Available online at http://journal-of-agroalimentary.ro

Journal of Agroalimentary Processes and Technologies 2026, 32 (2), pp.306-316

Journal of Agroalimentary Processes and Technologies

Determination of Elemental Contents of Tea Obtained by Brewing Commonly used Herbal Teas for Different Times

Ayşegül Korkmaz[1], Hakan Vatansev[2], Nurhan Uslu[3], Mehmet Musa Özcan[3]*

[1]Selçuk University, Department of Soil Science and Plant Nutrition, Faculty of Agricultural, 42031, Konya-Turkey

[2]Necmettin Erbakan University, Meram Vocational School, Department of Food Processing, Konya, Turkey.

[3]Selçuk University, Department of Food Engineering, Faculty of Agriculture, 42079 Konya, Turkey

**Corresponding author: mozcan@selcuk.edu.tr*

Received 17 May 2026; Revised 17 June 2026, Published 24 June 2026

Abstract

The aim of this paper was to analyse the elemental contents of tea obtained by brewing commonly used herbal teas for different times. Ca and K contents of plants used as herbal tea were found between 6862.25 (rosehip) and 24822.56 mg/kg (thyme) and 4891.49 (mint) and 33325.24 mg/kg (sage),respectively. Among microelements, the highest amounts of Fe and Mn in plants were defined as 9.20 (rosehip) and 540.50 mg/kg (mint) and 12.25 (linden) and 87.87 mg/kg (mint),respectively. The highest As was found in marshmallow flower (21.98 mg/kg),followed by thyme (18.07 mg/kg),linden (18.06 mg/kg), anise (16.94 mg/kg), mint (16.20 mg/kg), chamomile (15.21 mg/kg) and rosehip (11.50 mg/kg) in decreasing order.The average Ca and K contents of herbal teas brewed at different times were determined between 3915.25 (30 min) and 12055.87mg/kg (10 min) and 5336.12 (10 min) and 8431.50mg/kg (30 min),respectively. Average Fe and Zn contents of the brewed teas depending on the brewing times were characterized as 55.21 (20 min) and 62.52 mg/kg (30 min) and 9.26 (20 min) and 11.72mg/kg (10 min),respectively.

Key words: *Herbal teas, infusion, macro and microelements, toxic elements, ICP-OES*

1. Introduction

Herbal teas are prepared from the leaves, flowers, seeds, fruits, stems or roots of plants by infusion or decoction methods in hot water [1,2]. Herbal teas are the most widely consumed natural beverages of plant origin, both for pleasure and because of their positive effects on health. Since the importance of the antioxidant substances that teas contain in high amounts in preventing and treating diseases has been clearly demonstrated, the consumption of these products is increasing day by day [3]. Infusion and decoction methods are mostly used in preparing herbal teas. In the infusion method, boiling water is poured over the plant and waited for 5-10 minutes depending on the plant tissue (e.g. leaves, flowers), while in the decoction (boiling) method, the plant is mixed with cold water and boiled for 5-10 minutes and the tea is filtered. Decoction is mostly applied to hard-textured plants (such as cinnamon, ginger) used as tea [4,5]. The popularity of herbal teas is mainly related to the large number of medicinal plants and herbal tea varieties, their low side effects and environmental damage, and their recent tendency to replace drugs or support the effects of drugs [6]. Herbal teas are rich in minerals such as iron, magnesium, manganese, potassium and zinc, various vitamins and antioxidant compounds [1,5,7,8]. For this reason, they are frequently used

Citation: P.C. A. Korkmaz, H. Vatansev, N. Uslu, M. M. Özcan, Determination of Elemental Contents of Tea Obtained by Brewing Commonly used Herbal Teas for Different Times, *Journal of Agroalimentary Processes and Technologies* 2026, 32 (2), 306-316
DOI:10.59463/JAPT2026.2.20

in alternative medicine for the prevention and treatment of some inflammatory diseases related to the respiratory system, gastrointestinal system and urinary tract [9]. Since some minerals have certain biological activities while others can be toxic, determining the mineral content of herbal teas and medicinal plants is also necessary to understand their roles in the human diet. Generally, herbal teas and medicinal plants contain high amounts of essential minerals (zinc (Zn), manganese (Mn), sodium (Na), potassium (K), calcium (Ca), iron (Fe), magnesium (Mg) and phosphorus (P)). When herbal tea is obtained from medicinal plants, minerals are extracted separately into the liquid medium together with the organic matrix components in the structure, and thus herbal tea becomes a source of major, minor and trace minerals that may have some health effects in the human diet [5,6]. Toxic metals contaminating nature from these polluting sources pass from nature to plants, are consumed by humans and animals, and accumulate in living organisms. In parallel with the development of industry, the amount of metals circulating in this circle is increasing [10]. The mineral content of some plants and teas obtained from those plants has been determined by some studies in the literature [5,11-14]. Most of the studies on teas have been done on dry herbal tea plants, but there has not been enough research on the amount of macro, micro and toxic elements that pass into the brew by infusing herbal teas for different times. The aim of this study was to reveal the amount of elemental content that passes into the brew by infusing commonly used herbal teas for different times.

2. Materials and methods

2.1.Material

The herbal tea samples, including oregano, hibiscus, anise, rosehip, marshmallow flower, sage, mint, linden, fennel, and chamomile, were purchased from a local market in Konya. For each sample, 2 g of dried herbal material was accurately weighed, followed by the addition of distilled water heated to 100 °C. The mixtures were infused for 10, 20, and 30 minutes under controlled conditions. Subsequently, the infusions were filtered, and the resulting tea extracts were prepared for elemental analysis.

