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Assessment of Element Concentrations in Soil, Root and Leaf of Spinach Plant (*Spinacia oleracea* L.) Grown in Manisa

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ABSTRACT: In this study, it was aimed to determine the concentration of 24 elements in root and leaves of spinach (*Spinacia oleracea* L.) and in soil using ICP-OES. Al, B, Ba, Ca, Cr, Cu, Fe, K, Mg, Mn, Na, Ni, Pb, Si, Sr, Ti and Zn metal concentrations in spinach samples were found to be 30–151.6 mg kg-1, 0.2–1.4 mg kg-1, 3.8–13.6 mg kg-1, 1615–14131 mg kg–1, 0.3–1.5 mg kg-1, 6.9–113.2 mg kg-1, 96.1–420.1 mg kg-1, 23215–132772 mg kg-1, 2109–7271 mg kg-1, 19 – 90.5 mg kg-1, 604.4 – 22750 mg kg-1, 0.1–1.3 mg kg-1, 5.5–7.5 mg kg-1, 140–475 mg kg-1, 24.6–66 mg kg-1, 2.0–28 mg kg-1 and 23.9–123.9 mg kg-1, respectively. Statistical comparisons for comment on the obtained results were done by using one-way Anova test. According to statistical evaluations, it was found that there are meaningful relations in $P < 0.01$ and $P < 0.05$ significant levels between element concentrations (Al, Ba, Co, Cr, Fe, K, Mn, Na, Ni, Pb, Si and Ti) in roots and leaves of the spinach and element concentrations of the soil.

Keywords: Anova, element concentrations, ICP- OES, spinach

Manisa'da Yetiştirilen Ispanak Bitkisinin (*Spinacia oleracea* L.) Toprak, Kök ve Yaprak Element Konsantrasyonlarının Değerlendirilmesi

ÖZET: Bu çalışmada ıspanağın (*Spinacia oleracea* L.) kök ve yapraklarında ve toprakta bulunan 24 element konsantrasyonunun ICP-OES kullanılarak belirlenmesi amaçlanmıştır. Ispanak numunelerinde Al, B, Ba, Ca, Cr, Cu, Fe, K, Mg, Mn, Na, Ni, Pb, Si, Sr, Ti ve Zn metal konsantrasyonları sırasıyla mg kg-1 olarak 30–151.6, 0.2–1.4, 3.8–13.6, 1615–14131, 0.3–1.5, 6.9–113.2, 96.1–420.1, 23215–132772, 2109–7271, 19–90.5, 604.4–22750, 0.1–1.3, 5.5–7.5, 140–475, 24.6–66, 2.0–28 and 23.9–123.9 mg kg-1 miktarlarında tespit edildi. Elde edilen sonuçlarla one-way Anova testi kullanılarak yapılan istatistiksel değerlendirmelere göre; Al, Ba, Co, Cr, Fe, K, Mn, Na, Ni, Pb, Si ve Ti element konsantrasyonları ile kök, gövde ve toprak arasında $P < 0.01$ ve $P < 0.05$ düzeylerinde anlamlı ilişki bulunduğu tespit edilmiştir.

Anahtar Kelimeler: Anova, element konsantrasyonu, ICP- OES, ıspanak

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INTRODUCTION

Food commodities are contaminated by toxic heavy metals from various sources of polluted ecosystem. Environmental view to the plant chemistry as a study field has been attracted attention a lot for last 20-40 years. Studies on plant chemistry have been basically focused on toxicity of specific elements and mineral substantiality of plants (Reimann, 2001; Carrilho, 2002; Babaoğlu, 2004; Basgel, 2006; Raju, 2006; Karak, 2010; Aziz, 2016; Shahzad, 2016; Shahzad, 2017; Antoniadis, 2017). Vegetables contain a lot of essential amino acid, carbohydrates, minerals, vitamins and dietary fibers. Human metabolic processes need them.

Manisa region is located in western part of Turkey. It has very rich agricultural soil. Spinach, which is one of plants grown in this soil, is an edible flowering plant consumed different forms especially by human and animals everyday life. Its leaves are eaten as a vegetable.

