.34	222.35±0.14	101.50±0.90
SG	150.22±8.53	813.84±7.70	168.76±5.09	97.72±1.05
AT	316.04±2.62	795.20±3.06	145.86±7.30	95.92±1.80
AC	422.16±6.86	813.84±7.70	165.00±7.16	94.10±2.26
PN	244.09±0.87	809.42±0.73	318.40±2.83	95.78±2.77
MO	298.09±5.81	765.11±11.86	128.15±3.54	96.37±2.13
SN	311.88±5.02	810.77±57.69	185.92±6.12	98.43±3.67
TF	327.60±7.28	797.49±25.94	169.63±1.03	99.77±1.70
SO	521.98±7.67	813.17±12.81	522.86±9.45	98.37±1.32
BR	378.73±1.06	812.99±6.99	211.84±6.92	96.71±1.74
AD	415.43±5.73	794.76±0.63	143.92±3.51	96.73±1.70

ND– Not detectabl .

Table 4.
Heavy metal contents in herbs and greens (mg/kg dry wt).

Samples	Pb	Cd	Cu	Zn
MS	9.89±0.36	0.74±0.07	29.833.16	49.76±4.12
HC	2.55±0.35	1.26±0.06	65.39±2.81	15.78±0.31
AP	2.87±0.36	1.03±0.13	70.48±3.29	10.92±2.62
MK	0.48±0.29	0.90±0.08	64.73±3.48	6.94±0.91
CS	2.87±0.26	0.90±0.06	74.41±3.65	16.99±0.58
SG	0.96±0.17	0.72±0.13	48.38±6.84	15.27±1.88
AT	0.64±0.03	0.72±0.15	19.43±3.35	15.03±0.26
AC	1.60±0.03	2.52±0.42	55.73±2.60	25.31±2.97
PN	1.44±0.05	1.22±0.37	15.20±1.13	37.87±4.26
MO	ND	0.68±0.06	11.51±1.77	14.67±3.22
SN	ND	0.89±0.04	17.47±1.84	8.53±0.29
TF	ND	0.79±0.06	15.48±1.89	9.85±2.54
SO	2.39±0.12	0.85±0.07	15.22±2.90	17.39±2.02
BR	1.60±0.01	1.11±0.08	15.12±1.99	31.60±2.48
AD	3.03±0.01	2.75±0.29	94.05±4.31	14.46±0.51

ND–Not detectable.

3.1. Mineral and Heavy metal contents

The mean concentration levels of mineral found in 15 medicinal are summarized in Table 3. A perusal of data in Table 3 shows that the mineral contents in analyzed plants are in wide range. Highest Na was found in *Spinacia olerracea*, *Amaranthus cruentus* and *Amaranthus dubius* whereas lowest Fe content was found in *Murraya koenigii*. *Sesbania grandiflora* and (813.84 mg/kg) whereas lowest. The amounts of Na in medicinal plants are found to be similar. The value of Na varied in a range of 765.11±11.86–813.84 ±7.70. The concentration of magnesium is much higher in *Mentha spicata* whereas much lower in *Murrya koenigii*. Manganese content in 15 medicinal plants varied in narrow range of 85.72±1.13 – 101.50±0.90. Manganese content found to be nil in *Hibiscus cannabinus*. Table 1 shows, for every element, the comparison between the arithmetical mean of all values and the maximum concentration. It was possible to note that the plants are very rich in Fe, Na, Mg and Mn.

The mean concentration levels of heavy found in analyzed medicinal are shown in Table 4. The levels of Pb in some plants were ranged from 0.48±0.29 to 9.89±0.36. Pb contents in *Moringa olefera, Solanum nigrum* and *Trigonella foenumgraecum* are below the detectable limit. Cd ranged from 0.68±0.06 to 2.75±0.29; Cu from 11.51±1.77 to 94.05 ±4.31; Zn from 6.94±0.91 to 49.76±4.12, respectively. The levels of Pb and Cd in all plants are very similar. But slightly higher levels of Cu were found in medicinal plants followed by Zn. The results shows that Pb, Cd, Cu and Zn content in 15 medicinal plants were within the prescribed.

