J Radioanal Nucl Chem (2011) 290:615–621
DOI 10.1007/s10967-011-1341-2

Elemental composition of herbal medicines sold over-the-counter in São Paulo city, Brazil

H. S. Moreira · M. B. A. Vasconcellos · E. R. Alves · F. M. Santos · M. Saiki

Received: 19 June 2011 / Published online: 10 July 2011

Abstract In Brazil, the use of herbal medicines is very popular due to its immense flora, cultural aspects and to the popular belief that herbs, which are of natural origin, are safe and without undesirable side effects. Aside from that public interest in natural therapies, the use of herbal medicines has increased expressively due to the high cost of synthetic medicines. In this study, elemental compositions of herbal medicines from the species *Ginseng*, *Ginkgo biloba*, *Centella asiatica*, *Mulberry* and *Aloe vera* supplied by different suppliers were evaluated by neutron activation analysis. The concentrations of As, Ba, Br, Ca, Cl, Co, Cr, Cs, Fe, Hf, K, Mg, Mn, Na, Rb, Sb, Sc, Th, Zn and some lanthanides were determined in these samples. Comparisons made between the results indicated differences in their elemental contents depending on the plant species, origins of the samples and the age of the leaves. The results also showed that the herbal medicines contain elements such as Ca, Co, K, Fe, Mg and Zn known as essential to humans and for treatment and prevention of diseases. Toxic elements such as Hg, Cd and Cu were not detected. Elements As and Sb were detected in some samples but at very low concentrations at the $\mu g\ kg^{-1}$ levels. Herbal medicine results were also compared to literature values. Biological certified reference material was analyzed for quality control of the analytical results.

H. S. Moreira · M. B. A. Vasconcellos ·
E. R. Alves · F. M. Santos · M. Saiki (✉)
Instituto de Pesquisas Energéticas e Nucleares, IPEN-CNEN/SP,
Avenida Professor Lineu Prestes 2242, São Paulo,
SP CEP 05508-000, Brazil
e-mail: mitiko@ipen.br

H. S. Moreira
Faculdade de Ciências Farmacêuticas, Universidade de São
Paulo, Avenida Professor Lineu Prestes, 580, São Paulo,
SP CEP 05508-000, Brazil

Keywords Herbal medicines · Elemental composition · Neutron activation analysis · Medicinal plants

Introduction

Medicinal plants have been used to treat diseases for thousands of years. This is true especially in third-world countries where herbal medicine has long played an important role in primary healthcare of the population. In Brazil, the use of herbal medicines is also very popular due to its immense flora, cultural aspects and to the popular belief that herbs, which are of natural origin, are safe and without undesirable side effects.

Furthermore, over the last decades, public interest in natural therapies mainly of herbal medicines has increased expressively due to the high cost of synthetic medicines. Besides that they are sold over-the-counter without the need of a medical prescription.

Plant products also called medicinal plant drugs are constituted of dried plants, in whole or parts of a plant and are mainly used for preparation of teas. On the other hand, herbal pharmaceutical medications or herbal medicines are technically more sophisticated and are presented in the forms of pills, capsules or syrups.

Since the production of medicinal plants in Brazil is increasing and the future of this market is promising, the Regional Council of Medicine of São Paulo State approved the policy of the national medicinal plant drugs and herbal medicines. It also created the municipal program for herbal medicine production [1]. In addition, the National Health Surveillance Agency (ANVISA) published a resolution in order to orientate the use of plant–based drugs [2].

Within this scenario, it becomes important to ensure the efficacy, safety and quality of herbal medicines [3].

Consequently, the determination of elemental composition in medicinal plant materials has attracted much attention as some elements are active components or are toxic to human health [4]. High levels of toxic elements can occur in medicinal plants depending on the soil or type of fertilizers used in their cultivation. In addition from a pharmacological point of view, the study of the role of trace elements is of great interest for finding ways to increase the active constituents in medicinal plants.

The determination of inorganic components in medicinal plant based drugs or herbal medicines has been undertaken in order to establish their levels of elements [5, 6] or to evaluate toxic elements [4]. Besides studies have been carried out in order to investigate the correlation of the elemental composition with therapeutic effects [7–9] as well as with some factors such as soil composition and climate where the plant was cultivated [10, 11]. In Brazil studies on elemental determination in herbal medicines is still very scarce.

