Pol. J. Environ. Stud. Vol. 23, No. 1 (2014), 177-186

Original Research

Effects of Brewing Time on the Content of Minerals in Infusions of Medicinal Herbs

Iwona Sembratowicz*, Elżbieta Rusinek-Prystupa**

Department of Biochemistry and Toxicology, Agricultural University in Lublin,
Akademicka 13, 20-950 Lublin, Poland

Received: 12 May 2013
Accepted: 22 December 2013

Abstract

The aim of this study was to analyze the influence of brewing time on the content of select trace elements (Cu, Zn, Fe, Mn) and heavy metals (Pb, Cd) in homogeneous and mixed herbs used in therapy of digestive system diseases and in regulation of digestive processes.

The study involved 10 types of preparations of herbal teas (mono- and multi-component sachets) acting on the gastrointestinal tract and digestive processes. Also, four types of black teas were examined for comparison. Aqueous extracts were made from each sample. As the manufacturers recommend herbal teas to be brewed for 5-15 min, in our study analyses were carried out for aqueous extracts brewed for 5 and 10 min.

Contents of minerals in dry matter of the analyzed herbal and black teas and herbal blends were very differentiated, which could be due to species diversity and origin of the raw material. The brewing time had no significant effect on the percentage of the analyzed microelements extraction to the aqueous phase, however in the case of copper, manganese and lead the longer time of extraction resulted in a reduced yield of this process. An opposite dependency was noted in the case of iron, cadmium, and zinc.

Keywords: time of brewing, infusion, medicinal herbs, black tea

Introduction

For thousands of years medicinal herbs have been used to treat diseases, to bring relief by alleviation of symptoms related to these diseases, and to ensure good health condition. Contemporary times – though characterized by a much higher number of drugs produced via chemical synthesis – did not curb the significance of plants as a source of therapeutic substances. On the contrary, interest in herbal medicine has been constantly increasing and the use of phytopharmaceutics currently reaches 25% [1, 2]. Owing to valuable therapeutic properties and flavor attributes of herbs and herbal blends, they are eagerly applied in the human diet. Herbal raw materials being components of herbal teas are rich sources of macro- and microelements as well as biologically-active compounds, vitamins, enzymes, or biocatalysts [3]. On the other hand, as a consequence of progressing contamination of the environment they may also contain hazardous concentrations of toxic substances, including heavy metals like lead and cadmium [4].

Owing to the fact that herbal materials are usually used in the form of aqueous extracts, it seems crucial to know the percentage of extraction of desirable substances, and also of the hazardous and even toxic ones to infusions. Interesting seems also to determine whether the yield of this process is determined by the duration of the extraction process.

In view of the above, the aim of this study was to analyze the effect of brewing time on contents of select microelements (Cu, Zn, Fe, Mn) and heavy metals (Pb, Cd) in homogenous herbs and herbal blends used in therapy of gastrointestinal tract diseases and in regulation of digestive functions.

*e-mail: iwona.s1969@interia.pl
**e-mail: elzbieta.rusinek@up.lublin.pl

Table 1. Origin, composition, and action of herbal preparations.

Preparation name	Producer	Composition	Indications
Herbal teas			
Menthae piperitae folium	Herbapol-Lublin	peppermint (leaves)	digestive disorders (dyspepsia, flatulence)
Chamomillae anthodium		chamomile (dried flower)	digestive disorders, cramps in the abdominal cavity, sensation of fullness, flatulence, external application in inflammatory states and paralysis
Absinthii herba		wormwood	lack of appetite, dyspepsia
Foeniculi fructus		fennel (fruit)	cramps of the stomach and intestines, sensation of fullness and flatulence, in airways infections as expectorant
Salviae folium		sage (leaves)	inflammatory states of oral cavity, gums, and throat; hyperhidrosis; digestive disorders
Hyperici herba		St. John's wort	digestive disorders, stimulation of gastric juice secretion
Herbal mixes			
"Slim line"	Vitax	mate leaf, common nettle, dill fruit, apple, bean pericarp, aroma, L-carnitine	slimming process enhancement, cleansing effects
"Slender line"		apple, Pu-erh tea, star aniseed fruit, mate leaf, mint leaf, lemon skin, inulin, dog rose fruit, orange skin, aromas, raspberry leaf	digestion facilitation, metabolism enhancement
"Good digestion"	US Pharmacia	mint, caraway fruit, thyme, green tea leaf, Pu-erh tea leaf, lemon grass, orange skin, marjoram	proper digestion enhancement
"Gastrosan"	Herbapol-Lublin	chamomile dry flower, marshmallow root, mint leaf	protective and anti-inflammatory agent to mucous membranes of the gastrointestinal tract, relaxating effect in the stomach and intestine
Black teas			
"Eternal finest"	Oskar	mixture of black Indian and Ceylon teas	rich source of antioxidants, slightly stimulating effect, digestive processes regulating effect
"Lipton Yellow Label Tea"	Unilever	composition of over 20 species of black teas of various origin	
"Saga"		classic black tea	
"Tetley Earl Grey"	Tata Tea Limited	Indian black tea with bergamot aroma	

Material and Methods

Experimental Material and Its Origin

Experiments were conducted with fix-type herbal teas (single-component and multi-component sachets) and infusions prepared from them. The teas were purchased in pharmacies and drugstores in the city of Lublin in February to April 2009. The study included 10 types of preparations affecting the gastrointestinal system and digestive processes. For comparison, analyses were also conducted for four types of black teas. From each kind of tea 5 samples were analyzed. Aqueous extracts were prepared from each sample. Table 1 presents data on the origin and composition of herbal preparations and on the spectrum of their actions.

