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Distribution of macro- and micro nutrient elements and heavy metals in the sugar beet (*Beta vulgaris* var. *saccharifera* L.) plant parts

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Abstract

Macro element concentrations of sugar beet parts exhibited some differences depending on sugar beet parts. P and K amounts of sugar beets changed between 470.44 mg/kg (tail) and 4209.92 mg/kg (leaf) to 6301.20 mg/kg (exterior of root) and 41092.03 mg/kg (leaf), respectively. In general, while the highest macroelement contents are determined in the sugar beet leaf, these values were found in the lowest amounts in the beet root tail (except interior part of beet root for P and Ca element). In general, micro element contents of the sugar beet parts were designated in the leaf as the highest, and followed by the head, outside part of beet root, inside part of beet root and root tail in descending order. The most heavy metal contents have been found in the sugar beet leaf. Also, Al, B and Pb have been the most common metals found in the sugar beet parts.

Keywords: sugar beet (*Beta vulgaris* L.), root, leaf, macro and micro elements, heavy metals, accumulation, ICP-OES

1. Introduction

Beet (*Beta vulgaris* var. *saccharifera* L.), a bright red-colored plant belonging to the Chenopodiaceae family, is an industrial plant widely grown in Europe and America [15]. It is known that the chemical composition of plants varies depending on the basic composition of the growth medium in general. They can absorb heavy metals from the air (or water) with plant shoots and the elements from the soil by absorption [14]. Soil pollution caused by heavy metals can become non-degradable and toxic at higher concentrations compared to organic pollutants or radionuclides [8]. The potential absorption by plants is considered to be high if the heavy metal content in the soil is present in high concentrations. Therefore, a detailed risk assessment of heavy metal accumulation in agricultural lands is required in the application of inorganic fertilizers, organic waste and pesticides to the soil to ensure safe and healthy crop production [18].

As a result of soil pollution caused by human activities and natural processes, it constitutes the biggest risk source that creates the potential of metals leaking into groundwater and threatening plant, animal and human life [3,7,31]. It has been stated that metals cause environmental concerns as they are harmful to humans and animals and tend to bioaccumulate in the food chain as large areas of agricultural land are contaminated with metals [19,34]. It is very important to know the impurity content of sugar beet by-products such as molasses and dried sugar beet pulp (fibers), which are common today as food supplements due to its health benefits [10]. Even low concentrations of arsenic, cadmium, chromium, mercury and lead are known to be the most common heavy metals that can pose a threat to humans [9].

Low intake of toxic heavy metals, which are risky not only to the environment but also to the human population, has harmful effects on humans and other animals [12] and there is no effective mechanism for their elimination.

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The harmful effects of heavy metals only become visible after a few years of exposure [2]. Heavy metal concentration, type of fertilizer applied, plant growth stage and species are considered to be the main factors affecting metal uptake from the soil by the plant [13, 17, 22]. As with sugar beet leaves and other vegetables, it has been reported that the metal concentrations accumulated on the plant surface are greatly influenced by the morpho-physiological nature of the vegetables [11, 24, 25]. The most dangerous pollutants of the soil ecosystem as well as the food chain around the world are heavy metals, and the sources of heavy metal contamination are wastewater irrigation, application of metal-based pesticides and fertilizers, industrial emissions, and transportation. Irrigation with wastewater is the main factor that causes the increase in the heavy metal content of the soil [16,33]. High concentrations of heavy metal accumulation have been reported in grown vegetables in agricultural areas irrigated with untreated [22]. Several previous studies have been conducted on the basic composition of sugar beet, sugar beet and the quality of final products [15, 23]. The aim of present study was to determine distribution of macro- and micro nutrient elements and heavy metals in the the parts (leaf, head, inerior part of beet root, exterior part of beet root and root tail) of sugar beet plant.

2. Materials and Method

The sugar beets (about 50 roots) used in this study were harvested from Konya-Karapınar district in 2020. Beets were washed thoroughly in tap water and then washed again with distilled water. Later, after the leaves of beet roots are separated from the beet body, the outer part of the head, tail and stem (root) is cut 2 cm thick and divided into parts. These parts are named leaf, head, tail, exterior root and interior root. The samples were air-dried and sieved through a 2-mm polyethylene sieve before analysis. All the prepared samples were stored in polyethylene bags at the temperature about 4°C till analysis.

