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Quantitative Evaluation of Biogenic Element and Heavy Metal Accumulation in Several Aromatic and Green Leafy Vegetables

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Abstract

P and K amounts of aromatic plants and green leafy vegetables were recorded to be between 1.37 (water cress) and 18.51 mg/kg (Early-flowering borage) to 26.46 (water cress) and 9888.12 mg/kg (Early-flowering borage), respectively. In addition, while P contents of the aerial parts of cauliflower vary between 1567 (floret stem) and 2436 mg/kg (stem leave), K amounts of the aerial parts of cauliflower were recorded between 1564 (floret stem) and 5364 mg/kg (stem leave). P and K results of broccoli aerial parts were recorded between 1741 (primary stem) and 2460 mg/kg (floret) to 2524 (stem leave) and 4723 mg/kg (floret), respectively. Fe and Zn results of plant samples were identified to be between 1.70 (water cress) and 251.11 mg/kg (rosemary) to 1.20 (Aysberg lettuce) and 13.97 mg/kg (pepper grass), respectively. Fe and Zn amounts of cauliflower parts were determined to be between 7.55 (main stalk) and 24.39 mg/kg (stem leave) to 2.48 (floret stem) and 9.76 mg/kg (stem leave), respectively. As and Ba contents of plant samples were recorded to be between 3.11 (Aysberg lettuce) and 22.40 µg/g (sourweed) to 0.244 (Oil lettuce) and 18.61 µg/g (Crocus), respectively. The heavy metals detected in the highest amounts in cauliflower and broccoli plants were As, Sr, Pb and Se. As and Sr levels of the parts of cauliflower plant were measured to be between 2.55 (main stalk) and 18.52 mg/kg (floret) to 0.90 (floret) and 10.61 mg/kg (stem leave), respectively.

Keywords: aromatic plants, green leafy vegetables, cauliflower and broccoli, different parts, biogenic elements, heavy metals, ICP-OES

1. Introduction

Since green leafy vegetables, which are popular around the world, constitute important components of human nutrition, heavy metal pollution in vegetables cannot be ignored in terms of food quality assurance [1]. Green leafy vegetables, the most nutritious foods, are rich in minerals and phytochemicals such as iron, calcium, potassium and magnesium [2-4]. Cauliflower (*Brassica oleracea* L. var. *botrytis*), which belongs to the Brassicaceae family, is a widely consumed vegetable because it contains a significant portion of dietary fiber, vitamins, minerals and bioactive compounds [5]. The characteristic taste of vegetables such as cauliflower, which belongs to the Cruciferae family, is related to the presence of sulfur compounds and their derivatives [6]. Broccoli (*Brassica oleracea* var. *italica*), which is native to the Eastern Mediterranean basin and Italy, and a member of the Crucifereae family, is a horticultural and a favorite winter vegetable with high nutritional value, bioactive compounds and antioxidant properties [7-9]. Consumption of Cauliflower, which belongs to the cruciferous family, is limited to florets. The parts of cauliflower that are considered vegetables are given names such as head, crown, flower and inflorescence. Crown size in cauliflower varies depending on sowing-planting time, planting density and variety characteristics [10]. Cauliflower is a widely consumed vegetable rich in glucosinolates, carotenoids, phenolic compounds, carbohydrates,

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proteins, and minerals such as copper, iron, selenium, calcium, manganese and zinc [5, 11]. Vegetables, a rich source of many antioxidants and nutrients necessary for human health, can contribute to 35%, 24% and 11% of the total daily potassium, magnesium and phosphorus needs in the human diet, respectively [12]. Even though some basic and necessary elements such as iron, cobalt, zinc, copper and magnesium are beneficial for both humans and animals, they are harmful to human health when taken in excessive amounts [13,14]. Consuming fruits and vegetables contaminated with high concentrations of heavy metals for a long time can cause damage to the brain, heart, nervous system, liver, kidney, blood, lungs, bones and spleen over time [15]. Heavy metals have emerged as one of the most important food contaminants that threaten human health. They can also mix with industrial wastes, groundwater and drinking water, soil and air [16,17]. Although solid and liquid wastes are the main factors causing soil pollution with the increase in urbanization and industrialization, these wastes accumulate in the soil, and they cause environmental pollution to groundwater [18]. Environmental impacts and related urbanization and industrialization, mining activities, production of electronic devices and their associated waste, fertilizers and pesticides used in agriculture, agricultural areas, sewage waste, paint and other industries can cause soil and water pollution [19, 20]. Heavy metals released into the air, water and soil by various environmental factors are used by plants and increase the heavy metal concentrations of foods [21-23]. Some of the vegetables used in the study grow wild in nature and some are cultivated. No detailed studies have been found on the biogenic element and heavy metal contents of plants with these growing conditions and/or it has been determined that a limited number of studies have been conducted on some of these plants. The aim of this study was to determine the degree of accumulation of macro-, micro element and heavy metal contents of various aromatic plants and green leafy vegetables different organs of the aerial parts of Broccoli and Cauliflower plants provided from Düzce and Konya provinces of Turkey.

2. Materials and Methods

2.1. Material

Some aromatic plants, green leafy vegetables and Broccoli and Cauliflower plants were collected from Düzce and Konya provinces in 2023. Aerial parts of the plants were collected for analysis (Table 1).

Table 1. Plants used in this study

Sample No:	Plant name	Botanic name	Locations
1	Sage	*Salvia officinalis* L.	Konya
2	Aysberg lettuce	*Lactuca sativa*	Konya
3	Rosemary	*Rosmarinus officinalis* L.	Konya
4	Crocus	*Crocus sativus* L.	Düzce
5	Mallow	*Malva vulgaris*	Konya
6	Sourweed	*Rumex acetosella*	Konya
7	Endive	*Lactuca sativa*	Konya
8	Dill (leave)	*Anethum graveolens* L.	Konya
9	Early-flowering Borage	*Trachystemon orientalis*	Düzce
10	Red Sour Weed	*Rumex acetosella*	Konya
11	Cilantro	*Coriandrum sativum* L.	Konya
12	Lemon Flower	*Melissa officinalis* L.	Konya
13	Lettuce	*Lactuca sativa*	Konya
14	Parsley	*Petroselinum crispum* L.	Konya
15	Purple lettuce	*Lactuca sativa*	Konya
16	Mint	*Mentha x piperita*	Konya
17	Rockette	*Eruca vesicaria*	Konya
18	Purslane	*Portulaca oleracea* L.	Konya
19	Water cress	*Nasturtium officinale*	Konya
20	Garlic chive	*Allium schoenoprasum*	Konya
21	Peppergrass	*Lepidium sativum*	Konya
22	Oil lettuce Marul	*Lactuca sativa*	Konya

Aromatic plants were chosen because they are consumed as herbal tea. After the samples were transferred to the laboratory, they were washed with distilled water to remove the dust particles and sliced to small pieces with knife, and the plant samples were prepared for analysis. The locations (Düzce and Konya) of the aromatic plants, green leafy vegetables and broccoli and cauliflower plants used in this study are shown on the map (Fig. 1 and 2).

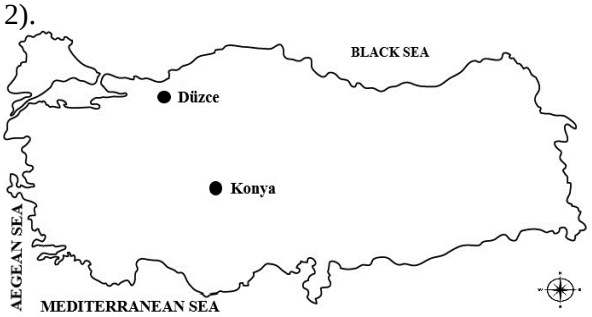

Figure 1. The locations (Düzce and Konya) of the plants used in this study Broccoli and Cauliflower plants

2.2. Methods

2.2.1. The moisture contents of plants

For the analysis of moisture of the plant samples [24], 2 g of the sample was placed in a tared beaker and the plant samples were kept in the oven at 70°C

for 48 hours until they reached a constant weight. The % moisture contents of plants was calculated gravimetrically [25].

