Food Anal. Methods (2010) 3:181–187
DOI 10.1007/s12161-009-9107-y

Determination of Mineral Composition and Heavy Metal Content of Some Nutraceutically Valued Plant Products

Rajeev Bhat · K. Kiran · A. B. Arun · A. A. Karim

Received: 1 July 2009 / Accepted: 24 August 2009 / Published online: 16 September 2009

Abstract Minerals and heavy metal concentrations of 23 plants (arial parts, leaves, bark, stem, root, rhizome, dried berries, seeds) possessing health-promoting effects and used in indigenous medicines (as medicinal food) were determined using inductively coupled plasma atomic spectrometry. Vital essential minerals and heavy metals were present in all the samples analyzed. The majority of the plant materials were rich in some of the essential minerals like Na, K, Ca, Fe, Mg, Cu, Mn, and Zn, which are known to be beneficial for health. The plant material of *Vitiveria zizinalis* had highest concentration of toxic heavy metals, including arsenic (53.1 mg/100 g), chromium (6.74 mg/100 g), cobalt (10.2 mg/100 g), mercury (3.6 mg/100 g), and nickel (3.28 mg/100 g). Results of the present study provide vital data on the availability of some essential minerals, which can be useful to provide dietary information for designing value-added foods and for food biofortification. Apart from this, data on the contaminant levels of heavy metals highlights the necessity on the quality and safety concerns about their use.

R. Bhat (✉) · A. A. Karim
Food Technology Division, School of Industrial Technology,
Universiti Sains Malaysia,
11800 Penang, Malaysia
e-mail: rajeevbhat@usm.my

K. Kiran
Indian Forensic Laboratory,
Madiwala,
Bangalore 560 068, India

A. B. Arun
College of Agriculture and Natural Resources,
Department of Soil Environmental Science,
National Chung Hsing University,
250 Kuo-Khang Road,
Taichung, Taiwan

Keywords Minerals · Heavy Metals · Nutraceuticals · Quality · Safety

Introduction

Plants and their products have always played a substantial role in human welfare by satisfying various essential needs ranging from food to medicines. Currently, functional foods or the nutraceuticals of plant origin have gained in popularity and constitute a major share of the health care market (Bhat and Sridhar 2008; Bhat and Karim 2009). Today, consumers are quite practical and choosy in their approach to diet; they are interested in incorporating high nutrient levels with adequate amount of essential minerals into their normal diet, preferably with sources from plant origin. The expansion of the mineral supplement industry is a direct indication of the gaining importance of minerals to consumers. In this regard, interest has grown in finding traditionally consumed plant products (e.g. herbs, spices) that might not only have culinary and medicinal properties but that also are abundant in essential micronutrients. Most of the minerals, even at threshold levels, contribute significantly to normal growth and play a pivotal role in biochemical functions and essential enzyme systems.

Plant products play a significant role in traditional medicine systems, and the majority of consumers have the misconception that these products are inherently safe for consumption. However, there is concern among researchers that plants might accumulate heavy metals at significantly high levels when grown in polluted soil (Kalăc and Svoboda 2000). If true, this will reflect the failure of good agricultural and manufacturing practices and quality assurance. Purity issues of plant-based drugs are also of high concern (Mazzanti et al. 2008). Hence, studying the presence of unwanted heavy metals and their concentrations in plant species used as traditional medicines and recommended to be incorporated in the normal food is a necessity.

Of late, numerous efforts have been made to determine the mineral and heavy metal contents of herbal, medicinal, and aromatic plants, vegetables, and even wines from various parts of the world (Aberoumand and Deokule 2009; Galgano et al. 2008; Lavilla et al. 1999; Miller-Cebert et al. 2009; Tuzen et al. 2007). Trace elements and heavy metals have certain health benefits at lower concentrations, but at higher levels, they can be toxic and pose health risks (Schumacher et al. 1991); thus, it is important to determine the levels of these compounds in common, popular, and widely used herbal plants (or as medicinal foods).