Spinach is herbaceous plant with tap-root. It likes warm, cool and wet weather. It begins to die from -5^{o}C degrees. Good products may be taken in sandy-loamy and fertilized soils. It has got A, B, C and D vitamins.

Also, it is rich of protein and Fe. It increases strength of body. It is useful for diabetes management, cancer prevention, asthma prevention, lowering blood pressure, bone health and healthy skin and hair (MNT, 2017). It threats anemia and decrease mental disease symptoms. Element analyzes of the spinach and some vegetables have been carried out by using many analytical method (flame atomic absorption spectrometry (FAAS) (Basgel, 2006; Szymczycha-Madeja, 2015), atomic absorption spectrometry (AAS) (Fung, 1978; Lajunen, 1992; Mohamed, 2003; Hanif, 2006), inductively coupled plasma mass spectrometry (ICP-MS) (Dressler, 2001), ICP-AES, (Basgel, 2006), ICP-OES (Durduran, 2015; Szymczycha-Madeja, 2015), neutron activation analysis (Kulkarni, 2006) and Thick Target Proton Induced X-ray Emission (TTPIXE) (Saarela, 1995). ICP-OES, is an analytically powerful device for many applications (Carrilho, 2002). It needs a liquid sample presentation. Organic material is destructed by wet or dry oxidation in sample preparation. Acid mixtures such as HNO_3 + $HClO_4$, HNO_3 + H_2O_2, or HNO_3 alone are used for multi-element analysis (Pöykio, 2000).

In this study, it was aimed to determine the concentration of 24 elements in root and leaves of spinach (*Spinacia oleracea* L.) and in soil collected from eight different stations in Manisa using ICP-OES. As results of these, meaningful relations between the elements in roots and leaves of spinach, have been investigated using statistical comparisons using one way analysis of variance.

MATERIALS AND METHODS

Element analyzes of vegetables have been carried out by using many analytical method. ICP-OES, is an analytically powerful device for many applications (Carrilho, 2002). It needs a liquid sample presentation.

Organic material is destructed by wet or dry oxidation in sample preparation. Acid mixtures such as HNO3 + HClO4, HNO3 + H2O2, or HNO3 alone are used for multi-element analysis (Pöykio, 2000). The spinach and soil samples were collected from 8 different stations in Manisa. The spinach samples were separately washed with deionized water. They dried in air. Root and leaves of spinach samples were digested in a grinder and weighed to be one gram sample in the glass beaker. HNO_3 (3 mL) and H_2O_2 (5 mL) was added to the samples and waited for one night.

The following day, the beakers were heated. But they weren't dry and they were heated until staying a little acid in the beaker. After, HNO_3 (3 mL) and HCl (9 mL) was added and heated. The residue was filtered by filter paper. The solutions were put to 100mL plastic flasks.

Then, it was completed to the volume with deionized water (Lajunen, 1992). Element concentrations in the solutions were determined

with Inductively Coupled Plasma Optic Emission Spectrometry (ICP-OES). The one way of ANOVA test was used for the statistical results. The significance was investigated at $P < 0.05$ and $P < 0.01$ levels (Schaefer, 1989).

RESULTS AND DISCUSSION

Element concentrations analyzed in the root and leaves of spinach collected from 8 different stations were given in Table 1 and 2, respectively. Elements can be categorized as essential (Cu, Fe, Mn, Se and Zn), probably essential (Co,V) and potentially toxic (As, Cd, Hg, Ni and Pb) (Oteef, 2015). While Al, B, Ba, Ca, Co, Fe, K, Mg, Mn, Na, Ni and Zn are an essential element, Cu and Pb are the toxic elements for plants.

