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Essential Plant Nutrients and Heavy Metals Concentrations of Some Medicinal and Aromatic Plants

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ABSTRACT

In Turkey, the majority of medicinal plants at the selling points are wildly harvested. Therefore, no control exists during their growth and development. The public awareness on effects of environmental pollution in this regard especially with respect to heavy metals in the herbs is increasing. With this objective, medicinal and aromatic plants were collected from herbalists in different, densely populated districts of Izmir Municipality. The concentrations of some essential plant nutrient elements (N, P, K, Ca, Mg, Na, Fe, Mn, Cu, Zn, B, and Mo) and toxic heavy metals (Co, Cd, Cr, Ni, and Pb) and Al were measured. Results showed that herbs are rich in the investigated mineral elements; however, some of the heavy metals are found to be at concentrations above the reported critical levels.

Keywords: Medicinal and aromatic plants; Heavy metal; Essential plant nutrients; Macro nutrients; Micro nutrients

Bazı Tıbbi ve Aromatik Bitkilerin Ağır Metal ve Temel Besin Elementi İçerikleri

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ÖZET

Türkiye'deki satış noktalarından alınan tıbbi bitkilerin çoğu doğadan toplama yoluyla sağlanmaktadır. Bu nedenle bitkilerin gelişim ve büyümesi kontrol altına alınamamaktadır. Özellikle çevresel kirliliğin tıbbi bitkilerin ağır metal içeriği üzerine yapabileceği olası etkiler ile ilgili toplumsal farkındalık her geçen gün artmaktadır. Bu amaçla İzmir'de nüfusun yoğun olarak bulunduğu ilçelerdeki farklı satış noktalarından tıbbi ve aromatik bitkiler toplanmıştır. Bazı bitki besin elementi konsantrasyonu (N, P, K, Ca, Mg, Na, Fe, Mn, Cu, Zn, B ve Mo) ile toksik ağır metal (Co, Cd, Cr, Ni, Pb ve Al) içerikleri ölçülmüştür. Sonuçta tıbbi bitkilerin zengin mineral içeriğine sahip olduğu ancak bazı ağır metallerin kritik düzeylerin üzerinde bulunduğu saptanmıştır.

Anahtar Kelimeler: Tıbbi ve aromatik bitkiler; Ağır metal; Temel besin elementleri; Makro besin elementleri; Mikro besin elementleri

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1. Introduction

Plants have been used for curing humans and protecting them from diseases throughout the history. In the Far East countries, some plants are commonly practiced for medical purposes (Polat & Satıl 2012), treating diseases. In recent years, their use has increased also in the Western countries. In the early 20th century, more than 40% of drugs were of plant origin, while the use of plant materials reduced to below 5% in the mid 1970's (Craker & Gardner 2005). On the other hand, with the increase in consumer awareness about health in 1980's-1990's, demand for organic and naturally grown medicinal and aromatic plants increased as well.

In 2000's, conservation of genetic variety and standardisation of essential oils of the medicinal and aromatic plants gained utmost importance. For this purpose, primarily the developed countries started to reconsider and passed effective laws and regulations about herbal drugs (Baser et al 1986). In countries such as Germany, France, Switzerland and Italy, where alternative treatment methods draw attention and are even officially approved, necessary measures are taken based on scientific findings of both treatment and drug use in order to minimize the probable problems to be caused by these products. In Turkey, evaluations in relation to preparation and marketing of plant products are carried out by the regulations of the Ministry of Health and the Ministry of Food, Agriculture and Livestock.

Turkey has a rich flora containing over 10.000 plant varieties. Aromatic plants account for about 1/3 of this flora and 3.000 of the varieties are endemic. Today, there are around 300 plant varieties sold in herbalists and 70 to 100 of them are exported (Baser 1997). Primarily thyme, bay leaf and cumin followed by sage, anise, locust, fennel, sumac and rosemary are among the most important export products.

The number of studies investigating the effects of environmental pollution on foods and medicinal plants due to advancing technology and examining the possible heavy metal accumulation has increased in the recent years. That's why these studies are closely related to human and environmental health (Kılınc & Kutbay 2004). Consumption of medicinal and aromatic plants is low compared to other food products; however, they could be dangerous due to possibly high heavy metal contents and improper use of them. For this reason, it is important to form a database for the mineral compositions of medicinal and aromatic plants commonly used in Turkey towards establishing verbal standardisation.

