

Selenium Concentrations of Selected Medicinal and Aromatic Plants in Turkey

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Recent scientific studies have proven the importance of trace elements on human health. The main food supplies are plants and animals, which are significant sources of these minerals. Studies on determining mineral compositions of herbs, spices and some other crops have increased all over the world. Published works revealed that spices, herbs and medicinal plants should be consumed to obtain beneficial trace elements. Selenium (Se), one of the most vital trace elements, has a significant role in human diet acting as a preventative agent against some serious illnesses. Despite numerous scientific works on mineral compositions of medicinal and aromatic plants, investigations of selenium content in these foods could not be successfully studied until recently due to the lack of suitable analytical methods for selenium analysis. Thus, publications on selenium concentrations of foods are recent. In this regard, selenium contents of some medicinal and aromatic plants commonly used as spices, herbal teas and traditional medicines in Turkey were studied in the present research. Selenium contents of the most used parts of these plants were analyzed by ICP-OES (Varian Vista-Pro, Australia). Of the analyzed 26 medicinal and aromatic plants, the highest Se concentration (1133 µg kg⁻¹) was found in sweet basil (*Ocimum basilicum* L.) and the lowest in sumac (*Rhus coriaria* L.) fruits (11 µg kg⁻¹).

Keywords: ICP, medicinal plants, microelements, selenium (Se).

Demand for medicinal and aromatic plants (MAPs) for preventing and treating illnesses and for general well being are greater than ever. Depending on this demand, plants and novel natural products from different plant species have emerged. Safety and quality aspects of these plant products strictly depend on their raw materials. Therefore, their effectiveness for special uses and safety for human health are related to their natural origins. Besides their health-related secondary metabolite contents and compositions, microelement concentrations of the plants are important. Deficiency of micronutrients in a diet might result in serious health problems. Since most of the micronutrients have immunomodulatory effects, malnutrition can cause immune system ailments, which mostly result in infectious diseases, besides increased mortality, poor cognitive ability in children, and decreased employee productivity [1-3].

Nontoxic heavy metal concentrations in these herbal materials, which have significant contents of some functional microelements, such as zinc, selenium, and iron, are desired for daily diets. Of these valuable microelements for human health and well being, selenium (Se) has gained special importance, as it is essential for a number of functions in humans and animals. The significance of Se in human diet was discovered in 1979

by a group of Chinese scientists who demonstrated that children living in Se-deficient regions were suffering from a cardiomyopathy [4]. Studies confirmed that the dietary supply of Se was not adequate to satisfy body needs, especially in some countries like Finland, New Zealand, and China, with low Se levels in the soil. Consequently, low dietary intake of Se in the diet may lead to Keshan and Kashin-Beck diseases, which predominantly effect children. Not only human beings, but also animals suffer when fodders are deficient in Se, which might cause animals to suffer from dietary muscular dystrophy known as 'white muscles disease', as well as decreased level of fertility, and high frequency of miscarriages [5,6]. Recommended appropriate dietary Se intake for healthy adult men is 80 µg day⁻¹ and 55 µg day⁻¹ for adult women, whereas a maximal daily safe dietary Se intake up to 400 µg has been suggested for adults by WHO/IPCS [7]. Selenium is an essential trace element in a very narrow concentration range; outside this range either deficiency or toxicity occurs [8]. The daily intake of selenium depends on its level in food and on the amount of food consumed. The Se in foods is very much changeable and relies on the geographic conditions where the food was produced. Nevertheless, selenium toxicity and availability both depend on the chemical form in which it is present in food and on dietary factors, as well [9,10].