Also, element concentrations in the soil samples on which spinaches are grown were given in Table 3. Al, B, Ba, Ca, Cd, Co, Cr, Cu, Fe, K, Mg, Mn, Na, Ni, Pb, Si, Sn, Sr, Ti and Zn element concentrations in root of spinach were found as 55 – 151.6 mg.kg^{-1}, 0.7 – 1.4 mg.kg^{-1}, 4.6 –9.2 mg.kg^{-1}, 6865 – 14131 mg.kg^{-1}, 0.01 – 226.9 mg.kg^{-1}, 2.0 – 2.6 mg.kg^{-1}, 0.8 – 1.5 mg.kg^{-1}, 9.6 – 113.2 mg.kg^{-1}, 221.4 – 420.1 mg.kg^{-1}, 46500 – 125625 mg.kg^{-1}, 3209 – 7271 mg.kg^{-1}, 30.2 – 90.5 mg.kg^{-1}, 823 – 22750 mg.kg^{-1}, 0.1 – 1.3 mg.kg^{-1}, 6.0 – 7.5 mg.kg^{-1}, 140 – 475 mg.kg^{-1}, 18.5 – 24.8 mg.kg^{-1}, 24.6 – 66 mg.kg^{-1}, 6.8 – 28 mg.kg^{-1} and 43.3 – 123.9 mg.kg^{-1}, respectively (Table 1).

Al, B, Ba, Ca, Cr, Cu, Fe, K, Mg, Mn, Na, Ni, Pb, Si, Sr, Ti and Zn element concentrations in leaves of spinach were ranged from 30–83 mg kg^{-1}, 0.2–0.4 mg kg^{-1}, 3.8–13.6 mg kg^{-1}, 1615–3482 mg kg^{-1}, 0.3-1.1 mg kg^{-1}, 6.9-11.5 mg kg^{-1}, 96.1-295.6 mg kg^{-1}, 23215–132772 mg kg^{-1}, 2109–2960 mg kg^{-1}, 19–49.8 mg kg^{-1}, 604.4–12340 mg kg^{-1}, 0.1–0.6 mg kg^{-1}, 5.5–7.3 mg kg^{-1}, 257.5–1140 mg kg^{-1}, 28.7–44.7 mg kg^{-1}, 2.0–10.7 mg kg^{-1} and 23.9–55.4 mg kg^{-1}, respectively (Table 2).

Measured Cd and Co concentrations were very low value. Sn element concentration was detected in only 3 samples. According to Table 3, Al, Ba, Ca, Cd, Co, Cr, Cu, Fe, K, La, Mg, Mn, Na, Ni, Pb, Sb, Si, Sr, Ti, Zn and Zr element concentrations in the soil samples were obtained to be 3150–11960 mg kg^{-1}, 38.4–156.1 mg kg^{-1}, 2330–29360 mg kg^{-1}, 0.1–0.4 mg kg^{-1}, 5.8–13 mg kg^{-1}, 28.7–56.5 mg kg^{-1}, 5.1–22.7 mg kg^{-1}, 5802–14060 mg kg^{-1}, 18.9–54.1 mg kg^{-1}, 5.3–12.5 mg kg^{-1}, 3199–7167 mg kg^{-1}, 151.6–359.8 mg kg^{-1}, 15–42 mg kg^{-1}, 33– 0.4 mg kg^{-1}, 5.9–14.7 mg kg^{-1}, 1.0–2.2 mg kg^{-1}, 22.9–47.1 mg kg^{-1}, 25.6–77.3 mg kg^{-1}, 315.9–1114 mg kg^{-1}, 21.3–72.7 mg kg^{-1}and 1.1–3.4 mg kg^{-1}, respectively (Table 3).

It was seen that element contents in root and leaves of spinach were similar rates in Table 1 and 2. Ca, K, Mg and Na element concentrations (> 1000 mg kg^{-1}) were higher than the other element concentrations in root and leaves of spinach. Similarly, B and Ni elements were minimum level in the root and leaves.

Cu and Zn elements have been concentrated in the roots. Li et al. reported that Cu and Zn concentrations were high value in the roots of the water spinach (Li, 2016) (Table 4). Although Al concentration is high in the soil, it is not more transfer from soil to the roots and leaves. The leaves have only high Si concentrations. The levels of Ba, Cr, Fe, Mn, Ni and Ti elements in the soil were high. While the K and Na values in the soil are low levels, they accumulated in both roots and leaves.