The objective of this study was to determine the heavy metal and plant nutrient contents (chemical composition) of 18 different medicinal and aromatic plants consumed as spices or used in traditional disease treatment. The plant samples were obtained from different herbalists and shops in highly populated districts of Izmir province.

2. Material and Methods

2.1. Materials

Total of 18 different medicinal plants were sampled from urban herbalists and/or selling points in 25 districts of Izmir with differing population in September-October 2012. The names, scientific names and commonly known labels of plant samples are shown in Table 1. Plant parts were separated in accordance with the purpose of usage and analysed for their chemical composition including heavy metals and minerals/essential plant nutrients.

2.2. Method

Plant samples were brought to laboratory and dried at 60-65 ^{o}C until the constant weight. From each sample, 5 g was weighed and ashed in a muffle furnace at 500 ^{o}C. The ash was then solubilized with 1:1 HCl solution and diluted (Kacar & Inal 2010; Ergün et al 2012). Nitrogen analysis was performed by Kjeldahl method (Kacar 1972). Plant nutrient elements and heavy metal concentrations were

determined with ICP-AES (Kacar & Inal 2010). The trade and model along with the operation conditions of the ICP-AES were given as the following: Device: ICP-AES (Varian 1.2–1.3 kw for axial); Plasma gas flow rate (Ar): 15 L min^{-1} (axial); Auxiliary gas flow rate (Ar): 1.5 L min^{-1}; Reading time; 45-60 sec.

3. Results and Discussion

The concentrations of essential plant nutrients (N, P, K, Ca, Mg, Na, Fe, Mn, Cu, Zn, B, and Mo) and toxic heavy metals (Co, Cd, Cr, Ni, and Pb) and Al of the 18 plant species under investigation are presented in Tables 2, 3 and 4, respectively. The essential primary plant nutrients are important for plant production and are vital for growth and development of all living bodies. Plants like nettle, parsley, dill and hibiscus, of which green parts can be freshly consumed, contain higher amounts of N, P, K, Ca and Mg compared to other elements (Table 2). Nitrogen (4.80%) and Ca (1.67%) concentrations of dill were found to be higher than those of other plants. Phosphorous content of sesame (0.93%) and K of parsley (1.65%) were found highest among the studied plants. Potassium, P, Ca and Mg concentrations determined in the current study are compatible with the findings of Ozcan (2004) and Ergün et al (2012) on different medicinal plants. Daily intake of mineral elements (N, Ca, P, Mg and K) by a person should be adjusted to 1% of body weight or less than 10 mg (Imelouane et al 2011). WHO (2012) reports that daily intake of K should be at least 3510 mg day^{-1} for the regulation of blood pressure and minimisation of cardiovascular risks and cardiac diseases. Equal amounts of Ca and P are recommended for P and Ca nutrition of an adult. For 1-10 year old children, 800 mg of P is recommended and for 11-24 years of age 1200 mg (Samur 2008). The daily intake of Mg is recommended to be 300-420 mg in adults (Vormann 2003).