2.1.Method

2.1.1. Element analysis of sugar beet parts

Sugar beet samples weighed 0.2 g for each sample were dissolved in microwave device (Cem MARSXpress) under high temperature (210 ºC) and pressure (200 PSI) with 5 ml concentrated HNO3 and 2 ml H_2O_2 (30% w / v) and a 40-cell microwave was used to ensure the reliability of the analysis. 1 blank and 1 certified reference material (1547a Wheat Flour, 8346 Condition Wheat Flour, 1547 Peach Leaves, NIST) was added to the set. The volumes of the dissolved samples are complemented to 20 ml with deionized water and the concentrations of heavy metals in the samples determined by Inductively coupled plasma optical emission spectrometry (ICP-OES; Varian-Vista Model) equipment [28].

2.1.2. Se Analysis of Samples:

Snack and dried fruit samples were dissolved in a microwave device (Cem MARSX press) with 5 ml concentrated HNO_3 and 2 ml H_2O_2 (30% w / v) under high temperature (210 ºC) and pressure (200 PSI) to ensure the reliability of the analysis. 1 blank and 1 certified reference material (1547a Wheat Flour, 1547 Peach Leaves, 1573a Tomato Leaves, NIST) was added to the 40-cell microwave set. The volumes of the dissolved samples were filled to 30 ml with deionized water and the selenium concentration in the samples was measured with the ICP-OES device to which the ETC-60 (Electro Thermal Temperature Controller) and HS 60 (Hydride System) apparatus were connected. First, 10 ml of the samples are taken and treated with 10 ml hydrochloric acid, then the Se (+ VI) form is reduced to the Se (+ IV) form by keeping it in a water bath at 90 C for 20 minutes, and then a hydride generator installed in front of the sample inlet system of the ICP-OES device Thanks to the module, Se measurements are made.

2.1.3. Statistical analyses

Statistical analysis of the data obtained on sugar beet plant parts was performed using the ANOVA test (JMP, SAS Institute, Cary, NC) in the JMP statistics program [21].

3. Results and discussion

3.1. Macro element contents of sugar beet parts

Macro nutrient elements of ripe sugar beet parts (leaf, head, exteriorof root, interior of root and tail) are given in Table 1. Macro element concentrations of sugar beet parts exhibited some differences depending on sugar beet parts. The highest macro elements were found in leaf of sugar beet. In this study, sugar beet leaf, head, root (exterior), root (interior) and tail were used to determine macro, micro elements and heavy metals. While N contents of sugar beets vary between 6708.29 mg/kg (tail) and 30438.81 mg/kg (leaf), Na contents of sugar beet portions were measured between 241.48 mg/kg (tail) and 14391.21 mg/kg (leaf). P and K amounts of sugar beets changed between 470.44 mg/kg (tail) and 4209.92 mg/kg (leaf) to 6301.20 mg/kg (exterior of root) and 41092.03 mg/kg (leaf), respectively. Also, Ca contents of sugar beet parts were determined between 1445.22 mg/kg (interior part of beet root) and 17557.59 mg/kg (leaf) while Mg amounts of sugar beet parts vary between 1532.54 mg/kg (tail) and 13867.36 mg/kg (leaf). S contents of sugar beet parts were detected between 139.37 mg/kg (tail) and 4382.53 mg/kg (leaf). In general, while the highest macroelement contents are determined in the sugar beet leaf, these values were found in the lowest amounts in the beet root tail (except inside part of beet root for P and Ca element). Depending on the beet parts of the descending order of the plant, the macro element contents consists of leaf, head, outside of beet root, inside part of beet rootand the tail of beet root. In addition, the highest amount of K in beet parts has been determined, followed by N, Mg, Ca and P in descending order (Fig.1). While high concentrations of fertilizers increase S, Na and Mg concentrations in plants, average fertilizer application to plants has been reported to reduce K and Ca in all applications [5]. It has been reported that vegetables play an important role in human nutrition, and elements such as calcium, potassium, iron and sodium, which provide an alkalizing effect and neutralize the acidity produced by other foods [20]. Škrbić et al. (2010) [26] reported that 18.11-37510 mg/kg K, 6.54-8945 mg/kg Na, 14.36-5220 mg/kg Ca, 0.09-2550 mg/kg Mg, 0.01-10.85 mg/kg Zn, 0.42-360.4 mg/kg Fe, and 0.07-7.09 mg/kg (dw) Cu were mean total contents of analyzed elements in sugar beet and different sugar beet based products. Also, Škrbić et al. (2010) [26] determined 7315 mg/kg K, 2370 mg/kg Na, 970 mg/kg Ca, 2275 mg/kg Mg, 6.76 mg/kg Zn, 360.4 Fe, 7.09 mg/kg Cu in Sugar beet. Van der Poel et al., (1998) [29] reported that the highest K and Na were detected in molasses, followed by sugar beet, sugar beet pulp, dried sugar beet pulp, soil and sugar. It has been reported that K and Na contents of Sugar beets fluctuate widely depending on location, weather conditions, soil, fertilizer use and harvest time [29].