2.2.2. Elemental analysis of some aromatic plants and green vegetables

Some aromatic plant and green leafy vegetables, different organs of the aerial parts of cauliflower and broccol were sliced with knife and then, it was crushed in blender, and then 0.2 g of each sample was weighed to a volumetric flask. After 5 ml 65% HNO_3 and 2 ml 30% H_2O_2 were added to each sample, the mixture was digestioned at 210ºC and 200 PSI in a closed microwave system (Cem-MARS Xpress). After this process, the mixture was completed to 20 mL with distilled water and the quantitative values of the elements were measured with inductively coupled plasma optical emission spectrometry (ICP-OES; Varian-Vista Model) [26].

2.3. Statistical analysis

JMP statistical program was used in the statistical analysis of the results. The results were reported by analysis of variance (ANOVA) [27]. A multivariate cluster analysis in order to examine the correlation between plant samples was carried out using the PAST statistical program to perform Principal Component Analysis (PCA) [28].

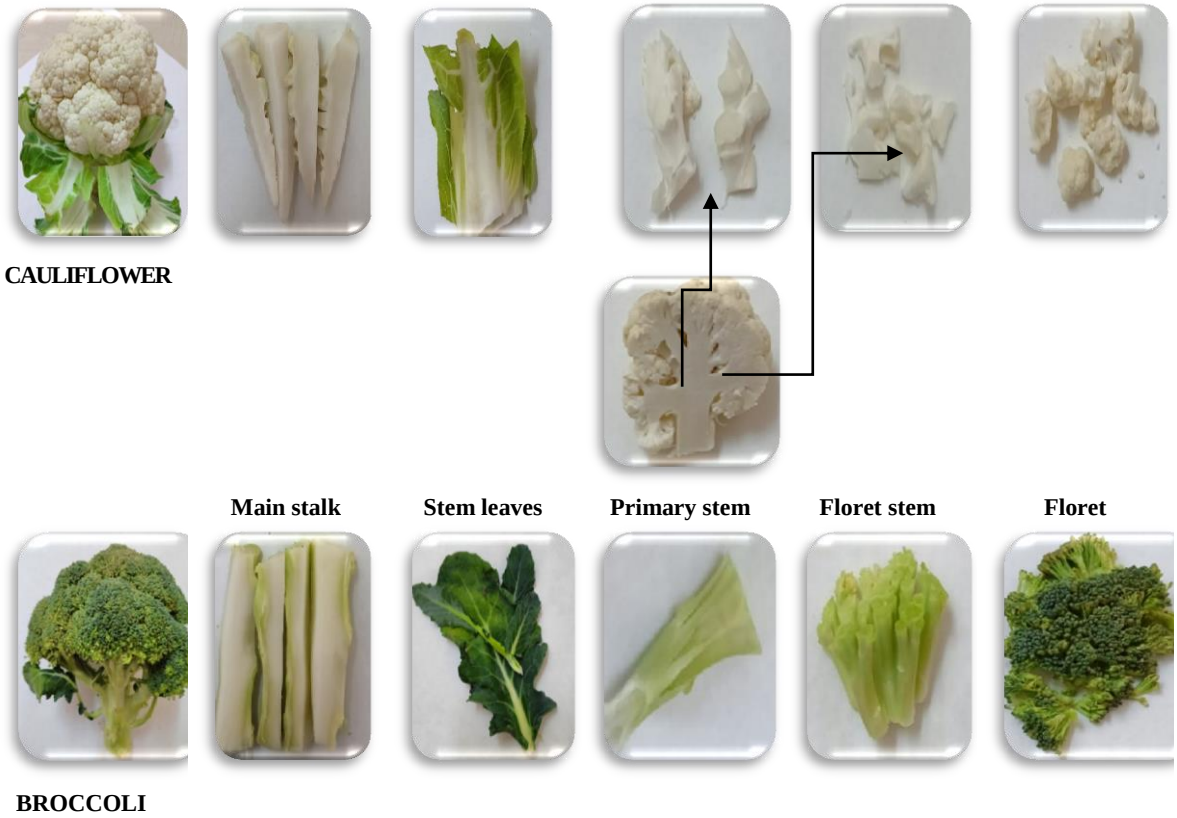

Figure 2. Aerial parts of cauliflower and broccoli used in this study

2. Results and Discussions

3.1.The moisture and macro element results of some aromatic plants, green vegetables and aerial parts of broccoli and cauliflower

The moisture and macro element contents of some aromatic plants and green leafy vegetables are offered in Table 2. Significant differences were observed in moisture and macro element results depending on the species of plants collected ($p<0.01$). The moisture amounts of plants were measured to be between 60.69 (rosemary) and 96.96% (Aysberg lettuce). In addition, the moisture contents of sage, crocus, dill and parsley were partially lower than the moisture contents of other plants. This may be due to the high dry matter content of these vegetables. Phosphorus (P) and potassium (K) results of aromatic plants and green leafy vegetables were recorded to be between 1.37 (water cress) and 18.51 mg/kg (Early-flowering borage) to 26.46 (water cress) and 9888.12 mg/kg (Early-flowering borage), respectively. Also, while Ca amounts of plants are detected between 7.78 (water cress) and 8924.86 mg/kg (Mallow), Mg

results of aromatic and green leafy vegetables were identified between 1.09 (water cress) and 1327.24 mg/kg (Parsley). The macro element and moisture contents of the plants showed statistical differences depending on the plant species ($p<0.01$). The lowest macro element content was detected in the water cress plant. Although the highest P content is detected in the Early-flowering borage plant, the P contents of sage, dill, cilantro, lemon flower and parsley plants were found to be close to the results of the Early-flowering borage plant. In addition, Ca contents of iceberg lettuce, red sourweed and oil lettuce plants were found to be at low levels. In addition, the plants with the Mg value closest to the Mg value of the parsley plant were sage, mallow, sourweed, dill, cilantro and mint. It can be seen in Table 2, the tested plants are rich in macro elements.

Table 2. Moisture (%) and macro element contents (mg/kg) of some aromatic and green leafy vegetables

