

Macro- and micro- elements in some herbal drug raw materials and their water extracts consumed in Poland

Research Article

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Abstract: The concentrations of seven macro- and microelements (K, Mg, Ca, Na, Fe, Zn, Mn) in 59 herbs (herbs, leaves, flowers, fruits, roots), which are commercially available and frequently used in Poland for medical purposes as well as in their water extracts (infusions and decoctions), were determined after microwave mineralization. The data obtained show that all herbal raw materials analysed contain macroelements in the range of mg g^{-1} on d.w. whereas microelements in the range of mg kg^{-1} on d.w. and that elemental concentrations varied widely. On the basis of a comparison of concentrations of elements in herbal raw materials examined and water extracts prepared from them, the extraction efficiency was expressed as a percent of the total content of each element present in the infusion or decoction. The percentages of macro- and micro- elements leaching from different morphological parts of plants into water extracts varied across a wide range of values, from 1% in the case of Na to 56% in the case of K. Real daily intake of the macro- and microelements elements through one cup of infusions or decoctions were shown that water extracts from herbal raw materials are not an important source of bioelements in human diet.

Keywords: Metallic elements • Herbal drug raw materials • Infusions and decoctions • Multivariate analysis • Dietary intake

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1. Introduction

Lately, herbal remedies are enjoying a growing popularity and this trend has been promoted by several factors: the return to natural products along with the ecologic movement in industrial countries; the belief that herbal medicines are innocuous in contrast to traditional synthetic drugs; the naive view that what is natural can be good and the advent of new diseases (e.g. HIV) that have drug treatment ineffective/established life saving drug treatment [1]. Numerous studies have shown that typical adult users of herbal products are educated, middle-class, white and aged between 25 to 49 years. Another group of users of herbal remedies has holistic beliefs in the integration of body, mind and spirit [2,3].

Medicinal properties of herbs depend on the content of active components and nature of their biological activity. Due to developments in nutrition and in biochemical surveying and mineral prospecting, the interest in chemical composition of medicinal plants has also been growing in recent years [4]. Elements play a vital role in metabolic processes and are essential for the general well

being of humans therefore, a determination of macro- and micro- elements is crucial for understanding their nutritive importance [5]. The most essential plant nutrients are probably K, Na and Ca. The K ions play a unique role in all living cells, Na ions are essential only for certain plant species but can also promote plant growth, while Ca is an essential plant nutrient required for long-distance transport [6]. The level of the elements in plants depends on many factors such as the age of plant when harvested, genetics of the plants, soil conditions, rainfall, altitude, and in case of infusions and decoctions – on preparation conditions, e.g. water temperature or time [7,8].

The main producers of herbs are Germany, France, Italy and Poland. Poland has about 50% of the Central and East European market share for herbs and about 16-20% in the world market. Every year Poland produces about 20 thousand tons of herbs and the herbal plantations cover an area of over 30 thousand hectares [9].

There are many medicinal herb products in Polish diet. In Poland herbal preparations, like in the other countries, are often used to treat menopausal symptoms, arthritis, heart and circulatory system, and gastrointestinal tract.

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Very popular are also the herbs with sedative properties [9]. Herbal teas are usually consumed because of their ease of use. For example, chamomile and fennel are extensively used for babies especially for spasmolytic and antiseptic purposes. Peppermint is recommended as a carminative, antispasmodic and antiseptic herb while yarrow is a very popular herb with antiseptic, spasmolytic, digestive and antimicrobial properties [10,11].

Herbal teas are widely consumed and are perceived to play a major role in the intake of a number of nutritional and trace elements in humans [7]. Numerous studies showed that regular consumption of herbal teas may contribute to the daily dietary requirements of several elements [12]. It is therefore, important to have a good quality control for herbal raw materials in order to protect consumers from contamination that is why plants used in therapeutics should be picked in areas free from any contamination sources [4].

The chemical composition of herbal raw materials is also important because of ongoing developments in nutrition, biochemical surveying and mineral prospecting. Taking into account the above, the objective of this study was to analyse and compare the level of some macro- (K, Mg, Ca) and micro- (Na, Fe, Zn, Mn) elements in 59 commercially available and frequently used herbs for medical purposes in Poland. Since many people are now consuming hot water infusions and decoctions prepared from dried herbal raw materials, it was also important to determine the level of above mentioned metals in these water extracts and to estimate the percentage of macro- and micro- elements leaching into infusions and decoctions. In this study, the estimated amount of elements released from plant samples into water extracts were used for calculation of the daily mineral intake during consumption of one cup of the infusions and decoctions.