While La weren't detected in the spinach samples, Bi weren't detected in the soil samples. While B, Bi and Sn were not detected in the soil samples, La, Sb and Zr were measured. Uranium concentrations weren't detected in all samples. The results obtained in this study have been compared with the reported literature studies in Table 4.

The potentially toxic elements (Cd, Ni and Pb) in this study are comparable with the literature values (0.0015-21.2 mg kg^{-1} for Cd, 0.122-2.54 for Ni and 0.046-71.6 for Pb).

Table 1. Concentrations of some elements in the root of spinach (mg kg^{-1}).

Elements	Sample Numbers								Min.	Max.	S.D*
	1	2	3	4	5	6	7	8			
Al	136	62.7	151.6	94.9	108.1	57.9	92.5	55.0	55.0	151.6	36.1
B	1.1	1.4	1.3	1.0	1.3	1.3	1.2	0.7	0.7	1.4	0.2
Ba	4.6	7.0	9.2	5.0	7.2	5.3	8.0	5.9	4.6	9.2	1.6
Bi	ND**	ND	ND	0.4	0.7	0.4	0.5	ND	ND	0.7	0.3
Ca	8385	14131	10510	13670	9645	9687	6865	10440	6865	14131	2457
Cd	10.5	226.9	82.2	0.01	56.5	123.6	33.3	0.2	0.01	226.9	77.8
Co	2.4	2.1	2.6	2.0	2.1	2.3	2.2	2.3	2.0	2.6	0.2
Cr	1.3	1.0	1.5	1.0	0.9	0.8	1.0	0.9	0.8	1.5	0.2
Cu	23.1	113.2	56.9	9.9	10.3	16.7	11.7	9.6	9.6	113.2	36.6
Fe	420.1	300.2	550.0	322.0	286.7	274.0	323.1	221.4	221.4	420.1	1029
K	67125	70350	82425	89000	90125	125625	110650	46500	46500	125625	24995
Mg	3209	5830	3781	7271	3963	4344	3274	4906	3209	7271	1392
Mn	75.1	61.5	90.5	30.2	48.6	86.9	46.0	48.5	30.2	90.5	21.5
Na	8829	3697	4418	22750	9889	823.4	10660	1308	823	22750	7133
Ni	1.0	ND	1.3	ND	0.3	1.2	0.3	0.1	0.1	1.3	0.5
Pb	6.9	6.0	6.4	6.5	6.4	7.1	6.4	7.5	6.0	7.5	0.5
Si	140.0	340.0	475.0	390.0	370.0	297.5	397.5	347.5	140.0	475.0	97.6
Sn	18.5	20.4	21.2	21.4	21.7	23.7	24.2	24.8	18.5	24.8	2.1
Sr	24.6	48.7	49.0	66.0	26.6	29.8	29.7	45.7	24.6	66.0	14.6
Ti	22.3	17.9	28.0	12.8	11.0	11.6	12.2	6.8	6.8	28.0	6.9
Zn	59.9	46.3	46.2	45.2	123.9	109.5	43.3	92.5	43.3	123.9	32.8

* S.D. Standard Deviation. **ND. Not Determined.

Table 2. Concentrations of some elements in the spinach leaves (mg kg^{-1}).