Plants	Moisture	P	K	Ca	Mg
Sage	75.98±4.06 **l***	1368.01±108.94 **b**	5934.89±144.19 **d**	4810.54±260.84 **c**	1173.21±200.88 **bcd**
Aysberg Lettuce	96.96±0.020 **a**	172.47±12.93 **j**	1707.20±101.71 **ı**	295.71±3.07 **mn**	75.67±5.02 **mn**
Rosemary	60.69±0.916 **m**	603.92±9.69 **fgh**	6981.91±324.49 **b**	4463.87±440.68 **c**	610.26±42.62 **f**
Crocus	82.99±3.68 **ıj**	628.59±3.08 **fg**	3068.96±244.68 **h**	1504.01±275.61 **hı**	249.28±43.05 **ıjk**
Mallow	89.70±3.02 **def**	233.59±14.43 **j**	835.87±21.44 **j**	8924.86±610.42 **a**	928.70±8.11 **e**
Sour Weed	93.41±0.356 **bc**	544.09±4.23 **ghı**	1794.14±151.74 **ı**	3265.35±155.47 **d**	1268.35±78.64 **ab**
Endive	92.57±0.085 **bcd**	531.60±34.49 **hı**	6770.04±128.29 **bc**	1155.14±61.30 **ıj**	158.60±37.44 **klm**
Dill	78.36±4.59 **kl**	1006.40±114.27 **d**	7139.86±219.55 **b**	6332.38±184.19 **b**	1217.84±72.18 **bc**
Early-flowering Borage	87.24±1.78 **fgh**	1851.12±44.86 **a**	9888.12±326.58 **a**	3552.64±346.15 **d**	443.31±13.13 **gh**
Red Sour Weed	92.58±0.240 **bcd**	690.13±82.52 **ef**	4971.19±114.75 **e**	728.64±11.93 **kl**	343.56±43.33 **hı**
Cilantro	86.49±2.64 **gh**	1014.06±82.19 **d**	7050.56±125.82 **b**	2187.14±69.85 **ef**	1155.96±96.99 **cd**
Lemon Flower	80.78±0.723 **jk**	1111.48±109.95 **c**	9849.84±83.33 **a**	1658.00±190.47 **gh**	899.54±54.31 **e**
Lettuce	94.69±0.580 **ab**	250.96±3.28 **j**	4183.67±352.38 **g**	916.75±17.99 **jk**	198.75±8.95 **jkl**
Parsley	82.88±0.066 **ıj**	979.05±39.18 **d**	5124.66±598.88 **e**	2373.66±363.51 **ef**	1327.24±99.75 **a**
Purple Lettuce	94.04±0.318 **abc**	539.56±59.96 **ghı**	4840.47±146.25 **ef**	1054.63±27.51 **jk**	255.67±16.64 **ıjk**
Mint	84.73±0.641 **hı**	777.08±17.57 **e**	4087.88±668.51 **g**	2539.22±307.13 **e**	1078.59±87.14 **d**
Roquette	92.77±0.382 **bc**	536.42±62.87 **ghı**	4382.77±266.20 **fg**	1990.78±150.95 **fg**	388.74±2.55 **h**
Purslane	95.50±0.006 **ab**	469.64±45.94 **ı**	5013.64±562.18 **e**	485.67±25.18 **lm**	276.14±6.18 **ıj**
Water Cress	88.08±0.938 **fg**	1.37±0.069 **k**	26.46±3.67 **k**	7.78±0.643 **n**	1.09±0.055 **n**
Garlic chive	89.47±0.078 **efg**	653.68±55.95 **f**	4813.33±42.85 **ef**	1140.31±15.17 **ıj**	131.96±11.63 **lm**
Peppergrass	91.64±0.082 **cde**	1053.91±4.13 **cd**	6423.63±237.02 **c**	2173.24±122.40 **ef**	540.55±46.20 **fg**
Oil Lettuce	94.70±0.173 **ab**	180.10±23.61 **j**	5280.57±196.81 **e**	417.67±28.60 **lm**	140.74±14.35 **lm**

*$p<0.01$

Macro element amounts of different organs of the aerial parts of broccoli and cauliflower plants are offered in Table 3. P, K, Ca, Mg and Na were determined as macro elements in both vegetables. While P contents of the aerial parts of cauliflower vary between 1567 (floret stem) and 2436 mg/kg (stem leave), K amounts of the aerial parts of cauliflower were recorded between 1564 (floret stem) and 5364 mg/kg (stem leave). P and K results of broccoli aerial parts were recorded between 1741 (primary stem) and 2460 mg/kg (floret) to 2524 (stem leave) and 4723 mg/kg (floret), respectively. Also, Ca and Mg amounts of cauliflower parts were reported to be between 195 (primary stem and floret) and 1125 mg/kg (stem leave) to 146 (primary stem and floret stem) and 808 mg/kg (stem leave), respectively. While Ca contents of broccoli parts vary between 279 (floret stem) and 3857 mg/kg (stem leave), Mg amounts of broccoli samples were established to be between 175 (floret stem) and 831 mg/kg (stem leave). Na amounts of the aerial parts of cauliflower and broccoli plants were recorded to be between 347 (floret) and 481 mg/kg (stem leave) to 331 (primary stem) and 432 mg/kg (floret),

respectively. The stems and leaves of cauliflower contained more P than those of broccoli. In broccoli, phosphorus was localized mostly in the floret part. In the aerial parts of cauliflower, the part with the highest macro element

Table 3. Macro element contents of the aerial parts of cauliflower and broccoli plants (mg/kg)

Samples		Stem leaves	Main stalk	Primary stem	Floret stem	Floret
Cauliflower	P	2436±13.9A	2054±32.47B	1636±16.36C	1567±27.88C	1844±20.16BC
	K	5364±21.3A	3562±27.3B	1808±41.46C	1564±10.90C	3658±103.28B
	Ca	1125±21.25	685±7.17	195±1.72	722±5.98	195±1.46
	Mg	808±3.73A	358±10.46B	146±1.81D	146±0.84D	227±7.83C
	Na	481±5.90A	452±21.75A	443±6.55A	462±18.82A	347±15.04B
Broccoli	P	2145±13.43B	1784±1.46D	1741±21.29D	1866±11.64C	2460±13.15A
	K	2524±21.8D	4308±18.1AB	3786±41.40BC	3370±16.7C	4723±11.9A
	Ca	3857±36.1A	648±4.23B	456±12.51B	279±18.99B	648±20.19B
	Mg	831±5.00A	231±11.69C	230±1.48C	175±1.32D	444±11.91B
	Na	353±17.90b	351±17.23b	331±3.96b	340±21.18b	432±15.30a

a,b; $p<0.05$; **A,B**; $p<0.01$

content was the stem leave. The distribution of macro element concentrations in other parts of cauliflower was heterogeneous. In addition, it can be said that the floret part of cauliflower was rich in P and K. In general, macro element contents were low in cauliflower stem parts. In cauliflower, the highest Mg was detected in stem leave, followed by main stalk, floret, primary stem and floret in decreasing order. The Mg contents of the primary stem and floret stem were found to be similar. While Na content was found to be low in cauliflower floret, it was found to be high in other parts of cauliflower. However, in broccoli, the highest amount of Na was detected in the floret part (432 mg/kg), followed by stem leave, main stalk, floret stem and primary stem in decreasing order. In general, macro element contents of broccoli parts were found to be higher than those of cauliflower. This probably varies depending on the nutrient element and water content of the soil where broccoli grows and the concentrations of H^+ and OH^- in the cuticle layer of the broccoli root. Because, in case of moisture in the soil, these ions transform the plant nutrients in compound form in the soil according to the pH of the environment into a form that the plant can benefit from.

3.2.The micro element contents of some aromatic plants, green vegetables and aerial parts of broccoli and cauliflower

The micro element amounts of aromatic plants and green leafy vegetables are distributed in Table 4.

The highest microelement content in plants was Fe, followed by Zn, B, Mn and Cu in descending order. Fe and Zn contents of plant samples were identified to be between 1.70 (water cress) and 251.11 mg/kg (rosemary) to 1.20 (Aysberg lettuce) and 13.97 mg/kg (pepper grass), respectively. While Cu contents of plants are recorded between 0.396 (Aysberg lettuce) and 5.05 mg/kg (sourweed), Mn amounts of plant samples were reported to be between 0.954 (Aysberg lettuce) and 40.19 mg/kg (Early-flowering borage). In addition, B amounts of plants tested were determined between 1.05 (water cress) and 15.79 mg/kg (sage). Among the plants studied, Sage and Early-flowering borage plants are among the plants richest in Fe content. In addition, rosemary, dill, early-flowering borage, cilantro and parsley plants had values close to peppergrass, which had the highest Zn content. After the Mn content of early-flowering borage plant, the highest Mn content was observed in sage plant, followed by roquette, rosemary, dill and pepper grass in descending order. Additionally, after pepper grass, the highest Zn contents were detected in cilantro, rosemary, early-flowering borage, dill and parsley plants. The difference in microelement contents of plants may probably be due to the metabolic activities of the plant, plant soil or plant-air element absorption abilities, and plant leaf and root tissue characteristics. The differences between the microelement contents of the plants were established to be statistically significant at the $p<0.01$ level.