Selenium shows its activity in the human body through a range of selenoproteins. Glutathione peroxidase (GPX) is one of the important selenoproteins, which has a role in detoxification of hydrogen peroxide and lipid hydrogen peroxides that can damage cell membranes and disrupt cellular functions [11]. Se deficiency is confirmed as a responsible factor in cardiovascular disease, some types of cancer, and iodine deficiency disorders. Furthermore, susceptibility to oxidative stress related with infection, inflammation, pain, muscle inflammation, and weakness, fragility in red blood cells, degeneration of cell and tissue in pancreas, and abnormal skin coloration are increased with Se deficit. For these reasons, effective ways of increasing Se intakes are of great public health interest for scientists and health related departments in many countries.

Information about the different forms of selenium in plants was limited till now due to the difficulties in their identification. Application of current techniques (ICP-MS, HPLC-MS, HPLC-ICP-MS) is only recently changing the detection and evaluation of Se in plants [12].

Although selenium is not essential for plant development, desired concentrations in food, water and soil are important for animal and human nutrition. Thus, in the present study, selenium contents of commonly used selected medicinal and aromatic plants were screened. Ten samples from each of twenty-six plant species (Table 1) were prepared; each sample (260 samples) was analyzed in triplicate to obtain statistically analyzable and reliable results. The Se content in the analyzed plants ranged between 11 and 1133 $\mu\text{g kg}^{-1}$.

Ocimum basilicum, which has widely been used as either a fresh or dried spice, presented the highest Se content with $1133 \pm 104 \mu\text{g kg}^{-1}$; this was followed by *Peganum harmala* L. ($951 \pm 22 \mu\text{g kg}^{-1}$). Aerial parts of *Urtica dioica* (content $271 \pm 16 \mu\text{g/kg}$) have been used either fresh or dried for prevention of cancer metastasis in Turkey. The seeds of *Linum usitatissimum* ($193 \pm 26 \mu\text{g kg}^{-1}$) are added, either directly or mostly ground, to food as a prebiotic in order to help digestion or to prevent and heal prostate symptoms.

Prunus mahaleb, *Trigonella foenum-graecum*, *Artemisia dracunculus*, and *Glycyrrhiza glabra* root displayed similar Se contents (154 ± 7 , 152 ± 6 , 150 ± 8 and $148 \pm 11 \mu\text{g kg}^{-1}$, respectively), whereas, *G. glabra* root extract contained $135 \pm 11 \mu\text{g kg}^{-1}$ Se. The values obtained for the other samples were: *Coriandrum sativum* ($141 \pm 7 \mu\text{g kg}^{-1}$), *Sideritis congesta* ($137 \pm 15 \mu\text{g kg}^{-1}$), *Papaver somniferum* ($134 \pm 12 \mu\text{g kg}^{-1}$), *Tilia cordata* ($125 \pm 8 \mu\text{g kg}^{-1}$), *Foeniculum vulgare* ($119 \pm 7 \mu\text{g kg}^{-1}$), *Salvia triloba* ($118 \pm 7 \mu\text{g kg}^{-1}$), *Cuminum cyminum* ($43 \pm 4 \mu\text{g kg}^{-1}$), *Erica vulgaris* ($85 \pm 10 \mu\text{g kg}^{-1}$), *Matricaria chamomillae* ($76 \pm 6 \mu\text{g kg}^{-1}$), *Thymbra spicata* ($68 \pm 6 \mu\text{g kg}^{-1}$), *Origanum onites* ($44 \pm 5 \mu\text{g kg}^{-1}$), *Teucrium polium* ($41 \pm 3 \mu\text{g kg}^{-1}$), *Rosmarinus officinalis* ($38 \pm 3 \mu\text{g kg}^{-1}$), *Tribulus terrestris* ($30 \pm 3 \mu\text{g kg}^{-1}$), *Mentha spicata* ($25 \pm 3 \mu\text{g kg}^{-1}$), *Laurus*

Table 1: Selected plants, their scientific, common English and Turkish names, used part, and usage.