4. Discussion

Na and Mn contents of all samples were found almost similar. Vast differences were established in Mg. These differences could probably be the result of plant nutrition, climate and soil conditions[29]. Lowest levels of Cu, Cd, Cr, Zn and Pb (0.823, 0.073, 0.546 and 1.893) in the leaves of spinach, cabbage, cauliflower, radish and coriander have been reported by Farooq *et al* 2008[32]. Fe, Zn and Mn (129.76), Zn (8.52) and Mn (6.8 μg/g) in leaves of *Mentha spicata*[33] and Pb (17.54-25.00 mg/kg) in leafy vegetables grown in wastewater industrial areas have been reported by other investigatorst (safe limit is 2.5 mg/kg)[34]. Zn (39.6-44.8), Cu (14.8-86.0), Pb (0.008-0.05) and Cd (0.69-1.09 mg/kg) in leaves of *Hibiscus cannabinus, Murraya koenigi* and *Coriandrum sativam*[35], Cu (9.445), Fe (62.610), Mg (1372.731), Mn (15.872), Pd (0.393) and Zn (54.612 μg/g) in *Trigonella foenum-graecum* seeds[36] have been reported. Especially, *Mentha spicata, Murraya koenigi* and *Coriandrum sativam* are daily used in Indian cooking for flavour and aroma. Several workers[37,38]) have determined the content of zinc, copper, or manganese in food samples. Zn is an essential metal for the normal functioning of various enzyme systems. Zn deficiency, particularly in children, can lead to loss of appetite, growth retardation, weakness, and even stagnation of sexual growth[39]. The maximum tolerable daily intake of Zn is 0.3-1 mg/ kg[40]. The herbs were shown to be a rich source of Zn in the present study. Total metal concentrations of Pb, Zn, Cu, Co, Ni, and Cr in plant samples collected from industrial zone of Islamabad, Pakistan, varied between 2.0-29.0, 61.9-172.6, 8.9 to 357.4, 7.3-24.7, 41.4-59.3, and 40.2-927.2 mg/kg, respectively[41]. 20.31- 37.60 mg/kg of Fe contents were reported by Jongrungruangchok *et al*[42]. Jaj and Goyal[43] have analyzed heavy metals in *Beta vulgaris, Coriandrum sativum* and *Trigonella foenumgraecum* from agricultural areas in and around Patiala city, India to assess level of post harvest contamination. Among all green leafy vegetables, nearly 67%-76% of samples were high in Pb, 18%-39% samples were high in Zn, which crossed Indian permissible limit of 50 mg/kg and 6%-9% in Cd, which was beyond 1.5 mg/kg as per European Standards. The concentrations of Pb and Zn in our results are within the Indian permissible limit. Demirezen and Ahmet[44] analyzed various vegetables (cucumber, tomato, green pepper, lettuce, parsley, onion, bean, eggplant, pepper mint, pumpkin and okra) and reported that the Zn concentration (3.56-4.59 mg/kg) was within the recommended international standards.

These culinary herbs and greens show great promise as a dietary source of these human essential minerals especially to village people. The result of present study revealed that all medicinal plants possess the highest Na followed by Fe, Mg and Mn concentration. The mineral and metal contents in the samples were found at different levels. The highest mean levels of Na (813.84), Fe (521.98), Mn (101.50, Cd (2.751), Cu (94.05), Mg (532.78), Pb (9.890) and Zn (49.76) were obtained in *Solanum nigrum, Spinacia oleracea, Coriandrum sativam, Amaranthus dubius* and *Mentha spicata*, respectively. The variation of elemental content from plant to plant is mainly attributed to the differences in botanical structure, as well as in the mineral composition of the soil in which the plants are cultivated. Other factors responsible for a variation in elemental content are preferential absorbability of the plant, use of fertilizers, irrigation water and climatic conditions[25].

The plants analyzed here are periodically used in curries and other side dishes in India. Overall it is a part of food along with vegetables in cooking. In this work, our result is well comparable with other findings.Therefore, these medicinal plants are rich in some essential minerals, especially Fe and Mg which are essential for human health. Results presented here clearly show that the examined medicinal plants play a meaningful role in human nutrition as micro-nutrients sources. The minerals and heavy metals found to be below the recommended maximum acceptable levels proposed by the Joint FAO/WHO Expert Committee on Food Additives.

Conflict of interest statement

We declare that we have no conflict of interest.

References

[1] Singh V, Garg AN. Availability of essential trace elements in Indian cereals, vegetables and spices using INAA and the contribution of spices to daily dietary intake. *Food Chem* 2006; **94**: 81-89.

[2] Arzani A, Zeinali H, Razmjo K. Iron and magnesium concentrations of mint accessions (*Mentha* spp.). *Plant Physiol Biochem* 2007; **45**: 323-329.

[3] Lesniewicz A, Jaworska K, Zyrnicki W. Macro- and micro-nutrients and their bioavailability in polish herbal medicaments. *Food Chem* 2006; **99**: 670-679.