The distributions of microelement contents of the aerial parts of cauliflower and broccoli plants are shown in Table 5. Differences were observed in the microelement contents of cauliflower and broccoli depending on the organs. The element established in the highest amounts in both vegetables was Fe,

followed by Zn, B, Mn and Cu in decreasing order. Fe and Zn contents of cauliflower parts were determined to be between 7.55 (main stalk) and 24.39 mg/kg (stem leave) to 2.48 (floret stem) and 9.76 mg/kg (stem leave), respectively. In addition, while Fe contents of broccoli parts vary between 6.48 (primary stem) and 26.38 mg/kg (stem leaves), Zn amounts of broccoli parts were recorded to be between

Table 4. Micro element contents of some aromatic and green leafy vegetables (mg/kg)

Plants	Fe	Zn	Cu	Mn	B
Sage	130.77±4.02 **c***	4.89±0.313 **de**	2.32±0.045 **c**	33.83±1.95 **b**	15.79±1.71 **a**
Aysberg Lettuce	2.69±0.025 **l**	1.20±0.182 **j**	0.396±0.060 **k**	0.954±0.047 **m**	1.55±0.315 **jk**
Rosemary	251.11±19.71 **a**	9.82±0.009 **b**	2.39±0.583 **c**	14.59±1.17 **d**	11.78±1.04 **b**
Crocus	36.87±1.71 **hıj**	5.30±0.110 **d**	0.824±0.080 **hıj**	5.70±0.269 **ıjk**	5.28±0.110 **g**
Mallow	46.41±0.407 **fgh**	4.40±0.209 de	1.61±0.071 **e**	7.45±0.088 **fg**	5.63±0.247 **fg**
Sour Weed	51.49±1.53 **efg**	5.09±0.389 **de**	1.01±0.093 **fgh**	7.95±0.230 **fg**	5.45±0.004 **g**
Endive	12.25±0.525 **kl**	1.60±0.240 **ıj**	5.05±0.363 **a**	1.90±0.103 **lm**	7.71±0.373 **cd**
Dill	51.62±7.66 **ef**	7.58±0.796 **c**	1.94±0.016 **d**	13.84±1.32 **d**	7.04±0.671 **de**
Early-flowering Borage	152.95±31.65 **b**	9.67±0.662 **b**	4.64±0.534 **b**	40.19±1.84 **a**	4.18±0.104 **h**
Red Sour Weed	38.05±1.44 **ghı**	2.80±0.690 **ghı**	0.690±0.001 **h-k**	4.30±0.149 **k**	4.17±0.687 **h**
Cilantro	64.20±0.328 **de**	9.95±0.963 **b**	1.63±0.172 **de**	7.22±0.044 **fgh**	5.20±0.670 **g**
Lemon Flower	23.96±2.19 **jk**	3.87±0.360 **efg**	0.850±0.017 **g-j**	13.26±1.54 **d**	8.13±0.593 **c**
Lettuce	10.51±0.425 **kl**	2.24±0.321 **hıj**	1.22±0.042 **f**	2.52±0.003 **l**	6.38±0.566 **ef**
Parsley	41.57±0.713 **f-ı**	7.02±0.830 **c**	0.963±0.009 **f-ı**	8.39±0.556 **ef**	6.81±0.005 **de**
Purple Lettuce	31.20±3.19 **ıj**	4.07±0.230 **d-g**	1.17±0.123 **fg**	7.40±0.298 **fg**	2.94±0.358 **ı**
Mint	69.15±0.458 **d**	4.02±0.645 **efg**	0.887±0.045 **ghı**	5.80±0.737 **hıj**	2.66±0.137 **ı**
Roquette	29.14±1.22 **ıj**	4.36±0.038 **def**	0.871±0.008 **ghı**	17.64±1.50 **c**	2.41±0.198 **ıj**
Purslane	6.09±0.571 **l**	4.91±0.406 **de**	0.657±0.007 **ıjk**	1.42±0.086 **lm**	0.588±0.083 **l**
Water Cress	1.70±0.259 **l**	1.37±0.069 **j**	0.844±0.007 **hıj**	1.22±0.009 **lm**	1.05±0.017 **kl**
Garlic chive	9.80±0.840 **l**	3.09±0.547 **fgh**	0.882±0.010 **ghı**	6.59±0.315 **ghı**	2.91±0.222 **ı**
Peppergrass	33.46±1.82 **hıj**	13.97±2.91 **a**	1.17±0.051 **fg**	9.50±0.215 **e**	4.76±0.110 **gh**
Oil Lettuce	9.33±0.811 **l**	2.08±0.183 **hıj**	0.539±0.023 **jk**	4.70±0.209 **jk**	2.50±0.320 **ı**

*p<0.01

Table 5. Micro-element contents of the aerial parts of cauliflower and broccoli plants (mg/kg)

Samples		Stem leaves	Main stalk	Primary stem	Floret stem	Floret
Cauliflower	**Fe**	24.39±0.20A	7.55±0.25D	8.34±0.33CD	9.32±0.14C	10.51±0.23B
	Zn	9.76±0.08A	6.48±0.15B	2.54±0.12D	2.48±0.23D	4.05±0.08C
	Cu	0.96±0.017a	0.90±0.029ab	0.87±0.025b	0.87±0.016b	0.86±0.014b
	Mn	6.82±0.07A	1.74±0.11B	0.84±0.03C	0.90±0.03C	1.74±0.13B
	B	5.79±0.08A	4.68±0.13B	2.51±0.08D	2.70±0.08D	4.17±0.15C
Broccoli	**Fe**	26.38±1.37A	7.50±0.22C	6.48±0.19C	7.64±0.24C	15.28±0.21B
	Zn	5.38±0.26BC	5.83±0.05B	4.60±0.23C	3.67±0.15D	8.59±0.15A
	Cu	0.84±0.01B	0.96±0.01B	0.86±0.01B	0.86±0.02B	1.82±0.07A
	Mn	14.43±1.08A	1.89±1.072C	1.78±0.39C	1.73±0.211C	5.42±1.531B
	B	9.4±0.13A	3.71±0.13E	5.30±0.10C	4.48±0.07D	6.62±0.17B

3.67 (floret stem) and 8.59 mg/kg (floret). In cauliflower and broccoli, the highest Mn (6.82 and 14.43 mg/kg, respectively) was detected in the stem leave parts. In both cauliflower and broccoli plants, the highest Fe, Mn and B amounts were accumulated in the floret parts after stem leave. While the highest Zn was found in the stem leave part of cauliflower, it was localized in the floret part of broccoli. In addition, the highest Zn

content after steam leave in cauliflower and broccoli was detected in the main stalk part of both plants. In general, microelement concentrations were found at the highest levels in the stem leave parts of both plants. Cu contents of both plant parts were at very low levels.

3.3. The heavy metal results of some aromatic plants, green vegetables and aerial parts of broccoli and cauliflower

Heavy metals and their quantitative values of some aromatic plants and green vegetables are illustrated in Table 6. Most of the heavy metals in the plants tested were found at very high levels, except for some heavy metals such as As, Ba and Se. However, the heavy metal contents of plants varied from plant to plant.

Table 6. Heavy metal contents of some aromatic and green leafy vegetables (µg /g)