Preparation of Aqueous Extracts

Aqueous extracts in the form of infusions were prepared by weighing 3 g of the raw material and pouring it with 100 mL of boiling distilled water. Considering that producers recommend a brewing time of 5-15 min, the study was conducted with aqueous extracts brewed for 5 and 10 min.

Determination of Contents of Mineral Compounds

Contents of minerals were determined in dry tea materials after incineration of the plant material in a muffle furnace at 450ºC. The resultant ash was solubilized in crucibles using 6N of spectrally pure hydrochloric acid. Determination of the elements in aqueous extracts was pre-

Table 2. Content of copper in the analyzed groups of teas.

	Product name	Copper (Cu)				
		Dry matter of product (mg·kg⁻¹ d.m.)	After 5 min of extraction (mg·dm⁻³)	Extraction rate (%)	After 10 min of extraction (mg·dm⁻³)	Extraction rate (%)
Herbal teas	Peppermint	12.12±1.88	0.016±0.004	13.26±1.71	0.013±0.004	10.96±1.16
	Chamomile	8.61±0.87	0.013±0.001	15.28±2.05	0.011±0.002	12.86±1.00
	Wormwood	6.56±0.96	0.012±0.001	18.32±1.21	0.008±0.007	15.23±1.15
	Fennel	8.92±1.00	0.028±0.001	31.27±2.31	0.020±0.004	22.22±1.96
	Sage	15.48±0.97	0.018±0.003	11.74±0.90	0.012±0.001	7.74±0.99
	St. John's wort	8.83±0.67	0.021±0.001	24.00±0.91	0.016±0.002	17.36±1.46
	Mean	10.09b	0.018b	18.98ab	0.014b	14.44ab
	SD	3.14	0.006	7.11	0.004	4.95
Herbal mixes	"Slim line"	13.13±2.08	0.015±0.003	11.25±0.81	0.013±0.003	9.71±1.12
	"Slender line"	17.04±0.88	0.016±0.001	9.69±0.95	0.014±0.002	8.14±0.90
	"Good digestion"	26.18±1.09	0.044±0.003	16.81±1.81	0.039±0.001	14.85±0.87
	"Gastrosan"	12.35±2.66	0.017±0.005	13.21±1.76	0.015±0.002	12.22±1.47
	Mean	17.18ab	0.023b	12.74b	0.020ab	11.23b
	SD	5.95	0.013	3.03	0.011	2.83
Black teas	"Eternal finest"	32.71±2.55	0.083±0.006	25.53±0.99	0.070±0.007	21.34±0.95
	"Lipton Yellow Label Tea"	20.51±0.85	0.035±0.003	17.07±1.06	0.025±0.004	12.02±1.63
	"Saga"	14.26±1.02	0.029±0.003	20.41±1.27	0.027±0.004	18.93±1.87
	"Tetley Earl Grey"	17.23±1.26	0.039±0.006	22.48±2.12	0.034±0.001	19.77±0.96
	Mean	21.18a	0.047a	21.39a	0.039a	18.02a
	SD	7.45	0.026	3.43	0.019	3.92

a, b – values in the same rows marked with different letters differ significantly at p≤0.05

ceded by solvent evaporation. Further procedure was analogous to that presented above for the dry material.

The contents of copper, zinc, iron, manganese, lead, and cadmium in the analyzed herbs were assayed by the Central Apparatus Laboratory, University of Life Science in Lublin. This analytical facility and their quality control system are certified under ISO 9001:2000 [5]. Copper, zinc, iron, and manganese were assayed by flame AAS. The content of Cd and Pb was determined by atomic absorption spectrometry in a Varian SpectraAA 880Z, including atomization in a graphite furnace and using the Zeeman background correction. Argon was used as pure gas. Copper was determined at a wavelength (λ) of 324.8 nm, zinc at λ = 213.9 nm, iron at λ = 248.3 nm, manganese λ = 279.5 nm, lead at λ = 217 nm, and cadmium at λ = 228.8 nm. The measuring analytical ranges were 0-1 $mg \cdot l^{-1}$ for copper, 0-2 $mg \cdot l^{-1}$ for zinc, 0-10 $mg \cdot l^{-1}$ for iron, and 0-1 $mg \cdot l^{-1}$ for manganese, 0-50 $\mu g \cdot l^{-1}$ for lead, and 0-5 $\mu g \cdot l^{-1}$ for cadmium. For calibration and validation of the analytical procedure we used certified reference material (CRM) – oriental tobacco (CTTA-OTL-1, Poland). Results were presented in $mg \cdot kg^{-1}$ d.m. (in dry materials) and in $mg \cdot dm^{-3}$ and $\mu g \cdot dm^{-3}$ (in extracts).

Results obtained for herbal dry materials and aqueous extracts enabled calculating the percentage of individual element extractions to infusions. Respective results were presented in percentages (%) of extraction. All chemical analyses were made in duplicate.

Statistical Analysis

The obtained numerical data were subject to statistical analysis by means of STATISITCA 6.0 PL. The statistical significance of differences between mean values was estimated by a one-way variance analysis ANOVA at a significance level of 0.05.

Results and Discussion

Contents of microelements in medicinal plants are influenced by genetically-determined properties of a plant as well as by external factors, including geographic location, soil type and profile, fertilization, availability of water, pollution by pesticides or dusts, and gases.

Table 3. Content of zinc in the analyzed groups of teas.