2. Experimental procedure

2.1. Materials

A set of total 59 samples of herbal raw materials was analysed. The distributors of these plant were two herbal enterprises from Poland – Kawon (Gostyń) and Labofarm (Starogard Gdański). Infusions (the number of sample were given in the parentheses) were prepared from: *Abrotani herba* (1), *Cnici benedicti herba* (2), *Millefolii herba* (3), *Thymi herba* (4), *Urticae herba* (5), *Althaeae folium* (6), *Farfarae folium* (7), *Melissae folium* (8), *Menthae piperitae folium* (9), *Rosmarini folium* (10), *Chamomillae flos* (11), *Ulmariae flos* (12), *Arnicae anthodium* (13), *Chamomillae anthodium* (14), *Anisi fructus* (15), *Carvi fructus* (16), *Crataegi fructus*

(17), *Sambuci fructus* (18), *Phaseoli pericarpium* (19), *Althaeae radix* (20), *Levistici radix* (21), *Valerianae radix* (22), while decoctions from: *Centaurii herba* (23), *Equiseti herba* (24), *Euphrasiae herba* (25), *Marrubii herba* (26), *Polygoni avicularis herba* (27), *Violae tricoloris herba* (28), *Menyanthidis folium* (29 and 30), *Plantaginis lanceolatae folium* (31), *Ribis nigri folium* (32), *Salviae folium* (33), *Urticae folium* (34 and 35), *Uvae ursi folium* (36), *Lavandulae flos* (37), *Millefolii flos* (38), *Sambuci flos* (39 and 40), *Verbasci flos* (41), *Crataegi inflorescentia* (42), *Tiliae inflorescentia* (43 and 44), *Carvi fructus* (45), *Foeniculi fructus* (46 and 47), *Juniperi fructus* (48), *Myrtylli fructus* (49), *Foenugraeci semen* (50), *Lini semen* (51), *Lupuli strobili* (52 and 53), *Cichorii radix* (54), *Gentianae radix* (55 and 56), *Levistici radix* (57), *Taraxaci radix* (58 and 59).

2.2 Sample preparation

Approximately 50 g samples were homogenized at 20°C for 20 s in a water-cooled grinder Knifetec 1095 (Foss Tecator, Höganäs, Sweden). After homogenization the herbs were sifted using a 500 µm sieve. Until further analysis, samples were kept in closed containers.

2.3. Sample analysis

Before macro- and micro- elements determination about 0.9 to 1.4 (± 0.0001) g of each plant sample was transferred to a teflon crucible and then 3 mL of 30% hydrogen peroxide (Selectipur®, Merck, Germany) and 5 mL of 65% nitric acid (Selectipur®, Merck, Germany) were added. The digestion was performed in a microwave system UniClever™, BM-1z (Plazmatronika, Wrocław, Poland), in one stage for 7 min at 85% power of magnetron and at programmed threshold pressure values.

After digestion, the sample solution was cooled for 10 min. Then the solution was transferred to the 50 mL volumetric flask and the volume made up using double distilled water from a Destamat® Bi-18 system (Heraeus Quarzglas, Hanau, Germany).

Infusions and decoctions of the herbal raw materials were prepared according to the manufacturer instructions. About 1.0 (± 0.0001) g portion of plant samples were placed in the quartz beakers. In the case of infusions, 50 mL of boiling redistilled water was added and the samples were left covered for 5 to 15 min, while for decoctions, after the addition of 50 mL of boiling redistilled water the samples were covered and boiled on a hot plate for about 5-15 min. After cooling, the water extracts were filtered using a qualitative filter paper (Whatman™, UK), transferred to a 50 mL volumetric flask and made up to the mark with redistilled water.

2.4. Determination of elements

The concentrations of the elements were measured in an air-acetylene flame by atomic absorption/emission methods on a Varian SpectrAA 250 Plus spectrometer (Australia). Mg, Fe, Zn and Mn was determined by atomic absorption spectrometry, whereas K, Na and Ca by atomic emission spectrometry. In the case of Ca determination, 1% solution (w/v) of lanthanum chloride (Sigma, USA) was added to the digested samples under study. The conditions for determination of the metals are presented in Table 1. Accuracy (as recovery) of the procedures was determined by analysis of the certified reference material Virginia Tobacco Leaves (CTA-VTL-2) obtained from The Institute of Nuclear Chemistry and Technology (Warsaw, Poland). The extent of the recovery was established in the range of 83.50-99.61% and was conditional upon the element. The lowest recovery was observed for Na and the highest for Mg ($n = 6$).

