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# Inorganic Biochemistry of Medicinal Plants

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## ABSTRACT

Most medicinal plants are flowering plants and they also serve as ornamental plants. Measurement of trace element content in medicinal plants, drugs and extracts may be relevant in view of e.g. human health, animal health and environmental relations. This fact has a great significance since about half of the plant drugs available in the trade originate from natural habitats and the element content of herbs may originate from soil or air pollution, or relate to the soil type on which the plant grows. Microelements in extracts may be relevant in nutritional point of view or for therapeutic purposes.

**Keywords:** extracts, herbs, *in vitro*, microelements, transfer

## INTRODUCTION

Medicinal plants are generally used for their organic agents. Nevertheless, plants and extracts contain inorganic mineral elements which are also able to contribute to their medicinal effect, favorably or unfavorably. In Hungary the use of medicinal plants is following a growing tendency. In the trade of herbs more than 300 plant species occur from which only about 200 plant species appear officially in the Hungarian Pharmacopoeia. About half part of the plant drugs are cultivated while the other half originate from their natural habitats and are collected from the wild. Therefore the determination of quality and quantity of inorganic elements in plant drugs and extracts may be essential to know more about the ingredients which are important in environmental, toxicological and phytotherapeutical aspects (Lesko *et al*. 2002; Szőke and Kéry 2003; Szentmihályi *et al*. 2005; Sagiroglu *et al*. 2006).

This paper presents some data on microelement content in medicinal plants and extracts, and possibilities for the evaluation of trace element content.

## MATERIALS AND METHODS

### Materials

Root of chicory (*Cichorium intybus* L), dandelion (*Taraxacum officinale* Web.), jerusalem artichoke (*Helianthus tuberosus* L.), nettle (*Urtica dioica* L.), aerial parts of goat's rue (*Galega officinalis* L.), hawthorn (*Crataegus monogyna* Jack.), Lady's mantle (*Alchemilla vulgaris* L.) seeds of chestnut (*Aesculus hippocastanum* L.), bark of buckthorn (*Rhamnus frangula* L.) were collected from natural habitat in Hungary. Aerial parts of chamomile (*Matricaria chamomilla* L.) meadow sage (*Salvia pratensis* L.), milk thistle (*Silybum marianum* L. Gaertner), muscat sage (*Salvia sclarea* L.), pot marigold (*Calendula officinalis* L.), sage (*Salvia officinals* L.) and all parts of poppy (*Papaverin somniferum* L.) were collected from Botanical Garden of Budapest, Hungary. Seeds of fennel (*Foeniculum vulgare* Mill.) were obtained from the commercial network. Aerial parts of blue hill sage (*Salvia nemorosa* L.), goldenrod (*Solidago virgaurea* L.), gum plant (*Grindelia robusta* Nutt.), Japanese quince (*Cydonia japonica* Thunb.), meadow sage (*Salvia pratensis* L.), muscat sage (*Salvia sclarea* L.), sage (*Salvia officinals* L.), thyme (*Thymus vulgaris* L.) white willow (*Salix alba* L.) were collected from Botanical Garden of Tirgu Mures, Transylvania. For the chemical investigation the air-dried plant parts of collected plants were used.

Oil of Gutta carminativa made from fennel (*Foeniculum vulgare* Mill.), caraway (*Carum carvi* L.) and peppermint (*Mentha piperita* L.) and volatile oil of peppermint (*Mentha piperita* L.), sage (*Salvia officinalis* L.), as well as fatty oil of elder (*Sambucus nigra* L.) were obtained from the commmercial network (Aromax Ltd., Hungary).

### Determination of microelement content

Concentrations of the elements of samples were determined by ICP-OES (inductively coupled plasma optical emission spectrometry). Type of instrument: AtomScan 25 (Thermo Jarrell Ash Co.). *Sample preparation for element measurement*: plant material (0.5 g) was digested with $HNO_3$ (5 mL) and $H_2O_2$ (3 mL). After digestion, the samples (three in parallel) were diluted to 25 mL from which the elements were determined in three parallel measurements (Szentmihályi *et al*. 2002; Ladó *et al*. 2007).