	Product name	Zinc (Zn)				
		Dry matter of product (mg·kg^{-1} d.m.)	After 5 min of extraction (mg·dm^{-3})	Extraction rate (%)	After 10 min of extraction (mg·dm^{-3})	Extraction rate (%)
Herbal teas	Peppermint	39.93±0.08	0.098±0.008	24.49±2.119	0.115±0.005	28.85±1.24
	Chamomile	45.76±2.99	0.091±0.004	19.95±1.523	0.152±0.013	33.20±2.75
	Wormwood	110.21±5.48	0.336±0.04	30.39±1.98	0.416±0.013	37.80±1.96
	Fennel	47.39±2.25	0.173±0.018	36.46±2.58	0.183±0.015	38.85±1.71
	Sage	57.04±2.14	0.168±0.018	29.55±3.23	0.243±0.002	42.59±1.85
	St. John's wort	32.31±2.12	0.145±0.014	44.73±2.008	0.171±0.002	53.12±3.56
	mean	55.44a	0.168ab	30.93b	0.213a	39.02ab
	SD	26.47	0.085	8.47	0.102	8.10
Herbal mixes	"Slim line"	62.05±2.11	0.317±0.003	51.16±1.37	0.327±0.010	52.73±0.12
	"Slender line"	34.05±1.41	0.184±0.003	54.19±1.48	0.200±0.014	58.61±2.02
	"Good digestion"	39.29±1.14	0.207±0.013	52.61±1.69	0.236±0.006	60.06±1.01
	"Gastrosan"	40.10±2.96	0.125±0.011	31.25±2.45	0.113±0.011	33.27±0.85
	mean	43.87ab	0.208a	47.30a	0.224a	51.17a
	SD	11.36	0.073	9.87	0.074	11.21
Black teas	"Eternal finest"	33.90±1.36	0.087±0.008	25.66±1.23	0.090±0.001	26.57±1.33
	"Lipton Yellow Label Tea"	43.21±1.57	0.098±0.006	22.78±2.06	0.124±0.013	28.74±2.14
	"Saga"	28.18±2.01	0.116±0.007	41.03±1.75	0.128±0.010	45.26±1.28
	"Tetley Earl Grey"	53.78±1.10	0.141±0.008	26.17±1.05	0.154±0.002	28.67±0.93
	mean	39.77b	0.110b	28.91b	0.124b	32.31b
	SD	10.22	0.022	7.55	0.025	7.96

a, b – values in the same rows marked with different letters differ significantly at p≤0.05

Concentrations of some elements are also affected by technological processes [6].

Results of determinations of the contents of the analyzed mineral compounds in the investigated products were presented in Tables 2-7.

The analysis of mean contents of copper (Table 2) in dry matter of the investigated groups of teas demonstrated that its concentration in leaves of black teas (21.18 mg·kg^{-1} d.m.) was significantly (P≤0.05) higher than in the mono-component herbal teas (10.09 mg·kg^{-1} d.m.). A study by Grela and Dzida [7] showed a higher concentration of copper in St. John's wort, at the mean content of this element in the analyzed herbs at 13.42 mg·kg^{-1} d.m. Błoniarz et al. [8], who were analyzing copper concentrations in herbal teas (mono- and multi-component) applied in therapy of cardiovascular diseases, obtained values fitting in the range of 3.19-25.72 mg·kg^{-1} d.m. According to Kabata-Pendias [6], the optimal content of copper in plants growing in Poland ranges from 5.0 to 20.0 mg·kg^{-1} d.m. A similar concentration of this element in black teas was reported by Mularczyk-Oliwa and Długaszek [9]. In turn, research by Gajewska et al. [10] indicated that copper content in dry matter of black teas was 31.3 mg·kg^{-1} d.m. on average. Such a high concentration of copper in dry materials of teas was, probably linked with the fact that it is a component of fungicides applied regularly on tea plantations for protection against pathogens inducing leaf infestation. Investigations by Buliński and Błoniarz [11], who were analyzing contents of different metals in infusions of black teas, demonstrated 10.8-25.6% extraction of copper to the aqueous phase (teas were brewed for 15 min). Results of our study show that the percentage of this metal extraction to infusions reached 21.39% after 5 min and 18.02% after 10 min of brewing, on average. These values were significantly (P≤0.05) higher than those noted for the multi-component herbal teas. The content of copper in black tea infusions brewed for 5 and 10 min accounted for 0.047 mg·dm^{-3} and 0.039 mg·dm^{-3}, respectively, which covers ca. 1.0-1.2% of recommended dietary allowance (RDA) for this microelement (assuming an intake of 3 cups of infusion a day). According to contemporary dietary guidelines, the RDA for copper in the case of an adult person reaches 2.6-3.1 mg [12].

The mean content of zinc (Table 3) in dry matter of the analyzed groups of teas fluctuated between 39.77 mg·kg^{-1}

Table 4. Content of iron in the analyzed groups of teas.

