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Investigation of Accumulation of Mineral and Toxic Element Contents of Different Mushrooms and their Parts

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Abstract

In this study, the macro, micro and toxic element distributions in cultivated and wild mushroom type and parts were investigated by ICP-OES. Some differences were observed in macro element contents among mushroom varieties and parts. P and K contents of mushroom varieties were determined between 4163.03 (Oyster mushroom (stem)) and 14387.06 mg/kg (Oyster mushroom (carpofor)) and 18736.73 (Oyster mushroom (stem)) and 37474.05 mg/kg (Oyster muchroom (Carpofor)), respectively. The macroelement found in the highest amounts in mushroom samples was K, followed by P, Mg and Ca in decreasing order. the highest Cu and B contents were detected in Chestnut mushroom samples. Cu and B contents of Chestnut mushroom samples were defined as 17.58 (stem) and 40.26 mg/kg (carpofor) to 25.86 (carpofor) and 54.79 mg/kg (stem), respectively. The Fe and Zn contents of Kanlıca mushroom samples were determined to be between 93.23 (carpophore) and 165.84 mg/kg (skin) and 69.39 (stem) and 76.11 mg/kg (carpophore), respectively. The toxic elements found in the highest amounts in mushroom samples were Cr, Pb and Se. Cr and Pb contents of mushroom samples were determined between 0.008 (Kanlıca mushroom (carpofor)) and 0.043 mg/kg (Chestnut mushroom (skin)) and 0.0055 (Oyster mushroom (skin)) and 0.234 mg/kg (Kanlıca muchroom (stem)), respectively. In addition, Se contents of the mushroom samples were determined between 0.005 (chestnut mushroom (skin)) and 0.203 mg/kg (Oyster mushroom (skin)). Carpophore and stem parts of oyster and kanlıca mushroom contained more Pb than skin parts.

***Keywords*:** mushroom, mushroom parts, minerals, toxic elements, ICP-OES.

1. Introduction

The mushrooms have different functionalities including nutritional values, palatability, physiological effects and cultural characteristics [1, 2]. Pleurotus genus oyster mushroom (*Pleurotus ostreatus*), which is a popular and delicious product with high protein, vitamin, fiber, saccharide and mineral content, almost fat-free, is one of the most popular edible mushrooms due to its favorable organoleptic and medicinal properties [3]. It has been reported that oyster mushrooms constitute important sources of mineral elements [4]. Due to the bioactive components of edible mushrooms, their stems are important not only for their taste but also for their chemical and nutritional properties [5,6]. Mushroom species have been reported to have the ability to bioaccumulate minerals in the fruit body depending on the growth environment due to ecological and genetic factors and are generally relatively rich in mineral components]7]. Since mushrooms are considered as functional foods with culinary and pharmacological values due to

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their high nutritional values and potential biological activities, their consumption has increased through diet and in the form of dietary supplements [8,9]. Increasing people's awareness of healthy foods encourages the use of edible wild and cultivated mushrooms as they provide important macro and micronutrients [10,11]. Many wild edible mushroom species are rich in essential nutrients such as vitamins, minerals (iron, manganese, magnesium, zinc and selenium), carbohydrates, proteins, various amino acids, fats and fiber, and many people consume them as a delicacy and especially for their unique aroma and consistency [12-14]. Known for their nutritional and health benefits for centuries due to their sensory properties and culinary suitability, fresh and dried mushrooms have low fat (4–5%) and caloric value, while being a good source of polysaccharides (37–48%), proteins (20–25%), fibers (13–24%) and minerals (e.g. K, P, Na, Ca, Mg) [15,16]. Dried mushrooms, which are mostly used in the food industry as an ingredient in spice mixtures or in the production of dried soups, are considered a functional food because they contain an important source of nutrients and physiologically active components. In addition to being a good source of protein and fiber, mushrooms have digestive properties and are low in energy due to their low fat content [9,17]. Since mushrooms have a high ability to absorb trace elements from the soil, a suitable microelement composition and concentration of these elements can be beneficial for humans [18,19]. Heavy metal contents of mushrooms are higher than those of agricultural plants such as vegetables and fruits due to their strong ability to absorb elements [20]. Wild forest mushrooms and also mushrooms grown with artificial intensive methods are delicious foods with nutritional value and are difficult to preserve due to their high water content and must be cooked and consumed in a short time. Since mushrooms are significantly popular in different parts of the world and are consumed in fresh and processed forms due to their taste and aroma, dried mushroom powder is used as a food ingredient to enrich the protein and fiber content and other nutrients in functional baked goods. The objective of this article was to investigate the macro, micro and toxic element distributions in cultivated and wild mushroom type and parts.