### Preparation of extracts

Preparation of extracts was performed by the usual method according to the description of Hungarian Pharmacopoeia (2004). A known amount of plant drug (1-5 g) in 100 mL solvent (deionized water, alcohol of 98%) was soaked, or infused.

Supercritical fluid extraction (SFE) with carbon dioxide was applied to obtain aromatic oil of fennel (*Foeniculum vulgare* Mill.). The extraction was made with a high pressure (400 bar), flow-up stream extraction apparatus (Illés *et al*. 1994).

Dissolution rate was calculated in percentage (%) of quantity of metal ion in solution per quantity of metal ion in plant drug used for extraction making.

### Measurement of *in vitro* bioavailability

The transfer of elements from the extract to buffer solution of plasma (pH = 7.5; $Na_2HPO_3$ [20.5 g] and $KH_2PO_4$ [2.8 g] in 1000 mL of water) was investigated in a dialysis system at 37°C (Szentmihályi *et al*. 2001). The extract (1 g) was dissolved in water (10 mL) and the solution was placed in the equipment. Fractions (10 mL) were taken from the outer container at the following time periods: 15, 30, 60 and 120 min.

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**Table 1** Microelement content ± standard deviation (mg/kg dry weight, n=3) in different plant drugs originated from a botanical garden in Transylvania.

| Elements | Herba | | | Dried leaves | |
|---|---|---|---|---|---|
| | **Japanese quince (*Cydonia japonica* L.)** | **Goldenrod (*Solidago virgaurea* L.)** | **Thyme (*Thymus vulgaris* L.)** | **Gum plant (*Grindelia robusta* Nutt.)** | **White willow (*Salix alba* L.)** |
| Al* | 109.00 ± 1.06 | 251.6 ± 34.5 | 2082.00 ± 56 | 336.2 ± 5.8 | 429.20 ± 32.8 |
| As | 3.63 ± 1.60 | <dl | <dl | <dl | <dl |
| B* | 40.53 ± 0.92 | <dl | 24.94 ± 0.38 | 120.90 ± 1.8 | 36.25 ± 1.73 |
| Ba* | 24.93 ± 0.07 | 9.04 ± 0.07 | 72.98 ± 1.89 | 13.56 ± 0.03 | 8.03 ± 0.25 |
| Cd | <dl | <dl | <dl | <dl | 6.96 ± 0.24 |
| Co | <dl | <dl | 3.09 ± 0.28 | <dl | 0.81 ± 0.126 |
| Cr* | 0.69 ± 0.23 | 2.14 ± 0.20 | 12.27 ± 0.52 | 1.01 ± 0.32 | 2.76 ± 0.16 |
| Cu* | 10.61 ± 0.29 | 14.05 ± 0.22 | 11.79 ± 0.68 | 12.49 ± 0.32 | 5.85 ± 0.20 |
| Fe* | 114.90 ± 1.1 | 107.00 ± 15.9 | 2854.00 ± 38 | 295.90 ± 0.96 | 119.90 ± 7.14 |
| Mn* | 19.22 ± 0.55 | 29.18 ± 4.08 | 131.40 ± 0.76 | 55.03 ± 0.27 | 702.00 ± 41.9 |
| Mo | <dl | <dl | <dl | <dl | <dl |
| Ni* | <dl | 2.39 ± 0.36 | 26.75 ± 0.96 | <dl | 2.53 ± 0.23 |
| Pb | <dl | <dl | <dl | <dl | <dl |
| Ti* | 3.39 ± 0.07 | 0.46 ± 0.11 | 65.66 ± 3.39 | 11.31 ± 0.21 | 2.16 ± 0.15 |
| V | <dl | <dl | 6.90 ± 0.21 | <dl | <dl |
| Zn* | 36.59 ± 0.63 | 45.26 ± 1.61 | 47.38 ± 0.04 | 187.40 ± 2.0 | 124.50 ± 4.3 |

<dl: Below detection limit

* Significant difference ($p<0.05$) between the element content of herba drugs according to the one way analysis of variance (ANOVA) test.

## Statistical calculations

The results were expressed as means and standard deviations. One way analysis of variance (ANOVA) was used for comparing the results between groups with the use of GraphPad software version 1.114 (1990). Significance level was determined at $P<0.05$.