	Product name	Iron (Fe)				
		Dry matter of product ($mg\cdot kg^{-1}$ d.m.)	After 5 min of extraction ($mg\cdot dm^{-3}$)	Extraction rate (%)	After 10 min of extraction ($mg\cdot dm^{-3}$)	Extraction rate (%)
Herbal teas	Peppermint	405.43±11.66	0.34±0.06	8.37±1.06	0.52±0.12	9.30±1.13
	Chamomile	163.97±36.63	0.09±0.02	5.66±1.44	0.11±0.04	7.61±0.54
	Wormwood	263.10±39.68	0.13±0.03	4.70±0.98	0.20±0.07	7.70±0.85
	Fennel	96.27±7.23	0.10±0.04	6.91±1.05	0.11±0.05	10.80±0.46
	Sage	188.43±35.03	0.11±0.05	6.55±1.09	0.12±0.06	8.83±0.92
	St. John's wort	83.50±14.40	0.09±0.04	11.20±0.79	0.10±0.04	12.73±0.70
	mean	200.12	0.14	7.23	0.18	9.50
	SD	111.97	0.10	1.44	0.11	2.05
Herbal mixes	"Slim line"	197.90±45.34	0.16±0.03	8.39±0.96	0.20±0.05	10.19±0.07
	"Slender line"	176.33±74.05	0.08±0.03	4.56±0.50	0.15±0.08	8.19±1.01
	"Good digestion"	279.59±44.15	0.15±0.05	5.13±0.98	0.20±0.11	7.08±1.00
	"Gastrosan"	155.35±27.95	0.10±0.01	9.12±1.57	0.11±0.04	9.66±0.98
	mean	192.30	0.12	6.80	0.17	8.78
	SD	75.09	0.04	2.26	0.06	1.48
Black teas	"Eternal finest"	195.73±39.80	0.10±0.03	5.05±0.48	0.14±0.04	6.88±1.27
	"Lipton Yellow Label Tea"	326.18±74.40	0.24±0.02	7.42±1.00	0.26±0.09	7.83±1.02
	"Saga"	402.22±70.71	0.22±0.02	5.50±1.32	0.24±0.04	6.11±1.45
	"Tetley Earl Grey"	333.73±36.27	0.20±0.07	5.96±0.99	0.22±0.08	6.55±1.16
	mean	314.41	0.19	5.98	0.21	6.84
	SD	91.66	0.03	1.26	0.06	1.24

d.m. in black teas to 55.44 $mg\cdot kg^{-1}$ d.m. in mono-component herbal teas ($P\leq0.05$). In the herbal teas examined, the concentration of this element fitted within a wide range from 32.31 $mg\cdot kg^{-1}$ d.m. in St. John's wort to 110.21 $mg\cdot kg^{-1}$ d.m. in wormwood. Blicharska et al. [13], who were investigating multi-component and mono-component herbal teas, also obtained very diversified contents of zinc that ranged from 4.3 $mg\cdot kg^{-1}$ d.m. to 64.4 $mg\cdot kg^{-1}$ d.m. In turn, results achieved by those authors for fennel and sage were slightly lower than zinc contents determined in our study. Czech and Rusinek [14] assayed slightly higher concentrations of this microelement (above 41 $mg\cdot kg^{-1}$ d.m.) in black teas. The percentage of zinc extraction to infusions of the analyzed teas may be deemed relatively high, after 5 min of brewing it accounted, on average, for 28.91% in black teas, 30.93% in herbal teas, and as much as 47.30% in herbal mixes. The difference between herbal mixes and the other groups of teas turned out to be statistically significant ($P\leq0.05$). In all groups of products, the extension of the brewing time caused a tangible increase in the yield of zinc extraction to the infusion, especially in herbal teas where it increased by over 8% on average. Among the analyzed groups of products, the best sources of this element appeared to be extracts from herbal mixes and from homogenous herbs (brewed for 10 min) that contained significantly ($P\leq0.05$) more zinc than the infusions from black teas. Three cups a day of multi-component herbal tea (brewed for 10 min) containing 0.224 mg of zinc per 1 dm^3 on average, may cover ca. 1.41% of RDA that reaches mean 9.5 mg for an adult person [12].

Among the analyzed products, the highest average content of iron was determined in black teas (314.41 $mg\cdot kg^{-1}$ d.m) (Table 4). Higher concentrations of this element in dry matter of black teas (from 556.8 to 623.2 $mg\cdot kg^{-1}$ d.m.) than those achieved in our study were reported by Czech and Rusinek [14]. Out of the analyzed herbal teas, especially rich in iron was the peppermint tea – 435.52 $mg\cdot kg^{-1}$ d.m., with the average iron concentration of 200.12 $mg\cdot kg^{-1}$ d.m. Ulewicz-Magulska et al. [15] demonstrated higher concentrations of this metal in herbs and leaves of therapeutic plants, i.e. 369.6 $mg\cdot kg^{-1}$ d.m. in herbs and 451.4 $mg\cdot kg^{-1}$ d.m. in leaves. Research by Bielicka-Giełdoń et al. [16], conducted with various herbal seasonings, demonstrated that the concentration of this metal might exceed 1,100

Table 5. Content of manganese in the analyzed groups of teas.

	Product name	Manganese (Mn)				
		Dry matter of product (mg·kg^{-1} d.m.)	After 5 min of extraction (mg·dm^{-3})	Extraction rate (%)	After 10 min of extraction (mg·dm^{-3})	Extraction rate (%)
Herbal teas	Peppermint	86.57±23.24	0.17±0.07	18.58±3.17	0.11±0.07	17.14±2.95
	Chamomile	121.00±4.20	0.25±0.03	20.54±3.56	0.21±0.04	17.26±2.71
	Wormwood	96.68±20.22	0.30±0.07	30.91±1.21	0.27±0.08	27.57±2.65
	Fennel	182.43±11.64	0.23±0.04	12.63±2.00	0.18±0.02	10.19±1.94
	Sage	203.62±22.75	0.45±0.10	21.97±2.75	0.30±0.04	14.64±0.99
	St. John's wort	144.37±22.98	0.57±0.12	39.21±3.21	0.48±0.14	33.07±4.13
	mean	139.11b	0.33b	23.97ab	0.27b	19.98ab
	SD	46.75	0.16	9.25	0.13	8.39
Herbal mixes	"Slim line"	94.41±7.33	0.20±0.03	21.41±4.41	0.15±0.02	16.20±3.18
	"Slender line"	182.34±17.53	0.32±0.05	17.81±3.26	0.29±0.03	16.09±2.35
	"Good digestion"	156.60±11.58	0.33±0.09	12.61±2.87	0.24±0.10	9.22±3.50
	"Gastrosan"	85.48±25.74	0.19±0.08	21.89±2.11	0.15±0.07	16.60±3.37
	mean	154.71ab	0.26b	18.43b	0.21b	14.53b
	SD	74.49	0.09	4.78	0.08	4.17
Black teas	"Eternal finest"	566.20±126.54	2.28±0.96	40.51±13.90	2.03±0.85	35.09±9.51
	"Lipton Yellow Label Tea"	616.10±86.57	1.78±0.05	29.18±3.55	1.58±0.06	26.01±4.25
	"Saga"	457.37±84.41	1.49±0.25	33.95±11.55	1.43±0.21	31.49±3.70
	"Tetley Earl Grey"	505.03±132.32	1.34±0.30	27.06±5.81	1.20±0.24	24.01±2.24
	mean	536.18a	1.72a	32.68a	1.56a	29.15a
	SD	112.67	0.58	9.85	0.50	6.64