2.5. Software and calculations

Cluster analysis (CA) and principal component analysis (PCA) calculations were done using *Statistica 7.1* (Statsoft®, Krakow, Poland) software. Starting point for all calculations was a matrix of the data with dimensions $n \times p$, where n is a number of rows, i.e., the water extracts (infusions and decoctions) prepared from 59 herbal raw materials (herbs, leaves, flowers, fruits, roots), and p is the number of variables, i.e., the percentage of leaching of macro- and microelements (K, Mg, Ca, Na, Fe, Zn, Mn) to the water extracts.

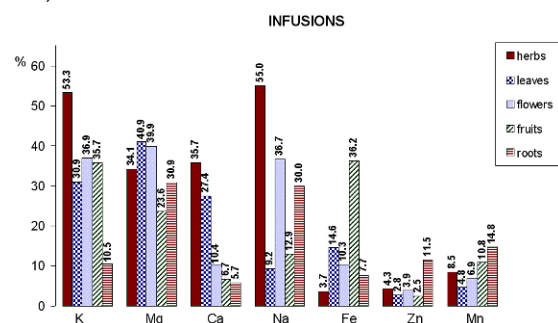


Figure 1. The percentage of leaching of essential metals from the analyzed herbal raw materials to the infusions.

3. Results and discussion

3.1. Bioelements in herbal raw materials and their water extracts

The data for seven macro- and micro- elements determined in 59 herbal raw materials are compiled in Table 2. The metal concentrations in the plant samples are characterized by ranges on a dry weight (d.w.) and arithmetic mean values given in the parentheses. On the basis of a comparison of elemental concentrations in herbal raw materials examined and water extracts prepared from them, the extraction efficiency was expressed as a percent of the total content of each element present in the infusion or decoction. The percentages of macro- and micro- elements leaching from different morphological parts of the plants to water extracts are illustrated graphically in Figs. 1 and 2.

The data obtained show that all herbal raw materials analyzed contain macroelements in the range of milligrams per gram on d.w. and that elemental concentrations varied widely. The content of K in all plant samples varied between $6.12 \text{ mg g}^{-1} \text{ d.w.}$ (*Myrtilly fructus*) and $38.69 \text{ mg g}^{-1} \text{ d.w.}$ (*Chamomillae flos*), whereas its concentrations in the water extracts were 1.64 mg g^{-1} (*Carvi fructus*) and 21.72 mg g^{-1} (*Cnici benedicti herba*) in infusions and 1.29 mg g^{-1} (*Uvae ursi folium*) and 30.20 mg g^{-1} (*Sambuci flos*) in decoctions. For the water extracts, only in two cases the amount of K was higher than 15 mg g^{-1} . *Sambuci flos* contained high level of K, i.e., 33.77 mg g^{-1} and also the percentage of K leached into the

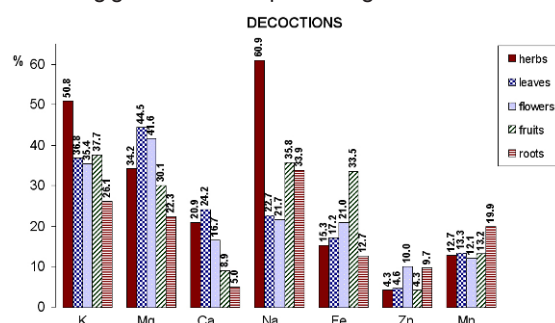


Figure 2. The percentage of leaching of essential metals from the analyzed medicinal herbs to the decoctions.

Table 1. Instrumental parameters employed to metals determination.

Element	Wavelength (nm)	Slit width (nm)	Lamp current (mA)	Fuel gas (L min ⁻¹)
K	766.5	0.2	—	13.5
Mg	285.2	0.5	4	13.5
Ca	422.7	0.5	—	13.8
Na	589.0	0.5	—	13.5
Fe	248.3	0.2	5	12.2
Zn	213.9	0.1	5	13.6
Mn	279.5	0.3	5	13.5

Table 2. Concentration of the elements studied in the selected morphological parts of medicinal plants.