## RESULTS AND DISCUSSION

### Significance of microelements in medicinal plants

Determination of elements in medicinal plants and plant drugs is essential in view of several points, e.g. plant health, environmental pollution, human and animal health.

Microelements generally form complexes with different organic agents in plants. According to the stability constants and solubilities, these metal compounds/complexes are able to dissolve in the solvents used (water, alcohol, etc.) and to transfer/absorb in human and animal body (Szentmihályi *et al*. 2005, 2006). Intake of essential and non-essential elements may be beneficial, harmful or toxic (Food and Nutritional Board 2002).

### Elements in plant drugs

The element content of plants depends on several factors. It may vary according to the species and in the case of the same species it may change by soil, climate and other parameters (Petri *et al*. 1994; Takács Hájos *et al*. 1999). The microelement content in herba of Japanese quince (*Cydonia japonica* L.), goldenrod (*Solidago virgaurea* L.) and thyme (*Thymus vulgaris* L.) growing on the same soil and year was significantly different ($P<0.05$) for most elements (Al, B, Ba, Cr, Cu, Fe, Mn, Ni, Ti and Zn; **Table 1**). A similar result could be observed in the case of *Salvia* species which were collected from the same site, in the botanical garden of Budapest (*S. officinalis*, *S. sclarea*, *S. pratensis*, *S. nemorosa*) and also three species (*S. officinalis*, *S. sclarea*, *S. pratensis*) were collected from a botanical garden in Transylvania at the same year. The element content of the different species originated from the same habitat were significantly different. In all cases significant differences were found in the Zn and Cr content of the Hungarian and Transylvanian species (**Figs. 1, 2**). The element content in a plant continouosly varies throughout the vegetative period (**Fig. 3**).

In phytotherapy different plant parts of the same species may be applied for different indicated fields. Since organic components of the plant parts may change and the microelement content of the different parts of plant drugs are also different, therefore, the phytotherapeutic effect may alter according to the plant species and plant parts (Szentmihályi *et al.* 2005; Stefanovits-Bányai *et al*. 2006). The microelement content of some parts of hawthorn (*Crataegus monogyna* Jack.) is summarized in **Table 2**. The samples were collected from the same area. Significant differences were found for Al, As, B, Ba, Cr, Cu, Fe, Mn, Ni, Pb, Ti and Zn concentrations between the plant parts. The results are comparable with the average element concentration or normal range of plants: Al < 200 mg/kg, As < 2 mg/kg, B 15-100

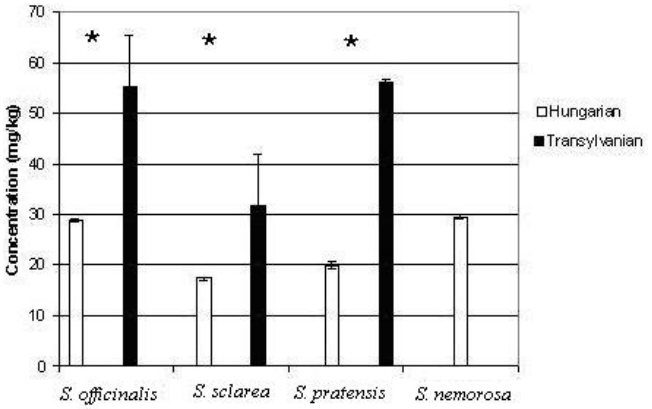


**Fig. 1 Zinc concentration in herba of *Salvia* species from different areas.** *Significant diference ($p<0.05$) between the Hungarian and Transylvanian samples calculated by one way analysis of variance (ANOVA).

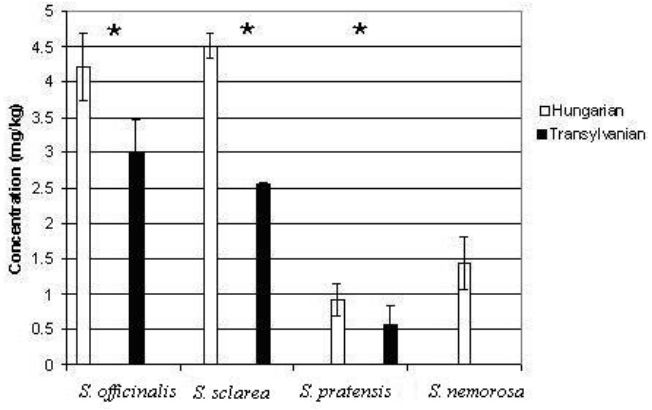


**Fig. 2 Chromium concentration in herba of *Salvia* species from different areas.** *Significant difference ($p<0.05$) between the Hungarian and Transylvanian samples calculated by one way analysis of variance (ANOVA).