a, b – values in the same rows marked with different letters differ significantly at $p \leq 0.05$

mg·kg^{-1} d.m. in e.g. marjoram. A high concentration of iron (above 500 mg·kg^{-1} d.m.) was also assayed in basil, oregano, and "Herbes de Provence," but some other herbs like fennel, oak bark, and St. John's wort were characterized by significantly lower levels (20.0-78.9 mg·kg^{-1} d.m.). Despite relatively high concentrations of iron in dry materials of the analyzed teas, its concentration in infusions was low and did not exceed 0.26 mg·dm^{-3}, which resulted from an insignificant extraction of this metal to the aqueous phase (max. 10.8% from fruits of fennel). Higher concentrations of iron were noted only in tea from peppermint, i.e. 0.34 mg·dm^{-3} and 0.52 mg·dm^{-3} after 5 and 10 min of brewing, with extraction rates of 8.37% and 9.3%, respectively. Peppermint tea may, therefore, be considered as a good source of this metal in a man's diet, as 3 cups of this tea drunk a day enable covering, respectively, 1.36% and 2.08% of RDA (depending on brewing time).

Generally, the mono-component herbal teas were characterized by better extraction parameters than the herbal blends, particularly the black teas with the lowest percentage of extraction reaching max. 6.84% after 10 min of brewing. Data from the study by Błoniarz et al. [8] indicate that the percentage of iron extraction from herbal teas and herbal tea blends ranged from 3.9% to 25.6%. A lower percentage of iron extraction, by ca. 3.5% on average, was assayed in the case of black teas [10, 14]. Results of our study demonstrate that in all groups of teas the longer time of brewing had an insignificant effect on the percentage of iron extraction to infusions.

The content of manganese (Table 5) in dry matter of the analyzed products ranged from 86.57 mg·kg^{-1} d.m. (peppermint tea) to 616.1 mg·kg^{-1} d.m. (black tea "Lipton"). Among the investigated herbal materials, the richest source of manganese turned out to be sage (203.62 mg·kg^{-1} d.m.). In contrast, Grela and Dzida [7] reported several times higher content of this element in St. John's wort, compared to other analyzed herbs. Results obtained by Błoniarz et al. [8] demonstrate that manganese content in homogenous herbs and in herbal blends applied in the therapy of cardiovascular diseases fitted within the range of 16.9-268.4 mg·kg^{-1} d.m. The mean concentration of manganese in the analyzed black teas reached 536.18 mg·kg^{-1} d.m. and was significantly ($P \leq 0.05$) higher than that noted in herbs (139.11 mg·kg^{-1} d.m.) and herbal blends (154.71 mg·kg^{-1}

Table 6. Content of lead in the analyzed groups of teas.

	Product name	Lead (Pb)				
		Dry matter of product (mg·kg⁻¹ d.m.)	After 5 min of extraction (μg·dm⁻³)	Extraction rate (%)	After 10 min of extraction (μg·dm⁻³)	Extraction rate (%)
Herbal teas	Peppermint	0.72±0.12	4.04±0.54	56.10±2.67	4.02±0.35	54.59±1.92
	Chamomile	0.56±0.08	2.93±0.38	52.08±1.07	2.25±0.37	39.82±1.20
	Wormwood	0.36±0.05	1.78±0.89	45.78±1.82	1.58±0.15	44.53±1.74
	Fennel	0.28±0.10	1.47±0.60	52.65±2.13	1.29±0.46	47.11±2.46
	Sage	0.69±0.16	4.20±0.97	61.22±1.94	3.89±0.95	56.56±0.65
	St. John's wort	0.48±0.10	3.27±0.79	67.30±2.01	2.06±0.53	42.46±1.70
	mean	0.51	2.92	55.85	2.52	47.51
	SD	0.19	1.22	7.30	1.18	6.47
Herbal mixes	"Slim line"	0.43±0.11	2.15±0.44	50.41±2.09	1.87±0.34	43.95±2.78
	"Slender line"	0.67±0.07	4.17±0.30	62.62±2.10	3.92±0.56	58.66±2.80
	"Good digestion"	0.77±0.08	4.41±0.56	57.20±1.24	4.33±0.56	56.20±1.75
	"Gastrosan"	0.25±0.05	1.52±0.31	61.67±1.10	1.29±0.27	52.17±1.05
	mean	0.53	3.06	57.98	2.85	52.75
	SD	0.21	1.24	13.94	1.28	12.52
Black teas	"Eternal finest"	0.66±0.08	2.35±0.18	35.69±1.41	2.21±0.29	33.46±0.64
	"Lipton Yellow Label Tea"	0.75±0.15	3.13±0.59	41.75±1.23	2.20±0.49	29.23±0.68
	"Saga"	0.85±0.06	4.84±0.31	46.77±1.01	4.31±0.39	50.51±1.41
	"Tetley Earl Grey"	1.07±0.10	4.55±0.60	46.20±1.26	4.47±0.75	41.90±0.92
	mean	0.83	3.72	44.25	3.30	38.78
	SD	0.31	1.37	12.92	1.34	11.69

d.m.). Czech and Rusinek [14], who were investigating contents of minerals in black, green, and red teas, determined even higher concentrations of this metal in black teas (771.5 mg·kg⁻¹ d.m. on average).