Detection of mineral and heavy metal concentrations in various foods has been conducted mainly using atomic absorption spectrophotometry (AAS) with flame atomization and a graphite furnace. However, other alternative, more reliable, and accurate methods are available, such as: inductively coupled plasma mass spectrometry, neutron activation analysis, and X-ray fluorescence methods (Knapp 1991). In this study, inductively coupled plasma optical emission spectrometry (ICP-OES) was used as this is a multi-element technique which allows fast and accurate analysis of nearly 75 elements of the periodic table.

The major objective of this study was to evaluate and provide baseline information on the mineral composition and heavy metal contents of some popular and commercially valuable plants from the Indian market that possess high nutraceutical value. If at least a few of the plants were found to have high mineral contents, they might have the potential to be used for biofortification and development of new food products.

Materials and Methods

Sample Collection and Identification

Certain common and popular plant materials that have therapeutic and nutraceutical value and are used in indigenous ayurvedic medicines were purchased from a leading local market dealer (from Mysore, India). The samples purchased were freshly harvested ones (less than 2 weeks) with no apparent physical damage. The materials (a total of 23 plants consisting of arial parts, leaves, bark, stem, root, rhizome, dried berries, seeds) were air dried at room temperature (25±1 °C) and ground into fine powder in a mortar and pestle to avoid chromium contamination from stainless steel utensils. The powder was placed temporarily in air-tight polyethylene pouches until further analysis. The identity of the plant material was confirmed with assistance from local practitioners and botanists. Table 1 lists the common name, scientific name, family, parts used, and the medicinal/health-promoting effects of the plant materials used in this study.

Preparation and Analysis

The minerals and heavy metal [aluminum (Al), arsenic (As), barium (Ba), calcium (Ca), cadmium (Cd), chromium (Cr), cobalt (Co), copper (Cu), iron (Fe), lead (Pb), magnesium (Mg), manganese (Mn), molybdenum (Mo), mercury (Hg), potassium (K), sodium (Na), nickel (Ni), and zinc (Zn)] contents of the powdered samples were determined using the AOAC (1990) method. Briefly, a known amount of the sample was digested with a mixture of concentrated nitric acid, sulfuric acid, and perchloric acid (10:0.5:2, *v*/*v*), and the analysis was conducted using the ICP-OES (Varian Inc., Walnut Creek, CA, USA). Table 2 lists the conditions and parameters used. All the glassware were cleaned by soaking overnight in a 10% nitric acid solution and then rinsing three times with deionized water.

Statistical Analysis

Analysis of minerals and heavy metals were performed in replicates, and data are presented as mean±SD (n=3) with one-way analysis of variance (significance level at $P<0.05$) was performed with statistical software (ORIGIN®, version 6.0, Microcal Software Inc., Northampton, MA).

Results and Discussion

Table 3 depicts the mineral and heavy metal concentrations of the samples analyzed in this study. Values varied widely among samples, but in general, most samples were rich in the following essential minerals: Cu, Fe, K, Mg, Mn, Na, and Zn. These minerals serve as structural components of tissues, function in cellular and basal metabolism, and help maintain water and acid–base balance (Smith 1988). The abundances of K, Mg, and Ca agree with earlier data from many of the plant specimens (Lavilla et al. 1999).

Artemisia vulgaris had the highest levels of Ca (3,441.8 mg/100 g), whereas *Annona squamosa* had the lowest (3.72 mg/100 g). Ca is a major component of bone, assists in tooth development, helps regulate endo- and exo-enzymes, and plays a significant role in regulating blood pressure (Brody 1994). Using plant-based Ca as a nutritional supplement might be advantageous for consumers who are allergic to animal-based food sources or who practice strict vegetarianism.