2. Material and methods

2.1. Material

The mushroom samples were provided from a local market in Düzce in TÜRKİYE (Fig.1). After the mushroom samples were washed with with distilled water, the mushroom sample was placed in a paper bag. Mushrooms were sliced with a knife to dry. The mushroom samples were dried in room temperature, and then, they were ground in an grinder.

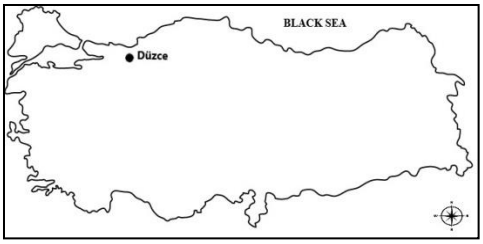


Figure 1. Location of the mushrooms used in this study

2.2 Methods

2.2.1 Digestion in the microwave

The mushroom samples were dried in an air circulation drying cabinet at 70°C until they reached constant weight. Ground mushroom samples were dissolved with 5 ml concentrated HNO_3 and 2 ml H_2O_2 (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

Element contents of the mushroom samples were determined with the ICP-OES device. After the samples were analyzed and made ready for reading by burning with different methods for elemental analysis, the results were expressed as mg/kg [21]. Study wavelengths, LOD, LOQ and R^2 values of elements assessed with ICP-OES are displayed in Table 1.

2.3.Statistical analysis

After the statistical analysis of the results was determined using the JMP statistical program, statistical differences were detected in all data with the analysis of variance (ANOVA) procedure ($p<0.05$) [22]. In order to examine the correlation between the nutrient element and heavy metal contents of mushroom varieties and parts samples, a multivariate

cluster analysis was performed using the PAST statistical program to perform Principal Component Analysis (PCA) [23].

3. Results and discussion

It is understood from Table 1 that the mushrooms used in this study are good sources of P and K. Ca and Mg contents of the mushrooms were also found to be relatively high. Some differences were observed in macro element contents among mushroom varieties and parts. P and K contents of mushroom varieties were determined between 4163.03 (Oyster mushroom (stem)) and 14387.06 mg/kg (Oyster mushroom (carpofor)) to 18736.73 (Oyster mushroom (stem)) and 37474.05 mg/kg (Oyster muchroom (Carpofor)), respectively. In addition, the Ca contents of the mushroom samples ranged from 57.66 (Oyster muchroom (stem)) to 670.52 mg/kg (Chestnut muchroom (skin)), while the Mg contents of the mushroom samples ranged from 547.09 (Chestnut mushroom (stem)) to 1076.13 mg/kg (Oyster mushroom (carpofor)). As seen in Table 1, the macroelement found in the highest amounts in mushroom samples was K, followed by P, Mg and Ca in decreasing order. The highest P, K and Mg were detected in the Oyster mushroom (carpophore) mushroom part. The P and K contents of all parts of chestnut mushrooms were higher than those of Oyster and kanlıca mushrooms. In general, the P and K contents of the carpophore parts of mushrooms were higher than those of other parts. The Ca contents of the Oyster mushroom parts were lower than those of kanlıca and chestnut mushrooms. The highest Mg was detected in the stem parts of Kanlıca and Chestnut mushrooms. In general, macro element accumulations in the stem parts of mushrooms were lower than those in the skin and carpophore parts. However, it was observed that mushrooms generally absorbed large amounts of macro elements from the soil [24].