Elements	Sample Numbers								Min.	Max.	S.D *
	1	2	3	4	5	6	7	8			
Al	45.9	45.9	56.3	70.0	77.6	30.0	83.0	75.2	30.0	83.0	18.8
B	0.3	0.2	0.3	0.2	0.4	0.2	0.3	0.4	0.2	0.4	0.1
Ba	8.0	8.7	13.1	3.8	13.6	9.9	13.5	7.5	3.8	13.6	3.5
Bi	0.4	0.7	0.2	0.3	0.1	0.7	ND**	0.4	ND	0.7	0.3
Ca	2086	2235	2554	1790	3482	1615	2258	2982	1615	3482	617
Cd	0.02	0.08	0.001	ND	0.08	0.05	0.001	0.001	ND	0.08	0.036
Co	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.001
Cr	0.6	0.7	0.8	0.6	0.8	0.3	0.9	1.1	0.3	1.1	0.2
Cu	9.3	11.5	12.0	6.9	7.2	8.3	8.2	6.7	6.9	11.5	2.0
Fe	155.2	177.3	226.2	170.4	241.7	96.10	295.6	258.3	96.1	295.6	64.50
K	132772	29550	33525	45950	80225	33025	47700	23215	23215	132772	36640
Mg	2694	2186	2294	2109	2960	2191	2520	2397	2109	2960	292.0
Mn	35.3	29.0	41.5	19.0	32.2	49.8	29.9	22.2	19.0	49.8	10.0
Na	12340	604.4	3756	8154	3958	2832	8053	1346	604.4	12340	4017
Ni	0.3	ND	0.1	ND	0.6	0.5	0.5	0.1	ND	0.6	0.3
Pb	7.1	6.8	6.2	5.5	6.2	6.2	6.3	7.3	5.5	7.3	583.0
Si	1140	362.5	455.0	305.0	412.5	257.5	342.5	320.0	257.5	1140	286.0
Sn	ND	ND	ND	18.9	21.2	20.0	ND	ND	ND	21.2	10.4
Sr	28.7	31.9	44.7	29.0	29.8	26.3	31.1	37.2	28.7	44.7	5.92
Ti	6.2	7.2	7.4	3.4	5.0	2.0	10.7	6.8	2.0	10.7	2.7
Zn	35.7	23.9	27.0	19.5	39.4	55.4	33.1	37.9	23.9	55.4	11.1

* S.D. Standard Deviation. **ND. Not Determined.

Table 3. Element concentrations of soil samples (mg kg^{-1}).

Elements (mg kg^{-1})	Sample Numbers								Min.	Max.	S.D *
	1	2	3	4	5	6	7	8			
Al	7144	3869	11960	7172	5280	5104	4040	3150	3150	11960	2828.9
Ba	93.7	72.0	156.1	123.5	111.5	109.1	108.9	38.4	38.4	156.1	35.0
Ca	25260	16280	10688	29360	4852	5008	4382	2330	2330	29360	10338
Cd	0.3	0.1	0.4	0.3	0.2	0.3	0.3	ND	0.1	0.4	0.1
Co	9.5	7.3	13.0	11.3	11.0	10.5	9.9	5.8	5.8	13.0	2.3
Cr	35.1	28.7	56.5	45.5	48.4	41.3	39.6	33.2	28.7	56.5	8.9
Cu	9.7	8.1	18.4	22.7	11.0	110.0	12.0	5.1	5.1	22.7	5.7
Fe	11470	8850	14060	12680	11970	10750	11110	5802	5802	14060	2531
K	33.1	29.7	54.1	46.2	40.4	43.3	50.4	18.9	18.9	54.1	11.7
La	8.4	5.3	12.5	10.4	10.4	11.5	9.4	5.3	5.3	12.5	2.7
Mg	5976	4648	7167	6329	5644	5036	4827	3199	3199	7167	1209
Mn	225.5	166.5	359.8	292.6	300.3	265.0	243.2	151.6	151.6	359.8	69.6
Na	26.0	19.0	42.0	33.0	36.0	30.0	39.0	15.0	15.0	42.0	9.5
Ni	44.5	33.0	70.0	53.6	64.9	56.2	54.5	40.3	33.0	70.4	12.5
Pb	7.7	5.9	14.7	14.3	12.8	8.6	11.3	6.7	5.9	14.7	3.5
Sb	1.3	1.0	2.1	1.1	1.4	1.7	2.2	1.8	1.0	2.2	0.4
Si	44.9	22.9	47.1	23.1	38.8	37.9	31.9	27.5	22.9	47.1	9.4
Sn	ND**	ND	ND	ND	ND	ND	0.8	ND	ND	0.8	-
Sr	38.4	25.6	77.3	51.3	47.8	48.7	54.1	26.4	25.6	77.3	16.7
Ti	879.9	663.2	1114	974.0	827.6	913.1	828.5	315.9	315.9	1114	239.3
Zn	29.2	21.3	72.7	44.2	42.5	34.4	39.4	21.9	21.3	72.7	16.4
Zr	1.9	1.6	3.4	2.2	2.8	2.6	2.5	1.1	1.1	3.4	0.7

* S.D. Standard Deviation. **ND. Not Determined.