[4] Dim LA, Funtua II, Oyewale AO, Grass F, Umar IM, Gwozdz R, et al. Determination of some elements in *Ageratum conyziodes*, a tropical medicinal plant, using instrumental neutron activation analysis. *J Radioanal Nucl Chem* 2004; **261**: 225-228.

[5] Ajasa A, Bello MO, Ibrahim AO, Ogunwande IA, Olawore NO. Heavy trace metals and macronutrients status in herbal plants of Nigeria. *Food Chem* 2004; **85**: 67-71.

[6] Brouns F, Vermeer C. Functional food ingredients for reducing the risks of osteoporosis. Trend. *Food Sci Technol* 2000; **11**: 22-33.

[7] Shirin K, Imad S, Shafiq S, Fatima K. Determination of major

and trace elements in the indigenous medicinal plant *Withania somnifera* and their possible correlation with therapeutic activity. *J Saudi Chem Soc* 2010; **14**: 97–100.

[8] Arulselvan P, Senthilkumar GP, Sathish Kumar D, Subramanian S. Anti-diabetic effect of *Murraya koenigii* leaves on streptozotocin induced diabetic rats. *Pharmazie* 2006; **61**: 874–877.

[9] Wangensteen H, Samuelsen AB, Malterud KE. Antioxidant activity in extracts from coriander. *Food Chem* 2004; **88**: 293–297.

[10] Emamghoreishi M, Khasaki M, Aazam MF. Coriandrum sativum: evaluation of its anxiolytic effect in the elevated plus-maze. *J Ethnopharmacol* 2005; **96**: 365–370.

[11] Choudhury RP, Garg AN. Variation in essential, trace and toxic elemental contents in *Murraya koenigii* – A spice and medicinal herb from different Indian states. *Food Chem* 2007; **104**: 1454–1463.

[12] Bagalkotkar G, Sagineedu SR, Saad MS, Stanslas J. Phytochemicals from *Phyllanthus niruri* Linn. and their pharmacological properties: a review. *J Pharmacy Pharmacol* 2006; **58**: 1559–1570.

[13] Deepa R, Senthilkumar P, Sivakumar S, Duraisamy P, Subbhuraam CV. Copper availability and accumulation by *Portulaca oleracea* Linn. stem cutting. *Environ Monit Assessment* 2006; **116**: 185–195.

[14] Michael L. Bioremediation of turbid surface water using seed extract from *Moringa oleifer* Lam. (Drumstick) tree. *Current Protocols Micribiol* 2010; 1G.2.1–1G.2.14.

[15] US Department of Agriculture, Agricultural Research Service. 2005. USDA National Nutrient Database for Standard Reference, Release 18. Nutrient Data Laboratory. [Online] Available from: http://www.nal.usda.gov/fnic/foodcomp.

[16] Nomita Devi K, Nandakumar Sarma H, Kumar S. Estimation of essential and trace elements in some medicinal plants by PIXE and PIGE techniques. *Nucl Instr Methods Physics Res B* 2008; **266**: 1605–1610.

[17] Nomita Devi K, Nandakumar Sarma H. PIXE-PIGE analysis of some Indian medicinal plants. *Nucl Instr Methods Physics Res B* 2010; **268**: 2144–2147.

[18] Bhargava A, Shukla S, Srivastava J, Singh N, Ohri D. Genetic diversity for mineral accumulation in the foliage of *Chenopodium* spp. *Scientia Horticul* 2008; **118**: 338–346.

[19] Srividhya B, Subramanian R, Raj V. Determination of lead, manganese, copper, zinc, cadmium, nickel and chromium in tea leaves. *Int J Pharm Pharm Sci* 2011; **13**: 257258.

[20] Scarpa GF. Medicinal plants used by the Criollos of Northwestern Argentine Chaco. *J Ethnopharmacol* 2004; **91**: 115–135.

[21] Khuder A, Sawan MKh, Karjou J, Razouk AK. Determination of trace elements in Syrian medicinal plants and their infusions by energy dispersive X-ray fluorescence and total reflection X-ray fluorescence spectrometry. *Spectrochim Acta Part B* 2009; **64**: 721–725.

[22] Archana K, Hong X, Mary M. Evaluation of mineral content of Chinese medicinal herbs used to improve kidney function with chemometrics. *Food Chem* 2011; **127**: 1465–1471.

[23] Radwan MA, Salama AK. Market basket survey for some heavy metals in Egyptian fruits and vegetables. *Food Chem Toxicol* 2006; **44**: 1273–1278.