Table 1. Macro element contents of the parts of Oyster, kanlıca mushroom and chestnut mushroom.

Mushroom samples	P	K	Ca	Mg
	---------- (mg/kg) ----------			
Oyster Mushroom (Skin)	8664.92±68.98 **C***	25953.64±1070.39 **D**	192.24±0.60 **D**	729.19±7.38 **C**
Oyster Mushroom (Carpofor)	14387.06±635.69 **A**	37474.05±1338.30 **A**	86.19±0.58 **G**	1076.13±26.87 **A**
Oyster Mushroom (Stem)	4163.03±47.75 **F**	18736.73±54.09 **E**	57.66±0.78 **H**	547.89±10.52 **D**
Kanlıca Mushroom (Skin)	5640.22±42.95 **DE**	20336.73±354.96 **E**	223.81±0.88 **C**	747.80±14.46 **C**
Kanlıca Mushroom (Carpofor)	5972.53±11.01 **D**	25474.67±489.22 **D**	126.52±0.24 **F**	744.17±11.32 **C**
Kanlıca Mushroom (Stem)	4648.08±55.02 **EF**	27609.79±406.98 **D**	154.12±0.97 **E**	562.18±6.82 **D**
Chestnut Mushroom (Skin)	10847.42±263.87 **B**	33785.25±287.15 **BC**	670.52±0.49 **A**	731.85±1.24 **C**
Chestnut Mushroom (Carpofor)	14370.47±478.21 **A**	36698.61±1061.68 **AB**	552.79±13.84 **B**	864.30±5.95 **B**
Chestnut Mushroom (Stem)	9659.85±98.82 **C**	32104.19±971.23 **C**	564.74±0.84 **B**	547.09±9.41 **D**

***** $p<0.05$

The microelement contents of mushroom samples are presented in Table 2. It was observed that mushroom types and parts were effective on microelement contents. The microelement found in the highest amounts in mushroom samples was Fe, followed by Zn, Cu, Mn and B in decreasing order. Fe, Zn and Mn contents of Kanlıca mushroom samples were higher than those of other mushrooms. In addition, the highest Cu and B contents were detected in Chestnut mushroom samples. Cu and B contents of Chestnut mushroom samples were defined as 17.58 (stem) and 40.26 mg/kg (carpofor) to 25.86 (carpofor) and 54.79 mg/kg (stem), respectively. Fe and Zn contents of Kanlıca mushroom samples were determined between 93.23 (carpofor) and 165.84 mg/kg (skin) to 69.39 (stem) and 76.11 mg/kg (carpofor), respectively.Mn contents of Oyster and Chestnut samples were lower than those of Kanlıca mushrooms. Mn contents of Kanlıca mushroom parts were determined between 12.57 (carpophore) and 22.24 mg/kg (skin). Carpophore part of Oyster mushroom contained more Fe, Zn, Cu and Mn than other parts.

Table 2. Microelement contents of the parts of Oyster, kanlıca mushroom and chestnut mushroom