Elements	Herbs (n = 11)	Leaves (n = 13)	Flowers (n = 12)	Fruits (n = 14)	Roots (n = 9)
Macroelements (mg g⁻¹ d.w.)					
K	12.80–33.19 (22.80)	10.60–32.57 (20.25)	10.59–38.69 (25.57)	6.12–23.74 (15.70)	4.75–30.28 (18.63)
Mg	1.97–15.97 (5.55)	0.48–22.83 (7.75)	1.59–6.34 (3.99)	0.73–6.70 (3.93)	1.18–3.56 (2.28)
Ca	4.96–42.20 (15.85)	12.86–162.11 (37.90)	6.41–18.52 (14.26)	2.69–25.17 (11.04)	3.11–15.82 (10.32)
Microelements (mg kg⁻¹ d.w.)					
Na	45.62–360.86 (138.78)	33.85–493.39 (120.70)	31.95–190.19 (99.07)	12.87–757.92 (153.79)	83.60–1022.56 (439.05)
Fe	29.92–189.81 (86.18)	23.43–260.74 (98.43)	27.09–79.84 (46.88)	5.99–89.29 (33.06)	27.51–224.01 (114.25)
Zn	25.64–57.65 (34.82)	19.18–106.07 (38.48)	18.79–55.61 (36.77)	9.57–84.58 (33.18)	14.06–35.61 (23.11)
Mn	30.94–166.65 (75.67)	35.90–1775.16 (272.68)	38.53–102.35 (64.70)	16.99–203.47 (65.53)	9.56–92.48 (38.23)

n – is the number of herbal raw materials under studies.

decoction was high (89.4%). In *Menthae piperitae folium*, 24.90 mg(K) g⁻¹ d.w. was found while the percentage of K leaching into the infusion was 12.1%. These values were lower than those reported for peppermint leaf by Gallaher *et al.* [10], who determined 40.20 mg(K) g⁻¹ and the percentage of K leaching into infusion at 80.64%.

The concentration of Mg in herbs was lower than the content of K and in the range from 0.48 mg g⁻¹ d.w. (*Uvae ursi folium*) to 22.83 mg g⁻¹ d.w. (*Rosmarini folium*), whereas its concentration in infusions ranged from 0.15 mg g⁻¹ (*Menthae piperitae folium*) to 17.88 mg g⁻¹ (*Levistici radix*). As compared to infusions, the Mg content in decoctions was lower and the highest was found in *Menyanthis folium* decoction that contained 9.11 mg(Mg) g⁻¹. In the case of water extracts, the value of 71.5% was the highest one for leaching of Mg from leaf to infusions, whereas leaching of this element into decoctions exceeded 90%.

The average levels of Ca varied from 2 to over 30 mg g⁻¹ d.w. in the plant samples examined. In infusions, the content of Ca was in the range from 0.2 to 10 mg g⁻¹ and only in three cases the level of Ca was higher than 10 mg g⁻¹ - *Urticae herba* (11.91 mg g⁻¹), *Althaeae folium* (10.92 mg g⁻¹) and *Farfarae folium* (14.89 mg g⁻¹). Calcium concentration found in *Menthae piperitae folium* and in infusions prepared from this herb was similar to those reported in literature [10]. In decoctions, the content of Ca in the most cases varied from 0.15 to 10 mg g⁻¹, with exception of *Equiseti herba*, *Ribis nigri folium* and *Urticae folium*. These plant samples contained 10.57, 13.04 and 16.33 mg(Ca), respectively, per g. The percentage of Ca released into infusions and decoctions was at similar concentrations at about 30–40%. Only for *Thymi herba*, the percentage of Ca transferred to infusion was 70.9%

and this value was the highest. In *Urticae herba* the percentage of Ca leaching to infusion was only 28.2%, whereas literature data reported twice as much value, *i.e.*, 58% [4].