With respect to secondary plant nutrients, Fe content of basil (689 mg kg^{-1}), Mn of galanga (315 mg kg^{-1}), Zn of black cumin (79 mg kg^{-1}) and Cu of basil (19.3 mg kg^{-1}) were found higher (Table 3) than the other plants in this study. Critical limit values for Cu and Zn are not given in the reports of WHO (2004). Therefore, critical concentrations could be different for perennial and annual plants. Copper concentration of plants is reported to range between 16–20 mg kg^{-1} in general (Mengel & Kirkby 2004). On the other hand, Bowen (1966) and Allaway (1968) stated that agricultural products could contain 4-15 mg kg^{-1} Cu and 15–200 mg kg^{-1} Zn. The Zn concentrations of the plants reported in this study are compatible with the values in literature, whereas Cu concentrations are higher for basil, cumin and coriander. Copper is a vital element for plants, animals and humans, but its excess intake might cause health problems. 2.5 mg of daily Cu intake can meet the daily requirement of adults. On the other hand, Zn, an essential element for nearly all living cells, is recommended to be consumed at the amount of 15 mg a day (Samur 2008; Ulger & Coskun 2003). In a study investigating the mineral constituents of edible wild plants, it is reported that Mn might be high in certain plants like hibiscus (56.0 mg kg^{-1}) and basil (65.1 mg kg^{-1}) (Chizzola et al 2003; Turan et al 2003). In the current study, it is noteworthy that Mn content is much higher in some plants than the values in literature. The recommended daily intake of Mn is 4.50 mg for humans. Considering the Fe contents of plants, most plants were determined to contain much higher concentration of Fe compared to 100-300 mg kg^{-1} interval reported by Reuter and Robinson (1986) for higher plants. Due to cereal-based nutritional habits in Turkey, the recommended daily intake of Fe, the most important functional component of human blood, is 10 mg for an adult male, 15-18 mg for females and 27-30 mg for pregnant women (Samur 2008). In addition, the intake of essential secondary plant nutrients / trace elements (Zn, Fe, Mn, Cu, Cr and Ni) is recommended not to exceed 0.01% of body weight (Imelouane 2011).

Table 1- Medicinal and aromatic plants, their; names, studied-parts and medical effects

Çizelge 1- Çalışma kapsamındaki tıbbi ve aromatik bitkilerin Latince isimleri, çalışılan parçaları ve tıbbi amaçlı kullanım özellikleri

Plant	*Botanical name*	*Parts studied*	*Medical effects*	*References*
Nettle	Urtica dioica L.	Leaf	Diuretic, astringent, antiallergenic, prostate treatment, hemorrhoids, baldness	Polat & Satıl 2012; Cakilcioglu et al 2011; Akgünlü 2012; Polat et al 2013
Mint	Mentha piperita L.	Leaf	Gas expectorant, antispasmodic, bile regulatory, antiseptic, cold, flu	Polat & Satıl 2012; Cakilcioglu et al 2011; Saganuwan 2010; Akgünlü 2012
Thyme	Thymus vulgaris L.	Leaf	Gas expectorant, antitussive, antiseptic, antispasmodic, cold, flu	Polat & Satıl 2012; Cakilcioglu et al 2011; Saganuwan 2010
Rosemary	Rosmarinus officinalis L.	Leaf	Antimicrobial, antifungal, antioxidant, antiseptic	Saganuwan 2010; Polat & Satıl 2012
Basil	Ocimum basilicum L.	Leaf	Antioxidant, cardioprotective, antispasmodic, antidiabetic, antimicrobial, antifungal, antioxidant, antiseptic, analgesic	Polat & Satıl 2012; Zeybek & Haksel 2010
Dill	Anethum graveolens L.	Leaf	Antispasmodic, analgesic, digestive problems, antioxidants, antimicrobial	Elik 2010; Zeybek & Haksel 2010; Faydaoglu & Surucuoglu 2011
Malva	Malva sylvestris L.	Leaf	Anti-inflammatory, colitis and mouth infections, chronic bronchitis, abscesses, haemorrhoids, laxatives, abdominal pain	Polat & Satıl 2012; Cakilcioglu et al 2011; Akgünlü 2012; Polat et al 2013
Parsley	Petroselinum crispum L.	Leaf	Antimicrobial, hypotensive, diuretic, laxative, spasmodic	Polat & Satıl 2012; Saganuwan 2010
Ginger	Zingiber officinale L.	Root	Nausea, antioxidant, antithrombotic, anticarcinogen, antioxidant, antimigraine and antilipidemic	Saganuwan 2010; Faydaoglu & Surucuoglu 2011; Zeybek & Haksel 2010
Turmeric	Curcuma longa L.	Root	Antioxidant, anti-inflammatory and anticarcinogen	Faydaoglu & Surucuoglu 2011; Zeybek & Haksel 2010
Galangal	Alpinia officinarum L.	Root	Anti-inflammatory, antitumour,anticarcinogen, antimutagenic, antimicrobial /antiviral	Faydaoglu & Surucuoglu 2011; Zeybek & Haksel 2010
Cinnamon	Cinnamomum aromaticum L.	Stem and branch	Anti-inflammatory, antitumour, anticarcinogen, antimutagenic, antimicrobial / antiviral	Saganuwan 2010; Zeybek & Haksel 2010
Cumin	Cuminum cyminum L.	Fruit	Antibacterial, antifungal, anti-inflammatory, antioxidant, astringent	Faydaoglu & Surucuoglu 2011; Zeybek & Haksel 2010
Black cumin	Nigella sativa L.	Fruit	Anti-inflammatory, antitumour, anticarcinogen, antimicrobial / antiviral, antitumour, colitis, peritonitis, arthritis, oedema	Saganuwan 2010; Zeybek & Haksel 2010
Coriander	Coriandrum sativum L.	Fruit	antimicrobial / antiviral, antiulcer, regulation of blood pressure, anti-inflammatory	Saganuwan 2010; Faydaoglu & Surucuoglu 2011
Fennel	Foeniculum vulgare L.	Fruit	Diuretic, anaemia, digestive system diseases	Polat & Satıl 2012; Saganuwan 2010
Sumac	Rhus coriaria L.	Fruit	Antibacterial, antifungal, Antidiaretic digestive, hemorrhoids, rheumatism	Cakilcioglu et al 2011; Saganuwan 2010; Faydaoglu & Surucuoglu 2011
Sesame	Sesamum indicum L.	Seed	Laxatives, anti-diabetic, anti-oxidant, tranquilisers, digestive system diseases	Saganuwan 2010