Mushroom samples	Fe	Zn	Cu	Mn	B
	(mg/ kg)				
Oyster Mushroom (Skin)	56.46±1.73 **F***	18.39±0.76 **E**	3.09±0.13 **E**	6.60±0.039 **DE**	8.45±0.15 **CD**
Oyster Mushroom (Carpofor)	76.94±0.45 **E**	55.81±0.99 **C**	12.70±0.50 **D**	11.07±0.587 **C**	4.55±0.02 **F**
Oyster Mushroom (Stem)	24.89±1.28 **G**	8.34±0.07 **F**	1.74±0.17 **E**	5.66±0.031 **E**	8.69±0.15 **C**
Kanlıca Mushroom (Skin)	165.84±1.32 **A**	74.46±1.35 **A**	13.41±0.08 **D**	22.24±0.581 **A**	5.49±0.03 **EF**
Kanlıca Mushroom (Carpofor)	93.23±0.49 **D**	76.11±1.14 **A**	18.34±0.04 **C**	12.57±0.030 **C**	6.74±0.001 **DE**
Kanlıca Mushroom (Stem)	124.62±1.01 **C**	69.39±0.66 **B**	11.47±0.07 **D**	14.99±0.992 **B**	4.50±0.10 **F**
Chestnut Mushroom (Skin)	152.97±1.039 **B**	36.47±1.83 **D**	27.35±0.52 **B**	8.21±0.130 **D**	27.44±1.04 **B**
Chestnut Mushroom (Carpofor)	56.88±1.25 **F**	58.30±0.09 **C**	40.26±1.52 **A**	6.03±0.102 **E**	25.86±0.93 **B**
Chestnut Mushroom (Stem)	73.13±0.95 **F**	36.37±0.94 **D**	17.58±1.29 **C**	5.35±0.044 **E**	54.79±0.25 **A**

***p<0.05

The microelement contents of the stem part of the oyster mushroom were found to be considerably lower than the stem parts of the Kanlıca and Chestnut mushrooms. It is seen that the Kanlıca mushroom parts are a good source of Fe and Zn. The Cu contents of the Kanlıca and Chestnut mushroom samples were found to be considerably higher than the oyster mushroom samples. In addition, the Mn contents of the Oyster and Kanlıca mushrooms were found to be higher than the chestnut samples. As a result, it can be said that the ability of the mushrooms to absorb the Fe and Zn nutrient elements from the soil is high.

Toxic element contents of three different natural mushroom samples are given in Table 3. In general, it was observed that the toxic element contents of mushrooms were at very low levels. Partial effects of mushroom parts and varieties on the toxic element contents of mushrooms were observed.

The toxic elements found in the highest amounts in mushroom samples were Cr, Pb and Se (Figure 2). Cr and Pb contents of mushroom samples were determined between 0.008 (Kanlıca mushroom (carpofor)) and 0.043 mg/kg (Chestnut mushroom (skin)) and 0.0055 (Oyster mushroom (skin)) and 0.234 mg/kg (Kanlıca muchroom (stem)), respectively. In addition, Se contents of the mushroom samples were determined between 0.005 (chestnut mushroom (skin)) and 0.203 mg/kg (Oyster mushroom (skin)). Carpophore and stem parts of oyster and kanlıca mushroom contained more Pb than skin parts. Carpophore part of oyster mushroom contained more Mo (0.156 mg/kg) than other mushrooms. Al and Cd contents of the mushroom samples were found between 0.001 (Oyster mushroom (skin)) and 0.021 (chestnut mushroom (skin)) and 0.0004 (chestnut mushroom (carpofor)) and 0.0023 mg/kg (Kanlıca mushroom (stem), respectively. Different mushrooms contained 1.3±0.1-3.9±0.3 Na, 1.5±1.0-22.3±2.1 K, 1.4±0.1-6.4±0.5 P, 0.20±0.01-1.4±0.1 Ca and 0.10±0.02-1.5±0.1 Mg, 42.1±3.3-65.4±5.3 Zn, 9.4±0.5-43.9±3.9 Cu, 13.9±1.2-94.3±8.1 Mn, 179±10.8-381±25.4 Fe, 7.9±0.8-12.2±1.1 Pb and 0.11±0.01-0.68±0.04 Cd mg/kg, [25]. From a nutritional perspective, mushrooms are a good source of inorganic elements such as phosphorus, potassium, selenium, zinc, magnesium and copper [26]. Michelot et al. [27]studied fifteen species from France (in the Paris region) reporting concentrations in the range of 340-1440 (Ca), 3-4 (Cd), 28-80 (Fe), 3-34 (Mn)52-67 (Zn) mg/kg (dw). Mushroom samples collected in Bangladesh contained 0.51 As, 0.38 Cd, 0.28 Cr, 0.01 Co, 13.7 Cu, 0.31 Pb, 11.7MN, 0.12 Hg, 0.28 Ni and 53.5 mg/kg Zn [28].