Table 4. Element concentrations in vegetables given in literature studies (mg kg^{-1}).

Sample	Country	Al	Ba	Ca	Cd	Cu	Fe	Mg	Mn	Ni	Pb	Zn	Reference
Collard Greens	Brazil	23.04	7.96	5906.5	0.01	1.26	111.08	2235.9	63.4	2.54	1.03	25.36	Amato-Lourenco, 2016
Malva Sylvestris	Turkey	42.90	13.6	15936	ND	8.30	88.62	203900	26.78	ND	1.54	19.90	Hicsonmez, 2009
Leafy Greens	USA	17	22	-	0.20	-	-	-	-	-	0.59	-	McBridea, 2014
Lettuce	Saudi Arabia	-	-	-	0.280	4.61	-	-	-	-	ND	31.32	Oteef, 2015
Roots	USA	3.6	8.9	-	0.070	-	-	-	-	-	1.90	-	McBridea, 2014
Spinach	Nigeria	-	-	-	0.430	0.33	0.240	-	-	0.02	0.07	0.060	Opaluwa, 2012
Spinach	Kosova	-	-	-	0.001	0.63	5.579	-	1.256	0.12	0.04	1.726	Micic, 2015
Spinach	Saudi Arabia	-	-	-	0.310	9.74	-	-	-	-	0.42	52.94	Oteef, 2015
Spinach	Brazil	65.74	7.59	7543.8	0.210	5.57	151.2	4738.0	317.1	0.74	0.42	58.23	Amato-Lourencoa, 2016
Water Spinach (Edible Parts)	China	-	-	-	10.90	42.1	-	-	-	-	71.6	276.0	Li, 2016
Water spinach (Roots)	China	-	-	-	21.20	63.0	-	-	-	-	64.0	446.0	Li, 2016
Spinach	Turkey	83	13.6	3482	0.080	11.5	295.6	29600	49.80	0.60	7.30	55.40	In this work

ANOVA, a powerful statistical technique, can be used to estimate and separate the different causes of variation. It can also be used in situations where there is more than one source of random variation (Miller, 1993). One-way ANOVA can be used when there is only one factor being considered and replicate data from changing the level of the factor are available.In the present study, one-way ANOVA was used to compare the means between all the spinach and soil samples, the statistical results of some element concentrations relating to the root and leaves of spinach were given in Table 5.

Table 5. Comparisons element concentrations in the root and leaves with Anova test.

Element	F-ratio	Probability	Significance	Element	F-ratio	Probability	Significance
Al	5.67	0.032	*	Na	0.85	0.371	NS
B	105.2	0.000	**	Mg	18.33	0.001	**
Ba	12.98	0.003	**	Mn	11.65	0.004	**
Bi	0.55	0.471	NS	Ni	1.74	0.209	NS
Ca	80.61	0.000	**	Pb	0.25	0.625	NS
Cd	1.49	0.242	NS	Si	1.94	0.185	NS
Co	7.47	0.016	*	Sn	14.94	0.002	**
Cr	8.24	0.012	*	Sr	1.94	0.185	NS
Cu	3.06	0.102	NS	Ti	12.46	0.003	**
Fe	1.87	0.193	NS	Zn	9.07	0.009	**
K	2.96	0.108	NS				
*P<0.05				**P<0.01	NS:Not significance		

According to the Table 5, there was a meaningful relation in P < .01 significant level between element concentrations of B, Ba, Ca, Mg, Mn, Sn, Ti and Zn in the root and leaves of spinach. It was determined that relation to between Al, Co and Cr is weaker than others and it is in P > .05 significant level. While these element concentrations in the root and leaves of spinach were changing with together, as seem to Table 4, there wasn't a meaningful relation for statistical comment between element concentrations of Bi, Cd, Cu, Fe, K, Na, Ni, Pb, Si and Sr. This result was indicated that a for mentioned element concentrations were independent from each other in the roots and leaves of spinach.