In this study, neutron activation analysis (NAA) was applied to evaluate the elemental composition of herbal medicines from the plants (*Ginseng*, *Ginkgo biloba*, *Centella asiatica*, *Mulberry* and *Aloe vera*) from different suppliers and sold over-the-counter, without a medical prescription. The results obtained may contribute for the investigations related to the link between elemental content and its curative effects.

Experimental

Herbal medicines and their preparation for analyses

Herbal medicines from the following plants were analyzed: *Ginseng*, *Ginkgo biloba*, *Centella asiatica*, *Mulberry* and *Aloe vera* that are among widely used by Brazilian population.

Ginseng is a slow growing perennial plant with fleshy roots of the *Panax* genus of the family *Araliaceae*. The *Ginseng* roots are traditionally taken orally as adaptogens, aphrodisiacs, nourishing stimulants, in the treatment of type II diabetes and of sexual dysfunctions in men.

Ginkgo biloba is a very large tree belonging to the family of *Ginkgoaceae*. Its leaves are used as a memory and concentration agent, to treat dizziness and tinnitus labyrinthitis, anti-vertigo agent, protector against cell oxidation and neuro- protective agent.

Centella asiatica is a small herbaceous plant of the *Mackinayceae* family. The leaves of this species are used as an antibacterial, anti-viral, anti-inflammatory, cerebral tonic, circulatory stimulant and diuretic agent.

Mulberry is also a tree of the *Moraceae* family and its leaves are used to make tea that helps to lower high blood pressure, regulate the digestive system, prevent and fight type II diabetes and to lose weight by blocking sugar. Its leaves are also used to help in the treatment of menopause and baldness.

Aloe vera is of the *Asphodelaceae* family and this species is frequently cultivated as an ornamental plant. However, its leaves are used due to its therapeutic effectiveness in the treatment of wounds or burns and for digestive problems as a laxative ingredient. As a cosmetic, *Aloe vera* is used in facial creams and also to untangle hair.

The samples of herbal medicines from different suppliers and sold over-the-counter (without a medical prescription) were obtained from drugstores or pharmacies in São Paulo city, SP, Brazil. All were in solid forms in capsules or pills. Eight pills/capsules of each sample were weighted to obtain the mean values of mass per capsule. For the analyses, contents of the capsules or pills were homogenized by grinding in an agate mortar to obtain a powder form. The *Gingko biloba* leaf samples of different ages, collected in Mirandópolis city, SP, Brazil, were cleaned by washing with purified MilliQ water and then freeze-dried and ground in an agate mortar for the analyses.

Data about plant species, plant parts used in the medicines, mass of the product in each capsule or pill are presented in Table 1.

Table 1 Data of plant species, of parts of the plant, sample form and mean mass with standard deviation of herbal medicines in each capsule or pill

Plant species (code given for the product supplier)	Part of the plant	Form	$M \pm SD$ (g)
Ginseng (MD)	Roots	Capsule	0.428 ± 0.019
Ginseng (VE)	Roots	Capsule	0.307 ± 0.006
Ginseng (HLB)	Roots	Capsule	0.338 ± 0.008
Ginseng (KG)	Roots	Capsule	0.256 ± 0.004
Gingko biloba from Mirandopolis, SP	Young leaves	a	a
Gingko biloba from Mirandopolis, SP	Adult leaves	b	b
Gingko biloba (MD)	Leaves	Capsule	0.328 ± 0.011
Gingko biloba (VE)	Leaves	Capsule	0.251 ± 0.009
Ginko biloba (EQ)	Leaf extract	Pill	0.288 ± 0.006
Centella asiatica (MD)	Leaves	Capsule	0.352 ± 0.011
Mulberry (EYE)	Leaves	Capsule	0.390 ± 0.053
Aloe vera (FCNA)	Leaves	Pill	0.0809 ± 0.0081

$M \pm SD$ = arithmetic mean and standard deviation of the mass in each capsule or pill

a and b indicate, respectively, young and adult leaves of *Gigko biloba* cultivated in Mirandópolis city, SP, Brazil and prepared in the laboratory for the analyses

Procedure for neutron activation analysis

Preparation of synthetic elemental standards

The synthetic standards were prepared by pippeting 50 or 100 μL of the elemental standard solutions onto sheets of Whatman No. 40 filter paper. These solutions containing one or more elements were prepared using certified standard solutions provided by Spex Certiprep Chemical, USA. All the pippetors and volumetric flasks were calibrated before use. These filter sheets were dried at room temperature inside a desiccator with fresh silica and then placed into clean polyethylene envelopes which were then heat sealed. In these standards the quantities of each element, in μg (in parentheses) were the following: As (1.50), Ba (499.0), Br (5.2), Ca (1,000), Cd (10,0), Ce (4.0), Cl (500.0), Co (0.150), Cr (2.0), Cs (12.0), Cu (100.0), Eu (0.10), Fe (280.0), Hf (1.00), Hg (6.8), K (1,000.0), Mg (997.9), Mn (4.0), La (0.998), Na (500.0), Nd (2.0), Rb (10.0), Sb (0.600), Sc (0.080), Sm (0.500), Th (0.999) and Zn (35.0).