Table 1. Macro nutrient element contents of sugar beet parts (mg/ kg)

Samples	N	P	K	Ca	Mg	S	Na
Sugar Beet Leaf	30438.81±112.64 a*	4209.92±119.05 a	41092.03±1845.13 a	17557.59±255.21 a	13867.36±1019.56 a	4382.53±147.21 a	14391.21±50.53 a
Sugar Beet Head	8465.79±698.07 b	800.41±6.79 b	12906.89±440.52 b	1919.84±92.02 b	1828.45±56.03 b	223.20±3.53 b	756.80±32.42 b
Sugar Beet Root (Exterior)	7843.25±526.83 b	474.70±4.87 d	6301.20±1547.13 b	1523.94±104.57 c	1653.13±108.65 b	174.93±0.83 b	296.64±13.70 c
Sugar Beet Root (Interior)	6936.84±39.98 c	597.42±7.73 c	13112.95±6770.75 b	1445.22±196.04 c	1585.27±218.27 b	175.83±3.74 b	315.61±67.62 c
Sugar Beet Tail	6708.29±503.17 c	470.44±26.87 d	12625.95±10012.90 b	1508.60±124.72 c	1532.54±36.84 b	139.37±6.24 b	241.48±27.07 c

*p<0.01

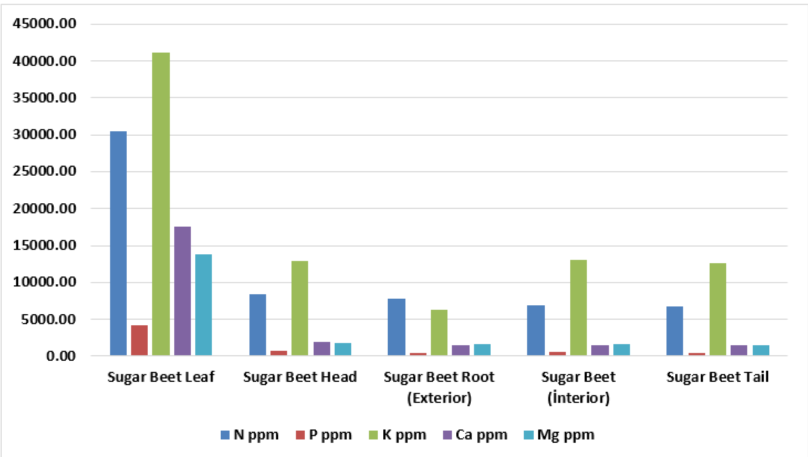

Figure 1. The highest macro nutrients of sugar beet parts (N, P, K, Ca ve Mg)