Plant Scientific Names & Family	Common Name	Turkish Name	Parts Used	Usage
<i>Artemisia dracunculus</i> L. Asteraceae	Tarragon	Tarhın	Aerial parts	Spice, Tr. Medicine
<i>Coriandrum sativum</i> L. Apiaceae	Coriander	Kişniş	Fruits	Spice, Tr. Medicine
<i>Cuminum cyminum</i> L. Apiaceae	Cumin	Kimyon	Fruits	Spice Tr. Medicine
<i>Erica vulgaris</i> L. Ericaceae	Common heather	Funda	Leaves	Tr. medicine
<i>Foeniculum vulgare</i> Mill. Apiaceae	Fennel	Rezene	Fruits	Spice Tr. Medicine
<i>Glycyrrhiza glabra</i> L. Leguminosae	Licorice	Meyankökü	Roots	Tr. Medicine, beverage
<i>Glycyrrhiza glabra</i> L. (extract) Leguminosae	Licorice extract	Meyanbalı	Extract	Tr. medicine
<i>Hypericum perforatum</i> L. Guttiferae	St. John's wort	Kantaron	Aerial parts	Tr. Medicine
<i>Laurus nobilis</i> L. Lauraceae	Bay leaf	Defne	Leaves	Spice, Tr. Medicine
<i>Linum usitatissimum</i> L. Linaceae	Flax, Linseed	Keten	Seeds	Tr. Medicine
<i>Matricaria chamomilla</i> L. Asteraceae	Chamomile	Papatya	Flowers	Tr. Medicine
<i>Mentha spicata</i> L. Lamiaceae	Spearmint	Nane	Leaves	Spice, Tr. Medicine
<i>Ocimum basilicum</i> L. Lamiaceae	Basil	Fesleğen	Leaves	Spice, Tr. Medicine
<i>Origanum onites</i> L. Lamiaceae	Turkish oregano	Kekik	Aerial parts	Spice, Herbal Tea
<i>Papaver somniferum</i> L. Papaveraceae	Poppy	Haşhaş	Seeds	Spice, Tr. Medicine
<i>Peganum harmala</i> L. Nitrariaceae	Harmal	Üzerlik	Seeds	Tr. Medicine, sacred
<i>Pimpinella anisum</i> L. Apiaceae	Anise	Anasaon	Fruits,	Spice, Tr. Medicine
<i>Prunus mahaleb</i> L. Rosaceae	Mahaleb cherry	Mahlep	Seeds	Spice, fragrant
<i>Rhus coriaria</i> L. Anacardiaceae	Sumac	Sumak	Fruit skin	Spice, Tr. Medicine
<i>Rosmarinus officinalis</i> L. Lamiaceae	Rosemary	Biberiye	Leaves	Spice, Herbal tea
<i>Salvia triloba</i> Mill. Lamiaceae	Sage	Adaçayı	Aerial parts	Herbal tea
<i>Sideritis congesta</i> P.H. Davis & Hub.-Mor., Lamiaceae	Sideritis	Dağçayı	Aerial parts	Herbal tea
<i>Teucrium polium</i> L. Lamiaceae	Germander	Paryavşan	Flowers	Tr. Medicine
<i>Thymbra spicata</i> L. Lamiaceae	Zahter	Zahter	Aerial parts	Spice, Herbal tea
<i>Tilia cordata</i> Mill. Tiliaceae	Linden	İhlamur	Flowers	Herbal tea
<i>Tribulus terrestris</i> L. Zygophyllaceae	Puncture weed	Demirdiken	Aerial parts	Tr. Medicine
<i>Trigonella foenum-graecum</i> L. Leguminosae	Fenugreek	Çemen otu	Seeds	Food, Tr. Medicine
<i>Urtica dioica</i> L. Urticaceae	Nettle	Isırgan	Aerial parts	Tr. Medicine

* Tr. Medicine: Traditional medicine

nobilis ($25 \pm 2 \mu\text{g kg}^{-1}$), *Hypericum perforatum* ($19 \pm 1 \mu\text{g kg}^{-1}$), *Pimpinella anisum* ($18 \pm 2 \mu\text{g kg}^{-1}$) and *Rhus coriaria* ($11 \pm 2 \mu\text{g kg}^{-1}$) [13].