Irradiation and counting

Aliquots of about 190 mg of each sample weighed in polyethylene envelopes were irradiated in the IEA-R1 nuclear research reactor along with the synthetic element standards for 12 s and 16 h under a thermal flux of about 5×10^{12} n cm^{-2} s^{-1}. After adequate decay times, the irradiated samples and standards were measured by a hyperpure Ge detector Model GC2018 from Canberra coupled to a DSA-1000 Multichannel Analyzer. The resolution (FWHM) of the system was 1.0 keV for 122 keV gamma-ray peak of ^{57}Co and 1.87 keV for 1332 keV gamma ray peak of ^{60}Co. Each sample and standards were measured at least twice for different decay times. Counting times from 200 to 50,000 s were used, depending on the half-lives or activities of the radionuclides considered. Spectra were collected and processed using Canberra Genie 2000 Version 3.1 software. The radionuclides measured were identified according to their half-lives and gamma-ray energies. The concentrations of elements were calculated by a comparative method. The short lived radionuclides used were ^{38}Cl, ^{42}K, ^{27}Mg, ^{56}Mn and ^{24}Na. Long lived radionuclides were: ^{76}As, ^{131}Ba, ^{82}Br, ^{47}Ca, ^{115}Cd, ^{141}Ce, ^{60}Co, ^{51}Cr, ^{134}Cs, ^{64}Cu, ^{152}Eu, ^{59}Fe, ^{182}Hf, ^{197}Hg, ^{42}K, ^{140}La, ^{147}Nd, ^{233}Pa (Th), ^{86}Rb, ^{122}Sb, ^{46}Sc, ^{153}Sm, and ^{65}Zn.

The control of the analytical results was evaluated by analyzing the certified reference material INCT-MPH-2 Mixed Polish Herbs provided by the Institute of Nuclear Chemistry and Technology, Poland. The elemental concentrations of the reference material were evaluated on a dry weight basis, as recommended in the certificate.

Table 2 Elemental concentrations obtained for certified reference material INCT-MPH-2 Mixed Polish Herbs

Elements	INCT-MPH-2 Mixed polish herbs				
	M ± SD	Value of the certificate [13]	RSD (%)	RE (%)	*Z*-sore
As, μg kg^{-1}	0.182 ± 0.015	0.191 ± 0.023	8.04	4.7	−0.48
Ba, mg kg^{-1}	33.2 ± 1.9	32.5 ± 2.5	5.7	2.2	0.30
Br, mg kg^{-1}	7.68 ± 0.29	7.71 ± 0.61	3.8	0.43	−0.08
Ca, %	1.046 ± 0.018	1.08 ± 0.07	1.7	3.2	−0.87
Cl, mg kg^{-1}	2825 ± 33	2840 ± 200	1.17	0.53	−0.14
Co, μg kg^{-1}	0.209 ± 0.014	0.210 ± 0.025	6.8	0.71	−0.08
Cr, mg kg^{-1}	1.763 ± 0.089	1.69 ± 0.13	5.1	4.4	0.66
Cs, μg kg^{-1}	79.0 ± 5.9	76.0 ± 7.0	7.5	4.0	0.44
Fe, mg kg^{-1}	497 ± 27	(460)[a]	5.5		
K, %	1.998 ± 0.097	1.91 ± 0.12	4.9	4.6	0.77
Mg, %	0.310 ± 0,005	0.292 ± 0.018	1.6	6.1	1.77
Mn, mg kg^{-1}	187 ± 13	191 ± 12	7.0	2.1	−0.28
Na, mg kg^{-1}	392 ± 30	(350)[a]	7.7		
Rb, mg kg^{-}	10.5 ± 0.6	10.7 ± 0.7	5.2	1.9	−0.31
Sb, μg kg^{-1}	55.8 ± 8.1	65.5 ± 9.1	14.5	14.8	−1.04
Sc, μg kg^{-1}	118 ± 6	123 ± 9	5.4	3.8	−0.60
Th, μg kg^{-1}	168 ± 20	154 ± 13	11.9	9.1	0.67
Zn, mg kg^{-1}	33.7 ± 1.0	33.5 ± 2.1	3.1	0.6	0.13
La, μg kg^{-1}	562 ± 55	571 ± 46	9.8	1.5	−0.15
Ce, mg kg^{-1}	1.14 ± 0.02	1.12 ± 0.10	1.8	1.8	0.37
Sm, μg kg^{-1}	85.7 ± 3.9	94.4 ± 8.2	4.6	9.2	−1.5

