Bartın Orman Fakültesi Dergisi | Journal of Bartin Faculty of Forestry
2024, 26(1): 55–63 | DOI: 10.24011/barofd.1380972
BAROFD

Elemental Composition of A Cultivated Mushroom (*Agaricus bisporus*) and Some Wild Mushroom Species

Sibel YILDIZ[1,*] Hasan Hüseyin DOĞAN[2] Ayşenur GÜRGEN[3] Uğur ÇEVİK[4]

[1]Karadeniz Technical University, Faculty of Forestry, Department of Forest Industry Engineering, Trabzon, Türkiye
[2]Selçuk University, Faculty of Science, Department of Biology, Konya, Türkiye
[3]Osmaniye Korkut Ata University, Faculty of Engineering, Department of Industrial Engineering, Osmaniye, Türkiye
[4]Karadeniz Technical University, Faculty of Science, Department of Physics, Trabzon, Türkiye

Article History

Received: 27.10.2023
Accepted: 15.02.2024
Published: 29.02.2024

Research Article

Abstract − In the study, a cultivation mushroom (*Agaricus bisporus*) and some wild mushroom species (*Schizophyllum commune*, *Pleurotus ostreatus*, *Lactarius deliciosus*, *Hebeloma sinapizans*, *Hygrophorus ligatus*, *Suillus luteus*, *Armillaria mellea*, *Coprinus comatus*, *Psathyrella candolleana*, *Russula torulosa*, *Trametes pubescens*) were investigated in terms of elemental compositions. The wild mushroom species were collected from Trabzon province. Mg, Al, Si, P, S, Cl, K, Ca, Ti, V, Cr, Mn, Fe, Ni, Cu, Zn, As, Se, Rb, Sr, Y, Zr, I, Hf, Hg, Pb metal concentrations were determined using Energy Dispersive X-ray Fluorescence (ED-XRF) device. The highest aliminium, silicium, vanadium, zirconium, iron and mercury were determined in *Lactarius deliciosus*. The highest potassium, arsenic, rubidium, iodine contents were determined in *Hebeloma sinapizans*. The highest manganese, zinc, lead contents were determined in *Hygrophorus ligatus*. The highest magnesium, chromium, nickel, yttrium contents were determined in *Coprinus comatus*. The highest titanium and selenium were determined in *Psathyrella candolleana*. The highest calcium and strontium were determined in *Russula torulosa*. The highest hafnium was determined in *Schizophyllum commune*. The highest phosphate was determined in *Agaricus bisporus*. The highest sulphur was determined in *Armilleria mella*. The highest copper was determined in *Suillus lutesus*. It was concluded that elemental composition of mushrooms was affected especially by mushroom specie.

Keywords − *Cultivated mushroom, elemental composition, wild mushroom*

Kültür Mantarı (*Agaricus bisporus*) ve Bazı Yabani Mantar Türlerinin Elementel Bileşimi

[1] Karadeniz Teknik Üniversitesi, Orman Fakültesi, Orman Endüstri Mühendisliği Bölümü, Trabzon, Türkiye
[2]Selçuk Üniversitesi, Fen Fakültesi, Biyoloji Bölümü, Konya, Türkiye
[3]Osmaniye Korkut Ata Üniversitesi, Mühendislik Fakültesi, Endüstri Mühendisliği Bölümü, Osmaniye, Türkiye
[4]Karadeniz Teknik Üniversitesi, Fen Fakültesi, Fizik Bölümü, Trabzon, Türkiye

Makale Tarihçesi

Gönderim: 27.10.2023
Kabul: 15.02.2024
Yayım: 29.02.2024

Araştırma Makalesi

Öz − Bu çalışmada kültür mantarı (*Agaricus bisporus*) ve bazı yabani mantar türlerinin (*Schizophyllum commune*, *Pleurotus ostreatus*, *Lactarius deliciosus*, *Hebeloma sinapizans*, *Hygrophorus ligatus*, *Suillus luteus*, *Armillaria mellea*, *Coprinus comatus*, *Psathyrella candolleana*, *Russula torulosa*, *Trametes pubescens*) element bileşimleri açısından incelenmiştir. Yabani mantar türleri Trabzon ilinden toplanmıştır. Mg, Al, Si, P, S, Cl, K, Ca, Ti, V, Cr, Mn, Fe, Ni, Cu, Zn, As, Se, Rb, Sr, Y, Zr, I, Hf, Hg, Pb metal konsantrasyonları Enerji dağınımlı X-ışını floresans (ED-XRF) cihazı kullanılarak belirlenmiştir. En yüksek aliminyum, silisyum, vanadyum, zirkonyum, demir ve cıva *Lactarius deliciosus*'ta belirlenmiştir. En yüksek potasyum, arsenik, rubidyum, iyot *Hebeloma sinapizans*'ta belirlenmiştir. En yüksek manganez, çinko ve kurşun *Hygrophorus ligatus*'ta tespit edilmiştir. En yüksek magnezyum, krom, nikel, itriyum ise *Coprinus comatus*'ta belirlenmiştir. En yüksek titanyum ve selenyum *Psathyrella candolleana*'da belirlenmiştir. En yüksek kalsiyum ve stronsiyum *Russula torulosa*'da tespit edilmiştir. En yüksek hafniyum *Schizophyllum commune* mantarında belirlenmiştir. En yüksek fosfat *Agaricus bisporus*'ta, en yüksek kükürt, *Armilleria mella*'da, en yüksek bakır ise *Suillus lutesus*'ta belirlenmiştir. Mantarların elementel kompozisyonunun özellikle mantar türünden etkilendiği sonucuna varılmıştır.