Mallikarjuna et al. [29] determined 59.3-3634 mg/100g K, 100.5-769.9 mg/100g P, 8.27-174.9 mg/100g Ca, 22.2-327.4 mg/100g Na, 21.1-40.7 mg/100g Mg, 6.27-35.3 mg/100g Fe, 1.58-9.44 mg/100g Zn, 0.97-1.48 mg/100g Cu, 0.54-1.12 mg/100g Mn and 0.048-0.19 mg/100g Se in four species of mushrooms.

Table 3. Toxic element contents of the parts of Oyster, kanlıca mushroom and chestnut mushroom.

Mushroom samples	Al	Ba	Cd	Co	Mo
	(mg/ kg)				
Oyster Mushroom (Skin)	0.001±0.0001 **I***	0.0005± 0.0001	0.0020±0.0001 **C**	0.0028±0.0001 **F**	0.003±0.00001
Oyster Mushroom (Carpofor)	0.006±0.00001 **C**	0.0019±0.0005	0.0014±0.0003 **F**	0.0057±.0007 **D**	0.156±0.0014
Oyster Mushroom (Stem)	0.005±0.00001 **E**	0.0004±0.0001	0.0015±0.0006 **E**	0.0042±0.0001 **E**	0.006±0.0008
Kanlıca Mushroom (Skin)	0.002±0.00081 **H**	0.0006±0.0002	0.0022±0.0003 **B**	0.0024±0.0007 **H**	0.004±0.0003
Kanlıca Mushroom (Carpofor)	0.005±0.00067 **D**	0.0006±0.0003	0.0005±0.0003 **H**	0.0076±0.0005 **C**	0.004±0.0006
Kanlıca Mushroom (Stem)	0.004±0.00022 **F**	0.0007±0.0003	0.0023±0.0007 **A**	0.0005±0.0001 **I**	0.012±0.0085
Chestnut Mushroom (Skin)	0.021±0.0068 **A**	0.0001±0.000	0.0009±0.0007 **G**	0.0093±0.0051 **A**	0.002±0.0009
Chestnut Mushroom (Carpofor)	0.004±0.0003 **G**	0.0009±0.0001	0.0004±0.0001 **I**	0.0082±0.0013 **B**	0.003±0.0006
Chestnut Mushroom (Stem)	0.009±0.0004 **B**	0.0005±0.0001	0.0017±0.0005 **D**	0.0026±0.0003 **G**	0.004±0.0007

Table 3 (continued)

Mushroom samples	Cr	Ni	Pb	As	Se
	(mg/ kg)				
Oyster Mushroom (Skin)	0.016±0.00007 **E***	0.0009±0.000015 **F**	0.0055±0.0033 **G**	0.014±0.003 **A**	0.203±0.00008 **E**
Oyster Mushroom (Carpofor)	0.011±0.00007 **G**	0.0003±0.000105 **H**	0.1280±0.0015 **C**	0.009±0.001 **F**	0.025±0.0008 **D**
Oyster Mushroom (Stem)	0.016±0.00007 **D**	0.0088±0.00001 **A**	0.228±0.0014 **B**	0.013±0.007 **D**	0.013±0.0002 **F**
Kanlıca Mushroom (Skin)	0.018±8.77097 **B**	0.0015±0.00006 **C**	0.007±0.0006 **G**	0.013±0.006 **C**	0.021±0.009 **E**
Kanlıca Mushroom (Carpofor)	0.008±0.00007 **H**	0.0003±0.00004 **H**	0.128±0.00008 **C**	0.009±0.001 **G**	0.032±0.0003 **B**
Kanlıca Mushroom (Stem)	0.016±1.211244 **C**	0.0077±0.0005 **B**	0.234±0.0077 **A**	0.013±0.003 **B**	0.009±0.0005 **G**
Chestnut Mushroom (Skin)	0.043±0.000007 **A**	0.0011±0.0003 **E**	0.072±0.0010 **D**	0.011±0.001 **E**	0.005±0.00036 **H**
Chestnut Mushroom (Carpofor)	0.014±0.000176 **F**	0.0006±0.00005 **G**	0.027±0.0003 **E**	0.008±0.003 **H**	0.028±0.000007 **C**
Chestnut Mushroom (Stem)	0.008±0.0002 **H**	0.0014±0.00012 **D**	0.0129±0.0015 **F**	0.013±0.006 **B**	0.041±0.0008 **A**