2.2.Methods

2.2.1.Digestion in the microwave

The plant parts were dried in an air circulation drying cabinet at 70°C until they reached constant weight. Ground herbal samples were dissolved with 5 ml concentrated HNO3 and 2 ml H2O2 (30% w/v) in a microwave device (Cem MARSXpress) under high temperature (210 °C) and pressure (200 PSI). After the volumes of the dissolved samples were completed to 20 ml with deionized water, it was filtered before analysing.

2.2.2.Element analysis of the samples

The elemental compositions of the herbal plant and tea samples were determined by inductively coupled plasma optical emission spectrometry (ICP-OES). Prior to instrumental analysis, all samples underwent microwave-assisted acid digestion to achieve complete mineralization and ensure accurate quantification of elemental constituents. The concentrations of the analyzed elements were subsequently reported in mg/kg on a dry weight basis [15].

2.3.Statistical analysis

Following statistical evaluation using the JMP statistical software package, significant differences among all datasets were identified through analysis of variance (ANOVA) at a significance level of $p < 0.05$ [16].

3. Results and Discussion

The macro and micro element contents of plants used as herbal tea are presented in Table 1. In general, the macro and micro element contents of plants were found to be high. The element found in the highest amounts as a macroelement in plants was Ca, followed by K, P and Mg in decreasing order. In addition, the microelement found in the highest amounts in plants was Fe, followed by Mn, B, Zn and Cu in decreasing order. Ca and K contents of plants used as herbal tea were found between 6862.25 (rosehip) and 24822.56 mg/kg (thyme) and 4891.49 (mint) and 33325.24 mg/kg (sage), respectively. Among microelements, the highest amounts of Fe and Mn in plants were defined as 9.20 (rosehip) and 540.50 mg/kg (mint) and 12.25 (linden) and 87.87 mg/kg (mint), respectively.

Table 1. Macro and microelement contents of plant samples (mg/kg)

Plants	P	K	Ca	Mg
	---------- (mg kg^{-1}) ----------			
Thyme	2085.30±56.76 EF*	5975.80±734.52c	24822.56±491.08 A	2469.59±67.96 C
Hibiscus	1575.18±40.83 F	22924.45±406.25ab	8788.79±303.46 D	1153.20±21.47 F
Anise	5563.93±230.61 A	9972.44±815.25bc	8594.59±304.22 D	2481.57±98.28 C
Rosehip	2311.34±232.67 E	10118.79±504.75bc	6862.25±525.13 E	2129.67±127.46 CDE
Marshmallow Flower	3916.43±117.05 BC	5877.48±32.33c	22020.19±358.23 B	2185.51±161.46 CDE
Sage	3358.34±79.12 CD	33325.24±119.23 a	9816.83±230.37 CD	2420.59±59.74 CD
Mint	3123.80±11.36 D	4891.49±282.76c	22732.99±337.87 B	4916.29±13.67 A
Linden	2143.52±94.14 EF	7569.44±373.28bc	10679.11±499.55 C	1806.23±37.85 E
Fennel	4149.34±110.85 B	14828.49±250.27bc	10332.56±344.63 C	3400.71±195.95 B
Chamomile	3062.35±218.71 D	10112.17±690.33bc	9446.26±382.09 CD	1959.46±147.73 E

Table 1(continued)

***p<0.01

Plants	Fe	Zn	Cu	Mn	B
	---------- (mg kg^{-1}) ----------				
Thyme	117.15±1.81 B*	11.59±0.27 CD	6.13±0.60 CD	42.67±22.22 B	24.07±0.90 C
Hibiscus	71.97±2.66 CD	2.81±0.06 F	1.45±0.10 F	14.07±0.30 B	3.75±0.08 F
Anise	108.67±8.39 B	51.51±4.07 A	17.29±1.52 A	31.80±2.51 B	14.78±0.57 DE
Rosehip	9.20±0.74 E	2.63±0.21 F	3.05±0.17 EF	80.16±4.44 A	15.87±1.10 D
Marshmallow Flower	114.68±4.02 B	4.24±0.37 EF	5.77±0.15 CD	19.31±0.66 B	30.50±0.84 B
Sage	74.14±1.52 CD	15.94±1.13 C	4.44±0.13 DE	20.37±0.62 B	11.17±1.04 E
Mint	540.50±21.98 A	22.12±0.27 B	6.16±0.36 CD	87.87±0.96 A	16.34±0.34 D
Linden	42.59±2.29 CDE	2.95±0.03 F	9.31±0.19 B	12.25±0.17 B	103.20±2.58 A
Fennel	38.05±0.73 E	22.40±1.38 B	4.86±0.79 DE	23.36±0.48 B	15.41±0.41 DE
Chamomile	86.52±2.44 BC	9.83±0.44 DE	1.51±0.09 F	21.06±0.54 B	6.25±0.28 F

***p<0.01

The highest amounts of P, K Ca and Mg were determined in anise, sage, thyme and fennel, respectively. In addition, the highest amounts of Fe, Zn, Cu, Mn and B in plant samples were determined in mint, anise, anise, peppermint and linden, respectively. The differences in the macro and microelement contents of plants include, in addition to the plant variety, root structure, soluble nutrient element concentration in the soil solution, ion exchange in the soil, root development, transport of nutrient elements to the root effect area, root secretions and the effects of mycorrhizae [17]. It has been reported that there may be differences among plants in terms of the nutrient elements taken up by plants [18]. The differences in the macro and microelement contents of plant samples are thought to be in accordance with the explanations of Alaoui et al.[17] and Setiyono et al.[18].