M ± SD = Arithmetic mean and standard deviation of at least three determinations

RSD relative standard deviation, *RE* relative error

[a] Numbers in parentheses are informative values

Table 3 Elemental concentrations in young and adult leaves of *Gingko biloba*

Elements	Young leaves	Adult leaves
Ba, mg kg^{-1}	28.6 ± 0.5	96.2 ± 1.9
Ca, mg g^{-1}	4.10 ± 0.10	15.30 ± 0.03
Cl, mg g^{-1}	1.390 ± 0.033	2.011 ± 0.034
Fe, mg kg^{-1}	39.3 ± 1.1	89.6 ± 9.0
K, mg g^{-1}	39.8 ± 0.2	48.4 ± 0.2
Mg, mg g^{-1}	1.60 ± 0.11	2.04 ± 0.07
Mn, mg kg^{-1}	10.2 ± 0.3	13.4 ± 0.1
Na, mg kg^{-1}	15.2 ± 0.6	17.1 ± 1.3
Rb, mg kg^{-1}	85.4 ± 2.5	92.5 ± 5.7
Sc, μg kg^{-1}	1.1 ± 0.1	1.8 ± 0.1
Zn, mg kg^{-1}	6.60 ± 0.04	5.26 ± 0.01

Moisture weight loss of 7.89% obtained for INCT-MPH-2 Mixed Polish Herbs was used to correct the final results.

Results and discussion

Results of mean elemental concentrations with standard deviations obtained in the analyses of certified reference material are listed in Table 2 along with relative standard deviations (RSD), relative errors (RE), *Z*-score [12] and certificate values. Most of the results agree with certified values presenting relative errors lower than 9.1%. They also presented good precision with relative standard deviations varying from 1.2 to 11.9%. The *Z*-score values obtained were $|Z\text{-score}| < 2$, indicating that the results are satisfactory and are within the ranges of certified values ($p \leq 0.05$).

A comparison of elemental contents in *Gingko biloba* leaves of different ages (Table 3) shows that adult leaves presented slightly higher concentrations than young ones for most of the elements determined. This means that elemental concentrations in herbal medicines depend on the age of the leaves utilized for its preparation.

Concentrations of elements obtained in *Ginseng* and *Gingko biloba* herbal medicines from different suppliers or origins are presented in Table 4 and those for *Centella asiatica*, *Mulberry* and *Aloe vera* herbal medicines are presented in Table 5. In these samples, Ca, Cl, K and Mg concentrations were obtained at highest concentrations at the mg g^{-1} levels, Ba, Br, Fe, Mn, Na, Rb and Zn at the mg kg^{-1} and As, Co, Cr, Cs, Sb, Sc, Th and the lanthanides at the μg kg^{-1} levels.

Table 4 Elemental concentrations for *Ginseng* and *Ginkgo biloba* herbal medicines from different suppliers