Table 2- The concentrations of primary nutrients in the investigeted plants/spices

Çizelge 2- Tıbbi ve aromatik bitkilerin makro element içeriği

Plants/Spices	*Nutrient elements (%)*				
	N	*P*	*K*	*Ca*	*Mg*
Cinnamon	0.57[a]±0.02[b]	0.07±0.07	0.60±0.09	1.11±0.02	0.06±0.003
Thyme	1.57±0.04	0.30±0.05	0.84±0.09	1.15±0.03	0.15±0.003
Cumin	2.54±0.04	0.48±0.02	1.02±0.01	1.03±0.01	0.17±0.001
Nettle	3.61±0.10	0.50±0.05	1.08±0.04	1.15±0.01	0.10±0.002
Ginger	1.65±0.05	0.27±0.01	1.03±0.01	0.30±0.09	0.16±0.001
Dill	4.80±0.14	0.52±0.03	1.58±0.11	1.67±0.10	0.26±0.001
Sumac	0.71±0.02	0.17±0.01	0.70±0.03	0.37±0.03	0.09±0.005
Malva	2.50±0.11	0.53±0.03	1.04±0.05	1.19±0.01	0.17±0.002
Parsley	3.31±0.04	0.55±0.03	1.65±0.10	1.54±0.13	0.26±0.010
Turmeric	1.41±0.03	0.37±0.01	1.05±0.01	0.18±0.01	0.17±0.003
Galanga	0.87±0.05	0.23±0.03	1.03±0.01	0.23±0.04	0.17±0.005
Mint	2.90±0.02	0.41±0.04	1.16±0.07	1.25±0.04	0.21±0.010
Sesame	4.14±0.03	0.93±0.06	0.62±0.02	0.13±0.02	0.24±0.020
Fennel	2.61±0.03	0.66±0.05	1.06±0.01	1.00±0.05	0.26±0.020
Basil	3.44±0.03	0.46±0.01	1.05±0.01	1.18±0.05	0.19±0.004
Black Cumin	3.54±0.04	0.84±0.01	0.82±0.05	0.73±0.02	0.15±0.005
Coriander	2.30±0.05	0.76±0.02	0.99±0.02	0.83±0.03	0.17±0.003
Rosemary	0.90±0.06	0.17±0.04	1.02±0.01	1.20±0.01	0.15±0.004

a, mean; b, standard deviation

Boron content of nettle (67.3 mg kg^{-1}) and Mo content of parsley (5.73 mg kg^{-1}) were found higher than other plants (Table 3). Many foods and especially plant products are rich in B and therefore, no limit value could be set for dietary intake of B for the human. World Health Organization (WHO) states that a healthy adult can take 1-13 mg of B in daily diet (Demirtas 2010). The most suitable and healthy daily intake of B is 1.5 mg for children, 2 mg for teenager males, 2 mg for females and 3 mg for females before menopause, 2.5 mg for pregnant women and 2.5 mg for breastfeeding mothers (Demirtas 2010). Molybdenum concentrations of plants changes by seasons as well as the Mo concentration and pH of the soil. Molybdenum concentrations can be 0.5-100 mg kg^{-1} in dry matter of plants grown in Mo rich soils. WHO (1993) recommends 0.1-0.3 mg of daily Mo intake for adults.