The toxic element contents of plants used as herbal tea are presented in Table 2. Differences were observed in the toxic element contents of plants depending on the plant species. The toxic element found in the highest amounts in plants was As, followed by Ba, Se and Ni in decreasing order. Statistically significant differences were observed between the toxic element contents of plants ($p<0.01$). As and Ba contents of the plants were determined between 2.28 (sage) and 21.98 mg/kg (marshmallow flower) and 0.402 (anise) and 26.43 mg/kg (fennel), respectively. In tea plant samples, the highest As was found in marshmallow flower (21.98 mg/kg), followed by thyme (18.07 mg/kg), linden (18.06 mg/kg), anise (16.94 mg/kg), mint (16.20 mg/kg), chamomile (15.21 mg/kg) and rosehip (11.50 mg/kg) in decreasing order.

Table 2. Toxic element contents of plant samples (mg/kg)

Plants	Al	Ba	Cd	Co
Thyme	0.050±0.0050 AB.	15.40±5.16 B	0.037±0.008 B	0.089±0.018 BC
Hibiscus	0.051±0.0003 A	13.46±0.78 B	0.031±0.001 B	0.127±0.009 A
Anise	0.053±0.0025 A	0.402±0.01 E	0.075±0.006 B	0.078±0.004 C
Rosehip	0.0307±0.0024 D	0.998±0.09 DE	0.060±0.025 B	0.062±0.005 CD
Marshmallow Flower	0.042±0.0020 BC	3.989±0.29 DE	0.197±0.145 AB	0.068±0.004 CD
Sage	0.045±0.0014 ABC	10.809±1.09 BC	0.123±0.012 B	0.082±0.002 C
Mint	0.0377±0.0065 CD	7.571±0.15 B-E	0.145±0.016 B	0.129±0.001 A
Linden	0.051±0.0005 AB	9.73±0.17 BCD	0.037±0.004 B	0.131±0.005 AB
Fennel	0.044±0.0029 ABC	26.43±3.18 A	0.389±0.017 A	0.003±0.002 E
Chamomile	0.048±0.0033 AB	1.490±0.07 DE	0.0421±0.016 B	0.048±0.001 D

***** $p<0.01$

Table 2 (continued)

Plants	Cr	Ni	Pb	As	Se
	---------- (mg kg^{-1}) ----------				
Thyme	0.728±0.099 C*	0.533±0.032 C	0.180±0.245 B	18.07±8.42 AB	1.522±0.75 AB
Hibiscus	2.269±0.137 A	0.488±0.009 C	0.161±0.029 BC	6.87±0.23 BCD	1.381±0.08 AB
Anise	0.699±0.028 C	1.213±0.048 B	0.831±0.011 A	16.94±1.86 ABC	2.213±0.18 A
Rosehip	0.483±0.028 C	0.437±0.005 C	0.055±0.027 CD	11.50±1.56 A-D	1.465±0.13 AB
Marshmallow Flower	0.554±0.015 C	3.138±0.026 A	0.239±0.058 B	21.98±1.19 A	2.191±0.22 A
Sage	0.614±0.012 C	0.542±0.003 C	0.052±0.352 CD	2.28±0.18 D	2.076±0.08 A
Mint	1.119±0.078 B	1.225±0.022 B	0.248±0.152 B	16.20±0.29 ABC	0.787±0.005 B
Linden	0.565±0.021 C	0.419±0.001 BC	0.132±0.013 BCD	18.06±0.48 ABC	1.102±0.135 AB
Fennel	0.593±0.049 C	0.346±0.063 C	0.141±0.721 BC	6.12±0.85 CD	1.161±0.137 B
Chamomile	0.655±0.014 C	0.391±0.008 C	0.019±0.079 D	15.21±0.36 ABC	0.722±0.049 B

*****$p<0.01$

In addition, the highest Ba was detected in fennel (26.43 mg/kg) and this was followed by thyme (15.40 mg/kg), hibiscus (13.46 mg/kg), sage (10.809 mg/kg), linden (19.73 mg/kg), mint (7.571 mg/kg) and mallow flower (3.898 mg/kg) in decreasing order. In addition, the highest Ba was detected in fennel (26.43 mg/kg) and this was followed by thyme (15.40 mg/kg), hibiscus (13.46 mg/kg), sage (10.809 mg/kg), linden (19.73 mg/kg), mint (7.571 mg/kg) and mallow flower (3.898 mg/kg) in decreasing order.

Se and Ni contents of tea plants were defined between 0.722 (chamomile) and 2.213 mg/kg (anise) and 0.346 (fennel) and 3.138 mg/kg (marshmallow flower), respectively. Also, the lowest and highest Cr were determined in rosehip (0.483 mg/kg) and hibiscus (2.269 mg/kg) plants, respectively. Other toxic elements were determined below 0.389 mg/kg. In general, toxic element contents of tea plants were found at quite low levels (except As and Ba), and this shows that tea plants can be used safely. It is thought that the Se and Ni element contents of plants may be close to tolerable limit values.