Cu was the highest in *Berberis aristata* (134.96 mg/100 g) and lowest in *Sida cordifolia* (0.05 mg/100 g). *Vitiveria*

Table 1 Plants and their parts used in the present study[a]

Botanical name	Common/English name	Family	Parts used	Therapeutic uses
Anethum sowa Kurz.	Sowa/dill/Indian dill	Umbelliferae	Seed	Appetizer/carminative/used to treat colic or gas in children
Aegle marmelos (Linn). Correa. ex Roxb.	Stone apple	Rutaceae	Bark	Astringent and antidysenteric, used to treat cough, acute gonorrhea dysentery, diarrhea, cancers, syphilitic affections, hypoglycemic activity (in albino rats)
Annona squamosa L.	Sugar-apple/ sweetsop/custard apple	Annonaceae	Arial part (leaves, twigs)	Cold remedy and to clarify urine/leaves are used for wound cleaning/also used to treat diarrhea
Artemisia vulgaris L.	Asian mugwort/ common wormwood	Asteraceae	Arial parts	Used in treating fatigue and to stimulate the nervous system (nervine and emmenagogue), have diuretic and diaphoretic action
Bacopa monnieri L.	Brahmi/water hyssop/herb-of-grace	Scrophulariaceae	Arial parts	Memory enhancing/relieves anxiety, stress and depression/longevity enhancer
Berberis aristata DC.	Indian berberi/tree turmeric	Berberidaceae	Dried stem	Blood purifier/antiperiodic and diaphoretic, anti-inflammatory activity
Chlorophytum borivilianum Sant. and Fernandes	Safed Musli/Safed Moosli	Liliaceae	Root	Aphrodisiac, tonic, pain reliever
Decalepis hamiltonii Wight and Arn.	Swallowroot	Asclepiadaceae	Root	Health drink/appetizer possess rich antioxidant and antifungal activity
Embelia ribes Burm.f.	False black pepper, false pepper/vidang	Myrsinaceae	Fruit (dried berries)	Used to treat worm infection, as carminative, anthelmintic, vermifuge, edema, fever, anorexia, urinary calculi, polyuria, fistula, pain and in vomiting
Hemidesmus indicus R.Br.	Hemidesmus/ Indian sarsaparilla	Asclepiadaceae	Root	Used to treat polyuria, hemorrhage, leprosy, blood disorders, anemia, jaundice, antibacterial and antilithic activity
Momordica charantia Linn.	Bitter melon or bitter gourd	Cucurbitaceae	Arial parts	Blood sugar support/used in diabetes
Piper longum Linn.	Dried Pepper/ Pepper	Piperaceae	Fruit	Appetizer and carminative agent, stimulates the appetite and dispels gas from the intestines, used to treat respiratory tract diseases like cough asthma, bronchitis
Picrorhiza Kurrooa Royle ex Benth	Picrorhiza/Gentian	Scrophulariaceae	Dried rhizomes	Used to treat viral hepatitis, antiasthmatic, anti-inflammatory activity
Rauvolfia serpentina Benth. Ex kurz	Serpentine wood/ sarpagandha/ Indian snakeroot	Apocynaceae	Root	Used for insomnia, psychosis, worm infection, epilepsy, nervous disorders, anorexia, mental disorders, pain and in poisoning
Sarcostemma acidum (Roxb) Voight.	Moon plant	Asclepiadaceae	Arial parts	As emetic used in leprosy
Sida cordifolia Linn.	Country mallow	Malvaceae	Roots	Anti-inflammatory, stimulant, used in cases of polyurea, spermatorrhea, leucorrhea, for nervous disorders, coryza and cardiac diseases
Syzygium cumini Linn.	Black plum, Java plum, bell fruit, water apple/ cherry	Myrtaceae	Dried whole fruit	Polyuria, diabetes and in hemorrhage
Terminalia bellarica Roxb.	*Acacia arabica*	Combretaceae	Fruit	Bronchial asthma, eye diseases, diarrhea, constipation, worm infections, cardiac diseases
Terminalia Chebula Retz.	Chebulic myrobalan	Combretaceae	Fruit	Jaundice, obesity, polyuria, anorexia, poisoning, cough, dyspnea, ascites, urinary disorders, carcinoma, laxative
Tribulus terrestris Linn.	Small caltrops	Zygophyllaceae	Arial parts	Urinary tract disorders/to overcome infertility
Cinnamomum zeylanicum Presl. +*Elettaria cardamomum* Maton.	Trijataka	Lauraceae Zingiberaceae	Mixed in equal	Respiratory related diseases