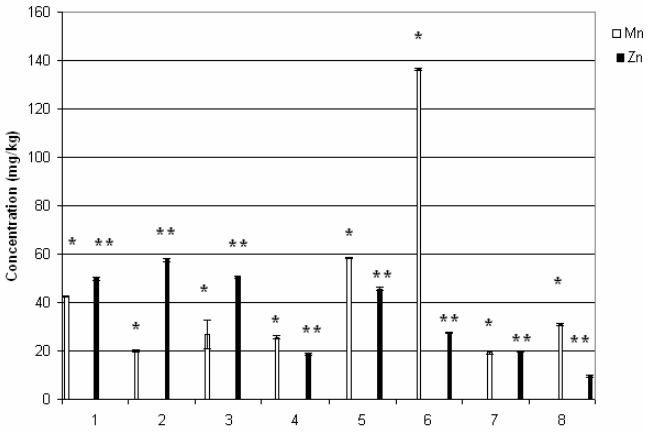


**Fig. 3 Changes in Mn and Zn concentration in poppy (*Papaverin somniferrum* L.) during vegetation period.** 1, rosetta plant steam; 2, rosetta plant radix; 3, green leaves in flowering state; 4, green steam in flowering state; 5, flower; 6, ripe leaves; 7, ripe stem; 8, brown capsule. * Significant difference between the Mn concentration of samples. ** Significant difference between the Zn concentration of samples.

**Table 2** Microelement content ± standard deviation (mg/kg dry weight, n=3) in different part of hawthorn (*Crataegus monogyna* Jack.) (Samples were collected from Vönöck, Hungary in 2001).

| Elements | Leaves | Branch | Fruit |
|---|---|---|---|
| Al* | 566.90 ± 3.90 | 129.80 ± 0.4 | 39.12 ± 1.89 |
| As* | 1.86 ± 0.66 | 2.90 ± 1.35 | 3.06 ± 0.14 |
| B* | 24.36 ± 0.79 | 28.26 ± 0.51 | 18.66 ± 0.49 |
| Ba* | 67.21 ± 1.36 | 39.04 ± 1.11 | 22.82 ± 0.11 |
| Cd | <dl | 0.22 ± 0.01 | <dl |
| Co | 0.35 ± 0.04 | <dl | <dl |
| Cr* | 1.23 ± 0.76 | <dl | 0.21 ± 0.10 |
| Cu* | 43.07 ± 0.64 | 16.04 ± 0.88 | 4.79 ± 0.24 |
| Fe* | 472.10 ± 8.70 | 134.60 ± 3.30 | 40.20 ± 0.55 |
| Mn* | 76.08 ± 0.87 | 18.85 ± 0.43 | 14.56 ± 0.18 |
| Mo | <dl | <dl | <dl |
| Ni* | 2.54 ± 0.05 | <dl | 1.81 ± 0.14 |
| Pb* | 4.22 ± 1.94 | 3.09 ± 0.73 | <dl |
| Ti | 11.48 ± 0.07 | 2.18 ± 1.03 | <dl |
| V | 1.32 ± 0.36 | <dl | <dl |
| Zn* | 31.50 ± 0.30 | 29.17 ± 0.29 | 97.71 ± 0.62 |

<dl: Below detection limit
* Significant difference ($p<0.05$) between the element content of herba drugs according to the one way of variance (ANOVA) test.