The analysis of concentrations of microelements in herbal raw materials and water extracts prepared from them revealed that the level of Na in the herbs examined varied from 12 to 400 mg kg⁻¹ d.w., with exception of *Plantaginis lanceolatae folium* (493.39 mg kg⁻¹), *Myrtilli fructus* (757.92 mg kg⁻¹) and *Cichorii radix* (1022.56 mg kg⁻¹), which contained more than 400 mg(Na) kg⁻¹ d.w. In the case of infusions, the average concentration of Na was in the range from 0.13 mg kg⁻¹ (*Levistici radix*) to 229.59 mg kg⁻¹ (*Abrotani herba*) and this range was similar to the Na range in decoctions. A high content of this element was determined in *Althaeae radix* (218.74 mg kg⁻¹) and the percentage of Na leaching into the infusion was also high (72.3%). Besides, higher contents of Na in infusions were also identified in the case of *Chamomillae anthodium* (85.9%) and *Cnici benedicti herba* (90.7%). In comparison to infusions, the percentage of Na leaching into decoctions was higher only in two cases, *i.e.*, *Euphrasiae herba* (98.2%) and *Juniperi fructus* (94.2%). A low percentage of leaching of Na into infusions was seen for *Menthae piperitae folium* (0.9%), whereas literature reported much higher value at 49.11% [10].

The content of Fe in herbs varied from 10 to 200 mg kg⁻¹ d.w. However, for *Juniperi fructus* (5.99 mg kg⁻¹ d.w.) and *Crataegi fructus* (8.36 mg kg⁻¹ d.w.), the level of this element was lower than 10 mg kg⁻¹ d.w., while for *Salviae folium* (260.74 mg kg⁻¹ d.w.) the Fe content was higher than 200 mg kg⁻¹ d.w. The concentration of Fe for all of herbs

was lower than those reported by Başgel & Erdemoğlu [4], who determined Fe in the range from 224 to 504.7 mg kg⁻¹ in herbs and from 4.90 to 107.4 mg kg⁻¹ in the infusions. The percentage of Fe leaching into infusions was not high at below 30%, with exception of *Chamomillae anthodium* (31.1%), *Carvi fructus* (56.7%), *Crataegi fructus* (35.4%) and *Sambuci fructus* (61.0%). The lowest level of Fe in infusions was determined for *Urticae herba*, i.e., 1.56 mg kg⁻¹. The concentration of Fe in decoctions varied from 3.61 to 20.19 mg kg⁻¹. The content of Fe in *Myrtylli fructus* was found only as 11.33 mg kg⁻¹ but the percentage of Fe leaching from the fruits into decoction was the highest at 85.9%.

The level of Zn in all the herbs analyzed was lower than the Fe content. Only *Menyanthis folium* (106.07 mg kg⁻¹ d.w.), *Salviae folium* (83.35 mg kg⁻¹ d.w.) and *Lupuli strobili* (84.58 mg kg⁻¹ d.w.) contained more than 80 mg(Zn) kg⁻¹ d.w. *Menthae piperitae folium* contained 29.61 mg(Zn) kg⁻¹ d.w., while Gallaher *et al.* [10] determined higher levels of Zn in this leaf. The concentration of Zn in *Chamomillae flos* was 46.85 mg kg⁻¹, while Başgel & Erdemoğlu [4] and Malik *et al.* [7] reported 30.6 and 32.9 mg(Zn), respectively, per kg d.w. The levels of Zn in the infusions and decoctions are very low and varied from 0.5 mg kg⁻¹ (*Menthae piperitae folium* infusion and *Juniperi fructus* decoction) to 4 mg kg⁻¹ (*Menyanthis folium* decoction). Only decoctions prepared from *Lavandulae flos* and *Tiliae inflorescentia* contained higher level of Zn, 7.08 and 5.09 mg kg⁻¹, respectively. For these two samples the percentage of Zn leaching into the decoction was the highest and found to be at 25.8% and 20.1% respectively. For the rest of plant samples, the percentage of Zn leaching into water extracts was about 12%.

The level of Mn in all morphological parts of plants examined varied between 20 and 200 mg kg⁻¹ d.w. Exceptions were *Menyanthis folium* (333.06 mg kg⁻¹ d.w.) and *Farfarae folium* (1775.16 mg kg⁻¹ d.w.), which contained more than

200 mg kg⁻¹ d.w. as well as *Foenugraneci semen* (16.99 mg kg⁻¹ d.w.) and *Sambuci fructus* (17.95 mg kg⁻¹ d.w.), which contained lower level of Mn than 20 mg kg⁻¹ d.w. The average level of Mn in infusions varied from 2 to 8 mg kg⁻¹, whereas according to the literature data, Mn content in infusions varied between 4.30 and 49.1 mg kg⁻¹ [4]. *Rosmarini folium* infusion contained the lowest amount of Mn, i.e., 1.99 mg kg⁻¹. That value represents only 2.7% of Mn found in *Rosmarini folium*. As compared to infusions, the concentration of Mn in decoctions was higher and varied in the range from 3.89 (*Cichorii radix*) to 52.61 mg kg⁻¹ (*Menyanthis folium*). The highest percentage of Mn leaching into decoctions was found in the case of *Urticae folium*, at 33.3%, whereas Başgel & Erdemoğlu [4] showed only 7.3% of Mn leaching to nettle infusion.