Among the analyzed teas (mono-component herbal teas, multi-component herbal teas, and black teas) the highest extraction rates of manganese to the aqueous phase were determined in black teas, where they accounted for 32.68% after 5 min and for 29.15% after 10 min of brewing. Similar extraction rates were noted by Buliński and Błoniarz [11] for black leaf teas, but they were brewed for 15 min. Owing to a high concentration of manganese in dry leaves of tea and to a relatively high percentage of its extraction to the aqueous phase, infusions from black tea may be considered a valuable source of this metal in a human diet. Drinking 3 cups a day of a tea infusion containing 1.56-1.72 mg of manganese per 1 dm³ on average (depending on brewing time), allows covering from 43% to 52% of AI (mean 2.1 mg for an adult person) [17].

In all analyzed groups of tea, the prolongation of brewing time to 10 min decreased manganese extraction rate by 3.5-3.9%. Research by Sędrowicz et al. [18] with black teas demonstrated the highest content of this element in infusions brewed for 5 min and 30 min.

Elements with the greatest toxicological significance include lead and cadmium. The regulation of the minister of health of 13 January 2003 stipulates the permissible contents of these elements in herbs and seasonings at 2 mg·kg⁻¹ d.m. for lead and at 0.3 mg·kg⁻¹ d.m. for cadmium [19]. In turn, EU regulations binding in Poland that refer to contaminants in food products do not stipulate the highest permissible levels of hazardous elements in tea and dry herbal materials [20]. Today, the provisional tolerable weekly intake (PTWI) of these metals from all sources specified by the FAO/WHO reaches: 25 μg/kg b.m. for Pb and Cd 7.0 μg/kg b.m. for Cd. As reported by Wojciechowska-Mazurek et al. [21], based on alarming epidemiological data, international experts postulate to decrease the existing PTWI values for toxic metals, i.e. for As, Hg, Pb, and Cd [22].

Under natural conditions, plants contain low quantities of lead that range from trace amounts to a few mg·kg⁻¹ d.m. Results of some studies suggest, however, that select herbal materials and tea leaves may be severely contaminated with lead [23-25]. Especially exposed to contamination with this

Table 7. Content of cadmium in the analyzed groups of teas.

	Product name	Cadmium (Cd)				
		Dry matter of product (mg·kg^{-1} d.m.)	After 5 min of extraction (µg·dm^{-3})	Extraction rate (%)	After 10 min of extraction (µg·dm^{-3})	Extraction rate (%)
Herbal teas	Peppermint	0.047±0.01	0.260±0.09	53.51±9.45	0.270±0.09	55.11±8.91
	Chamomile	0.038±0.01	0.174±0.06	44.57±8.76	0.234±0.07	60.27±10.10
	Wormwood	0.061±0.02	0.340±0.03	57.73±12.58	0.359±0.04	60.59±10.99
	Fennel	0.044±0.01	0.205±0.07	45.36±9.06	0.218±0.07	48.37±8.16
	Sage	0.067±0.01	0.264±0.07	38.97±5.45	0.376±0.09	55.64±6.30
	St. John's wort	0.113±0.02	0.475±0.16	41.19±6.99	0.500±0.17	43.38±7.51
	mean	0.061a	0.285a	46.67	0.321a	53.10
	SD	0.03	0.13	9.83	0.14	9.58
Herbal mixes	"Slim line"	0.037±0.01	0.160±0.08	41.76±8.00	0.185±0.08	48.70±6.80
	"Slender line"	0.025±0.01	0.062±0.04	22.76±7.10	0.069±0.05	25.21±8.45
	"Good digestion"	0.032±0.01	0.178±0.09	53.30±8.02	0.186±0.09	55.90±7.60
	"Gastrosan"	0.052±0.01	0.200±0.06	38.02±7.02	0.212±0.07	70.31±7.50
	mean	0.037ab	0.150b	38.96	0.163b	42.53
	SD	0.01	0.08	13.10	0.08	13.58
Black teas	"Eternal finest"	0.021±0.009	0.119±0.053	55.70±6.00	0.127±0.06	59.27±44.20
	"Lipton Yellow Label Tea"	0.018±0.005	0.078±0.03	43.17±4.79	0.078±0.02	44.30±8.88
	"Saga"	0.026±0.008	0.132±0.011	51.73±7.21	0.134±0.01	52.20±8.34
	"Tetley Earl Grey"	0.044±0.01	0.208±0.04	47.77±6.57	0.210±0.03	48.37±4.99
	mean	0.027b	0.134b	49.60	0.137b	50.93
	SD	0.012	0.06	5.32	0.06	6.43

a, b – values in the same rows marked with different letters differ significantly at $p \leq 0.05$

metal are plants originating from industrialized areas and these growing alongside heavy traffic roads [26].

As it results from data compiled in Table 6, the concentration of lead in dry matter of the analyzed products ranged from 0.28 mg·kg^{-1} d.m. in fennel to 1.07 mg·kg^{-1} d.m. in "Tetley Earl Grey" tea. Among the analyzed groups of teas, the most contaminated with lead turned out to be the black teas, where its concentration reached 0.83 mg·kg^{-1} d.m. on average. Results of our study are in agreement with findings of Buliński and Błoniarz [27], who were analyzing, among other things, the same types of black teas. Monitoring studies conducted by Sanitary and Epidemilogical Stations in Poland indicate that the mean concentration of lead in teas available on the Polish market reaches 0.36 mg·kg^{-1} [20]. In a few analyzed samples of Indian tea, however, analyses showed hazardously high levels of this metal (above 20.0 mg·kg^{-1}). Similar lead concentrations in herbal teas to these from our study were reported by Blicharska et al. [13] and Błoniarz et al. [28].