Plants	As	Ba	Cr	Mo	Ni	Pb	Se
Sage	8.03±0.049 **mn***	2.92±0.0727 **d**	0.668±0.034 **b**	0.533±0.021 **bc**	1.10±0.038 **b**	0.314±0.005 **j**	0.098±0.002 **l**
Aysberg Lettuce	3.11±0.110 **p**	0.397±0.004 **ıj**	0.061±0.006 **n**	0.152±0.007 **ıj**	0.437±0.035 **g**	0.324±0.014 **j**	0.462±0.035 **g**
Rosemary	16.27±0.405 **fg**	3.04±0.369 **d**	0.884±0.048 **a**	0.344±0.028 **f**	0.560±0.030 **f**	0.520±0.011 **gh**	1.28±0.009 **b**
Crocus	14.23±0.427 **hı**	18.61±0.569 **a**	0.305±0.010 **j**	0.274±0.008 **h**	0.438±0.039 **g**	0.288±0.001 **jk**	0.933±0.029 **e**
Mallow	21.41±1.40 **bc**	4.02±0.141 **c**	0.344±0.018 **hı**	0.406±0.019 **e**	0.066±0.001 **mn**	1.14±0.096 **b**	1.26±0.045 **bc**
Sour Weed	22.40±0.638 **b**	1.97±0.022 **ef**	0.317±0.015 **ıj**	0.250±0.001 **h**	0.197±0.010 **jk**	0.460±0.035 **hı**	1.29±0.124 **b**
Endive	14.01±0.084 **hı**	1.05±0.123 **gh**	0.186±0.017 **l**	0.377±0.001 **e**	0.255±0.041 **ıj**	0.033±0.002 **m**	0.773±0.035 **f**
Dill	20.13±0.813 **cd**	4.24±0.929 **c**	0.490±0.017 **d**	0.406±0.038 **e**	1.25±0.166 **a**	0.458±0.042 **ı**	0.364±0.014 **ıj**
Early-flowering Borage	3.47±0.101 **p**	12.46±0.427 **b**	0.439±0.017 **ef**	0.377±0.021 **e**	0.882±0.018 **d**	0.634±0.021 **e**	0.425±0.016 **ghı**
Red Sour Weed	10.70±0.322 **kl**	1.53±0.040 **fg**	0.351±0.046 **hı**	0.142±0.008 **j**	0.319±0.025 **hı**	0.573±0.004 **fg**	0.124±0.002 **kl**
Cilantro	11.76±1.12 **jk**	2.15±0.304 **e**	0.418±0.024 **fg**	0.328±0.003 **fg**	0.359±0.023 **h**	0.535±0.028 **g**	0.172±0.019 **k**
Lemon Flower	15.41±0.359 **gh**	1.99±0.190 **ef**	0.556±0.020 **c**	0.546±0.009 **b**	0.482±0.012 **g**	0.560±0.021 **fg**	0.107±0.005 **kl**
Lettuce	13.70±2.08 **hı**	0.619±0.008 **hıj**	0.193±0.016 **l**	0.310±0.042 **g**	0.980±0.059 **c**	0.613±0.004 **ef**	0.123±0.001 **kl**
Parsley	17.74±0.196 **ef**	3.15±0.680 **d**	0.382±0.014 **gh**	0.513±0.011 **c**	0.811±0.069 **d**	0.327±0.017 **j**	2.01±0.049 **a**
Purple Lettuce	13.41±0.030 **ıj**	0.968±0.140 **ghı**	0.257±0.013 **k**	0.176±0.007 **ı**	0.108±0.005 **lmn**	0.955±0.031 **d**	1.21±0.106 **c**
Mint	19.26±0.381 **de**	2.85±0.194 **d**	0.475±0.045 **de**	0.405±0.023 **e**	0.458±0.023 **g**	1.02±0.025 **c**	1.33±0.001 **b**
Roquette	17.46±0.452 **ef**	0.958±0.072 **ghı**	0.330±0.017 **ıj**	0.461±0.009 **d**	0.285±0.015 **hı**	0.321±0.007 **j**	0.457±0.030 **gh**
Purslane	9.15±0.878 **lm**	2.76±0.123 **d**	0.105±0.006 **m**	0.168±0.005 **ıj**	0.156±0.007 **kl**	0.404±0.018 **ı**	1.03±0.062 **d**
Water Cress	6.38±0.593 **no**	0.248±0.015 **j**	0.123±0.013 **m**	0.096±0.001 **k**	0.729±0.052 **e**	0.097±0.002 **l**	0.388±0.006 **hıj**
Garlic chive	7.68±0.520 **mn**	0.305±0.020 **j**	0.254±0.008 **k**	0.339±0.043 **fg**	0.183±0.009 **jkl**	0.536±0.014 **g**	0.798±0.011 **f**
Peppergrass	31.48±4.18 **a**	1.82±0.299 **ef**	0.464±0.029 **de**	0.766±0.011 **a**	0.139±0.001 **klm**	1.40±0.113 **a**	0.160±0.008 **kl**
Oil Lettuce	5.41±0.729 **o**	0.244±0.027 **j**	0.178±0.004 **l**	0.095±0.003 **k**	0.047±0.002 **n**	0.248±0.017 **k**	0.328±0.001 **j**

*$p<0.01$

These differences were determined to be statistically significant ($p<0.01$). The highest heavy metal detected in plants was As, followed by Ba and Se in descending order. As and Ba contents of plant samples were recorded to be beetween 3.11 (Aysberg lettuce) and 22.40 µg/g (sourweed) to 0.244 (Oil lettuce) and 18.61 µg/g (Crocus), respectively. While Cr amounts of plant samples vary between 0.061 (Aysberg lettuce) and 0.884 µg/g (rosemary), Mo amounts of plants were reported to be between 0.095 (oil lettuce) and 0.766 µg/g (peppergrass). While As and Cr are found at low levels in the iceberg lettuce plant, Ba, Mo and Ni were detected at the lowest levels in the oil lettuce plant. Ni and Pb results of plant samples were recorded between 0.047 (oil lettuce) and 1.25 µg/g (dill) to 0.033 (Endive) and 1.40 µg/g (peppergrass), respectively. Also, Se amounts of green leafy vegetables ranged from 0.098 (sage) to 2.01 µg/g (parsley). The Se results of rosemary,

mallow, sourweed, purple lettuce, mint and purslane plants were found to be close to that of the parsley plant, which contains the highest Se. Since these plants grow mostly in places where vegetables are grown, applications such as fertilizers, pesticides and the use of water contaminated with industrial waste may have increased the Se result. In addition, since it is an irrigated area, these plants can easily absorb Se from the soil. The Pb values closest to peppergrass were detected in mallow and mint plants. In general, early-flowering borage plants contained low amounts of As, Cr, Mo, and Se, while this plant also contained high amounts of Ba, Ni, and Pb. In general, As, Ba, Pb and Se results of mallow plant were slightly higher than those of other plants. However, As, Ba, Cr and Se results of rosemary were detected in high concentrations. Additionally, As, Ba, Cr, Mo and Ni contents were found at high levels in dill plant. In general, the high content of heavy metals such as As, Ba, Se and Pb in the plants studied may be due to the heavy metal contents of the soil of the region where they grow, industrial gases in the environment, pesticides and irrigation water contaminated with industrial wastes. High levels of these heavy metals (As and Ba) may be caused by contamination of the soil where the green leafy vegetables grow. The result shows that these plants can be used safely, as most heavy metals are found at low levels in the analyzed plants. It has been reported that the accumulation of Cd, Pb and Cr, which are found in higher amounts in leafy vegetables, is due to atmospheric pollution Because leaf surfaces are larger, they come into more contact with polluted air [29]. In general, it has been reported that leafy vegetables have higher levels of heavy metal accumulation than fruits, seeds and grains [30,31]. Soil is the main source of essential and toxic minerals found in foods. Fertile soils contain metals in large amounts and varying concentrations, along with the elements necessary for plant growth [17, 32]. One of the important factors in metallic contamination in foods is wastewater. Wastewater from various industrial activities contains heavy metals in high concentrations [33-34]. Some fertilizers and chemicals used in agriculture contain high levels of toxic metals, which can cause contamination in foods [17,35]. In a study conducted by the International Atomic Energy Agency (IAEA) on different foods in 12 different countries, the elements that need to be carefully considered in terms of health and contamination risks are arsenic, cadmium, lead and mercury; Antimony, iron, copper and zinc were stated to be elements of lower importance [17,36]. Arsenic occurs naturally in two forms: inorganic and organic. However, its contamination to food and the environment occurs mainly through agricultural pesticides and industrial practices [17, 37]. While the Cd contents of the cress plant vary between 0.32 and 0.66, lead contents of cress were determined between 30.13 and 38.94 mg/kg [38]. Also, parsley contained 13.21 and 18.21 mg/kg Pb, while Ni contents of cress plant are reported between 35.98 and 48.16 mg/kg [38]. Cd, Cu, Pd and Zn contents of green vegetables grown in Tanzania (Dar es Salaam) were determined between 0.1 and 0.6, 2.5 and 16, 1.9 and 6.6, and 14.8 and 49.3 mg/kg (dw), respectively [39]. Vegetables collected from Saudi Arabian markets contained 0.93 to 4.13 mg/kg Cd, 2.06 to 33.22 mg/kg Cu, 0.54 to 6.98 mg/kg Pb and 8.27 to 71.77 mg/kg Zn, 31.96 to 543.5 mg/kg Fe, and 4.16 to 94.16 mg/kg Mn [40]. Cd, Co, Cr, Cu, Fe, Mn, Pb and Zn contents of leafy vegetables were determined between 0.242–1.249, 0.457–0.764, 1.10–3.534, 5.36–9.18, 355.4 –1195.9, 31.90–132.63, 0.858–1.175 and 18.20–36.72 mg/kg Zn (dw) [20]. Sharma *et al.* [41] determined 2.25–5.42 mg/ kg Cu and 17.54–25.00 mg/ kg Pb in vegetables grown in Varanasi. In a study conducted in Saudi Arabia, high concentrations of Pb were detected in coriander and purslane among six washed and unwashed green leafy vegetables [42]. Pb results in this study were to be lower than WHO safe limit (2 mg/kg) [41,42]. Our study revealed that leafy vegetable accumulated Cu lower than the permissible level (10.00 mg/kg) [43]. Generally, Zn amounts of pepper grass, parsley, cilantro (coriander), dill, sourweed, crocus and rosemary in present study were found higher of international standards (5.00 mg /kg) [43]. Manganese contents of Sage, rosemary, dill, early-flowering Borage, roquette, peppergrass were out of the safe limit permitted for food since WHO recommended 2–9 mg per day for an adult [43]. In our study, concentration of Ni was noted to be above the critical level of 0.1 mg/ kg as reported by FAO/WHO [44] and thus might be a great threat for the human consumers. In addition, Al Jassir *et al.*, [42] detected high concentrations of Cd in washed and unwashed garden rocket vegetables. Factors such as climate, atmospheric accumulation, air pollution, heavy metal concentrations in the soil, characteristics of the soil where vegetables grow, and harvest time of plants are among the main factors that determine the uptake of heavy metals by vegetables [45,46]. Air pollution may be the main