3.2. Micro element contents of sugar beet parts

The micro nutrient contents of sugar beet parts (leaf, head, exterior of root, interior of root and tail) are presented in Table 2. The micro element contents of sugar beet parts showed some differences depending on beet parts (Fig. 2). In general, the highest micro elements were found in leafs of sugar beet while the lowest micro elements are determined in sugar beet root tail. While Fe amounts of sugar beet parts change between 16.87 mg/kg (exterior part of sugar beet root) and 92.13 mg/kg (leaf), Cu contents of beet parts were determined between 4.35 mg/kg (tail) and 17.43 mg/kg (leaf). Copper mean level in the studied sugar beet (4.35-17.43 mg/kg) was higher than the concentrations given by Mantovi et al., (2003) of 1.5-6 mg/kg and Bojinova et al., (1996) [3] of 11.8 mg/kg determined for beet grown at contaminated area in Bulgaria.

Also, Mn and Zn amounts of sugar beet parts were identified between 9.55 mg/kg (interior part of beet root) and 38.34 mg/kg (leaf) to 3.06 mg/kg (tail) and 21.29 mg/kg (leaf), respectively. The mean Zn content in the sugar beet found to be 3.06-21.29 mg/kg was found the higher value of the range 7-19 mg/kg reported by Mantovi et al., (2003), and much lower than the data given for the beet grown at contaminated area in Bulgaria of 37.1 mg/kg (Bojinova et al., 1996). In addition, B amounts of sugar beet parts varied between 5.15 mg/kg (tail) and 36.47 mg/kg (leaf). In general, micro element contents of the sugar beet parts were designated in the leaf as the highest, and followed by the head, outside part of beet root, inside part of beet root and root tail in descending order. In addition, the microelement amounts of the outside and internal parts of the beet root with minör differences were partially similar. Also, Iron as the highest element in all parts of the sugar beet plant.

Table 2. Micro nutrient element contents of sugar beet parts (mg/ kg)

Samples	Fe	Cu	Mn	Zn	B
Sugar Beet Leaf	92.13±2.37 a*	17.43±0.98 a	38.34±1.03 a	21.29±1.75 a	36.47±1.29 a
Sugar Beet Head	32.77±3.77 b	7.35±0.23 bc	11.54±0.46 b	3.29±0.16 b	7.79±0.22 b
Sugar Beet Root (Exterior)	16.87±1.36 c	6.18±0.65 c	10.51±0.41 bc	3.25±0.08 b	6.49±0.30 bc
Sugar Beet Root (Interior)	18.17±1.72 c	7.68±0.72 b	9.55±1.14 c	3.19±0.23 b	6.71±0.23 bc
Sugar Beet Tail	18.05±0.30 c	4.35±0.49 d	9.67±0.38 c	3.06±0.25 b	5.15±1.78 c

* p<0.01

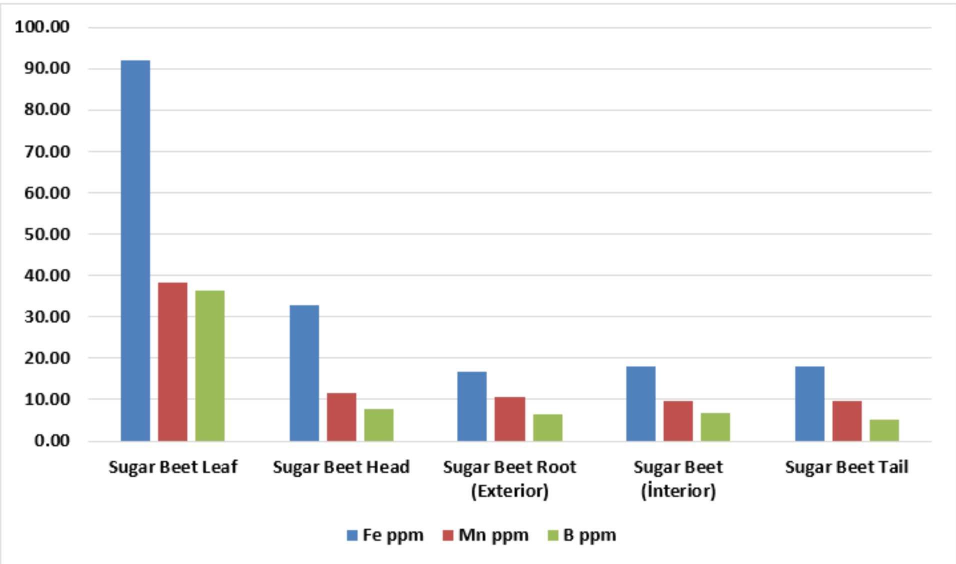

Figure 2. The highest micro nutrients of sugar beet parts (Fe, Mn ve B)