The macro and microelement contents of herbal teas brewed for different periods of time are shown in Table

Table 3. Macro and microelement contents of teas brewed at different times (mg/kg)

Tea samples	**P**				**K**				**Ca**				**Mg**			
	---------- **(mg kg^{-1})** ----------															
	10 min	20 min	30min	Mean	10 min	20 min	30min	Mean	10 min	20 min	30min	Mean	10 min	20 min	30min	Mean
Thyme	1421.26	1366.76	1100.78	1296.27 D	2012.81	4233.05	2734.30	2993.39 D	21394.24 A	20541.56 AB	10979.93 F	17638.58 A	1122.94 J-M	1418.87 HI	1080.69 J-N	1207.50 D
Hibiscus	1070.99	1030.80	828.68	976.83 E	7739.20	16272.79	10522.28	11511.42 AB	7563.49 HI	7260.26 IJ	3872.04 N	6231.93 EF	521.42 S	657.15 QRS	495.64 S	558.07 F
Anise	3809.81	3657.03	2960.38	3475.74 A	3363.14	7072.13	4570.78	5002.02 CD	7395.98 IJ	7099.41 IJK	2081.43 O	5525.60 G	1128.41 J-M	1425.80 HI	1086.02 J-N	1213.41 D
Rosehip	1576.26	1514.90	1225.44	1438.94 D	3412.59	10554.60	4638.03	6201.74 BCD	5901.65 LM	5664.44 LM	1657.40 O	4407.83 H	967.61 L-O	1222.18 IJK	929.62 M-P	1039.80 E
Marshmallow Flower	2678.58	2572.00	2081.60	2444.06 B	1979.28	2580.19	2688.62	2416.03 D	18976.91 CD	18220.27 D	5368.52 M	14188.57 B	993.13 K-O	1255.35 IJ	953.37 L-O	1067.28 DE
Sage	2300.50	2204.44	1783.91	2096.27 C	11252.99	14672.84	27653.43	17859.75 A	8449.09 GH	6185.17 KLM	2381.47 O	5671.90 FG	1100.55 J-M	841.16 N-R	2531.34 C	1491.01 C
Mint	2139.43	2049.98	1658.81	1949.40 C	2138.25	2145.80	4046.57	2776.87 D	19590.60 BC	14347.56 E	5542.99 LM	13160.38 C	2240.94 D	1717.01 FG	5163.82 A	3040.59 A
Linden	1459.05	1397.39	1129.25	1328.56 D	5302.67	3598.08	6783.36	5228.04 BCD	8762.02 G	6412.17 KLM	2470.27 O	5881.49 EFG	815.07 O-R	621.90 RS	1872.33 EF	1103.10 DE
Fennel	2843.60	2719.49	2204.81	2589.30 B	9610.12	6523.74	12296.66	9476.84 BC	11767.97 F	6508.83 JKL	2507.71 O	6928.17 D	1548.19 GH	1185.13 I-L	3565.18 B	2099.50 B
Chamomile	2097.24	2003.60	1625.01	1908.62 C	6550.15	4445.87	8380.98	6459.00 BCD	10756.68 F	5948.73 LM	2290.77 O	6332.06 E	889.62 M-Q	679.33 P-S	2044.94 DE	1204.63 D
Mean	**2139.69 A**	**2051.64 A**	**1659.87 B**		**5336.12**	**7209.91**	**8431.50**		**12055.87 A**	**9818.84 B**	**3915.25 C**		**1132.79 B**	**1102.39 B**	**1972.29 A**	

***** $p<0.01$

Table 3 (continued) (mg/kg)

Tea samples	**Fe**				**Zn**				**Cu**				**Mn**				**B**			
	---------- **(mg kg^{-1})** ----------																			
	10 min	20 min	30min	Mean	10 min	20 min	30min	Mean	10 min	20 min	30min	Mean	10 min	20 min	30min	Mean	10 min	20 min	30 min	Mean
Thyme	87.58 D	42.99 E-I	57.73 E	62.77 B	10.20 DEF	5.95 FGH	10.31 DEF	8.82 D	4.66 C-G	5.65 B-E	4.85 C-F	5.05 C	23.19	16.85	11.42	17.15 B	19.63 D	19.63 D	20.80 D	20.02 B
Hibiscus	50.12 H-I	22.84 KL	31.09 IJK	34.68 C	1.56 HI	0.48 I	1.67 HI	1.24 F	0.25 L	0.35 KL	0.47 KL	0.36 F	4.75	3.54	1.44	3.24 D	1.26 IJ	1.26 IJ	0.42 IJ	0.98 E
Anise	80.55 D	39.21 G-K	52.73 EFG	57.60 B	49.54 A	30.82 B	49.65 A	43.34 A	17.30 A	16.03 A	15.22 A	16.18 A	16.18	11.74	9.33	12.42 BC	11.23 EF	12.56 E	1.49 HIJ	8.43 C
Rosehip	2.97 M	1.59 M	0.84 M	1.80 E	1.37 HI	0.37 I	1.48 HI	1.07 F	1.16 I-L	0.81 JKL	0.26 KL	0.74 F	47.37	34.15	29.17	36.90 A	12.22 E	13.66 E	1.71 HIJ	9.20 C

Marshmallow Flower	85.53 D	41.90 E-J	56.27 EF	61.23 B	2.96 HI	1.38 HI	3.07 HI	2.47 F	4.25 D-H	2.98 F-J	2.18 G-L	3.13 D	8.12	5.95	4.20	6.09 CD	25.44 C	28.33 C	4.65 H	19.48 B
Sage	25.66 JKL	32.37 IJK	34.30 H-K	30.78 C	13.70 C	9.23 D-G	13.53 D	12.15 C	2.74 F-K	1.47 I-L	0.66 JKL	1.62 EF	8.81	6.44	4.64	6.63 CD	7.97 G	8.95 FG	0.76 IJ	5.89 D
Mint	233.71 C	307.34 B	324.43 A	288.49 A	19.79 C	13.08 DE	19.61 C	17.49 B	4.69 C-F	3.42 E-I	2.62 F-L	3.57 D	52.35	37.73	32.79	40.96 A	12.64 E	14.13 E	1.80 HIJ	9.53 C
Linden	11.04 LM	13.05 LM	13.92 LM	12.67 D	0.56 I	1.79 HI	0.36 HI	0.91 F	8.06 B	6.79 BC	5.98 BCD	6.94 B	3.79	1.59	1.73	2.37 D	91.60 B	101.71	19.37 D	70.89 A
Fennel	9.56 LM	11.09 LM	11.86 LM	10.84 DE	12.69 DE	20.97 C	10.14 DEF	14.60 C	1.98 H-L	1.45 I-L	4.43 G-L	2.62 DE	10.94	6.72	6.27	7.98 CD	11.80 EF	12.11 EF	1.62 HIJ	8.51 C
Chamomile	31.18 IJK	39.67 F-J	42.01 E-J	37.62 C	4.85 GHI	8.57 EFG	3.82 HI	5.75 E	0.44 KL	0.54 JKL	0.64 JKL	0.54 F	9.52	5.52	5.37	6.80 CD	3.52 HI	2.93 HIJ	0.01 J	2.15 E
Mean	**61.79 A**	**55.21 B**	**62.52 A**		**11.72 A**	**9.26 B**	**11.36 A**		**4.55 A**	**3.95 AB**	**3.73 B**		**18.50 A**	**13.02 B**	**10.64 B**		**19.73 B**	**21.53 A**	**5.26 C**	