Table 1 (continued)

Botanical name	Common/English name	Family	Parts used	Therapeutic uses
+*Cinnamomum Tamala* Buch. Ham		Lauraceae	parts	
Piper longum Linn+*Zingiber officinale* Rosc.+*Piper nigrum* L.	Trikatu (three pungents)	Piperaceae Zingiberaceae Piperaceae	Mixed equally	Stimulant used for digestion
Vetiveria zizanioides (Linn.) Nash	Vetiver, Khas-Khas	Poaceae	Root	Ceases muscular pain, (rheumatism), liver congestion, coolant

Sources: Chopra et al. 1956; Vasant Lad 1998; Shetty et al. 2002

zizinalis had the highest concentrations of Fe and Zn (6,413.3 and 5.93 mg/100 g, respectively). Deficiency of zinc and iron in the diet is a widespread problem and a matter of great concern, especially in developing countries where people rely more on vegetarian diets. These essential trace elements are involved with vital immune system (Zn) and metabolic functions and are intrinsic components of hemoglobin, myoglobin, and cytochrome (Fe) (Hemalatha et al. 2007). Hence, further study of *V. zizinalis* might prove this species to be a useful dietary supplement to provide Zn and Fe, especially for vegetarians.

Piper longum had the highest potassium content (1,352.3 mg/100 g), *Anethum sowa* had the highest sodium concentration (170.69 mg/100 g), and *Rauvolfia serpentina* had the highest Mn concentration (856.4 mg/100 g). Perry (1972) reported a correlation between therapeutic properties of Cr and Mn in plants with diabetic and cardiovascular diseases. Plant materials with high concentrations of the above-mentioned micronutrient elements will definitely play an important role in maintenance of human health when taken at recommended levels.

Table 2 Operating conditions of the ICP-OES

Parameters	Specifications
Analysis mode	Normal
Rinsing time	Fixed (5.0 s)
Rinsing pump speed	High speed
Transfer time	10.0 s
Stabilization time	5.0 s
Transfer pump speed	Normal
Delay of synchronization	0 s
Stop of pump during replacement	No
Power	1,000 W
Normal speed of pump	20
Plasma gas flow rate	12 L/min
Sheath gas flow rate	0.2 L/min
Auxiliary flow rate	0.0
Sheath gas stability time	3.0 s
Nebulization flow rate	0.02
Nebulization pressure	1.0 bar
Sample uptake	1 mL/min
Argon humidifier	No

Earlier research on humans and livestock has shown that optimal intakes of elements such as Na, K, Mg, Ca, Mn, Cu, and Zn can reduce individual risk factors for health problems such as cardiovascular disease (Mertz 1982; Sanchez-Castillo et al. 1998). Mayer and Vyklicky (1989) reported that these elements play a significant role in neurochemical transmission and also serve as constituents of biological molecules as a cofactor for various enzymes and in a variety of different metabolic processes. Minerals like Fe, Zn, and Mn are also recognized to be potential antioxidants (Talwar et al. 1989), which are involved in strengthening the immune system. Similarly, Mg, and Zn are known to prevent cardiomyopathy, muscle degeneration, growth retardation, alopecia, dermatitis, immunological dysfunction, gonadal atrophy, impaired spermatogenesis, congenital malformations, and bleeding disorders (Chaturvedi et al. 2004).

Monitoring the presence and concentrations of heavy metals in plants/herbs used for medicinal and health-promoting effects is crucial because these levels can be used as an indicator of the surrounding pollution and because they can have ill effects when consumed directly. According to Schilcher et al. (1987), the presence of toxic metals in the environment is quite varied and depends on various factors, such as pollution from industrial and traffic emissions, the use of purification mud and agricultural expedients such as Cd-containing dung and the use of organic Hg fungicides and insecticides containing lead arsenate.