**Table 3** Concentration of Al, Cr, Fe and Ti ± standard deviation (mg/kg dry weight, n = 3) in some root and herbal drugs.

| Elements | Root | Root | Root | Herba |
|---|---|---|---|---|
| | Jerusalem artichoke (*Helianthus tuberosus* L.) | Nettle (*Urtica dioica* L.) | Chicory (*Cichorium intybus* L.) | Milk thistle (*Silybum marianum* L. Gaertner) |
| Al | 489.20 ± 0.7 | 2114.00 ± 34 | 1159.00 ± 92 | 3470.00 ± 175 |
| Cr | 1.89 ± 0.08 | 4.35 ± 0.21 | 3.08 ± 0.55 | 13.48 ± 0.01 |
| Fe | 430.40 ± 7.3 | 1289.00 ± 6 | 1203.00 ± 99 | 3109.00 ± 102 |
| Ti | 16.31 ± 2.77 | 36.14 ± 1.02 | 10.70 ± 0.76 | 66.33 ± 6.49 |

mg/kg, Ba < 100 mg/kg, Cd 0.005-0.2 mg/kg, Co 0.02-1 mg/kg, Cr < 1 mg/kg, Cu 12-30 mg/kg, Fe < 300 mg/kg, Mn 20-200 mg/kg, Mo 0.1-2 mg/kg, Ni 1.1-10 mg/kg, Pb < 2 mg/kg, Ti < 2 mg/kg, V 0.2-1.5 mg/kg and Zn 20-200 mg/kg (Kabata-Pendias and Pendias 1984; Pais 1984; Eifert *et al*. 1987; Colak *et al*. 2005; Divrikli *et al*. 2006; Szentmihályi *et al*. 2007). The fruit and branch samples did not show element accumulation although the leaves contained Al, Fe, Pb and Ti in higer concentration which may be explained that the area was near to the road.

In most cases scientists know nothing of the soil or habitat where the plants grow; despite this, we have to evaluate the element content of drugs. We have to pay close attention to the unsoluble remaining material during the digestion which could be silicic acid from the plant or from soil pollution. The joint occurence of typical soil-forming elements in herb such as Al, Cr, Fe and Ti in higher concentration than the normal range indicates soil pollution of the drug or may indicate that the plant is growing on soil with acidic pH. These statements were based on the examination of barley, oats, sweet corn, cabbage, spinach, lettuce, carrot, onion, potato, tomato, apple, orange, grasses, chicory, cinnamon, nettle, etc. (Kabata-Pendias and Pendias 1984; Mino *et al.* 1990; Szentmihályi *et al*. 1992, 1999). Frequently roots are polluted (**Table 3**) although sometimes aerial parts of the plant drugs may contain these elements over the average concentration as in the herba of milk thistle (*Silybum marianum* L.) (**Table 3**) or in the herba of thyme (**Table 1**).

Lead is a typical environmental pollutant, the concentration of which may indicate mainly air pollution. Therefore, plants near roads and in cities frequently contain Pb in different plant parts in a concentration higher than 2 mg/kg (Kabata-Pendias and Pendias 1984).

## Elements in the extracts

The elevated concentration of toxic elements in plant drugs, e.g. As or Pb, may be harmful, since the elements are dissolved in the extracts and may get into the human and animal body (Alvarez-Tinaut *et al.* 1980; Blázovics *et al*. 2004; Mattina *et al*. 2006). For example, Pb in the root of *Taraxacum officinalis* L. is dissolved in the alcoholic solution (**Table 4**). Other essential elements in plants may contri-

**Table 4** Element content ± standard deviation of dandelion (*Taraxacum officinalis* L.) root and extracts (n=3).

| Elements | Root drug (mg/kg) | Aqueous extract (µg/100 mL) | Dissolution (%) | Alcoholic extract (µg/100 mL) | Dissolution (%) |
|---|---|---|---|---|---|
| B* | 27.57 ± 0.19 | 6.83 ± 0.21 | 25 | <dl | |
| Cd | <dl | <dl | | <dl | |
| Co | <dl | <dl | | <dl | |
| Cr | 16.32 ± 0.16 | 0.75 ± 0.02 | 5 | <dl | |
| Cu* | 28.79 ± 0.40 | 14.80 ± 0.28 | 51 | 2.71 ± 0.26 | 10 |
| Fe* | 2688.00 ± 4.33 | 52.80 ± 0.92 | 2 | 0.87 ± 0.02 | 0.05 |
| Hg | <dl | <dl | | <dl | |
| Mn* | 85.22 ± 1.65 | 11.49 ± 0.13 | 14 | 0.31 ± 0.03 | 0.4 |
| Mo* | 1.08 ± 0.02 | 0.23 ± 0.04 | 21 | 0.70 ± 0.01 | 63 |
| Pb | 8.02 ± 0.23 | <dl | | 0.31 ± 0.01 | 4 |
| Zn* | 57.72 ± 0.91 | 8.85 ± 0.11 | 16 | 3.22 ± 0.09 | 6 |

<dl: Below detection limit
* Significant difference ($p<0.05$) between the element content of aqueous and alcoholic extract according to the one way analysis of variance (ANOVA) test.