3.2. Multivariate analysis

Data describing concentrations of 7 elements in 59 infusions and decoctions prepared from herbal drug raw materials were statistically evaluated with the goal to compare the mean concentration values of the elements examined in the water extracts. Two pattern recognition methods of Cluster Analysis (CA) and Principal Component Analysis (PCA), were applied in order to detect, whether infusions and decoctions differed widely in the concentrations of elements leaching on one hand to identification of which herbal raw materials released the highest amounts of elements to water extracts from the other hand [13,14].

CA enables a diagrammatic representation by way of grouping of water extracts into particular clusters characterized by high mutual similarity - in this case percentage of leaching of 7 macro- and micro- elements into water, and simultaneously differing by a maximum from the other sample clusters. Using this analysis for the plant materials, the best results were obtained by Ward method by the way of calculation of cluster distances, and applying Euclidean distance for a measure of a distance

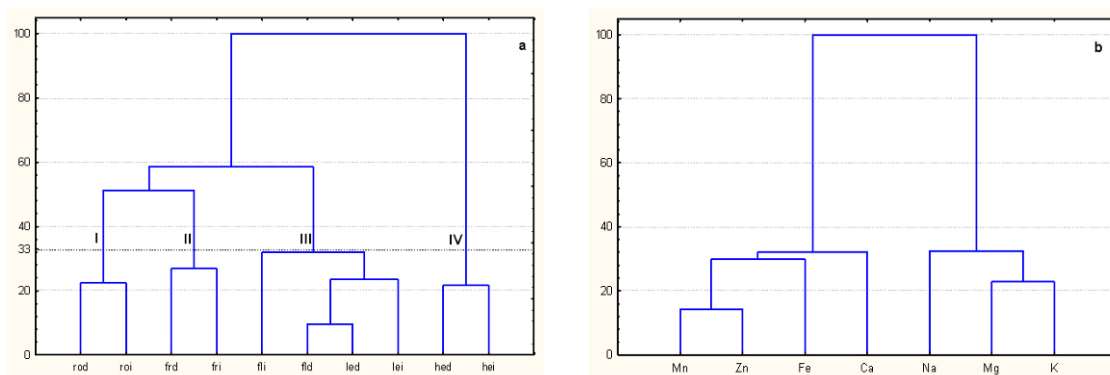


Figure 3. The CA diagram presenting – (a) the way of grouping of analyzed infusions and decoctions, and (b) the relation between the level of elements leaching to water extracts.

between the plant samples. The number of significant clusters in the diagram was based on Sneath index using 33% of maximum distance measure.

Interpretation of CA diagram showed in Fig. 3a indicated that all infusions and decoctions analyzed create four clusters, and the basis for the classification is not the way in which the elements are extracted into water (the preparation method of the infusion or decoction) but based on the kind of herbal raw materials (the morphological part of a medicinal plant) from which the given water extract was prepared. Cluster I relates to all infusions (roi) and decoctions (rod) prepared from the roots of medicinal plants (9 herbal raw materials). Cluster II contains water extracts obtained from the fruits of the medicinal plant. Infusions (fri) were prepared from 5 kinds of fruits, whereas decoctions (frd) were obtained from 9 plant materials. Also, a high similarity in extraction yield of elements into water for the extracts prepared from flowers and leaves, grouped in cluster III, containing 25 of analyzed plant materials, was obtained. Within this group of water extracts, it is possible to indicate the very high similarity taking into consideration the extraction yield of elements into the decoctions from leaves (led) and flowers (fld), which is confirmed by creation of cluster on the lowest aggregation level. Infusions from leaves (lei) differ from the plant materials described above in lower degree, but the infusions from flowers (fli) in higher degree. The last cluster (IV) includes infusions (hei) and decoctions (hed) obtained from herbs. Taking into consideration the fact that herbs are not homogenous group with respect to the morphological parts such as stems, leaves and flowers, the extraction yield depends to a higher degree on the kind of plant material, than on the way of preparation of an extract.