factor that poses a threat to the increase in heavy metal levels of vegetables during transportation and marketing of vegetables after harvest [47]. It is thought that in order to prevent heavy metal pollution, after identifying the sources of pollution, it is necessary to eliminate these sources and ensure traceability of environmental exposure and hazard situations.

The distributions of heavy metal contents of different organs of the aerial parts of cauliflower and broccoli are presented in Table 7. The heavy metals determined in the highest amounts in both plant parts were As, Sr, Pb and Se. Of these, As and Sr were the

Table 7. Heavy metal contents of the aerial parts of cauliflower and broccoli plants (mg/kg)

Samples		Stem leaves	Main stalk	Primary stem	Floret stem	Floret
As	**Cauliflower**	7.43±0.22C	2.55±0.23D	8.67±0.08B	17.75±0.07A	18.52±0.21A
Ba		1.56±0.16A	1.64±0.15A	0.76±0.02B	0.76±0.02B	0.37±0.02B
Cd		0.05±0.001B	0.03±0.002C	0.06±0.0001A	0.006±0.0001D	0.001±0.0001D
Cr		0.87±0.008AB	0.92±0.01A	0.77±0.01C	0.83±0.02B	0.84±0.02B
Mo		0.77±0.06A	0.50±0.007B	0.30±0.009C	0.33±0.02C	0.35±0.009C
Ni		0.86±0.01A	0.65±0.02B	0.29±0.001B	0.35±0.02C	0.65±0.01C
Pb		0.47±0.009E	1.03±0.006C	0.86±0.03D	1.55±0.02A	1.17±0.009B
Se		1.32±0.19B	0.68±0.04C	0.27±0.004D	1.76±0.003A	0.45±0.017CD
As	**Broccoli**	1.28±0.09A	0.86±0.03B	0.67±0.002C	0.62±0.003C	0.25±0.006D
Ba		0.05±0.004A	0.009±0.0001C	0.02±0.003B	0.001±0.0001C	0.04±0.0009A
Cd		0.86±0.02A	0.87±0.01A	0.74±0.02B	0.77±0.02B	0.86±0.02A
Cr		0.44±0.005A	0.06±0.001C	0.09±0.0002C	0.26±0.01B	0.43±0.01A
Mo		40.04±1.29A	13.80±0.32B	12.08±0.06B	6.40±0.13C	5.45±0.19C
Ni		0.77±0.006B	0.47±0.005C	0.95±0.002A	0.17±0.20D	0.93±0.03A
Pb		0.65±0.017C	1.14±0.006B	1.51±0.17A	0.75±0.019C	0.20±0.001D
Se		0.22 ±0.004D	0.54±0.03C	1.64±0.14A	1.35±0.009A	0.91±0.016B

heavy metals found in the highest amounts. Both plant species and organ differences had an impact on the heavy metal concentrations of the plants. As and Sr levels of the parts of cauliflower plant were measured to be between 2.55 (main stalk) and 18.52 mg/kg (floret) to 0.90 (floret) and 10.61 mg/kg (stem leave), respectively. In addition, As and Sr contents of the parts of broccoli plant were reported between 4.39 (floret) and 18.79 mg/kg (stem leave) to 5.45 (floret) and 40.04 mg/kg (stem leave), respectively. As and Sr contents of the floret and floret stem parts of broccoli were determined at very low levels compared to the other parts. In cauliflower, As was determined in the highest amounts in the floret and floret stem parts, while Sr was detected in the stem leave and main stalk parts of cauliflower. Pb contents of cauliflower and broccoli parts were determined between 0.47 (stem leave) and 1.55 mg/kg (floret stem) to 0.20 (floret) and 1.51 mg/kg (primary stem), respectively. Se amounts of both cauliflower and broccoli parts were reported to be between 0.27 (primary stem) and 1.76 mg/kg (floret stem) to 0.22 (stem leave) and 1.64 mg/kg (primary stem), respectively. Cd, Cr, Mo and Ni levels of both plants were found to be well below 0.95 mg/kg. Ba contents of cauliflower and broccoli were found to be higher in stem leaves and main stalk parts than in other parts. Especially the Cd contents of both plants were recorded below 0.06 mg/kg. The arsenic contents of the floret and floret stem parts of broccoli were found to be at much lower levels than that of cauliflower. In general, the heavy metal concentration values in the floret and floret stem parts of both plants were at very low levels compared to other parts, which is important for consumer health. In general, the low As and Sr heavy metal amounts of both cauliflower and broccoli parts were an indication that both vegetables can be consumed safely. Looking at the contents of different mineral elements, it can be said that the edible parts of cauliflower and broccoli are rich in macro elements (K, Ca, Mg and P) and trace elements (Mn and Zn). K and P were abundant in both broccoli and caulifloer parts, while Fe and Zn show the highest contents in cauliflower and broccoli, respectively. The leaf parts of cauliflower and broccoli are thought to be the part where macro and micro nutrients are most accumulated and heavy metals were localized at low levels. The limited Na concentrations in aerial parts of cauliflower and broccoli point to the existence of effective Na exclusion systems in cauliflower and broccoli, which may contribute to its healthy mineral-element profile. Broccoli is a good source of the elements