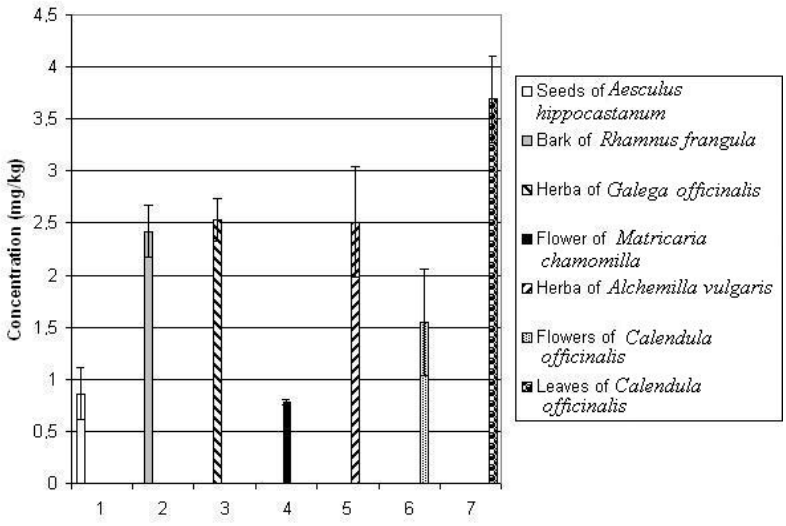


**Fig. 4 Cr concentrations (mg/kg) in some medicinal plants used in the treatment of diabetes (n=3).**

**Table 5** Element content in tea of milk thistle seed (*Sylibum marianum*) and the relationship to some reference values.

| Elements | Concentration in tea (mg/L) | RDA | DRI (mg/day) | UL |
|---|---|---|---|---|
| Al | 3.72 | | 3.1-4.1* | |
| B | 0.576 | | 0.75-0.96 | 20 |
| Ba | 0.16 | | 0.49-1.0* | |
| Cd | 0.009 | | 0.07-0.017* | |
| Co | 0.033 | | | |
| Cr | 0.015 | 0.035-0.05 | 0.020-0.035 | Not determined |
| Cu | 0.22 | 0.9-1.5 | 0.7-0.9 | 10 |
| Fe | 0.916 | 8-18 | 8-15 | 45 |
| Mn | 0.700 | 2.5-5 | 1.6-2.3 | 11 |
| Mo | 0.0057 | 0,045 | 0.034-0.045 | 2 |
| Ni | 0.382 | | 0.25-0.38 | 1 |
| Zn | 0.448 | 8-11 | 8-11 | 40 |

* There are no DRI values (intake by Merian *et al.* 2004)
Orange: nutrients; blue: over the 10% RDA value; pink: values of RDA (Recommended Dietary Allowances); light blue: intake by Merian *et al.*; green: values of DRI (Dietary Reference Intake); red: UL (tolerable Upper Limit).

bute to the advantageous therapeutic effect. The mineral element content in extracts shows significant differences. The aqueous extract of *T. officinalis* contains B, Cr, Cu, Fe, Mn and Zn in higher amount, while alcohol of 96% dissolves more Mo and Pb from the root drug. The plant drugs recommended in folk medicine for the diabetes therapy contain Cr in higher concentration (Castro 2001) than the normal concentration range for plants which is below 0.2 mg/kg (**Fig. 4**).