Data presented in Fig. 3b showed that taking into consideration the level of elements leaching to water extracts, seven macro- and micro- elements under study create two clusters. In the first cluster there are Mn, Zn, Fe and Ca, which are leached into infusions and decoctions at a higher degree, whereas the second cluster includes Na, Mg and K, the elements characterized by lower percentage of leaching into water extracts.

The results of PCA greatly make easier interpretation of multidimensional databases by reduction of multidimensionality and by clear way of presentation of the results. The calculations gave three principal components (PCs) with eigen values higher than 1. First two PCs explain more than 63% of variability.

As it is shown in Fig. 4a the graphical presentation of the results obtained after PCA calculations confirms fully the conclusions drawn from CA. Also in this case, four groups of water extracts with the same contents as in the case of CA, were obtained. Simultaneously,

the most influencing factors on the distribution of water extracts in the two-dimensional plot of PC1 vs. PC2 were shown in Fig. 4b. Taking into consideration the variables with loadings greater than 0.7 which were regarded as significant, analysis of the factor loadings showed high impact of the leaching yield of Ca, K and Mn on the distinct differentiation of infusions and decoctions along PC1 axis, and the effect of Na was strong on the differentiation of extracts along PC2 axis. Weak influence on the location of water extracts in the two-dimensional plane PC1 vs. PC2 was noticed in the case of extraction yield for Mg, Fe and Zn.

Striving for identification of relations between individual samples from which water extracts were prepared, two independent matrices (each for infusions and decoctions), were also studied by CA and PCA. The results of calculations indicated that it is not possible to relate the level of elements leached with the species or botanical family of the plant, from which the samples were obtained. However, the CA and PCA studies showed that in numerous cases it is possible to relate the level of elements leached with the morphological part of the plant used for extract preparation.

3.3. Daily intake of elements

In order to estimate whether the infusions and decoctions prepared from the herbal raw materials examined represent an important source of macro- and micro-elements, the real daily intake of the essential elements on the basis of the elemental content found in the water extracts was calculated. The calculations were done based on the assumption that a patient will drink one glass of infusion or decoction daily, and its preparation will take one spoon of herbal raw material, that is about 4 g of a plant material. Results obtained were compared with the norms of daily needs of mineral constituents for a human being (Recommended Daily Allowance, RDA) [15]. Table 3 lists the data for the levels of the elements the day following the intake. Range of the elements, which are taken daily by patients through consumption of one glass of the water extract are presented as percentages of RDA. The arithmetic means are given in the parentheses.

Detailed analysis of the data indicated that infusions and decoctions prepared from the herbal raw materials are not rich sources of essential elements for a patient's diet. Macro-elements (K, Mg, Ca) are delivered to the human being only as percent of the daily needs for these elements, and the other elements (Na, Fe, Zn, Mn) are given to organism in very small amounts, which doesn't depend on the fact, whether a patient drinks infusions or decoctions. The only exception is for Mn, which is found to be extracted more into decoction than to infusion.

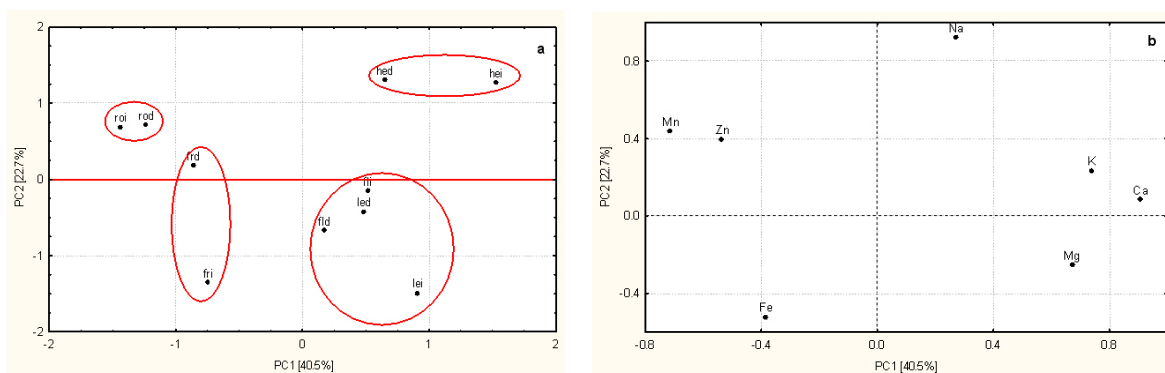


Figure 4. The PCA score plot for the first two principal components – (a) for analyzed infusions and decoctions, and (b) for the loading of principal components.