Anahtar Kelimeler – *Elementel kompozisyon, kültür mantarı, yabani mantar*

[1] sibelyildizz@gmail.com
[2] hhdogan@selcuk.edu.tr
[3] aysenur.yilmaz@ktu.edu.tr
[4] ugurc@ktu.edu.tr
*Sorumlu Yazar / Corresponding Author

1. Introduction

Mushrooms are one of the most important parts of ecological balance (Sarikurkcu ve ark. 2021). Many types of wild edible mushroom and cultivated mushrooms species are considered very delicious foods in different geographies of the world. Additionally, a part of the wild mushrooms is evaluated in many countries as medicine (Isildak et al., 2004). On the other hand, some mushrooms have the ability to accumulate some toxic metals and metalloids such as copper, arsenic cadmium, mercury, lead, and radionuclides (Falandysz et al., 2003; Yamaç et al., 2007; Kokkoris et al., 2019). It was recorded that especially mercury, cadmium and to a lesser content lead are the importance metals in terms of toxicological (Kalač and Svoboda, 2000). The heavy metal contents are generally correlated to the physiology of mushroom species, age of the mushroom mycelium, mineral structure of the soil and pollution level of the area of sampling (Kalač et al., 1991). According to the Gadd (2007), accumulation of heavy metals is very complicated process affected by both environmental (pH of the soil, amount of organic material etc.) and internal (taxon, mycelium etc.) factors.

Agaricus bisporus is the most cultivated and consumed mushroom specie (Siwulski et al., 2020) in the world and it has been recorded that a very susceptible mushroom to increasing content of mercury and to a lesser extent of cadmium in substrate (Sanglimsuwan et al., 1993; Rácz et al., 1995; Kalač and Svoboda, 2000). It has been declared that *Agaricus bisporus* has uptake metals from substrate in the following order: Hg>Zn>Cd and Pb (Lasota et., al 1990). Some researchers have noted that heavy metals in the cultivated mushrooms are remarkably lower than that of in the same related wild growing species (Stmisková et al., 1990; Kalač and Svoboda 2000).

Because of the favorable conditions for the growth of fungi, Turkey has a very rich macro-fungal flora. In particular, the Eastern Black Sea region of Turkey has very suitable climatic conditions for the development of various wild mushroom species. Several studies of heavy metal concentrations in mushrooms have been carried out until today (Kalač et al., 1991; Falandysz et al., 2003; Nikkarinen and Mertanen, 2004; Kokkoris et al. 2019; Fu et al., 2020; Dowlati et al., 2021) and in Turkey (Tüzen et al., 1998; Sesli and Tuzen, 1999; Demirbaş, 2000; Isiloglu and Yılmaz, 2001; Isildak et al., 2004; Yamaç et al., 2007; Sarıkurkcu et al., 2021).

Heavy metals widely accepted that the harmful to the human health even at low concentration levels. (Cocchi et al., 2006). Additionally, the consumption of the mushrooms including heavy metals may impair heart, immunological systems, skeletal and nervous, systems. (Anwar et al., 2016; Atamaleki et al., 2019). Therefore, investigate the metal levels in mushroom is very important to know the risk level that affects the human health.

In the literature, there are several studies about heavy metal content of mushroom species (Sevindik, 2020; Mushtaq et al., 2020). But there are limited edition studies comparing the metal contents of cultivation mushroom and wild mushrooms in the same article. For that reason, in the study, a cultivation mushroom (*Agaricus bisporus*) and some wild mushroom species (*Schizophyllum commune*, *Pleurotus ostreatus*, *Lactarius deliciosus*, *Hebeloma sinapizans*, *Hygrophorus ligatus*, *Suillus luteus*, *Armillaria mellea*, *Coprinus comatus*, *Psathyrella candolleana*, *Russula torulosa*, *Trametes pubescens*) were investigated in terms of elemental compositions.