***** $p<0.01$

In general, a significant portion of the elements in the plants passed into the tea water with brewing. In addition, it can be said that brewed teas are rich in macro and microelement contents and can provide a tonic effect. The average Ca and K contents of herbal teas brewed at different times were determined between 3915.25 (30 min) and 12055.87 mg/kg (10 min) to 5336.12 (10 min) and 8431.50 mg/kg (30 min), respectively. Depending on the brewing times, the average P and Mg contents of the teas brewed were determined between 1659.87 (30 min) and 2139.69 mg/kg (10 min) to 1102.39 (20 min) and 1972.29 mg/kg (30 min), respectively. Regarding herbal teas, the lowest and highest average Ca were determined in rosehip (4407.83 mg/kg) and thyme (17638.58 mg/kg) teas, while the lowest and highest average K were determined in mallow flower (2416.03 mg/kg) and sage (17859.75 mg/kg) teas, respectively. The highest average P was determined in anise tea (3475.74 mg/kg). In addition, depending on the brewing times, average Fe and Zn contents of the teas were characterized as 55.21 (20 min) and 62.52 mg/kg (30 min) to 9.26 (20 min) and 11.72 mg/kg (10 min), respectively. Depending on the brewed tea types, the lowest average Fe, Zn, Cu, Mn and B were determined in rosehip (81.80 mg/kg), linden (0.91 mg/kg), hibiscus (0.36 mg/kg), linden (2.37 mg/kg) and hibiscus (0.98 mg/kg) teas, respectively. Depending on the tea types, the highest average Fe, Zn, Cu, Mn and B contents were determined in mint (288.49 mg/kg), anise (43.34 mg/kg), anise (16.18 mg/kg), mint (40.96 mg/kg) and linden (70.89 mg/kg) teas, respectively. In general, it was concluded that the microelement levels were within the safe range for human health.

Toxic element contents of herbal teas brewed for different times are determined in Table 4.

Toxic element contents of teas differed according to tea types and brewing times. Therefore, differences in toxic element contents of brewed teas depending on brewing times and tea types were found to be statistically significant ($p<0.01$). Although the amounts of As, Ba, Ni and Se were relatively high in brewed teas, they were found to be at very low levels compared to the toxic element contents in plants. However, an increase was observed in the Al contents of brewed teas compared to normal tea plants. In general, the toxic element contents of brewed teas decreased significantly compared to the plants. The increased Al content of brewed teas may have been probably due to contamination from the tea brewing vessel. The average Al content of brewed teas ranged from 1.14 (fennel) to 3.48 mg/kg (marshmallow flower), while the average Al content of teas was determined to be between 1.76 (20 min) and 2.34 mg/kg (30 min), depending on the brewing time. In addition, the average As contents of brewed teas varied between 7.73 (10 min) and 10.79 mg/kg (30 min) depending on the brewing times, while the average As contents of brewed teas varied between 3.6 (linden) and 13.2 mg/kg (rosehip) depending on the tea types. However, depending on the brewing time, the average Ba content of brewed teas varied between 0.35 (20 min) and 0.57 mg/kg (30 min), while depending on the tea variety, the average Ba content of brewed teas was defined as between 0.08 (chamomile) and 3.75 mg/kg (hibiscus). The amounts of other toxic elements in brewed teas were found to be below 0.358 mg/kg.

There was a significant decrease in the average P, K, Ca and Mg contents of the teas brewed at three different brewing times. It was observed that approximately 30-60% of the elements passed into the brewed tea during the brewing of the herbal teas detected in the highest amounts. The highest decrease in the plants during brewing was observed in P and K in anise tea, i.e. the amounts of P and K passing into the tea increased significantly. While the Fe and Mn contents of the brewed teas partially decreased compared to the herbal samples, an increase was observed in the Zn and Cu contents of the teas. This increase may have been due to the materials used in the preparation of the teas and/or the water used. While a partial increase was observed in the Al and Pb contents of the brewed teas depending on the brewing times, the amounts of other toxic elements decreased significantly compared to the plant samples.

However, the increase in the Pb contents of the brewed teas was detected at very low levels compared to the increase in the Al content. As a result, the increased toxic elements in the brewed teas may have probably originated from the containers and water used during brewing. Depending on the brewing times, the P and Ca contents of the teas were determined at the highest 10-minute brewing time, while the highest K and Mg element contents were identified at the 30-minute brewing time. In addition, depending on the brewing times, the highest microelements occurred at the 30-minute brewing time (except Fe). Depending on the brewing times, the highest Al, Ba, Co, Ni and As in brewed teas were determined in 30-minute brewing times, while the highest Cr and Pb were determined in 10-minute brewing times.