In most diets, the major food supply for Se is animal products such as fish and meat. Although vegetables and fruits are low in Se and contribute only small amounts ($< 8\%$ total intake), a number of exceptions were recorded [14]. In previous studies, Se contents of some plants are reported as follows; Brazil nuts ($14,700 \mu\text{g kg}^{-1}$) and mosses growing in the Scandinavian countries ($390 \mu\text{g kg}^{-1}$ - $2900 \mu\text{g kg}^{-1}$). Se concentrations of grass and alfalfa grown in different countries displayed highly different Se contents. The lowest values were in Canada, whereas the highest values were recorded in India for grass ($352 \mu\text{g kg}^{-1}$) and alfalfa ($672 \mu\text{g kg}^{-1}$) [15]. Another recent study conducted in Poland aimed to assess differences in Se accumulation between 5 grass species and 5 herb species belonging to meadows [16]. *Arrhenatherum elatius* L. had the highest average Se content ($46 \mu\text{g Se} \cdot \text{kg}^{-1} \text{ d.m.}$),

whereas *Holcus lanatus* L. demonstrated the lowest (24 $\mu\text{g Se} \cdot \text{kg}^{-1} \text{ d.m.}$). The content of Se in meadow herbs (70 $\mu\text{g Se} \cdot \text{kg}^{-1} \text{ d.m.}$) was approximately twice as high as that in grasses (32 $\mu\text{g Se} \cdot \text{kg}^{-1} \text{ d.m.}$). Among this group of plants, the highest Se accumulation occurred in *Equisetum arvense* L. (103 $\mu\text{g Se} \cdot \text{kg}^{-1} \text{ d.m.}$) and the lowest in *Taraxacum officinale* (59 $\mu\text{g Se} \cdot \text{kg}^{-1} \text{ d.m.}$) [16].

Se concentrations in plant-derived foods are highly variable due to the genetic variation for Se accumulation and environmental conditions [17,18]. Redox potential, pH, organic and inorganic compounds of soil, type of rocks, draining waters, climatic conditions, and the oxidation state of the element would affect both the total amount of Se and its availability to plants through roots. Se is mainly found in the form of selenite in acidic soils, which is poorly absorbed by plants, whereas it is oxidized to selenate in alkaline soils, which is more soluble and absorbed by plants [19]. Se-enriched crops may be divided into two groups: primary accumulators (hyper-accumulators) rarely over 100 mg g^{-1} dry weight and secondary accumulators (indicator species) with low foliar concentrations of Se, of less than 25 mg g^{-1} dry weight that are termed non-accumulators [20]. Wheat grown in the United States contains 0.2 to 0.4 g/g^{-1} Se; however, wheat grown in Se-rich soils may contain between 5 and 15 g g^{-1} [21]. Plants that hyper-accumulate Se include garlic and broccoli followed by various *Astragalus* species, as well as *Stanleya pinnata*, a member of the Brassicaceae; Se concentrations may exceed 1 mg Se g^{-1} dry plant tissue [22-25]. There are limited reports about the chemical forms of Se in these plants, but the available information suggests that it is often in a methylated form, such as SeMSC, -glutamyl SeMSC, selenocystathione, selenohomocysteine-glutamyl selenocystathione, and methyl selenol [26]. These forms of Se may be safely stored in membrane-bound structures within the plant; Se hyper-accumulators have a relatively small percentage of their total Se sequestered in the protein fractions of the plant. High-Se garlic has been extensively studied because of its effectiveness in the decline of mammary tumors in experimental animals [24,25].

Se-accumulating plants provide a rich genetic resource that should be exploited to develop food crops that are enriched in Se compounds for improving public health, particularly the prevention of cancer or decreasing the cancer rate. These genetic resources may also be used to develop plants for the remediation of Se-contaminated soil and water.