Ca, Mg, Na, K, Ca, Cl, P and S, and trace elements such as Fe, Zn, Mn and Cu are essential for human nutrition [49]. Fresh broccoli contained 562.22 Mg, 3992.4 K and 576.52 Na, 8.67 Zn, 2.66 Fe and 112.52 Ca mg/100g (dw) [50]. Liu *et al.* [50] determined 4.65, 7.10 and 28.99 mg/g Ca, 1.78, 1.67 and 1.33 mg/g Mg, 7.01, 5.07 and 3.42 m/g P, 0.39, 6.43 and 2.63 mg/g Na and 145, 182 and 136 mg/g K in floret, stem and leaf of broccoli, respectively. According to USDA [51], broccoli contains 0.52 mg/100 g Fe (fw), 0.35 mg/100 g Zn, and 0.151 mg/100 g Mn. Cauliflower contained 0.2 mg/100 g Fe (fw), 0.11 mg/100 g Zn, and 0.082 mg/100 g Mn 100 (USDA (2013). Liu *et al.* [50] determined 45.83, 15.83 and 40.50 µg/g Fe, 54.0, 22.67 and 23.33 µg/g Zn, 18.83, 7.00 and 26.17 µg/g Mn and 0.29, 0.24 and 0.21 µg/g Cu in floret, stem and leaf of broccoli, respectively. Cauliflower contained 3146.67–6773.33 mg/kg K, 3449.59–6378.23 mg/kg P, 1563.67–2566.67 mg/kg Ca, 1747.00–3160.00 mg/kg Mg, 1.84–5.69 mg/kg Cu, 19.11–62.30 mg/kg Fe , 2.80–7.28 mg/kg Mn and 18.52–26.16 mg/kg Zn [52]. According to the World Health Organization (WHO), the daily B intake of adult men and women is reported to be 1.2 mg/day [53]. Since the leaves of both plants are rich in As and Sr, consumption of other parts is not considered to be at levels that would threaten human health according to WHO data. Heavy metal contents (except As and Sr) obtained from the organs of both vegetables studied are thought to be within tolerable limits. The results regarding the macro and micro element amounts of different organs of the aerial parts of cauliflower and broccoli plants were similar to the results of previous reports in terms of element concentrations, but there were differences in their amounts. These differences may be due to factors such as the climate characteristics of the regions where the plants grow, soil structure, variety and harvest time.

3.4. Pearson correlation

Pearson correlation (r) between macro (P, K, Ca, Mg and S) and micro (Fe, Zn, Cu, Mn and B) nutrient contents and moisture contents of aromatic plant and green vegetables is given in Figure 2. As can be seen by examining Figure 3, although there is a negative relationship between the moisture content and nutritional elements of plants, the relationships between the contents of Ca, Mg and Mn are significant and moderately strong negative relationships ($p < 0.05$, $r = 0.30$-0.70), Fe and B. The relationships between their contents and their contents were determined to be significant and high-

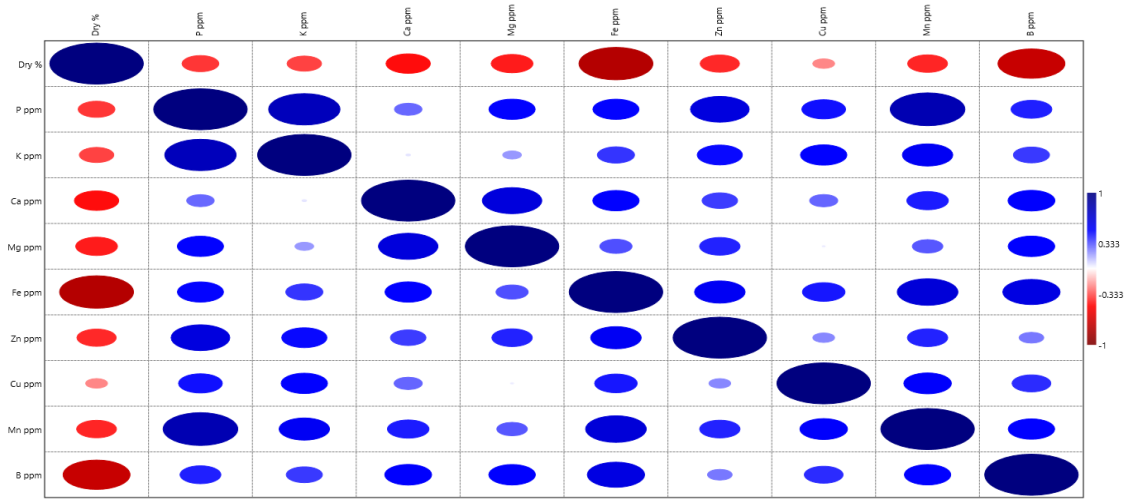

Figure 3. Pearson correlation (r) between macro (P, K, Ca, Mg and S) and micro (Fe, Zn, Cu, Mn and B) nutrient contents and moisture contents of plants

strength negative relationships ($p<0.05$, $r>0.70$). Although there are positive relationships between the P contents of vegetables and other nutritional elements, it has been stated that there are significant and moderately strong positive relationships with Mg, Fe, Zn, Cu and B contents, and significant and high strong positive relationships with K and Mn contents. While a significant and moderately strong positive relationship are found between K contents and Zn, Cu and Mn contents of the plants, a significant and moderately strong positive relationship was determined between the Ca contents and the Mg, Fe, Mn and B contents. In addition, it was determined by Pearson correlation

that the Mg and Fe contents of the greens showed significant and moderately strong positive relationships with the Zn and B contents and also with the Zn, Cu, Mn and B contents. When looking at the Zn, Cu and Mn contents of greens, The study determined that there were significant and moderately strong positive relationships between Zn contents and Mn contents, Cu contents and Mn contents, and Mn contents and B contents, respectively.

Pearson correlation (r) between heavy metal contents (As, Ba, Cr, Mo, Ni, Pb and Se) of greenery varieties is given in Figure 4.

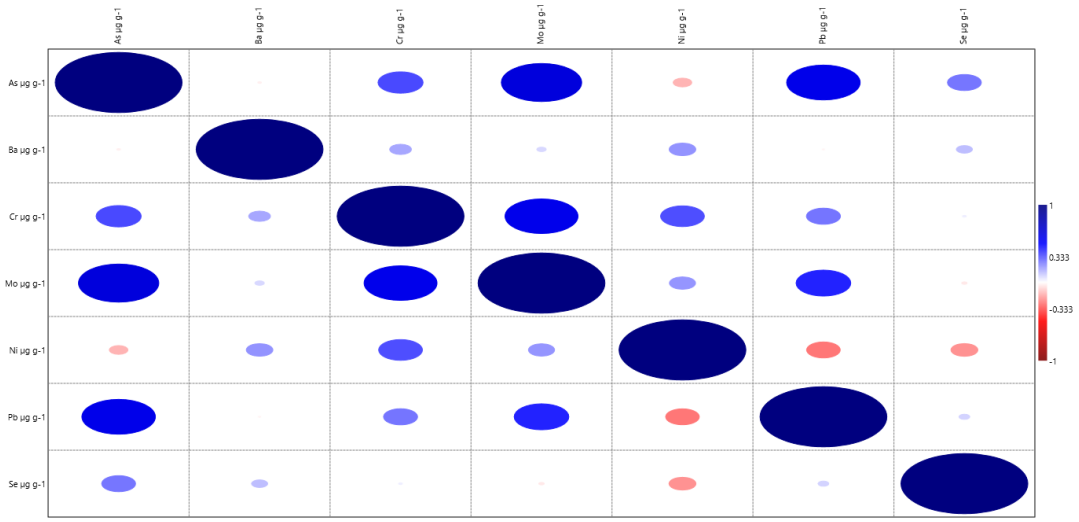

Figure 4. Pearson correlation (r) between heavy metal contents (As, Ba, Cr, Mo, Ni, Pb and Se) of plants.

As can be seen from examining the correlation between heavy metal contents of plants, there is a positive relationship between the heavy metal contents of the plant types. Significant and moderately strong positive relationships were determined between As contents and Mo and Pb contents of plants. In addition, when looking at the Cr and Mo contents of plant varieties, it was revealed that a significant positive relationships was determined between Cr contents and Mo contents, and between Mo contents and Pb contents [28].

Pearson correlation (r) between heavy metal contents (Sr, As, Ba, Cd, Cr, Mo, Ni, Pb and Se) of cauliflower parts is given in Figure 5.