Pharmacology uses several extracts for internal and external application, but tea (decoction and infusion) is the most frequently applied remedy. Calculations were performed to determination of nutritional value of teas of dog rose (*Rosa canina* L.), dwarf everlast (*Helichrysum arenarium* L. Moench) and goldenrod (*Solidago canadensis* L.) based on the evaluation of quantities of metal ions in an adequate amount of aqueous extract and the metal ion quantities were compared to reference data (Lemberkovics *et al.* 2002; Stefanovits-Bányai *et al*. 2002; Apáti *et al*. 2003). **Table 5** summarizes the most important reference values, Recommended Dietary Allowances (RDA 2002), Dietary Referece Intake (DRI, Food and Nutritional Board 2002) and tolerable Upper Limit (UL; These data are obtainable from the book of Food and Nutritional Board 2002), available in the literature and their comparison to a valuable tea made from the seeds of milk thistle. The orange elements are known as nutrients for which there are RDA values available. According to this and taking into consideration the consumption of 1 L of tea, in some cases the teas cover 10% or more of the daily requirement for several elements. The tea of *S. marianum* seeds is used in liver protection where the supplementation of Zn is important (Kawase *et al*. 2004). When comparing of the amount of elements in tea with the RDA values (pink values) we can state that tea is good source of Cr, Cu, Fe, Mn and Mo as is highlighted in blue in **Table 5**. The DRI values (green) and RDA are almost the same. The difference is that DRI includes some other reference intakes and there are reference values for some non-nutritional elements as well in DRI. There is no reference value for Al, Ba, and Cd, but Merian and co-authors (2004) published some data for their intake (light blue values). The amount of Al, Cd and Ni in 1 L of tea covers the DRI values. This may be harmful for example in the case of Ni the total Ni consumption gets near the upper limit. By administration of nickel compounds, this element can accumulate in different cells and organs, and finaly may cause allergy. Accumulation was observed in skin, lung, brain, kidney, liver, placenta (Mushak 1980; Ermolli *et al*. 2001). The most general reported symptoms for nickel overload are headache, vertigo, nausea, vomiting, insomnia, constrictive chest pains, dry coughing, hyperpnea, cyanosis, gastrointestinal disturbances, visual disturbances and severe weakness that are followed by contact dermatitis, or pulmonary fibrosis, or asthmatic lung, or hyperglycemia, or nephropathy (Mushak 1980; van Joost and van Everdingen 1982). In short term rat experiment administration of Chinese Beiquishen tea (According to the description, the composition of tea is leaves and flowers of wild *Astragalus mongolicus* growing in Danxing' anling, glossy ganoderma and the fruit of Chinese wolfberry) containing relatively high amount of nickel caused accumulation of nickel in liver and elevated free radicals in the blood and liver (Blázovics *et al*. 2006).

Two decades ago it was expressed that the element contents of oils are negligible, therefore no need to measure them (Then *et al*. 1994). Today we say that it is important to measure them since they may determine the antioxidant value and the rancidity of oil (Szentmihályi *et al.* 2002). Fatty and volatile oils also contain elements and these concentrations are not negligible and the concentrations are comparable with the element content of plants (**Table 6**). Interestingly the concentration range of microelement contents in oils is very similar and narrow for most elements. Taking into consideration the normal range of elements in plants and the oil content of plants, the accumulation of some elements, e.g. Cr could be observed. Chromium may be detected frequently, the concentration of which is comparable with the Cu content. The element content of oils varies depending on the extraction method. Supercritical fluid extraction with carbon dioxide makes it possible to yield oil in a maximum amount with an environmentally-friend solvent. The pressed and the SFE oils were made from the same *Foeniculum vulgare* L. sample and the element content of the two oils prepared by diverse ways differ significantly from each other and from the commercial oil. The

**Table 6** Microelement concentration of fatty and volatile oils ± SD (μg/g, n=3).

| Elements | Fatty oil | Aromatic oil of fennel (*Foeniculum vulgare* Mill.) | | | Volatile oil |
|---|---|---|---|---|---|
| | Elder (*Sambucus nigra* L.) | Oil from commercial network | Pressed oil | Oil obtained by supercritical fluid extraction (SFE) | Sage (*Salvia officinalis* L.) |
| Cr | <0.04 | <0.04 | <0.04 | 0.38 ± 0.07 | 0.05 ± 0.03 |
| Cu | <0.002 | 1.62 ± 0.45 | <0.002 | 1.53 ± 0.26 | < 0.002 |
| Fe* | 4.61 ± 0.43 | 3.29 ± 0.32 | 1.65 ± 0.57 | 7.79 ± 0.49 | 0.36 ± 0.17 |
| Mn* | 0.22 ± 0.26 | 0.56 ± 0.02 | 1.21 ± 0.04 | 0.54 ± 0.03 | < 0.001 |
| Zn* | 3.77 ± 2.61 | 2.74 ± 0.02 | 2.08 ± 0.35 | 1.55 ± 0.09 | 0.18 ± 0.01 |

* Significant difference ($p<0.05$) between the element content of fennel oils, and of different oils according to the one way analysis of variance (ANOVA) test.