Statistical comparisons (between element concentrations in the roots of spinach and element concentrations of soils which spinaches were grown on; between element concentrations in the leaves of spinach and element concentrations of soils which spinaches were grown on) was given in Table 6 and 7, respectively.

Table 6. Comparisons of element concentrations in root and soil with Anova test

Elements	F- ratio	Probability	Significance	Elements	F- ratio	Probability	Significance
Al	34.44	0.000	**	Mn	54.16	0.000	**
Ba	58.47	0.000	**	Na	7.61	0.015	*
Ca	0.240	0.629	NS	Ni	138.9	0.000	**
Co	87.16	0.000	**	Pb	9.40	0.008	**
Cr	156.3	0.000	**	Si	79.80	0.000	**
Cu	0.08	0.786	NS	Sr	0.57	0.463	NS
Fe	137.4	0.000	**	Ti	89.14	0.000	**
K	92.92	0.000	**	Zn	6.23	0.026	*
Mg	1.44	0.251	NS				
*P<0.05			**P<0.01				

As can be seen in Table 6, there was not a meaningful relation for statistical comment between element concentrations of Ca, Cu, Mg and Sr in the root of spinach and element concentrations of Ca, Cu, Mg and Sr in soil. For other elements (Al, Ba, Co, Cr, Fe, K, Mn, Na, Ni, Pb, Si, Ti and Zn), it was determined that there was a meaningful relation in $P < .01$ and $P < .05$ significant levels (Table 6).

Table 7. Comparisons of element concentrations in leaves and soil with Anova test

Elements	F- ratio	Probability	Significance	Elements	F- ratio	Probability	Significance
Al	34.85	0.000	**	Mn	76.54	0.000	**
Ba	58.47	0.000	**	Na	12.89	0.003	**
Ca	7.30	0.017	*	Ni	140.3	0.000	**
Co	92.89	0.000	**	Pb	11.43	0.004	**
Cr	158.8	0.000	**	Si	16.82	0.001	**
Cu	1.54	0.235	NS	Sr	4.86	0.045	NS
Fe	141.1	0.000	**	Ti	91.31	0.000	**
K	16.85	0.001	**	Zn	0.34	0.567	NS
Mg	44.54	0.000	**				
*P<0.05			**P<0.01				

As given in Table 7, while there was not a meaningful relation for statistical between Cu, Sr and Zn element concentrations of the spinach leaves and Cu, Sr and Zn element concentrations of soil, there was a meaningful relation in $P < .01$ and $P < .05$ significant levels for other elements.

CONCLUSION

Generally, the levels of the analyzed elements in the root of spinaches were higher than in the leaves of plants because of the transportation of the elements from the roots to leaves. The results of this study indicated that the element concentrations in the root of spinach were higher than the results of leaves. Change of the element concentration in root of spinach is in the order of K > Na > Ca > Mg > Si > Fe > Cd > Al > Zn > Cu > Mn > Sr > Ti > Sn. The levels of other elements are lower than 10 $mg.kg^{-1}$. Accumulation of the elements in leaves of spinach is similar to the results of root. In the soil samples, element concentrations are Ca > Fe > Al > Mg > Ti > Mn > Ba > Sn > Zn > Ni > Cr > K > Si > Na > Cu > Pb > Co > La.

Concentrations of elements between samples were also compared using one-way ANOVA. The results of ANOVA analysis indicated that there was not a meaningful relation between element concentrations of Cu and Sr in the spinach and in the soil and that there was a meaningful relation in $P < 0.01$ and $P < 0.05$ significant levels for other elements. According to this result, it can be deduced that Cu and Sr element concentration shows variation independently from the other element concentrations in spinach. The forceful relation ($P \leq 0.001$) between elements in spinach and soil is found for Al, Ba, Co, Cr, Fe, Mn, K, Mg, Mn, Ni and Ti.

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