The analysis of the percentage of lead extraction to the aqueous phase demonstrated that it was similar in all groups of products and simultaneously very high, especially in the herbal teas (55.85% after 5 min and 47.51% after 10 min of extraction). Likewise, in the herbal teas, the longer time of brewing caused a decrease in lead extraction rate also in black teas, i.e. 44.25% after 5 min and 38.78% after 10 min. A study by Sędrowicz et al. [18] on the effect of extraction conditions on contents of minerals in black teas demonstrates that the maximal extraction of lead to infusions occurred after 2 min of brewing, which was followed by a decrease in the extraction rate. These authors emphasize that the percentage of lead and also cadmium extraction was positively influenced by infusion acidification with lemon juice or citric acid. Despite the lowest extraction rate of lead from the analyzed black teas, their infusions were characterized by the highest concentrations of this metal (3.72 µg·dm^{-3} on average). Considering that the PTWI value for lead is at 1.75 mg (for an adult person with a body mass of 70 kg), 3 cups of tea may provide ca. 0.91% of PTWI for this metal. Winiarska-Mieczan et al. [29], who were assaying contents of lead and cadmium in herbal mixes brewed for 10 min, report that the same quantities of multi-component herbal teas provide 0.34% of PTWI for lead at ca. 44% extraction of this metal to infusion, on average.

Plants usually contain low quantities of cadmium, which do not exceed 1 mg mg·kg^{-1} d.m., and its absorption from soil is determined by soil pH value and the presence of other minerals like Zn, Cu, and Pb. An increased level of lead in soil stimulates the process of cadmium absorption by plants. Some plants, e.g. field horsetail, are characterized by exceptional capabilities to accumulate cadmium, which may be exploited in phytoremediation. Wesołowski and Radecka [24] claim that over 90% of plant materials used in medicinal therapy were contaminated with cadmium. Also, investigations from other regions of the world report hazardous concentrations of this metal in plants [13, 23, 30].

Results presented in Table 7 show that all analyzed products were characterized by low concentrations of cadmium that did not exceed 0.1 mg·kg^{-1} d.m. A slightly higher cadmium concentration, i.e. 0.113 mg·kg^{-1} d.m., was assayed only in tea from St. John's wort. Out of the analyzed groups of teas, a lower content of cadmium – 0.027 mg·kg^{-1} d.m., compared to the herbal teas, was noted in black teas. In contrast, after 5 min of brewing, the percentage of cadmium extraction from these teas was the highest – 49.60%, but after 10 min of brewing a higher percentage of cadmium extraction to infusion was noted for monocomponent herbal teas (53.10%), where the elongation of the brewing time caused a tangible increase in the extraction rate (by 6.43%). Sędrowicz et al. [18] reported on a similar dependency in black teas, where the prolongation of the brewing time was accompanied by a successive increase in the extraction rate, with its maximum reached after 20 min of brewing. Results of a study by Winiarska-Mieczan et al. [29] demonstrate that the average percentage of cadmium extraction from herbal teas brewed for 10 min was 44.13%. In turn, Błoniarz et al. [28] reported on a higher extraction rate of cadmium from green teas (46.23% on average), but in their case the teas were brewed following the producer's recommendations, i.e. for 15 min.

The analysis of consumers exposure to cadmium likely to result from the intake of the analyzed herbal teas, which after both 5 and 10 min of brewing contained the highest concentrations of cadmium (i.e. 0.285 μg·dm^{-3} and 0.321 μg·dm^{-3}), enables concluding that the risk of contamination was slight. Taking into account the PTWI value for this metal reaching 0.49 mg, these teas may cover barely ca. 0.41-0.46% of PTWI.

Conclusions

1. Contents of mineral components in dry matter of the analyzed herbal teas and black teas were very diversified, which could have been due to species diversity and origin of the raw material.
2. Apart from having a therapeutic effect, infusions from the analyzed teas may constitute an additional source of microelements in the human diet, manganese in particular.
3. The percentage of toxic elements (lead and cadmium) extraction to infusion was very high (the highest out of all investigated microelements), however, owing to their low concentrations in dry materials, its should not pose any risk to consumer health.
4. Brewing time had no significant effect on the percentage of microelement extraction to the aqueous phase, but in the case of copper, manganese, and lead, the longer brewing time resulted in a slight decrease in this process yield. An opposite dependency was noted in the case of iron, cadmium, and zinc.