Elements	*Ginseng* herbal medicine				*Gingko biloba* herbal medicine		
	MD	VE	HLB	KG	MD	VE	EQ
As, mg kg^{-1}	<0.04	0.162 ± 0.004	0.066 ± 0.004	0.111 ± 0.004	0.342 ± 0.006	0.341 ± 0.007	***0.134 ± 0.002***
Ba, mg kg^{-1}	82.9 ± 2.2	110.2 ± 1.6	104.0 ± 1.7	***61.4 ± 1.3***	154.6 ± 2.4	126.0 ± 2.5	<3.8
Br, mg kg^{-1}	16.451 ± 0.005	3.60 ± 0.02	3.469 ± 0.002	***1.19 ± 0.02***	3.518 ± 0.001	3.082 ± 0.013	3.508 ± 0.008
Ca, mg g^{-1}	4.162 ± 0.101	***2.855 ± 0.0 68***	3.783 ± 0.088	3.016 ± 0.069	22.39 ± 1.14	25.07 ± 1.28	***0.99 ± 0.11***
Cl, mg g^{-1}	1.058 ± 0.020	0.913 ± 0.022	1.065 ± 0.033	***0.550 ± 0.021***	2.33 ± 0.06	3.314 ± 0.047	***0.312 ± 0.011***
Co, mg kg^{-1}	0.545 ± 0.007	1.26 ± 0.02	1.43 ± 0.02	***0.234 ± 0.003***	0.249 ± 0.003	0.280 ± 0.004	***0.113 ± 0.002***
Cr, mg kg^{-1}	***0.362 ± 0.014***	0.430 ± 0.014	0.470 ± 0.015	1.325 ± 0.019	1.806 ± 0.025	1.449 ± 0.025	***0.646 ± 0.011***
Cs, mg kg^{-1}	0.290 ± 0.003	0.667 ± 0.006	0.846 ± 0.007	***0.033 ± 0.002***	0.136 ± 0.002	0.162 ± 0.002	<0.05
Hf, mg kg^{-1}	0.034 ± 0.001	0.057 ± 0.001	0.038 ± 0.002	***0.010 ± 0.001***	0.022 ± 0.002	0.176 ± 0.001	***0.010 ± 0.001***
Fe, mg kg^{-1}	287.3 ± 2.0	445.3 ± 2.9	489.0 ± 3.1	***95.6 ± 1.0***	730.0 ± 5.2	***690.4 ± 4.5***	1333.8 ± 7.6
K, mg g^{-1}	11.68 ± 0.04	16.51 ± 0.07	19.48 ± 0.07	***15.32 ± 0.06***	8,96 ± 0.03	13.18 ± 0.05	***0.571 ± 0.00 2***
Mg, mg g^{-1}	***0.647 ± 0.059***	0.729 ± 0.069	1.207 ± 0.085	3.239 ± 0.061	6.027 ± 0.161	8217 ± 204	6315 ± 79
Mn, mg kg^{-1}	***35.1 ± 0.3***	61.7 ± 1.3	84.1 ± 0.6	58.4 ± 1.3	84.6 ± 4.1	95.0 ± 1.6	***2.73 ± 0.05***
Na, mg kg^{-1}	***120.9 ± 4.8***	151.3 ± 5.6	727.9 ± 10.0	508.1 ± 7.6	432.8 ± 8.2	776.6 ± 12.5	***72.4 ± 2.6***
Rb, mg kg^{-1}	***25.9 ± 0.***2	62.3 ± 0.5	84.6 ± 0.7	6.55 ± 0.07	***6.09 ± 0.09***	8.38 ± 0.12	***0.26 ± 0.05***
Sb, mg kg^{-1}	0.016 ± 0.001	0.032 ± 0.001	0.038 ± 0.001	***0.0046 ± 0.0006***	0.086 ± 0.001	0.107 ± 0.001	***0.0241 ± 0.0003***
Sc, mg kg^{-1}	0.067 ± 0.003	0.1010 ± 0.0004	0.1428 ± 0.0005	***0.0205 ± 0.0001***	0.1808 ± 0.008	0.162 ± 0.002	***0.0217 ± 0.0002***
Th, mg kg^{-1}	0.0730 ± 0.0001	0.047 ± 0.001	0.053 ± 0.001	***0.035 ± 0.002***	0.160 ± 0.002	0.234 ± 0.001	***0.0022 ± 0.0005***
Zn, mg kg^{-1}	***13.5 ± 0.1***	19.35 ± 0.12	26.90 ± 0.15	35.05 ± 0.18	13.04 ± 0.08	11.69 ± 0.08	***5.87 ± 0.05***
La, mg kg^{-1}	1.772 ± 0.006	***0.458 ± 0.002***	0.650 ± 0.014	0.866 ± 0.005	2.263 ± 0.006	0.934 ± 0.003	***0.008 ± 0.001***
Ce, mg kg^{-1}	1.73 ± 0.01	0.96 ± 0.01	1.35 ± 0.01	***0.72 ± 0.02***	0.745 ± 0.008	1.715 ± 0.012	<0.046

MD, VE, HLB, KG and EQ are the codes given to the supplier of the herbal medicines. Results written in italic bold are the lowest concentrations among herbal medicines of the same plant species

Table 5 Elemental concentrations obtained for *Centella asiatica, Mulberry* and *Aloe vera* herbal medicines