Table 3. Real daily dietary intakes of the elements studied through consumption of one glass of infusion or decoction.

Element	Daily intake of elements (%)		Recommended Daily Allowance (mg/day)
	Infusion	Decoction	
K	0.41–4.34 (2.54)	0.12–6.04 (1.31)	2000
Mg	0.17–4.31 (2.60)	0.13–10.41 (2.03)	350
Ca	0.10–5.95 (0.69)	0.08–6.53 (1.90)	1000
Na	0.01–0.18 (0.11)	0.01–0.21 (0.02)	500
Fe	0.07–0.56 (0.09)	0.09–0.53 (0.18)	15
Zn	0.01–0.09 (0.01)	0.01–0.25 (0.04)	15
Mn	0.19–0.64 (0.23)	0.31–4.20 (0.83)	5

4. Conclusions

On the basis of investigation of the contents of essential macro- (K, Mg, Ca) and micro- (Na, Fe, Zn, Mn) elements in 59 herbal raw materials (herbs, leaves, flowers, fruits, roots), it can be concluded that the elements significantly differed in their concentrations in the material. K was the element that was found in the highest amounts in plant materials analyzed followed by slightly lower levels of Mg and Ca, whereas the other elements were found in the range of several tens of mg kg⁻¹ d.w. of the plant sample.

The studies also showed that the aqueous extracts (infusions and decoctions) obtained from the herbal raw materials used for medical purposes, are not rich sources of the elements in a patient's diet. Only some of the essential elements (K, Mg, Ca) are found in the infusions and decoctions studied in such amounts that can supply the mineral constituents at only several percents of the daily needs of a patient.

The use of multivariate statistical analysis (CA and PCA) showed that the method of preparation of an aqueous extract from the herbs had no significant impact on the concentration of essential elements in the infusions and decoctions.

References

- [1] D. Larrey, J. Hepatol. 26, 47 (1997)
- [2] P.S. Adusumilli, L. Ben-Porat, M. Pereira, D. Roesler, M. Leitman, Surg. Forum 198, 583 (2004)
- [3] W.R. Snodgrass, Curr. Therap. Res. 62, 724 (2001)
- [4] S. Başgel, S.B. Erdemoğlu, Sci. Total Environ. 359, 82 (2006)
- [5] A. Kumar, A.G.C. Nair, A.V.R. Reddy, A.N. Garg, Food Chem. 89, 441 (2005)
- [6] I. Shtangeeva, D. Alber, G. Bukalis, B. Stanik, F. Zepezauer, Plant Soil 322, 219 (2009)
- [7] J. Malik, J. Szakova, O. Drabek, J. Balík, L. Kokoska, Food Chem. 111, 520 (2008)
- [8] T.P. Flaten, Coord. Chem. Rev. 228, 385 (2002)
- [9] J. Jambor, Herba Pol. 53, 25(2007)
- [10] R.N. Gallaher, K. Gallaher, A.J. Marshall, A.C. Marshall, J. Food Compos. Anal. 19, S53 (2006)
- [11] B. Benedek, N. Geisz, W. Jager, T. Thalhammer, B. Kopp, Phytomedicine 13, 702 (2006)
- [12] P.L. Fernández, F. Pablos, M.J. Martín, A.G. González, Food Chem. 76, 483 (2002)
- [13] T. Hill, P. Lewicki, Statistics, methods and applications: A comprehensive reference for science, industry, and data mining (StatSoft, Inc., Tulsa, 2006)

- [14] M. Otto, Chemometrics: Statistics and computer application in analytical chemistry (Wiley-VCH, New York, 1999)
- [15] D.I.T. Fávaro, V.A. Maihara, D. Mafra, S.A. Souza, M.B.A. Vasconcellos, M.B.C. Cordeiro, S.M.F. Cozzolino, J. Radioanal. Nucl. Chem. 244, 241 (2000)