The results of heavy metal analyses indicated that Al concentration of rosemary (2087 mg kg^{-1}), Co of galanga (1.35 mg kg^{-1}), Cr of cumin (1.36 mg kg^{-1}), Cd of thyme (0.26 mg kg^{-1}), Ni of mint (4.39 mg kg^{-1}) and Pb of malva (1.69 mg kg^{-1}) are higher than those of the other plants. Daghan et al (2013) stated that the critical Ni concentrations for susceptible plants is >10 mg kg^{-1} and for slightly tolerant plants is >50 mg kg^{-1}. The Ni findings in the current study are lower than the specified reports of the same author.

The concentrations of Pb and Cd reported by WHO (1999) for medicinal and aromatic plants

Table 3- The concentrations of secondary nutrients in the investigated plants/spices

Çizelge 3- Tıbbi ve aromatik bitkilerin mikro element içeriği

Spices	*Elements (mg kg^{-1})*					
	Fe	*Mn*	*Zn*	*Cu*	*B*	*Mo*
Cinnamon	59[a]±9[b]	193±4	14±0.71	1.8±0.20	12.8±0.31	0.41±0.26
Thyme	221±21	50±5	28±2.43	8.2±0.77	32.6±1.72	0.56±0.07
Cumin	579±99	51±7	38±1.49	3.8±0.31	23.6±2.14	0.39±0.05
Nettle	237±15	65±6	31±2.34	8.7±0.25	67.3±5.19	0.44±0.09
Ginger	321±20	227±11	30±1.61	6.4± 0.55	7.3±0.35	0.52±0.06
Dill	214±7	86±5	48±2.90	9.7±0.74	39.0±2.27	0.90±0.09
Sumac	132±25	7±1	12±0.92	4.1±0.29	11.5±0.66	0.15±0.01
Malva	253±37	45±2	49±1.86	8.9±0.70	39.7±3.30	0.96±0.28
Parsley	242±24	110±11	70±5.65	10.4±0.56	55.0±6.38	5.73±2.82
Turmeric	294±15	59±9	16±1.68	3.3±0.26	5.4±0.07	0.90±0.02
Galanga	502±40	315±16	33±2.78	3.8±0.29	6.2±0.30	0.24±0.08
Mint	543±54	122±3	33±1.67	9.3±0.87	41.4±1.30	0.44±0.08
Sesame	83±3	24±1	76±1.01	2.4±0.38	12.9±0.09	1.76±0.35
Fennel	103±14	42±3	44±1.18	12.5±0.94	36.1±2.20	0.12±0.02
Basil	689±17	90±2	53±0.90	19.3±0.60	39.9±0.98	0.82±0.03
Black Cumin	107±5	32±1	79±1.36	13.9±1.39	37.9±1.75	0.21±0.02
Coriander	197±51	47±5	57±2.49	18.6±3.95	30.0±1.51	0.36±0.05
Rosemary	338±25	49±3	28±2.65	7.0±0.65	44.5±1.80	0.40±0.03

a, mean; b, standard deviation

are 10 and 0.3 mg kg^{-1}, respectively. In our study, Pb and Cd concentrations were found to be much lower than these values (Table 4). Previous studies have established that medicinal and aromatic plants can contain some toxic heavy metals like Cd, As, Pb and Hg (Obiajunwa et al 2002; Olukayode Ajasa et al 2004). Hina et al (2011) analysed heavy metal concentrations of 7 different medicinal plants taken from public markets in Karachi and reported the highest Cd concentration for *Onosma bracteatum* (4.91 mg kg^{-1}) and fennel (4.89 mg kg^{-1}) samples. In another study carried out by Dwivedi & Dey (2002), Pb and Cd concentrations were determined to change between 2.62-32.76 mg kg^{-1} and 0.002-0.056 mg kg^{-1}, respectively, in the heavy metal analysis conducted on 28 different commonly used medicinal plants.