3.3. Heavy metal contents of sugar beet parts

Table 3 shows heavy metal contents of all parts of the sugar beet. The most heavy metal contents have been found in the sugar beet leaf (Fig. 3). Also, Al, B and Pb have been the most common metals found in the sugar beet parts. While Al contents of sugar beet parts change between 3.62 µg/g (interior of sugar beet root) and 734.58 µg/g (leaf), Ba amounts of sugar beet parts were identified between 3.35 (exterior part of beet root). Also, Cr contents of sugar beet portions were determined between 0.18168 (interior part of beet root) and 3.47330 µg/g (leaf) while Pb amounts of sugar beet root parts vary between 1.10931 (head) and 2.20716 µg/g (leaf). It has been reported that lead toxicity causes disturbances in hemoglobin synthesis, joint pain, kidney damage, reproductive, cardiovascular and nervous systems [17b]. In general, Cd, Co and Ni has been element found in the lowest amounts in the sugar beet parts. Ar, Mo and Se were found partially high compared to results of Cd, Co and Ni elements established. The highest Ni was found in sugar beet leaf. Se contents of sugar beet parts changed between 0.15799 (head) and µg/g 0.41374 (exterior part of sugar beet). Selenium, which has significant benefits for animal and human nutrition and is a micronutrient source, can be toxic to animals at high doses, and it has been reported that a plant's ability to absorb selenium from the soil can be altered [27].

Also, Mo contents of sugar beet parts varied between 0.08390 (internal part of sugar beet root) and 0.40389 µg/g (leaf). While Ar contents of sugar beet parts vary between 0.14211 (exterior part of beet root) and 0.27559 µg/g (leaf), Cd contents of sugar beet parts changed between 0.02832 (head) and 0.33396 µg/g (leaf). Arsenic pollution has become an important problem due to its carcinogenic nature and its negative impact on the ecosystem. It has been reported that arsenic pollution in the soil is generally caused by human activities such as mining, incineration, and pesticide application [6]. In general, heavy metal contents belong to sugar beet root were lower than the leaf of sugar beet plant. The fact that the Al concentration is at the highest level in the leaf and head od sugar beet is an advantage for the sugar industry. Because, these parts during the processing of sugar beet are removed due to contained various undesired substances such as nitrogen, heavy metals etc. In addition, it is very llow levels of heavy metal in the beet body constitute an important advantage in the health care. Heavy metals accumulating in vegetables and fruits through intake from soil, water and the atmosphere have been reported to cause various disorders such as kidney damage, nervous disorders, bone disease and tubular growth as a result of dietary intake [20].

Table 3. Heavy metal contents of sugar beet parts (µg/ g)