[24] Donatella D, Maria AM, Carla R. Determination of essential and non-essential elements in some medicinal plants by polarised X ray fluorescence spectrometer (EDPXRF). *Microchemical J* 2010; **95**: 174–180.

[25] Masson P, Dalix T, Bussière S. Determination of major and trace elements in plant samples by inductively coupled plasma-mass spectrometry. *Comm Soil Sci Plant Anal* 2010; **41**: 231–243.

[26] Albert Cosmas A, Dayo O. Quantitative assessment of heavy metals in some tea marketed in Nigeria: Bioaccumulation of heavy metals in tea. *Health* 2010; **9**: 1097–1100.

[27] Iwaoka WT, Kartika H, Shido J, Nakamoto ST, Li QX. Nutrient and mineral composition of dried Mamaki leaves (*Pipturus albidus*) and infusions, *J Food Compos Anal* 2011; **24**: 44–48.

[28] Wang HW, Liu YQ. Evaluation of trace and toxic element concentrations in Paris polyphylla from China with empirical and chemometric approaches. *Food Chem* 2010; **121**: 887–892.

[29] Hamurcu M, Musa Ozcan M, Dursun N, Gezgin S. Mineral and heavy metal levels of some fruits grown at the roadsides. Food Chem. *Toxicol* 2010; **48**: 1767–1770.

[30] Kumar A, Nair AGC, Reddy AVR, Garg AN. Availability of essential elements in Indian and US tea brands. *Food Chem* 2005; **89**: 441–448.

[31] AOAC. *Official methods of analysis*. 17th ed. AOAC International; 2000.

[32] Farooq M, Anwar F, Rashid U. Appraisal of heavy metal contents in different vegetables grown in the vicinity of an industrial area. *Pakistan J Bot* 2008; **40**: 2099–2106.

[33] Ebrahimzadeh MA, Eslami S, Nabavi SM, Nabavi SF, Moghaddam AH, Bekhradnia AR. Estimation of essential and toxic mineral elements in *Mentha* species. *Asian J Chem* 2011; **23**: 1648–1650.

[34] Sharma RK, Agrawal M, Marshall F. Heavy metals contamination in vegetables grown in wastewater irrigated areas of Varanasi, India. *Bull Environ Contam Toxicol* 2006; **77**: 312–318.

[35] Vijaya Jothi NV, Chandra Mouli P, Jayarama Reddy SR. Determination of zinc, copper, lead and cadmium in some medicinally important leaves by differential pulse anodic stripping analysis. *J Trace Elem Med Biol* 2003; **17**: 79–83.

[36] Kan Y, Kan A, Ceyhan T, Sayar E, Kartal M, Altun L, et al. Atomic absorption spectrometric analysis of *Trigonella foenum*-graecuml L. seeds cultivated in Turkey. *Turkish J Pharma Sci* 2005; **2**: 187–191.

[37] Khajeh M, Moghaddam ARA, Sanchooli E. Application of Doehlert design in the optimization of microwave-assisted extraction for determination of zinc and copper in cereal samples using FAAS. *Food Anal Methods* 2010; **3**: 133–137.

[38] Lemos VA, David GT. An on-line cloud point extraction system for flame atomic absorption spectrometric determination of trace manganese in food samples. *Microchem J* 2010; **94**: 42–47.

[39] Saracoglu S, Tuzen M, Soylak M. Evaluation of trace element contents of dried apricot samples from Turkey. *J Hazard Mate*r 2009; **156**: 647–652.

[40] World Health Organization. *Twenty sixth report of the Joint FAO/WHO Expert Com.* Genewa: WHO; 1982, p. 683.

[41] Malik RN, Husain SZ, Nazir I. Heavy metal contamination and accumulation in soil and wild plant species from industrial area of Islamabad, Pakistan. *Pakistan J Bot* 2010; **42**: 291–301.

[42] Jongrungruangchok S, Bunrathep S, Songsak T. Nutrients and minerals content of eleven different samples of *Moringa oleifera* cultivated in Thailand. *J Health Res* 2010; **24**: 123–127.

[43] Jaj N, Goyal D. Coliforms and heavy metal contamination in green leafy vegetables. *Indian J Microbiol* 2006; **46**: 217–221.

[44] Demirezen D, Ahmet A. Heavy metal levels in vegetables in turkey are within safe limits for Cu, Zn, Ni and exceeded for Cd and Pb. *J Food Quality* 2006; **29**: 252–265.