***** $p<0.05$

In another study, K, Mg, P, Ca, S and Na contents of *P ostreatus* mushroom samples were determined between 5685.74-6373.72, 2292.70-2686.98, 1381.19-1531.60, 993.58-1223.16,1791.06-2838.82 and 707.82-1223.92 mg/kg [30]. The minimum and maximum K, Mg, Ca, Mn, Fe, Zn, Cu, Ni, Cd, Pb contents of mushrooms varied between 930-10370,424.3-1686.1, 44.2-1669.7, 3.01-37.49, 26.6-258.9, 23.18-83.17, 2.84-128.94, 1.1-18.37, 0.01-59.16 and 0.00-1.75 mg/kg [31]. The toxic element detected in the highest amounts in both fresh and dried mushroom samples was Cr, followed by Pb and Se in decreasing order. This shows that the mushrooms used in the study are safe food in terms of toxic elements. The macro, micro and toxic element results of 3 different mushroom and their parts showed differences with the element contents of mushrooms studied by Michelot *et al.* [27], Chittaragi and Naika [25], Mallikarjuna *et al*. [29], Beyhan [30] and Keleş *et al*. [31]. These differences may have been affected by the drying process applied, mushroom variety, whether it is cultivated or wild mushroom, plant nutrient element concentrations of compost and/or soil where the mushrooms grow, digestion

methods applied and chemicals.

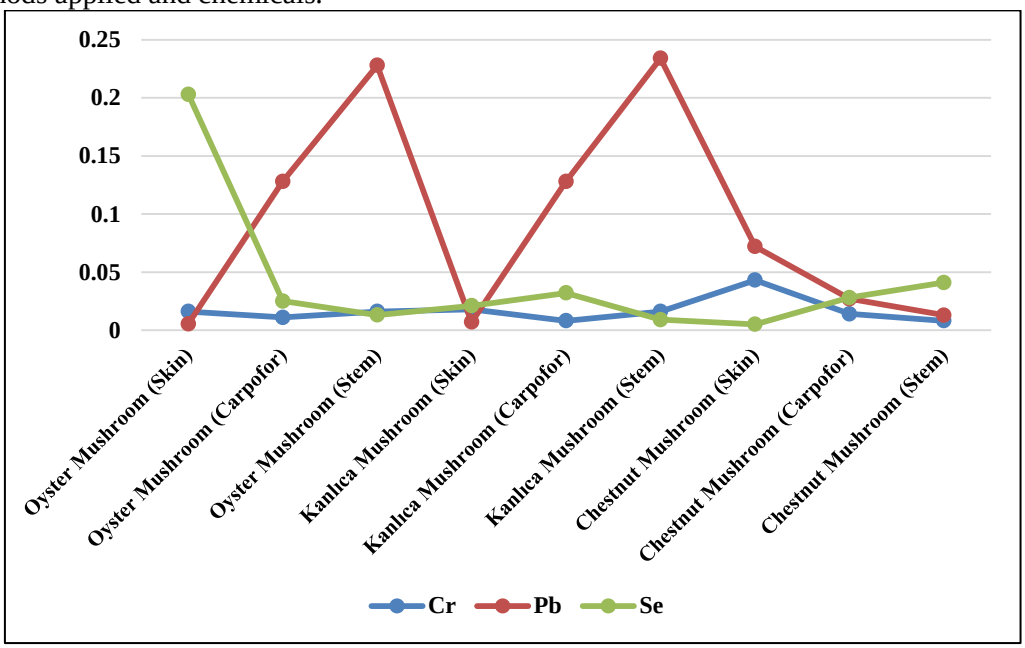
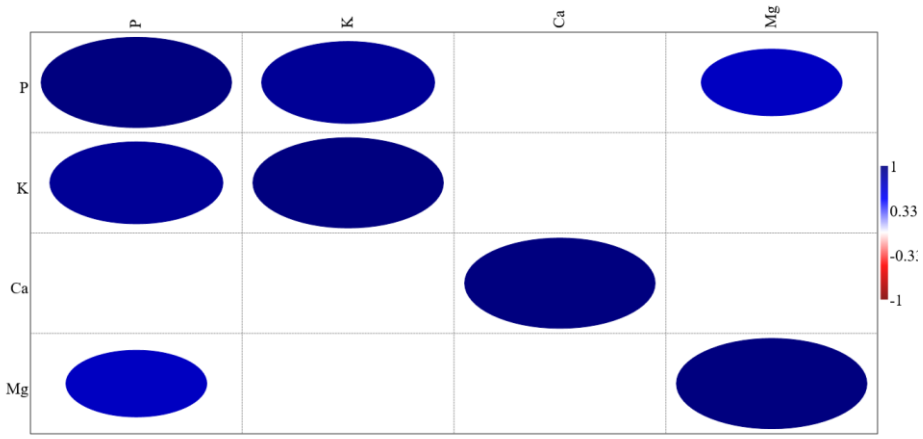