It is known that Al concentration is higher in plants than in animal feed and the Al content of plants differ due to the soil and atmospheric conditions. In different studies, daily Al intake of humans is predicted to be 1.53-160 mg (Sorensen et al 1974). Chromium concentration of wheat flour was reported to be 5-10 µg kg^{-1} (Anderson et al 1992) and in some spices like black pepper it could present at higher concentrations than those of the other foods (Akgünlü 2012). Daily dietary Cr intake of human is recommended as 60 µg by WHO (Krejpcio 2001). With respect to Co which is an element found in the structure of B12 vitamin,

Table 4- Heavy metal concentrations of the investigeted spices

Çizelge 4- Tıbbi ve aromatik bitkilerin ağır metal içeriği

Spices	*Elements (mg kg^{-1})*					
	Al	*Co*	*Ni*	*Pb*	*Cd*	*Cr*
Cinnamon	402[a]±52[b]	0.05±0.002	0.14±0.01	0.28±0.04	0.16±0.01	0.10±0.01
Thyme	810±72	0.20±0.02	3.52±0.31	0.48±0.09	0.26±0.04	0.42±0.05
Cumin	1020±66	0.30±0.03	3.39±0.25	0.42±0.05	0.05±0.005	1.36±0.16
Nettle	730±41	0.17±0.02	1.96±0.27	0.49±0.07	0.03±0.003	0.93±0.13
Ginger	1215± 57	0.23±0.02	1.32±0.05	1.67±0.05	0.05±0.02	0.56±0.06
Dill	496±42	0.23±0.03	2.02±0.18	0.81±0.09	0.13±0.04	0.70±0.10
Sumac	358±49	0.08±0.01	1.41±0.13	0.73±0.10	0.02±0.003	0.85±0.17
Malva	578±46	0.18±0.02	1.45±0.19	1.69±0.24	0.08±0.01	0.96±0.16
Parsley	267±52	0.22±0.03	4.26±0.64	1.14±0.09	0.12±0.04	0.61±0.06
Turmeric	263±8	0.24±0.02	0.64±0.04	0.33±0.07	0.03±0.02	0.55±0.04
Galanga	483±11	1.35±0.12	2.80±0.21	0.86±0.07	0.03±0.02	1.28±0.24
Mint	345±12	0.61±0.05	4.39±0.65	0.85±0.13	0.04±0.02	1.17±0.16
Sesame	3±1	0.17±0.01	0.46±0.03	0.17±0.01	0.04±0.003	0.18±0.005
Fennel	21±7	0.21±0.02	3.53±0.19	0.31±0.06	0.03±0.002	0.44±0.02
Basil	574±182	0.48±0.01	0.90±0.02	0.91±0.09	0.04±0.003	0.74±0.02
Black Cumin	330±29	0.08±0.01	4.25±0.43	0.23±0.02	0.07±0.005	0.22±0.02
Coriander	427±94	0.18±0.02	3.29±0.33	0.23±0.03	0.07±0.007	0.38±0.05
Rosemary	2087±100	0.16±0.01	1.81±0.10	1.19±0.11	0.03±0.002	0.72±0.07

a, mean; b, standard deviation

WHO (2006) recommends 0.1 µg of daily intake through 2.4 µg B12 vitamin. In a recent study, only trace amounts of Ni, Al, Cr and Co have been found necessary for all living beings, except for other heavy metals (Imelouane 2011).

4. Conclusions

It is concluded that it is important to analyse the chemical compositions of medicinal and aromatic plants, commonly used as spices and traditional health aids, in order to assure their safety. The medicinal plants investigated in the current study, which has well known positive effects on human health are determined to be rich in minerals. However, it is noteworthy that some heavy metals such as Pb, Cd, Cr could be harmful to health according to international references, were measured above the reported critical levels. Therefore, if possible, controlling the growth conditions of medicinal plants, unless otherwise constantly monitoring the market, are recommended for health friendly supply of medicinal and aromatic plants.

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