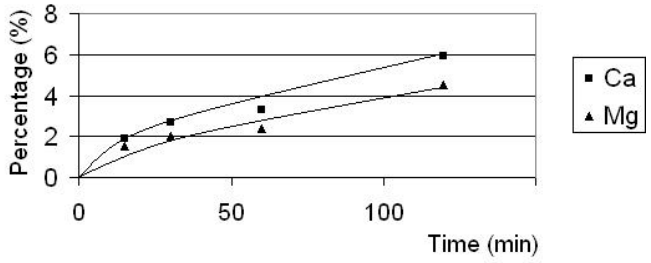


**Fig. 5 Transfer of calcium and magnesium from peppermint (*Mentha piperita* L.) volatile oil into plasma (buffer solution of pH = 7.5).**

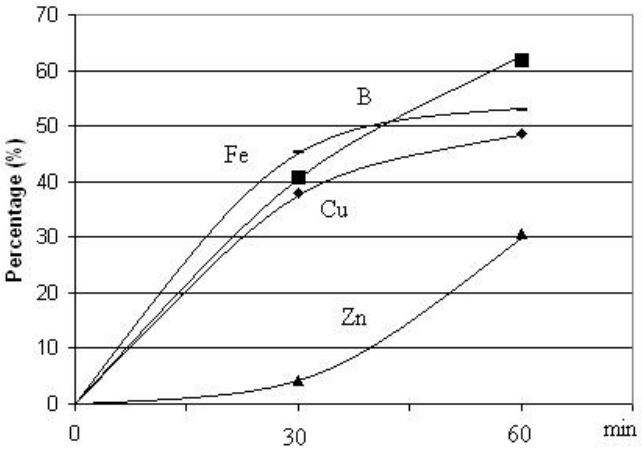


**Fig. 6 Transfer of trace elements from Gutta carminativa (fennel, caraway, mint) into plasma (buffer solution of pH = 7.5).**

value of fatty oil also depends on trace element content which affects, however, the lasting nature of the oil. A higher heavy metal content may induce auto-oxidation processes by which oil becomes rancid (Luzia *et al*. 1998).

### *In vitro* measurements for transfer of elements

Bioavailability of elements from different extracts, e.g. teas or volatile oils, may be examined *in vitro* by a dialysis system. Elements in the extracts are able to pass through different membranes. The transfer of elements greatly changes depending on the element content of the initial extract and time. Microelements from teas into the plasma (buffer solution pH = 7.5) transfer in relatively high percentages, the value of which ranges between 7 and 90% (Szentmihályi *et al*. 2006). Microelements from oils and volatile oils hardly transfer to buffer solution stomach (pH = 1.1) and from stomach to plasma (pH = 7.5) or in most cases the transfer is no measurable (Szentmihályi *et al*. 2001). Only the transfer of some macroelements may be detected (**Fig. 5**). In contrary to the above, microelements from a mixture of three volatile oils, Gutta carminative (fennel, *Foeniculum vulgare*; caraway, *Carum carvi*; peppermint, *Mentha piperita*), can pass in a relatively high amount. The less transferable element is Zn: 30.70% of the initial amount can pass during 60 min. The other elements transferred in higher rates, Al 52.73%, B 61.80%, Ba 52.49%, Cr 48.32%, Cu 48.73% and Fe 52.89% (**Fig. 6**).

## CONCLUSION

The determination of element content in medicinal plant drugs and extracts has several important aspects. The element content in drugs may refer to quality as cleanness and possible pollutants while their measurement in extracts is relevant for the determination of nutritional value and possible therapeutic and harmful effects. Since elements are able to pass through different membranes essential and non-essential elements get into the cells and organs of human and animal bodies that causes favorable or nonfavorable processes.

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