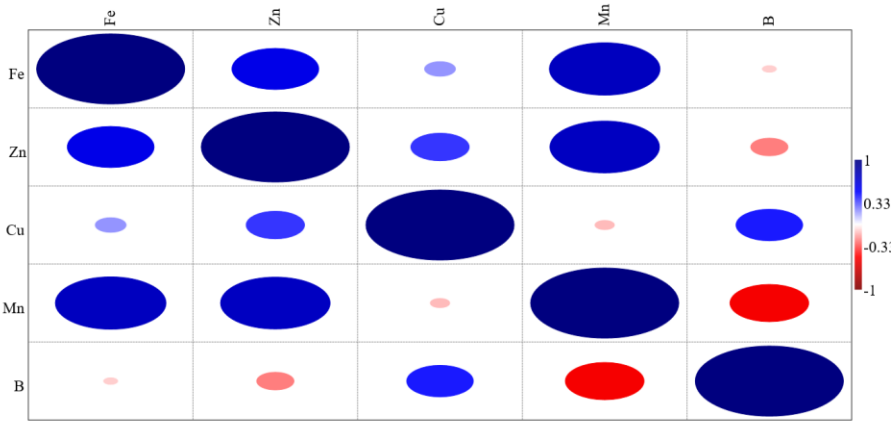
Figure 2. The highest amount of toxic element contents in mushroom varieties and parts