Table 4. Toxic element contents of tea samples brewed at different times (mg/kg)

	Al				**Ba**				**Cd**				**Co**			
	10 min	20 min	30min	Mean	10 min	20 min	30min	Mean	10 min	20 min	30min	Mean	10 min	20 min	30min	Mean
Thyme	3.15 G	0.48 S	1.97 K	1.87 E	0.12 I	0.13 I	0.12 I	0.12 D	0.021	0.033	0.031	0.025	0.037 D	0.012 JK	0.001 R	0.017 C
Hibiscus	0.60 R	0.22 T	0.2.96 H	1.26 F	4.24 B	2.48 C	4.53 A	3.75 A	0.014	0.025	0.021	0.018	0.080 A	0.071 B	0.080 A	0.077 A
Anise	2.22 J	3.40 F	0.45 S	2.02 CD	0.26 G	0.20 H	0.28 FG	0.25 C	0.029	0.027	0.021	0.026	0.019 H	0.007 MN	0.008 MN	0.011 F
Rosehip	1.10 O	1.77 L	3.09 G	1.99 D	0.02 O	0.05 N	0.08 KLM	0.05 G	0.032	0.019	0.023	0.027	0.004 OP	0.006 NO	0.032 E	0.014 D
Marshmallow Flower	2.61 I	2.04 K	5.80 A	3.48 A	0.07 LMN	0.06 MN	0.08 KL	0.07 F	0.015	0.025	0.021	0.020	0.022 G	0.006 NO	0.009 LM	0.013 DE
Sage	1.07 O	0.75 PQ	4.74 B	2.19 B	0.02 O	0.02 O	0.05 N	0.03 H	0.028	0.119	0.031	0.059	0.011 K	0.045 C	0.020 H	0.025 B
Mint	1.39 M	4.08 C	0.68 QR	2.05 C	0.29 EF	0.31 E	0.34 D	0.31 B	0.017	0.023	0.060	0.034	0.002 PQR	0.014 IJ	0.018 H	0.011 F
Linden	3.96 D	0.83 P	0.92 P	1.87 E	0.02 O	0.02 O	0.03 O	0.02 H	0.026	0.031	0.017	0.024	0.012 JK	0.004 PQ	0.018 H	0.011 F
Fennel	1.24 N	0.43 S	1.74 L	1.14 G	0.12 I	0.12 I	0.09 JK	0.11 D	0.039	0.004	0.041	0.027	0.002 QR	0.024 FG	0.015 I	0.014 DE
Chamomile	0.79 P	3.61 E	1.10 O	1.83 E	0.05 N	0.11 IJ	0.09 JK	0.08 E	0.026	0.024	0.023	0.024	0.011 KL	0.004 PQR	0.026 F	0.014 DE
Mean	1.81 B	1.76 C	2.34 A		0.52 B	0.35 C	0.57 A		0.024	0.033	0.029		0.020 B	0.019 C	0.023 A	

***** $p<0.01$

Table 4 (continued) (mg/kg)

Tea samples	**Cr**			**Ni**				**Pb**				**As**			
	---------- (mg kg^{-1}) ----------														
	10 min	20 min	30 min	Mean	10 min	20 min	30 min	Mean	10 min	20 min	30 min	Mean	10 min	20 min	30 min	Mean
Thyme	0.013 B-E	0.015 B-E	0.009 CDE	0.013 BC	0.320 C	0.131 G	0.267 D	0.24 B	0.039 Q	0.005 R	0.060 N	0.035 I	14.56 E	1.97 PQ	3.62 N	6.72 F
Hibiscus	0.006 CDE	0.005 CDE	0.025 ABC	0.012 BC	0.409 A	0.248 E	0.358 B	0.034 A	0.108 F	0.149 B	0.099 G	0.119 B	7.57 J	10.18 I	11.68 H	9.81 D
Anise	0.015 B-E	0.011 B-E	0.003 E	0.009 BC	0.029 OP	0.054 L	0.060 K	0.047 G	0.073 KLM	0.070 LM	0.069 M	0.101 C	1.09 R	2.89 O	14.50 E	6.16 G
Rosehip	0.013 B-E	0.005 CDE	0.002 E	0.006 C	0.035 N	0.052 L	0.131 G	0.073 D	0.071 LM	0.038 Q	0.075 JKL	0.061 G	7.31 J	17.25 C	15.18 D	13.25 A

Marshmallow Flower	0.023 A-D	0.018 B-E	0.017 B-E	0.019 AB	0.023 Q	0.015 R	0.090 J	0.042 H	0.149 B	0.005 R	0.095 GH	0.083 D	18.19 B	1.15 R	20.22 A	13.19 A
Sage	0.006 CDE	0.016 B-E	0.008 CDE	0.009 BC	0.021 Q	0.009 S	0.026 PQ	0.019 I	0.096 G	0.070 LM	0.069 M	0.079 E	1.79 Q	12.59 G	10.50 I	8.29 E
Mint	0.015 B-E	0.012 B-E	0.016 B-E	0.014 BC	0.129 G	0.195 F	0.124 H	0.019 I	0.090 H	0.0007 R	0.076 IJK	0.056 H	5.46 L	18.41 B	10.47 I	11.45 B
Linden	0.005 DE	0.0001E	0.023 A-D	0.009 BC	0.029 OP	0.064 K	0.049 L	0.048 G	0.194 A	0.137 C	0.045 P	0.126 A	2.28 P	6.53 K	2.15 PQ	3.66 I
Fennel	0.012 B-E	0.012 B-E	0.003 E	0.009 BC	0.031NO	0.102 J	0.032 NO	0.055 E	0.054 O	0.079 IJ	0.081 I	0.071 F	4.52 M	5.67 L	4.81 M	5.01 H
Chamomile	0.040 A	0.008 E	0.030 AB	0.026 A	0.042 N	0.049 L	0.061 K	0.051 F	0.119 E	0.072 KLM	0.051 O	0.081 DE	14.51 E	5.39 L	13.73 F	11.21 C
Mean	0.015	0.010	0.014		0.107 B	0.092 C	0.119 A		0.099 A	0.069 C	0.075 B		7.73 C	8.20 B	10.69 A	

***** $p<0.01$

The average highest Cd content of the teas was determined in 20-minute brewing times. In general, the lowest toxic elements were determined in 20-minute brewing times (except As and Cd).