References

- [1] Bhaskaram P. (2002) Micronutrient malnutrition, infection, and immunity: an overview. *Nutrition Reviews*, **60**, 40-45.
- [2] WHO (1999) Malnutrition worldwide. World Health Organization, Geneva, Switzerland, 1-13. 148.
- [3] WHO (2002) The World Health Report 2002. In *Reducing risks, promoting healthy life*. Campanini B. (Ed.). World Health Organization, Geneva, Switzerland. 1-68.

Experimental

Plant materials: Plant materials from 26 species (100 g each) were obtained from spice wholesalers and local spice shops in southeastern Turkey in November 2010. The plants were botanically identified according to the Flora of Turkey at Kilis 7 Aralik University, Arts and Sciences Faculty, Biology Department [27]. The plant samples were kept in plastic bags at room temperature until the analysis. Some characteristics of the plant species used in the study are given in Table 1. For chemical analysis, 10 different samples, each of 100 g, from each of the 19 plant species (totally 260 plant samples) were obtained from the shops.

Sample processing and analysis: After cleaning and washing with deionized (D.I.) water, all the plant samples were air dried. Then, the samples were dried at 70°C for 48 h in an oven, ground for chemical analysis, and bottled in polyethylene for storage at room temperature. For chemical analysis, 0.2 g ground sample was put into a burning cup and 5 mL HNO_3 65% (Merck, Darmstadt, Germany), and 2 mL H_2O_2 30%, (Merck, Darmstadt, Germany) were added. The samples were incinerated in a HP-500 CEM MARS 5 microwave (crop. Mathews NC, USA) at 200°C and cooled at room temperature for 45 mins. The extracts were passed through a Whatman 42 Filter Paper and the total volume was made up to 20 mL. Se concentration of the samples was measured by atomic absorption spectroscopy (Varian, Cary 300 BIO, UV Visible equipped with VGA 77 (vapor generation accessories) and ETC-60 (electro thermal temperature controller)). All Se measurement in plant materials were checked against certificated Se values in different reference plant materials obtained from the National Institute of Standards and Technology (Gaithersburg, USA). Each sample was analyzed in triplicate.

Reagents: For all analytical works, distilled-deionized water was used. All the polyethylene bottles and glassware were carefully leached with 2-4 % HCl. Afterwards, they were passed through deionized water 3 times. Merck standard analytical reagent grade chemicals were used. Standard solution of Se was prepared in 1% HNO_3 immediately before the analysis by serial dilution of a 1000 mg L^{-1} stock solution stored in polyethylene bottles. Peach Leaves (Standard Reference Material, 1547) and Corn Bran (Standard Reference Material, 8433) were used as reference materials.