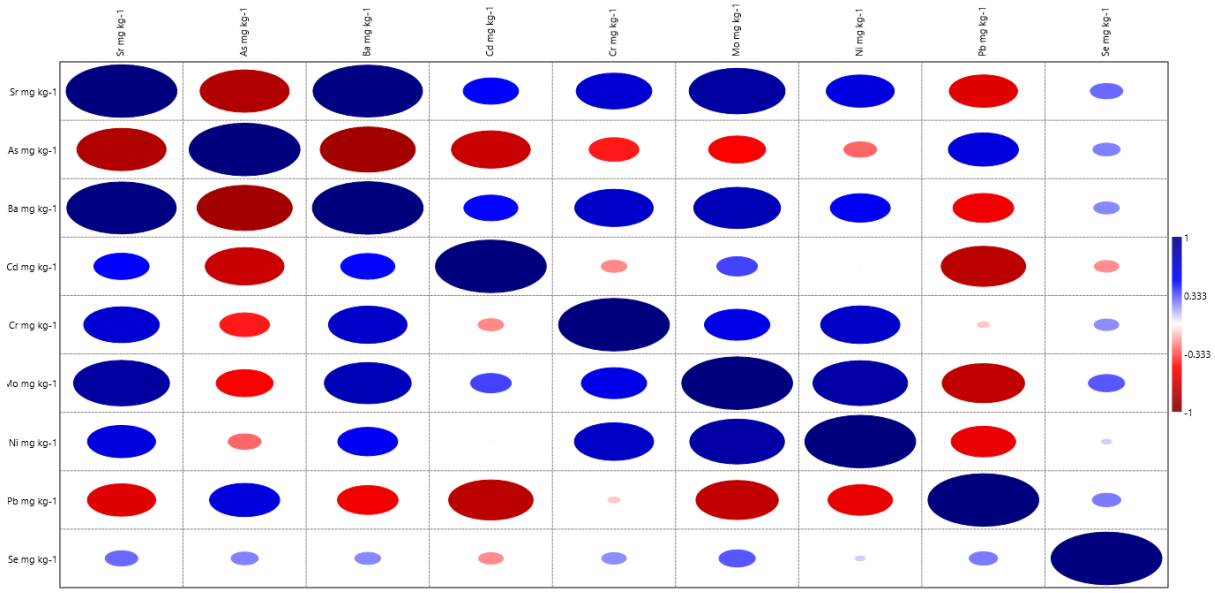

Figure 5. Pearson correlation (r) between heavy metal contents (Sr, As, Ba, Cd, Cr, Mo, Ni, Pb and Se) of cauliflower parts

As can be seen from examining the correlation between heavy metal contents of cauliflower, although there were positive and negative relationships between the heavy metal amounts of the parts, it was determined that there were significant and high strength ($p<0.05$, $r>0.70$) positive relationships between the Sr contents and Ba contents.

Pearson correlation (r) between heavy metal contents (Sr, As, Ba, Cd, Cr, Mo, Ni, Pb and Se) of broccoli parts is given in Figure 6. As can be seen from examining the correlation between heavy metal contents of broccoli parts, although there were positive and negative relationships between the heavy

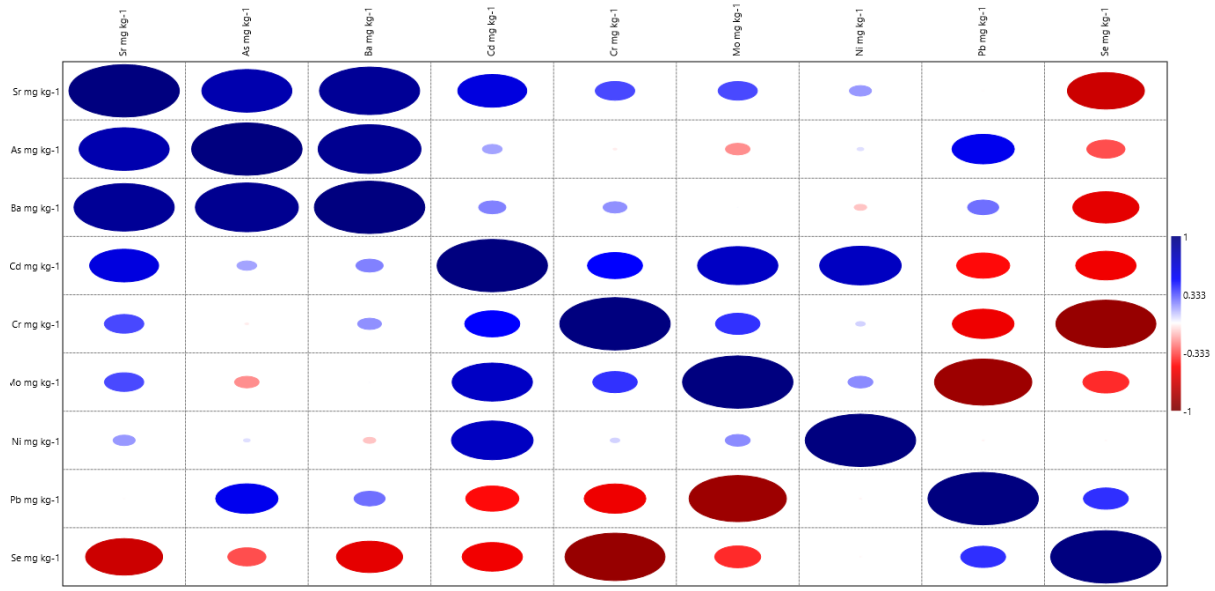

Figure 6. Pearson correlation (r) between heavy metal contents (Sr, As, Ba, Cd, Cr, Mo, Ni, Pb and Se) of broccoli parts

metal amounts of the parts, significant and high-strength ($p<0.05$, $r>0.70$) positive relationships were found between the Sr contents and Ba contents. Considering the heavy metal contents (Cr and M) of broccoli parts with significant negative relationships, this study determined that there were high strong relationships between Cr contents and Se contents of broccoli samples, and high strong relationships between Mo and Pb contents.

4. Conclusions

The results of the present study showed that As, Ba and Se contents in plants significantly higher than other leafy vegetables. Most of the heavy metals in the plants tested were found at very low levels, except for some heavy metals such as As, Ba and Se. Its higher absorption of the said heavy metal can be linked with the high absorption ratesof a large surface area of leafy vegetables bearing. Some differences in the heavy metal content of plants;

- The Se contents of rosemary, mallow, sourweed, purple lettuce, mint and purslane plants were found to be close to that of the parsley plant, which contains the highest Se.
- In general, early-flowering borage plants contained low amounts of As, Cr, Mo, and Se, while this plant also contained high amounts of Ba, Ni, and Pb.
- As, Ba, Cr, Mo and Ni contents were found at high levels in dill plant.
- The stems and leaves of cauliflower contain more P than those of broccoli.
- Phosphorus in broccoli is localized mostly in the floret part.
- In cauliflower, the highest Mg was detected in stem leave, followed by main stalk, floret, primary stem and floret in decreasing order
- In both cauliflower and broccoli, the highest Fe, Mn and B results were accumulated in the floret parts after stem leave.
- While the highest Zn was found in the stem leave part of cauliflower, it was localized in the floret part of broccoli. In addition, the highest Zn content after steam leave in cauliflower and broccoli was detected in the main stalk part of both plants.
- As and Sr contents of the floret and floret stem

parts of broccoli were determined at very low levels compared to the other parts. In cauliflower, As was determined in the highest amounts in the floret and floret stem parts, while Sr was detected in the stem leave and nain stalk parts of cauliflower.

- Ba contents of cauliflower and broccoli were found to be higher in stem leaves and main stalk parts than in other parts.
- The arsenic content of the floret and floret stem parts of broccoli was found to be at much lower levels than that of cauliflower.

Future studies will focus on the change in heavy metal concentrations as a result of cooking broccoli and cauliflower parts, which have low heavy metal content, with different heat treatments.

Data availability Not applicable.

Competing interests The authors declare no competing interests

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