References

1. SUCHACZ B., WESOŁOWSKI M. Relations between the content of zinc, copper, lead and nickel in water extracts of herbal mixtures. Bromat. Chem. Toksykol., **43**, (4), 485, **2010** [In Polish].
2. STRZELECKA H. Herbs in the XXI Century - Perspectives and trends of drug plant. Wiad. Ziel., **2**, 10, **2002** [In Polish].
3. GORECKI P. Plant materials in medicine and prevention, in nutrition and cosmetics. Herba Pol., **47**, (2), 85, **2001** [In Polish].
4. MALIK J., SZAKOVA J., DRABEK O., BALIK J., KOKOSKA L. Determination of certain micro and macroelements in plant stimulants and their infusions. Food Chem., **111**, (2), 520, **2008**.
5. PN-EN 14082. **2004** Foodstuffs-Determination of trace elements-Determination of lead, cadmium, zinc, cooper, iron and chromium by atomic absorption spectrometry (AAS) after dry ashing [In Polish].
6. KABATA-PENDIAS A., PENDIAS H. Biogeochemistry of trace elements. Wyd. Nauk. PWN, Warszawa **1999** [In Polish].
7. GRELA E.R., DZIDA.K. The environmental impact of mineral content in selected herbs. Annal. UMCS sec. EEE, **9**, 159, **2001** [In Polish].
8. BŁONIARZ J., ZARĘBA M., BARTOSIAK M. Evaluation of zinc, copper, manganese and iron levels in herbs and their infusions applied in cardiac diseases and diseases of the circulatory system. Pol. J. Environ. Stud., **17**, (1B), 23, **2008**.
9. MULARCZYK-OLIWA M., DŁUGASZEK M. Comparative analysis of the content of selected elements in the leaves and infusions (by AAS). Żyw. Człow. Metab., **30**, (3/4), 925, **2003** [In Polish].
10. GAJEWSKA R., NABRZYSKI M., GANOWIAK Z., CYBULSKI M., KUŁAKOWSKA D. The content of some minerals in the green and black teas. Roczn. PZH, **51**, (3), 251, **2000** [In Polish].
11. BULIŃSKI R., BŁONIARZ J. Part I. The research content of some trace elements in teas. Bromat. Chem. Toksykol., **29**, (2), 157, **1996** [In Polish].
12. JAROSZ M. Feeding Standards for the Polish population-amendment. IŻiŻ, Warszawa, **2012** [In Polish].
13. BLICHARSKA E., KOCJAN R., BŁAŻEWICZ A. Determination of the content of iron, manganese, zinc, copper, cadmium and lead in the herbal teas. Bromat. Chem Toksykol., **40**, (2), 145, **2007** [In Polish].
14. CZECH A., RUSINEK E. Content of zinc, copper, manganese and iron in black, red and green teas and their infusions. Pol. J. Environ. Stud., **15**, (2a), 246, **2006**.
15. ULEWICZ-MAGULSKA B., BARANOWSKA M., WESOŁOWSKI M. Assessment of the content of copper, manganese, zinc and iron in herbs and leaves of medicinal plants. Bromat. Chem. Toksykol., **42**, (3), 815, **2009** [In Polish].

16. BIELICKA-GIEŁDOŃ A., RYŁKO E., BOJANOWSKA I. Evaluation of metals content in herbs and spices available on the polish market. Ochr Śr. Zasobów Nat., **48**, 492, **2011** [In Polish].
17. fnic.nal.usda.gov. National Academy of Sciences. Institute of Medicine. Food and Nutrition Board. Dietary Reference Intakes: RDA and AI for Vitamins and Elements.
18. SĘDROWICZ L., OLĘDZKA R., CZAJKOWSKA M., GURDAK E. Testing conditions influence the infusion of zinc, cadmium, manganese, copper, nickel and lead in tea infusions. Bromat. Chem. Toksykol., **29**, (4), 353, **1996** [In Polish].
19. DECREE OF HEATH MINISTER. **2003**. (Dz. U. Nr 37, poz. 326) [In Polish].
20. REGULATION OF THE COMMISSION (EC) No 1881/ 2006 of the 19 December **2006** laying down the highest permissible levels of selected contaminants in food products [In Polish].
21. WOJCIECHOWSKA-MAZUREK M., STOLARSKA K., MANIA M., REBENIAK M., KARŁOWSKI K. Elements harmful to heath in tea - estimation of heath hazard. Bromat. Chem. Toksykol., **43**, (3), 233, **2010** [In Polish].
22. Global Environment Monitoring System, Food Contamination Monitoring and Assessment Programme (GEMS/Food) Instructions for Electronic Submission of Data on Chemical Contaminants in Food and Diet. Food Safety Department, WHO, Geneva, **2003**.
23. BAŞGEL S., ERDMOĞLU S.B. Determination of mineral and trace elements in some medicinal herbs and their infusions consumed in Turkey. Sci. Total Environ., **359**, (1-3), 82, **2006**.
24. WESOŁOWSKI M., RADECKA I. Medicinal plants, elemental composition, sources of mineral constituents for plants, heavy metals pollution indicators for environment. Farmacja Pol., **59**, (20), 911, **2003** [In Polish].
25. KWAPULIŃSKI J., FISCHER A., NOGAJ E., ŁAZARYCZYK-HENKE J., WOJTANOWSKA M., MORAWIEC M. Investigation on the application some species of fungi to contemporary bioindication of pb and cd. Bromat. Chem. Toksykol., **42**, (1), 81, **2009** [In Polish].
26. JANKOWSKA J., SOSNOWSKI J., CIEPIELA G., JANKOWSKI K. Content of lead in some dicotyledonus growed near by the higway. Ochr Śr. Zasobów Nat., **30**, 99, **2007** [In Polish].
27. BULIŃSKI R., BŁONIARZ J. Part II. Studies on some trace elements in various grades of tea. Part II. Lead, cadmium and trace elements content in dry tea and tea infusions Bromat. Chem. Toksykol., **31**, (1), 39, **1998** [In Polish].
28. BŁONIARZ J., ZARĘBA S., KOCJAN R., ZARĘBA A. Lead and cadmium contents of herbal and herbal-fruits teas as an indication of environmental pollution. Pol. J. Environ. Stud., **15**, (2b), 66, **2006**.
29. WINIARSKA-MIECZAN A., KWIECIEŃ M., KWIATKOWSKA K. Lead and cadmium content in herbal teas. Probl. Hig. Epidemiol., **92**, (3), 667, **2011** [In Polish].
30. DWIVEDI S.K., DEY S. Medicinal herbs: a potential source of toxic metal exposure for man and animals in India. Arch. Environ. Health., **57**, (3), 229, **2002**.