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- [4] Keshan Disease Research Group (1979) Epidemiologic studies on the etiologic relationship of selenium and Keshan disease. *Chinese Medical Journal*, **92**, 477-82. doi: 114372.
- [5] Debski B. (1992) A diagnostic role of milk in the assessment of hyposelenosis. Warszawa Agricultural University, pr. habilit. p. 37.
- [6] Zabrocki Z. (1991) Selenium in surface layers of soil and in alfalfa growing in deficit areas. *Materials VII Symposium Microelements in Agriculture*, Wroclaw, 109-113.
- [7] IPCS (1988) (International programme on chemical safety) Chromium. environmental health criteria 61. Jeejeebhoy KN. (Ed.), World Health Organization, Geneva.
- [8] Ferri T, De Luca C, Ticconi L. (2001) Selenium speciation in environmental matrices: A preliminary study on plants. *Analytical Letters*, **34**, 975-988.
- [9] Whanger PD. (2002) Selenocompounds in plants and animals and their biological significance. *Journal of the American College of Nutrition*, **21**, 223-232.
- [10] Munshi CB, Mondy NI. (1992) Glycoalkaloid and nitrate content of potatoes as affected by method of selenium application, *Biological Trace Element Research*, **33**, 121-127.
- [11] Rotruck JT, Pope AL, Ganther HE, Swanson AB, Hafeman DG, Hoekstra WG. (1973) *Selenium: Biochemical Role as a Component of Glutathione Peroxidase*, **179**, 588-590.
- [12] Guerin T, Astruc A, Astruc M. (1999) Speciation of arsenic and selenium compounds by HPLC hyphenated to specific detectors: a review of the main separation techniques. *Talanta*, **50**, 1-24.
- [13] Sekeroglu N, Kaya DA, Inan M, Kirpik M. (2006) Essential oil contents and ethnopharmacological characteristics of some spices and herbal drugs traded in Turkey. *International Journal of Pharmacology*, **2**, 256-261.
- [14] Combs GF. (2007) Selenium in global food systems. *British Journal of Nutrition*, **85**, 517-547.
- [15] Kabata-Pendias A, Mukherjee AB. (2007) *Trace Elements from Soil to Human*. Springer-Verlag, Berlin, Heidelberg. II-16.1. Selenium, 401-420.
- [16] Patorczyk-Pytlik B. (2009) The content of selenium in some species of meadow plants. *Journal of Elementology*, **14**, 745-753.
- [17] Levander OA, Burk RF. (1994) Selenium. In *Modern nutrition in health and disease*. Shils ME, Olson JA, Shike M. (Eds), Lea and Febiger, Philadelphia. 242-251.
- [18] Spallholz JE. (1994) On the nature of selenium toxicity and carcinostatic activity. *Free Radical Biology & Medicine*, **17**, 45-64.
- [19] Gondi F, Panto G, Feher J, Bogye G, Alfthan G. (1992) Selenium in Hungary. The rock-soil-human system. *Biological Trace Element Research*, **35**, 299-306.
- [20] Berken A, Mulholland M, Le Duc D, Terry N. (2002) Genetic engineering of plants to enhance selenium phytoremediation. *Critical Reviews in Plant Sciences*, **21**, 567-582.
- [21] Curtin D, Hanson R, Lindley TN, Butler RC. (2006) Selenium concentration in wheat (*Triticum aestivum*) grain as influenced by method, rate, and timing of sodium selenate application. *New Zealand Journal of Crop and Horticultural Science*, **34**, 329-339.
- [22] Freeman JL, Zhang LH, Marcus MA, Fakra S, McGrath SP, Pilon- Smits EAH. (2006) Spatial imaging, speciation and quantification of selenium in the hyperaccumulator plants *Astragalus bisulcatus* and *Stanleya pinnata*. *Plant Physiology*, **142**, 124-134.
- [23] Cai XJ, Block E, Uden PC, Zhang X, Quimby BD, Sullivan JJ. (1995) Allium chemistry: Identification of selenoamino acids in ordinary and selenium-enriched garlic, onion, and broccoli using gas chromatography with atomic emission detection. *Journal of Agricultural and Food Chemistry*, **43**, 1754-1757.
- [24] Ip C, Birringer M, Block E, Kotrebai M, Tyson JF, Uden PC, Lisk DJ. (2000) Chemical speciation influences comparative activity of selenium-enriched garlic and yeast in mammary cancer prevention. *Journal of Agricultural and Food Chemistry*, **48**, 2062-2070.
- [25] Finley JW. (2003) Reduction of cancer risk by consumption of selenium-enriched plants: enrichment of broccoli with selenium increases the anticarcinogenic properties of broccoli. *Journal of Medicinal Food*, **6**, 19-26.
- [26] Lauchli A. (1993) Selenium in plants: Uptake, functions and environmental toxicity. *Botanica Acta*, **106**, 455-468.
- [27] Davis PH. (1982) *Flora of Turkey and Aegean Islands*. Volume 7, Edinburgh University Press, Edinburgh.