Elements	Herbal medicines		
	Centella Asiatica (MD)	*Mulberry* (EYE)	*Aloe vera* (FCNA)
As, mg kg^{-1}	<0.04	<0.03	<0.03
Ba, mg kg^{-1}	202.6 ± 2.4	96.3 ± 2.1	75.3 ± 2.3
Br, mg kg^{-1}	61.33 ± 0.10	7.54 ± 0.02	5.58 ± 0.04
Ca mg g^{-1}	7.699 ± 0.163	8.302 ± 0.169	31.729 ± 0.314
Cl, mg g^{-1}	4.036 ± 0.101	0.614 ± 0.022	11.954 ± 30.14
Co, mg kg^{-1}	1.57 ± 0.02	0.180 ± 0.003	0.156 ± 0.002
Cr, mg kg^{-1}	6.42 ± 0.12	0.903 ± 0.021	0.491 ± 0.025
Cs, mg kg^{-1}	0.274 ± 0.002	0.091 ± 0.004	0.170 ± 0.002
Fe, mg kg^{-1}	3997 ± 19	8325 ± 84	293 ± 2
Hf, mg kg^{-1}	2.11 ± 0.01	0.0572 ± 0.0009	0.0132 ± 0.0007
K, mg g^{-1}	23.89 ± 0.07	11.471 ± 0.032	20.25 ± 0.18
Mg, mg g^{-1}	2.75 ± 0.37	2.132 ± 0.065	5.92 ± 0.37
Mn, mg kg^{-1}	475.0 ± 20.2	97.4 ± 0.7	212.0 ± 2.7
Na, mg kg^{-1}	414.1 ± 11.0	89.1 ± 4.9	8272 ± 128
Rb, mg kg^{-1}	115.2 ± 1.2	20.2 ± 0.2	49.2 ± 0.4
Sb, mg kg^{-1}	0.018 ± 0.001	0.0180 ± 0.0003	0.0226 ± 0.0009
Sc, mg kg^{-1}	0.936 ± 0.004	0.1364 ± 0.0006	0.0295 ± 0.0003
Th, mg kg^{-1}	0.957 ± 0.007	0.0679 ± 0.0009	0.149 ± 0.002
Zn, mg kg^{-1}	74.9 ± 0.6	24.5 ± 0.1	138.5 ± 0.6
La, mg kg^{-1}	7.86 ± 0.02	1.084 ± 0.003	0.472 ± 0.007
Ce, mg kg^{-1}	12.42 ± 0.02	1.168 ± 0.009	0.82 ± 0.01
Nd, mg kg^{-1}	5.25 ± 0.73	0.94 ± 0.11	0.37 ± 0.10
Sm, mg kg^{-1}	0.536 ± 0.006	0.144 ± 0.003	0.0178 ± 0.0007

Results obtained for *Ginseng* and *Gingko biloba* herbal medicines show that elemental concentrations depend on the origin or on the suppliers of the products (Table 4).The lowest element concentrations obtained for these two herbal medicines are indicated in italic bold in Table 4. Toxic elements such as Cd, Cu and Hg were not detected in the samples analyzed. In these cases, detection limit values were evaluated according to the Currie criteria [14]. Elements As and Sb were detected in some samples but at very low concentrations at μg kg^{-1} levels. The detection limits, in μg kg^{-1}, (in parentheses) obtained for herbal medicines are the following: As (0.04), Cd (0.8), Cu (0.45), Hg (0.04) and Sb (0.015).

The differences found in the elemental concentrations among herbal medicines can be attributed to the plant species, its preferential absorbability of the element, mineral composition of the soil in which the plant was grown, as well as, its surrounding climatic conditions [15].

Table 6 presents the mean elemental concentrations of the herbal medicines analyzed in this study and those reported literature values [9, 16, 17] for comparison. These literature values are those reported recently and also determined by neutron activation analysis. Our results of mean elemental concentrations obtained for Br, Ca, Cl, Co, Cr, Cs, Sc, Th and lanthanides of Table 6 are the same order of magnitude or are within the mean concentration values of reported literature data. For Ba, Mg and Mn results are not similar. For Rb our result is of the same order of magnitude with that presented by Garg et al. [16] but not with those presented by two other authors [9, 17]. The elements obtained at highest concentrations in this study were also found in high concentrations by other authors [9, 16, 17] for different kinds of medicinal herbs.

The high concentrations of Ca and Mg found in the samples can be associated to the absence of collateral side effects of herbal medicines. The high concentrations of these elements may prevent stomach lesions. The high concentrations of K found in herbal medicines have been related to the diuretic actions of these products. K is present in natural diuretics, as well as, in drugs used for eliminating phlegm and to invigorate the stomach [18]. In addition, it is known that K salts can regulate body fluids and also participate in cardiac muscle contraction.