In the present study, the heavy metals Al, Ba, Cd, and Mo were not detectable, and lead was present but below detection levels in all samples analyzed. In contrast, As, Co, Cr, and Ni were detected in almost all samples, but they were present in low concentrations (Table 3). The concentrations of As and Co were highest in *V. zizinalis*, (53.1 and 10.2 mg/100 g, respectively), and this was the only plant material that was positive for the presence of Hg (3.6 mg/100 g). Arsenic is considered to be one of the most toxic elements, and the provisional tolerance (weekly intake) is

Table 3 Minerals and heavy metal contents of plants (mg/100 g, dry wt. basis)

Plant name	As	Ca	Co	Cr	Cu	Fe	Hg	K	Mg	Mn	Na	Ni	Zn
Anethum sowa	1.62±0.01	3.82±0.03	ND	0.16±0.00	8.59±0.01	60.5±0.20	ND	1,275.9±2.73	128.34±0.16	1.98±0.01	170.69±0.10	0.16±0.00	3.48±0.01
Aegle marmelos	1.72±0.01	3.89±0.02	ND	0.34±0.00	0.98±0.00	77.68±0.16	ND	261.74±0.00	105.36±0.18	2.50±0.06	51.4±0.01	0.74±0.19	0.72±0.02
Annona squamosa	1.67±0.00	3.72±0.03	ND	0.31±0.00	1.81±0.01	34.90±0.08	ND	616.39±1.16	169.7±0.31	2.76±0.01	15.97±0.01	0.33±0.00	2.13±0.01
Artemisia vulgaris	5.06±0.01	3,441.8±0.01	ND	1.43±0.01	3.80±0.01	357.09±0.59	ND	1,074.8±1.21	189.43±0.29	12.6±0.01	59.80±0.16	2.34±0.01	2.20±0.02
Bacopa monnieri	6.73±0.01	675.60±1.25	0.38±0.0	2.88±0.1	5.01±0.04	54.96±0.88	ND	1,245.0±2.26	228.86±0.18	10.44±0.02	96.85±0.24	1.04±0.1	2.68±0.01
Berberis aristata	14.50±0.02	637.30±0.59	ND	0.17±0.00	134. 96±0.20	133.6±0.13	ND	215.40±0.39	39.20±0.02	2.30±0.01	16.08±0.01	0.18±0.00	3.94±0.01
Chlorophytum borivilianum	1.22±0.01	201.04±0.29	ND	0.08±0.00	4.07±0.03	8.52±0.01	ND	706.98±0.75	85.29±0.16	0.03±0.00	48.92±0.06	0.09±0.01	3.58±0.01
Decalepis hamiltonii	2.89±0.12	515.9±0.64	ND	0.42±0.00	1.06±0.10	143.8±0.32	ND	516.77±0.42	130.2±0.10	4.47±0.00	70.06±0.14	0.13±0.00	2.04±0.02
Embelia ribes	1.01±0.01	227.6±0.12	ND	0.16±0.00	2.32±0.02	44.2±0.05	ND	753.20±0.85	47.98±0.06	1.71±0.01	37.31±0.01	0.19±0.01	1.24±0.03
Hemidesmus indicus	2.81±0.03	800.63±1.18	ND	0.41±0.01	7.95±0.41	195.8±0.01	ND	392.05±0.18	85.52±0.01	4.87±0.01	25.81±0.01	0.19±0.01	5.64±0.01
Momardica chasintia	3.07±0.01	3.90±0.12	ND	0.85±0.01	2.95±0.01	162.66±0.18	ND	1,272.2±3.99	236.72±0.34	7.65±0.01	46.42±0.15	3.86±0.01	4.08±0.01
Piper longum	7.36±1.2	344.4±0.59	ND	0.49±0.00	4.69±0.04	29.13±0.07	ND	1,352.3±1.13	135.39±0.29	1.63±0.01	13.96±0.02	0.16±0.00	1.46±0.00
Picrorhiza kurroa	1.14±0.01	285.4±0.44	ND	0.14±0.00	2.01±0.01	46.79±1.40	ND	382.78±0.50	68.65±0.07	5.27±0.01	119.2±0.31	0.49±0.00	3.22±0.01
Rauvolfia serpentina	1.45±0.03	307.9±0.86	ND	0.29±0.00	1.31±0.01	83.56±0.20	ND	234.03±0.46	47.12±0.11	856.4±0.01	158.31±0.21	0.19±0.00	1.32±0.01
Sarcostemma acidum	1.77±0.20	3.73±0.01	ND	0.19±0.00	0.86±0.01	59.8±0.20	ND	474.72±0.10	170.36±0.13	2.73±0.01	21.14±0.04	0.36±0.00	0.70±0.01
Sida cordifolia	3.59±0.14	269.9±5.40	ND	NP	0.05±0.00	0.75±0.15	ND	5.99±1.2	0.30±0.06	0.05±0.01	0.15±0.03	0.01±0.00	0.01±0.00
Syzygium cumini	1.23±0.01	99.72±0.30	ND	0.24±0.00	1.13±0.10	68.5±0.16	ND	439.97±0.47	62.72±0.10	0.96±0.01	32.10±0.05	0.18±0.01	0.43±0.02
Terminalia bellarica	1.23±0.12	255.20±0.83	ND	0.11±0.00	0.97±0.00	18.95±0.04	ND	594.17±0.26	50.30±0.08	0.18±0.01	15.95±0.04	0.09±0.00	1.36±0.01
Terminalia Chebula	7.62±1.2	113.2±0.09	ND	0.28±0.00	2.15±0.01	19.95±0.02	ND	620.52±1.17	41.97±0.08	NP	18.82±0.03	0.17±0.00	0.84±0.01
Tribulus terrestris	1.81±0.00	3.82±0.02	ND	0.23±0.00	2.49±0.01	71.87±0.10	ND	769.95±0.20	157.29±0.01	3.49±0.01	17.02±0.02	0.32±0.02	3.68±0.01
Trijataka	1.78±0.10	631.9±0.58	ND	0.50±0.00	2.22±0.15	61.07±0.80	ND	818.21±0.15	124.01±0.09	46.97±0.10	83.60±0.09	0.99±0.00	1.60±0.02
Trikatu	1.33±0.00	194.82±0.58	ND	0.13±0.01	2.56±0.01	27.96±0.04	ND	998.36±2.69	106.42±0.20	17.92±0.01	15.15±0.04	0.53±0.01	0.85±0.01
V. zizinalis	53.1±0.03	84.8±0.03	10.2±0.1	6.74±0.01	11.97±0.01	6,413.3±13.70	3.6±0.1	308.05±0.75	111.38±0.01	67.63±0.14	39.06±0.02	3.28±0.01	5.93±0.01