In his study, Acar [19] determined 7.73-16.88 Cu, 0.72-3.86 Cr, 54.89-142.9 Fe, 219.5-655 Mn, 0.03-0.16 Co, 4.06-1.35 Ni, and 4.02-12.6 ppm Pb in a total of 15 commercial tea samples, 13 of which were imported and 2 Rize black teas consumed in Şanlıurfa province. In another study, Seenivasan et al. (2008) determined the Ni content in black tea to be between 0.4 and 9.2 ppm in their study conducted in India [20]. In general, the values in our study were determined to be partially lower than the values of Acar [19]). While sage (1.61 mg/200 mL), green tea (1.59 mg/200 mL) and linden tea (1.59 mg/200 mL) are the tea types with the highest K content ($p>0.05$), mint tea has the lowest K content (0.72 mg/200 mL) [5]. It has been observed that the Cu contents of plants and herbal teas are quite low compared to other minerals, and the lowest Cu (6.44 μg/g) was detected in mint plant. The plants with the lowest amount of Cu are senna (2.26 μg/g) and rosemary (2.35 μg/g) [5]. In the teas obtained as infusion from the same plants, 29.23-76.15 μg/200 mL Zn, 10.10-192.72 μg/200 mL Mn, 0.08-0.46 mg/200 mL Na, 0.56-1.61 mg/200 mL K, 0.93-8.65 mg/200 mL Cu, 0.03-0.95 mg/200 mL Ca, 2.24-33.37 mg/200 mL Fe, 0.05-0.36 mg/200 mL Mg and 1.50-2.05 mg/200 mL P were determined [5]. Okut [21] determined the levels of Fe, Mn, Al, Zn, Ni, As, Pb, Cr, Cd, Cu, Sr and Co in 9 plant species (St. John's wort, yarrow, mallow, sage, nettle, thyme, bitter buckthorn, chamomile and sow's rue) and determined the levels of Al (0.597-32.852), Fe (0.331-18.797), Mn (0.08-1.06), Zn (0.1-0.409), Ni (0.015), As (0.104), Cd (0.00-0.03), Pb (0.00-0.16), Cr (0.002-0.111), Cu (0.063-0.292), Co (0.01-0.09) and Sr in 34 different parts. (0.107-1.925 ppm) were detected. Since tea plant is known to accumulate Al, it has been reported that most of the analyzed tea samples have high Al content [22]. The analysis results of copper content in nine analyzed tea samples are between 2-20 ppm which is considered as normal [22]. Nickel content in teas is reported to be between 3-10 ppm [22]. The data obtained in this study contain similarities or differences with the literature. The reason for the differences observed in the mineral contents of plants is that the type and amount of minerals in the structure are closely related to the soil structure in which the plant grows, the climate, the ability of the soil and the plant to accumulate nutrients, and environmental pollution [8]. It is expected that the mineral content of plants will vary greatly as a result of seasonal changes in the plant growth environment, including the physical and chemical properties of the soil. The mineral content of herbal teas is strongly affected by a number of parameters, such as the composition of the herbal tea and its preparation method (infusion, decoction or cold maceration), the mineral content of the plant, the solubility of minerals and other matrix components such as phenolic compounds, and the pH of the water used in tea preparation. Extraction of mineral substances from the plant to water varies considerably at low, medium and high levels, depending on the tea preparation technique. The main reason for this may be due to the infusion or decoction medium from the plant material, the levels of phenolic substances and other chelating and/or binding components in the medium, the concentrations of mineral substances in the tea, the pH of the water used and finally the extraction/preparation procedures applied [5,8].

4.Conclusion

The element found in the highest amounts as a macroelement in plants was Ca, followed by K, P and Mg in decreasing order. In addition, the microelement found in the highest amounts in plants was Fe, followed by Mn, B, Zn and Cu in decreasing order. The toxic element found in the highest amounts in plants was As, followed by Ba, Se and Ni in decreasing order. In general, a significant portion of the elements in the plants passed into the tea water with brewing. In addition, it can be said that brewed teas are rich in macro and microelement contents and can provide a tonic effect. Although the amounts of As, Ba, Ni and Se were relatively high in brewed teas, they were found to be at very low levels compared to the toxic element contents in plants. The importance given to herbal teas, which provide many health benefits, is increasing in recent days, but if not used carefully, it can cause heavy metal accumulation in the human body and cause diseases caused by heavy metals in the future. For this reason, attention should be paid to the quality of the selected teas, the brewing time and the daily consumption amount.

Conflicts of interest / Competing interests: No conflict of interest.

Ethics approval: No ethic situation.

Availability of data and material: The datasets generated and/or analyzed during the current study are available from the corresponding author upon reasonable request.