Some elements such as Ca, Co, K, Fe, Mg and Zn found in herbal medicines are also essential to humans. For example, Fe is an important component of hemoglobin in the human body and helps in energy metabolism, facilitates the oxidation of carbohydrates and proteins and to control

Table 6 Mean elemental concentrations in herbal medicines and literature reported values for medicinal plants or herbal preparations

Elements	This study[a]	Garg et al. [16][b]	Abugassa et al. [17][c]	Fei et al. [9][d]
Ba, mg kg^{-1}	112.6 ± 41.2	20.9 ± 4.0	29.5 ± 13.8	73.1 ± 82.0
Br, mg kg^{-1}	10.9 ± 17.3	42.4 ± 76.4	69.1 ± 112.6	-[e]
Ca, mg g^{-1}	11.0 ± 10.5	5.1 ± 7.6	27.6 ± 6.7	5.3 ± 7.4
Cl, mg g^{-1}	2.61 ± 3.33	2.11 ± 0730	–	–
Co, mg kg^{-1}	0.60 ± 0.55	0.77 ± 0.22	0.47 ± 0.27	0.48 ± 0.07
Cr, mg kg^{-1}	1.43 ± 1.73	2.55 ± 0.65	1.90 ± 1.43	2.00 ± 0.59
Cs, mg kg^{-1}	0.296 ± 0.260	0.0960 ± 0.0016	0.210 ± 0.410	0.160 ± 0.060
Fe, mg g^{-1}	1.67 ± 2.47	1.07 ± 0.16	0.95 ± 1.02	0.63 ± 0.18
Hf, mg kg^{-1}	0.30 ± 0.64	0.17 ± 0.09	0.26 ± 0.20	0.087 ± 0.025
K, mg g^{-1}	14.13 ± 6.27	12.65 ± 1.05	6.42 ± 5.80	–
Mg, mg g^{-1}	3.72 ± 2.559	0.91 ± 0.32	–	–
Mn, mg kg^{-1}	121.6 ± 128.7	27.03 ± 7.48	–	–
Na, mg g^{-1}	1.16 ± 2.38	0.49 ± 0.53	6.54 ± 13.08	0.81 ± 0.76
Rb, mg kg^{-1}	37.9 ± 36.9	20.7 ± 1.5	7.59 ± 6.08	6.94 ± 1.46
Sb, mg kg^{-1}	0.037 ± 0.032	0.060 ± 0.02	0.060 ± 0.050	0.130 ± 0.040
Sc, mg kg^{-1}	0.180 ± 0.258	0.195 ± 0.043	0.170 ± 0.160	0.150 ± 0.680
Th, mg kg^{-1}	0.164 ± 0.272	0.295 ± 0.099	0.310 ± 0.380	0.150 ± 0.080
Zn, mg kg^{-1}	36.3 ± 37.8	45.3 ± 7.5	32.4 ± 31.2	–
La, mg kg^{-1}	1.64 ± 2.17	1.01 ± 0.70	1.03 ± 0.86	1.17 ± 0.30
Ce, mg kg^{-1}	2.40 ± 3.56	–	1.46 ± 1.70	6.86 ± 2.29
Nd, mg kg^{-1}	1.44 ± 1.51	–	3.40 ± 0.30	–
Sm, mg kg^{-1}	0.149 ± 0.146	–	0.140 ± 0.130	0.120 ± 0.030
Eu, mg kg^{-1}	0.041 ± 0.049	0.0179 ± 0.0055	0.030 ± 0.020	0.0416

[a] Mean elemental concentrations in herbal medicine samples analyzed in this study

[b] Mean elemental concentrations in eight brands of *Trifala* herbal preparations

[c] Mean elemental concentrations in nine medicinal herb samples

[d] Mean elemental concentrations in four Chinese medicinal herbs

body weight. It is also an important preventive factor in diabetes [19]. Zn is present in drugs used in the treatment and prevention of ulcers and to heal wounds.