Al, Ba, Cd, and Mo were not present; mean $n=3$, ±SD

NP not present; *ND* not detectable

15 mg/kg body weight (FAO/WHO 1989). In an earlier work, Liang et al. (1998) measured various metallic elements in commercial Chinese medicines using AAS and reported approximately 10 mg/100 g of arsenic in the samples analyzed. However, the results on Hg (Table 3) were contradictory to an earlier report by Dahanukar et al. (1998) who found high levels of Hg (in six samples) that exceeded the permissible amounts (1–7.5 ppm). Contamination by Hg occurs mainly via its usage in dental amalgam, electric switches, and batteries, which then finds its way into soil. Hg poisoning causes inflammation of the mouth, stomach, and colon and acute abdominal pain, and it affects the kidneys.

Chromium is one of the trace metal nutrients that are essential to humans and animals. Its principal role appears to be in helping to maintain normal glucose tolerance in the body (Strickland et al. 1972). Chromium was highest in *V. zizinalis* (6.74 mg/100 g), followed by *Bacopa monnieri* (2.88 mg/100 g), and it was lowest in *Chlorophytum borivilianum* (0.08 mg/100 g). The main source of Cr contamination occurs via the use of plating metal, as an alloy of stainless steel, and in tanning of hides. Because Cr is not known to have any toxic effects, no maximum intake limit has been set. However, in the UK, the Committee on Medical Aspects of Food Policy has recommended that Cr intake should be >25 µg/kg body weight for adults and between 0.1 and 1.0 µg/kg body weight for children and adolescents (COMA 1991).