Samples	Al	As	Ba	Cd	Co
Sugar Beet Leaf	734.58±20.78 a*	0.27559±0.06472 a	49.40±2.08 a	0.33396±0.03843 a	0.32817±0.05599 a
Sugar Beet Head	19.68±2.88 b	0.19275±0.01791 bc	4.38±0.02 b	0.02832±0.00715 b	0.07329±0.02168 b
Sugar Beet Root (Exterior)	4.08±0.51 b	0.14211±0.01595 c	3.35±0.06 b	0.03974±0.00168 b	0.01593±0.00124 c
Sugar Beet Root (Interior)	3.62±0.15 b	0.27514±0.03521 a	4.03±0.09 b	0.03387±0.00303 b	0.03979±0.00179 bc
Sugar Beet Tail	7.21±0.28 b	0.22179±0.03413 ab	4.19±0.23 b	0.03485±0.00107 b	0.05362±0.00804 bc
Samples	**Cr**	**Mo**	**Ni**	**Pb**	**Se**
Sugar Beet Leaf	3.47330±0.10020 a	0.40389±0.05303 a	2.76107±0.15250 a	2.20716±0.06326 a	0.37021±0.01645 a
Sugar Beet Head	0.26386±0.02874 b	0.13133±0.02951 b	0.00768±0.00166 c	1.10931±0.12962 c	0.15799±0.00310 c
Sugar Beet Root (Exterior)	0.19838±0.00997 b	0.12461±0.00689 b	0.01655±0.00167 bc	1.68858±0.07562 b	0.41374±0.03898 a
Sugar Beet Root (Interior)	0.18168±0.06982 b	0.08390±0.00445 b	0.12272±0.02006 bc	1.55825±0.06809 b	0.25878±0.02519b
Sugar Beet Tail	0.18913±0.05411 b	0.13896±0.03090 b	0.13873±0.02952 b	1.60723±0.26993 b	0.37778±0.05732 a

* p<0.01

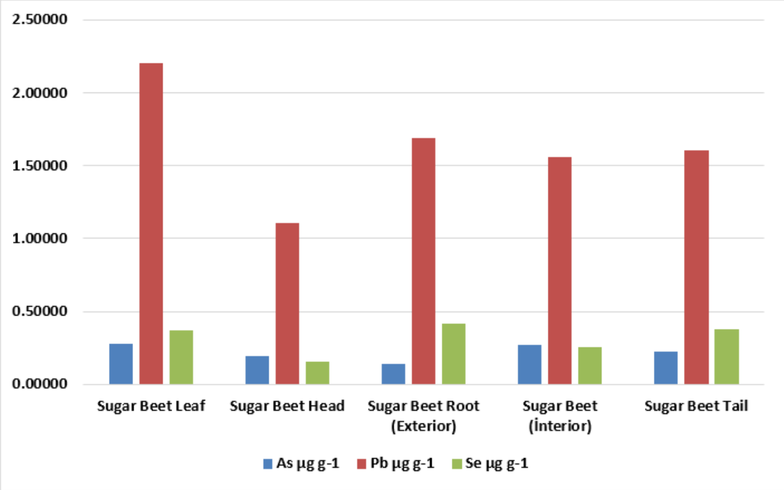

Figure 3. The highest heavy metals of sugar beet parts (As, Pb ve Se)

Agronomic practices such as the use of industrial wastewater and mining activities as a water source or fertilizer for irrigation of crop plants constitute the main sources of metal pollution in agricultural lands [4, 32]. Leafy vegetables, which are more exposed to environmental pollution, take up much higher levels of toxic metals than other vegetables. It has been determined that lead, cadmium and chromium element concentrations accumulate at low, medium or high levels in the shoots and roots of plants [1,30]. As a result, In general, it has been determined that the macro, micro and heavy metal elements of the beet parts accumulate in the highest concentrations in the leaf and the lowest in the tail part. Considering the sugar industrial use of beets, the high amount of these elements in the leaf constitutes an advantage. However, when considered as animal feed, it poses a disadvantage.

4. Conclusion

Macro element concentrations of sugar beet parts exhibited some differences depending on sugar beet parts. The highest macro elements were found in leaf of sugar beet. In this study, sugar beet leaf, head, root (outside), root (inside) and tail were used to determine macro, micro elements and heavy metals.

In general, the highest micro elements were found in leafs of sugar beet while the lowest micro elements are determined in sugar beet root tail. The most heavy metal contents have been found in the sugar beet leaf. Ar, Mo and Se were found partially high compared to results of Cd, Co and Ni elements established.

It has been determined that the macro, micro and heavy metal elements of the beet parts accumulate in the highest concentrations in the leaf and the lowest in the tail part. Considering the sugar industrial use of beets, the high amount of these elements in the leaf constitutes an advantage.

Compliance with Ethics Requirements. Authors declare that they respect the journal's ethics requirements. Authors declare that they have no conflict of interest and all procedures involving human or animal subjects (if exist) respect the specific regulation and standards.

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