The Pearson correlation analysis

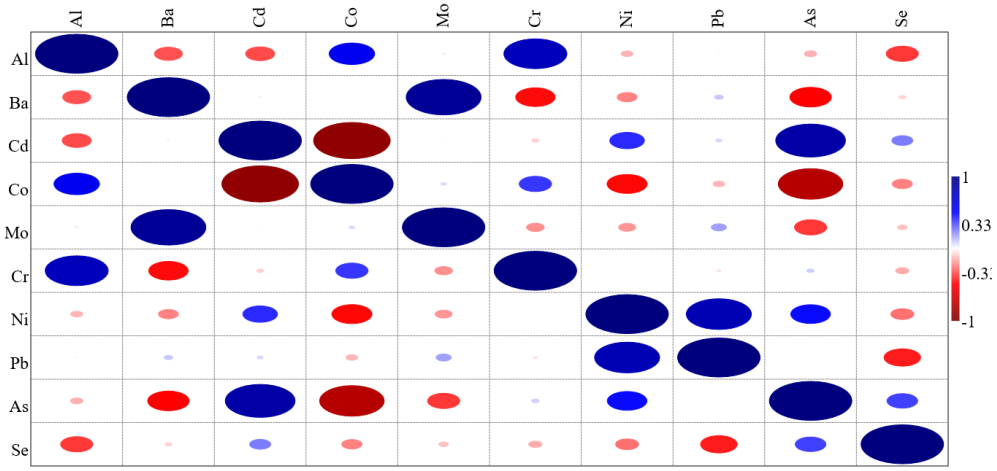
Pearson correlation (r) between the macro (P, K, Ca and Mg) and micro (Fe, Zn, Cu, Mn and B) nutrient elements and heavy metal (Al, Ba, Cd, Co, Mo, Cr, Ni, Pb, As and Se) contents of mushroom varieties and parts samples are given in Figures 3. When the macro element contents of different mushroom varieties were examined; it was stated that there were significant and highly strong positive relationships ($p<0.05$, $r>0.70$) between P content and K content (r=0.908**) and Mg (r=0.739**). In the micro element contents of mushroom samples; significant and highly strong positive relationships were determined between Fe content and Mn content (r=0.747**) and between Zn content and Mn content (r=0.740**). In addition, when the heavy metal contents of the mushroom samples were observed; significant and highly strong positive relationships were determined between the Al contents and Cr contents (r=0.764**), Ba contents and Mo contents (r=0.908**) and Cd contents and As contents (r=0.845**) of the mushroom varieties and parts samples, while significant and highly strong negative relationships were revealed between the Cd content and Co content (r= -0.928**) and Co content and As content (r= -0.782**). The Pearson correlation analysis, which was conducted with samples of variable mushroom varieties and parts, aimed to determine the strength and direction of the relationship between the nutrient or heavy metal contents of mushroom samples, and with this Pearson correlation, the best fit line was tried to be drawn over the data of mushroom samples and nutrient content or mushroom samples and heavy metal content. Thus, the Pearson correlation coefficient (r) revealed how far all these data points were from the best fit line [32].



a-macroelements



b-microelements



c- Toxic elements

Figure 3. Pearson correlation (r) between the macro (P, K, Ca and Mg) and micro (Fe, Zn, Cu, Mn and B) nutrient elements and heavy metal (Al, Ba, Cd, Co, Mo, Cr, Ni, Pb, As and Se) contents of mushroom varieties and parts samples

4. Conclusion

The microelement found in the highest amounts in mushroom samples was Fe, followed by Zn, Cu, Mn and B in decreasing order. Fe, Zn and Mn contents of Kanlıca mushroom samples were higher than those of other mushrooms. In addition, the highest Cu and B contents were detected in Chestnut mushroom samples. Carpophore part of Oyster mushroom contained more Fe, Zn, Cu and Mn than other parts. The microelement contents of the stem part of the oyster mushroom were found to be considerably lower than the stem parts of the Kanlıca and Chestnut mushrooms. As a result, it can be said that the ability of the mushrooms to absorb the Fe and Zn nutrient elements from the soil is high. Partial effects of mushroom parts and varieties on the toxic element contents of mushrooms were observed. The toxic elements found in the highest amounts in mushroom samples were Cr, Pb and Se. Carpophore and stem parts of oyster and kanlıca mushroom contained more Pb than skin parts. Mushrooms, which are consumed with pleasure by people, have the ability to absorb large amounts of heavy metals as well as macro and micro element absorption from the soil. Therefore, the places where mushrooms are collected should be far from the fields caused by industrial pollution. Our future studies will compare the toxic element contents of mushrooms obtained from places with industrial pollution and from regions far from these places and in which parts of the mushrooms they accumulate the most.

Data availability statement: the original contributions presented in the study are included in the article, further inquiries can be directed to the corresponding author.

Competing interests No conflict of interest.

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