Momardica chasintia contained the highest levels of Ni (3.86 mg/100 g), while *S. cordifolia* (0.01 mg/100 g) had the lowest. Ni is exclusively used as an alloy in stainless steel, in coins, in metal plating (electric water heaters), and in batteries. It has been reported to cause allergies and eczema of skin (Jorhem et al. 1996). However, no maximum limit has been set for Nickel in food.

The presence of heavy metals in plant samples can be directly attributed to the surrounding pollution in the environment (e.g., atmospheric and water pollution). Wong et al. (1993) reported the presence of heavy metals (cadmium, cobalt, copper, iron, manganese, nickel, lead, zinc, and mercury) in 42 Chinese herbal medicines and attributed their presence to contamination occurring during air-drying and preservation. Soil condition (e.g., heavily polluted) also plays a significant role in determining the heavy metal concentrations of plant materials used for medicinal purposes (Kabelitz 1998). Januz et al. (1994) ascertained the contents of heavy metals to be correlated to industrialized regions, and they concluded that the plants grown in an industrialized region had higher contents of heavy metals than plants grown in a second less-industrialized region.

The mineral and heavy metal concentrations reported herein might not be on par with some of the earlier reports on medicinal plants. The differences observed might be due to different growth conditions, genetic factors, geographical variations in the level of soil fertility, efficiency of mineral uptake, and the analytical procedures employed (Özcan and Akgül 1998).

From the study, we conclude that measuring minerals and heavy metal concentrations in nutraceutically valued plant produce is highly significant not only from nutritional point of view but also to assess the quality when used as herbal drugs. The result of the present study provides vital information on the mineral composition for a few of the popular and nutraceutically valued plants of India, which need to be explored further to be used as a food supplement or for food biofortification to exploit the potential health-promoting properties.

References

Aberoumand A, Deokule SS (2009) Determination of elements profile of some wild edible plants. Food Anal Methods 2:116–119

AOAC (1990) Official methods of analysis of the Association of Official Agricultural Chemists, 15th edn. AOAC, Washington

Bhat R, Sridhar KR (2008) Nutritional quality evaluation of electron beam-irradiated lotus (*Nelumbo nucifera*) seeds. Food Chem 107:174–184

Bhat R, Karim AA (2009) Exploring the nutritional potential of wild and underutilized legumes. Comp Rev Food Sci Food Safety (in press)

Brody T (1994) Nutritional biochemistry. Academic, San Diego, pp 555–556

Chaturvedi VC, Shrivastava R, Upreti RK (2004) Viral infections and trace elements: a complex interaction. Curr Sci 87:1536–1554

Chopra RN, Nayar SL, Chopra IC (1956) Glossary of Indian medicinal plants. Council of Scientific Industrial Research, New Delhi, pp 1–330

COMA, Committee on medical aspects of food policy (1991) Dietary reference values for Food Energy and Nutrients in the United Kingdom. Department of Health, HSMO, London

Dahanukar SA, Thatte UM, Rege NN (1998) Pharmacology in Ayurveda: VI. Adverse reactions to Ayurvedic drugs. Indian Pract 51:815–821

FAO/WHO (1989) Joint FAO/WHO expert committee on food additives: *Evaluation of certain food additives and contaminants*, 33rd Report, Tech Rep Series 776. World Health Organization, Geneva, pp 27–38

Galgano F, Favati F, Caruso M, Scarpa T, Palma A (2008) Analysis of trace elements in southern Italian wines and their classification according to provenance. LWT - Food Sci Technol 41:1808–1815

Hemalatha S, Patel K, Srinivasan K (2007) Zinc and iron contents and their bioaccessibility in cereals and pulses consumed in India. Food Chem 102:1328–1336