References

1. Özcan, M. (**2004**). Mineral contents of some plants used as condiments in Turkey. Food Chemistry 84: 437-440.
2. Zhao, J., Deng, J. W., Chen, N, Y. W., Li, S. P. (**2013**). Advanced Phytochemical Analysis of Herbal Tea in China. J. Chromatography A, 1313:2–23, 2013.
3. Ivanova, D., Gerova, D., Chervenkov, T., Yankova, T., (**2005**). Polyphenols and antioxidant capacity of Bulgarian medicinal plants. J. Ethnopharmacol. 96: 145-150.
4. Schulz, V., Hansel, R., Tyler, V. E. (**2001**). Rational Phytotherapy : A Physicians' Guide to Herbal Medicine. Germany: Springer Berlin Heidelberg,
5. Nakilcioğlu-Taş, E. (**2019**). Mineral madde kaynaği olarak bazi bitki ve bitki çaylarının araştırması. Ömer Halisdemir Üniversitesi Mühendislik Bilimleri Dergisi,(ÖHÜ Müh. Bilim. Derg. / OHU J. Eng. Sci 8: 863-874
6. Poswal, F. S., Russell, G., Mackonochie, M., MacLennan, E., Adukwu, E. C. **(2019**). Herbal teas and their health benefits: A scoping review. Plant Foods Human Nutr. 74(3): 266–276. https://doi.org/10.1007/s11130-019-00750-w
7. Milani, R. F., De Paiva, E.L., Peron, L. I., Morgano, M. A., Cadore, S. (**2018**). Arsenic Species in Herbal Tea Leaves and Infusions Determination by HPLC-ICP-MS. LWT - Food Sci. Technol 98: 606–612, 2018.
8. Milani, R. F., Silvestre, L. K., Morgano, M. A., Cadore, S. **(2019**). Investigation of Twelve Trace Elements in Herbal Tea Commercialized in Brazil. J. Trace Elements Med. Biol. 52: 111–117.
9. Martin-Domingo, M.C., Pla, A.I., Hernandez, A.F., Olmedo, P., Navas-Acien, A., Lozano-Paniagua, D., Gil, F. (**2017).** Determination of Metalloid, Metallic and Mineral Elements in Herbal Teas. Risk Assessment for the Consumers. J. Food Comp. Analysis, 60: 81–89, 2017.
10. Algan, G. (**2002**). Konya Yöresi Sütlerinde Bazı Ağır Metallerin Đncelenmesi, Selçuk Üniversitesi, Sağlık Bilimleri Enstitüsü, Besin Hijyeni ve Teknoloji Anabilim Dalı,Konya 2002.
11. Başgel, S., Erdemoğlu, S.B. (**2006**). Determination of Mineral and Trace Elements Some Medicinal Herbs and Their Infusions Consumed in Turkey. Sci. Total Environ. 359: 82–89, 2006.
12. Nookabkaew, S., Rangkadilok, N., Satayavicad, J. (**2006**). Determination of Trace Elements in Herbal Tea Products and Their Infusions Consumed in Thailand. J. Agric. Food Chem. 54:6939–6944.
13. Özcan, M. M., Ünver, A., Uçar, T., Arslan, D. (**2008**). Mineral Content of Some Herbs and Herbal Teas by Infusion and Decoction. Food Chem. 106: 1120–1127.
14. Olivier, J., Symington, E.A., Jonker, C.Z., Rampedi, I.T., Van Eeden, T. S. (**2012**). Comparison of the Mineral Composition of Leaves and Infusions of Traditional and Herbal Teas. The South African J. Sci. 108 (1/2): 1–7.
15. Tošic, S.B., Mitic S.S., Velimirovic, D.S., Stojanovic, G.S., Pavlovic, A.N., Pecev-Marinkovic, E.T. (**2015**). Elemental composition of edible nuts: fast optimization and validation procedure of an ICP-OES method. J. Sci. Food Agric. 95: 2271–2278.
16. Savaşlı, E., Önder, O., Karaduman, Y., Dayıoğlu, R., Özen, D., Özdemir, S., Akın, A., Tunca, Z.S., Demir, B., Aydın, N. (**2019**). The effect of soil and foliar ürea application at headng stage on grain yield and quality traits of bread wheat (Triticium aestivum L.). Turkish J. Agric. Sci. Technol. 7: 1928-1936.
17. Alaoui, I., El Ghadraoui, O., Serbouti, S., Ahmed, H., Mansouri, I., El Kamari, F., Taroq, A., Ousaaid D., Squailli, W., Farah, A. (**2022**). The mechanisms of absorption and nutrients transpot in plants: a review. Tropical J. Natural Prod. Res. 6(1): 8-14
18. Setiyono, T. D., Walters, D. T., Cassman, K. G., Witt, C., Dobermann, A. (**2010**). Estimating maize nutrient uptake requirements. Field Crops Research, 118(2): 158-168.
19. Acar, S. (**2019**). Şanlıurfa'da Tüketilen Siyah Çay Çeşitlerinin Ağır Metal İçeriklerinin Saptanması, Harran Üniversitesi, Fen Bilimleri Enstitüsü, Yüksek Lisans Tezi, p 45, Şanlıurfa
20. Seengvasan, S., Mangkandan, N., Muraleedharan, N., and Selvasundaram, R., (**2008**). Heavy metal content of black teas from South India. Food Control 19: 746-749.
21. Okut, N., (**2019**). Van İlinden Seçilmiş Bazı Tıbbi Bitkilerin Ağır Metal İçerikleri, Iğdır Üniv. Fen Bil. Enst. Derg. 9 (1): 533-544
22. Mehra, A., Baker, C.L., (**2007**). Leaching and Bioavailability of Aluminium, Copper and Manganese From Tea (Camellia sinensis). Food Chem. 100: 1456-1463