The amount of each element present in each capsule or pill of herbal medicine was calculated using the elemental concentration presented in Tables 4 and 5 and the mass of the content in each capsule or pill. These calculations indicated that each capsule of *Ginseng* herbal medicine from the KG supplier presented the lowest quantities of Ba, Br, Cl, Co, Cs, Fe, K, Rb, Sb, Sc and Th while the *Ginseng* capsule from the VE supplier presented low quantities of Cr, Mg and Na. For the *Gingko biloba* herbal medicine capsules, the lowest quantities of As, Ba, Ca, Cl, Cr, K, Mg, Mn, Na, Rb, Sb, Sc, Th, Zn and La were found in that from the EQ supplier. According to medical label, this herbal medicine from the EQ supplier is a dried extract of the *Gingko biloba* leaves containing some excipients such as cellulose, silicon dioxide, talc, magnesium steararte, iron oxide, and alcohol. Therefore, this pill prepared from medicinal extract of the leaves presented very different quantities of elements when compared with those prepared directly with the leaves. This means that the amount of an element in each capsule or pill depends not only on the concentration of the element of herbal medicine but also the mass of the material contained therein.

Among the herbal medicines analyzed in this study, the capsule of *Centella asiatica* presented the largest amounts of most of the elements. An exception was found for Na in which its largest quantity was obtained in the pill of *Vera aloe* herbal medicine.

Conclusion

Results obtained in this study indicated elemental concentration differences in herbal medicines from the same plant species for *Ginseng* and *Gingko biloba* depending on the supplier of the products. These elemental concentration variations may be attributed to the environmental conditions and local soil characteristics where the medicinal plant was cultivated, as well as to the age of plant material used and its preparations. Toxic elements such as Cd, Cu and Hg not detected in the samples analyzed indicate that these medicinal plants were not cultivated in contaminated areas. Elements As and Sb were found in some samples but at very low concentrations. On the other hand, herbal medicines contain several essential elements to humans.

The findings of this study for over-the-counter herbal medicines are preliminary baseline information about inorganic constituents for the understanding of the relationship between elemental contents and their therapeutic effects.

Neutron activation analysis proved to be an accurate and precise method for several element determinations in plant material. The application of this technique may contribute to pharmacological studies of medicinal plants and to assess about its efficacy and risks of use.

Acknowledgments The authors gratefully acknowledge CNPq and FAPESP for the financial support and scholarships for H. S. Moreira and F. M. Santos.

References

1. CREMESP (2009) Legislação, Decreto no. 51435. http://www.cremesp.org.br. Accessed 17 June 2010
2. ANVISA (2008) National health surveillance agency. Resolução RDC no. 95, http://portal.anvisa.gov.br/wps/portal/anvisa/home/medicamentos. Accessed 12 June 2011
3. Calixto JB (2000) Braz J Med Biol Res 33:179–189
4. Caldas ED, Machado LL (2004) Food Chem Toxicol 42:599–603
5. Basgel S, Erdemoglu SP (2006) Sci Total Environ 359:82–89
6. Serfor-Arah Y, Nyarko BJB, Akaho EHK, Kyere AWK, Osae S, Oppong-Boachie K, Osae EK (2001) J Radioanal Nucl Chem 250:173–176
7. Mohauta B, Chakraborty A, Sudarshan M, Dutta RK, Baruah M (2003) J Radioanal Nucl Chem 258:175–179
8. Choudhury RP, Garg AN (2007) Food Chem 104:1454–1463
9. Fei T, Dehong L, Fenqqun Z, Junhua L, Hua T, Xiangzhong K (2010) J Radioanal Nucl Chem 284:507–511
10. Poutaraud A, Girardin P (2004) Environ Exp Bot 54:101–106
11. Serfor-Arah Y, Nyarko BJB, Akaho EHK, Kyere AWK, Osae S, Oppong-Boachie K (2002) J Trace Microprobe Techn 20: 419–427
12. Konieczka P, Namiesnik J (2009) Quality assurance and analytical control in the analytical laboratory: a practical approach. CRC Press, New York, p 27
13. INCT, Institute of Nuclear Chemistry and Technology (2002) Polish certified reference material, Mixed Polish herbs (INCT-MPH-2), p 4
14. Currie LA (1968) Anal Chem 40:586–592
15. Rajurkar NC, Damame MM (1998) Appl Radiat Isot 49:773–776
16. Garg AN, Kumar A, Nair AGC, Reddy AVR (2005) J Radioanal Nucl Chem 263:751–758
17. Abugassa IO, Bashir AT, Doubali K, Etwir RH, Abu-Anawel M, Abugassa SO (2008) J Radioanal Nucl Chem 278:559–563
18. Chen KS, Tseng CL, Lin THJ (1993) J Radioanal Nucl Chem 170:265–280
19. Rajurkar NS, Pardeshi BM (1997) Appl Radiat Isot 48: 1059–1062