Januz M, Danutra W, Jerzy K, Robart R, Krysztof L, Jerzy C (1994) The occurrence of Pb, Cd, Cu, Mn, Ni, Co, and Cr in selected species of medicinal plants in Poland. Bromatol Toksypol 28:363–368

Jorhem L, Svensson K, Thuvander A, Glynn WA, Grawé PK (1996) Nickel in foodstuffs and nickel allergy (in Swedish). SLV-Rapport 8/96. National Food Administration, Uppsala

Kabelitz L (1998) Heavy metals in herbal drugs. Eur J Herbal Med 4:25–29

Kalăc P, Svoboda L (2000) A review of trace element concentrations in edible mushrooms. Food Chem 69:273–281

Knapp G (1991) Mechanized techniques for sample decomposition and element pre-concentration. Microcemica Acta 2:445–455

Lavilla I, Filgueiras AV, Bendicho C (1999) Comparison of digestion methods for determination of trace and minor metals in plant samples. J Agric Food Chem 47:5072–5077

Liang W-L, Lin S-W, Yen K-Y, Yang L-L (1998) Metal element analysis of commercial Chinese medicines. Taiwan Kexue 51:37–56

Mayer ML, Vyklicky L (1989) The action of Zinc on synaptic transmission of mouse neuronal excitability in culture of mouse hippocampus. The J Physiol 415:351–365

Mazzanti G, Battinelli L, Daniele C, Costantini S, Ciaralli L, Evandri MG (2008) Purity control of some Chinese crude herbal drugs marketed in Italy. Food Chem Toxicol 46:3043–3047

Mertz W (1982) Trace minerals and atherosclerosis. J Food Process 41:2807–2812

Miller-Cebert RL, Sistani NA, Cebert E (2009) Comparative mineral composition among canola cultivars and other cruciferous leafy greens. J Food Comp Anal 22:112–116

Özcan M, Akgül A (1998) Influence of species, harvest date and size on composition of capers (*Capparis spp*.) flower buds. Nahrung 42:102–105

Perry HM (1972) Hypertension and true geochemical environments in relation to health and diseases. Academic, New York

Sanchez-Castillo CP, Dewey PJS, Aguirre A, Lara JJ, Vaca R, Leon de la Barra P, Ortiz M, Escamilla I, James WPT (1998) The mineral content of Mexican fruits and vegetables. J Food Comp Anal 1:340–356

Schilcher H, Peters H, Wank H (1987) Pestiszide and Schmermretalle in Arzneipmanzen and Arzneiplanzen Zubereitungen. Pharmazeutische Industrie 49:202–211

Schumacher M, Bosque MA, Domingo JL, Corbella J (1991) Dietary intake of lead and cadmium from foods in Tarragona Province, Spain. Bull of Environ Contam Toxicol 46:320–328

Shetty BV, Kaveriappa KM, Bhat GK (2002) Plant resources of Western Ghats and lowlands of Dakshina Kannada and Udupi districts Published in 2002. Pilikula Nisarga Dhama Society, Mangalore, p 264

Smith KT (1988) Trace minerals in foods. Marcel Dekker, New York, pp 1–430

Strickland GT, Beckner WM, Leu ML, O'Reilly S (1972) Turnover studies of copper in homozygotes and heterozygotes for Wilson's disease and controls: isotope tracer studies with ^{27}Cu. Clinical Sci 43:605–615

Talwar GP, Srivastava LM, Mudgil KD (1989) Textbook of biochemistry and human biology (2nd edition). Prentice Hall of India Private Ltd, India, p 1292

Tuzen M, Sesli E, Soylak M (2007) Trace element levels of mushroom species from East Black Sea region of Turkey. Food Cont 18:806–810

Vasant L (1998) The complete book of ayurvedic home remedies. Harmony, New York, p 325

Wong MK, Tan P, Wee YC (1993) Heavy metals in some Chinese herbal plants. Biol Trace Elem Res 36:135–142