2. Material and Method

Mushroom

The mushrooms used in the study are shown in Table 1. In the study, the elemental composition of cultivated mushroom *Agaricus bisporus* and some wild mushroom species such as *Schizophyllum commune*, *Pleurotus ostreatus*, *Lactarius deliciosus*, *Hebeloma sinapizans*, *Hygrophorus ligatus*, *Suillus luteus*, *Armillaria mellea*, *Coprinus comatus*, *Psathyrella candolleana*, *Russula torulosa*, *Trametes pubescens* were investigated. Cultivated mushroom (*Agaricus bisporus*) was bought from a market in Trabzon province. Similarly, wild mushrooms were collected from Trabzon province (Table 1). Wild mushrooms were identified according to macroscopic and microscopic analyses by Prof. Dr. Hasan Hüseyin DOĞAN.

Table 1
Mushrooms used in the study.

Code Number	Mushroom	Type
1	*Schizophyllum commune* Fr	Wild
2	*Pleurotus ostreatus* (Jacq.) P. Kumm.	Wild
3	*Lactarius deliciosus* (L.) Gray	Wild
4	*Hebeloma sinapizans* (Paulet) Gillet	Wild
5	*Hygrophorus ligatus* (Fr.) Fr.	Wild
6	*Suillus luteus* (L.) Roussel	Wild
7	*Armillaria mellea* (Vahl) P. Kumm.	Wild
8	*Coprinus comatus* (O.F. Müll.) Pers.	Wild
9	*Psathyrella candolleana* (Fr.) Maire	Wild
10	*Russula torulosa* Bres.	Wild
11	*Trametes pubescens* (Schumach.) Pilát	Wild
12	*Agaricus bisporus*	Cultivated

2.2. Elemental analysis

In the study, some metals (Mg, Al, Si, P, S, Cl, K, Ca, Ti, V, Cr, Mn, Fe, Ni, Cu, Zn, As, Se, Rb, Sr, Y, Zr, I, Hf, Hg and Pb) accumulations of studied mushrooms were determined. Metal accumulations were determined using Energy Dispersive X-ray Fluorescence (ED-XRF) device (Epsilon5, PANalytical, Almelo, the Netherlands). For measurements, the mushroom samples were pressed with a 7-ton hydraulic press for 20 s and thus pellets with a diameter of 40 mm and a mass of 500±3 mg were prepared.

3. Results and Discussion

Metal contents of mushrooms were presented at Table 2. Magnesium (Mg) content of mushrooms was ranged 551.217- 2400 mg/kg. The highest Mg was determined in *C. comatus.* Mg was not detected in *H. sinapizans*, *H. ligatus*, *P. candolleana* and *R. torulosa.* In a previous study, Mg content of some edible mushooms 641.36-2185.62 mg/kg (Bulam et al., 2019). It was seen that the mg values of this study are parallel to the literature data.

Aluminium (Al) was not detected only in *C. comatus* among the studied mushrooms. The highest Al was determined in *L. deliciosus* with 3.608 % while the lowest Al was determined in *Armillaria mellea* with 0.335 %. It was reported that Al concentrations of collected from West Macedonia and Epirus, Greece were under the detection limit of the used method (Ouzouni et al., 2009).

Silicon (Si) content of studied mushrooms was ranged between 0.545 and 6.301 %. The highest Si content was determined in *L. deliciosus* mushroom. Si was not detected *P. ostreatus, T. pubescens, A. bisporus*. Koyyalamudi et al., (2013) reported that Si content of *A. bisporus* mushrooms obtained from two farms was ranged between 1.6 and 3.7 mg/100 g.

Phosphate (P) was detected in all the studied mushrooms. The highest and the lowest P were found in *A. bisporus* (4.385 %) and *C. comatus* (0.135 %), respectively. In a previous study, P content of *Ganoderma lucidum* collected from the nature and cultured on orange stump were determined as 4.270 % and 4.722 %, respectively (Turfan et al., 2016).

Sulphur (S) content of studied mushrooms was ranged 0.353-0.919 %. The highest S content was determined in *A. mellea* mushroom. Turfan et al., (2016) reported that S content of *G. lucidum* mushrooms were ranged between 1.006% and 1.174 %, respectively.

Potasium (K) was detected in all the studied mushrooms. K content of studied mushrooms was ranged between 2.189 and 27.885 %. The highest K content was determined in *H. sinapizans*. Li and Chang (1982) stated that the amount of K, P, Na and Mg in mushrooms is around 50-70% and only K covers 45% of the total mineral content.

Table 2
Metal contents of mushrooms

Metal	1	2	3	4	5	6	7	8	9	10	11	12	Unit
MgO	551.217	760.828	1263.504	ND*	ND	885.462	950.581	**2400**	ND	ND	1243.115	1577.573	mg/kg
Al_2O_3	1.484	0.757	**3.608**	1.115	2.199	1	0.335	ND	1.34	1.993	0.897	1.207	%
SiO_2	2.123	ND	**6.301**	0.78	3.362	0.545	0.989	3.233	0.978	2.006	ND	ND	%
P_2O_5	1.682	2.927	2.323	2.411	1.918	3.725	3.004	0.135	1.111	0.57	3.949	**4.385**	%
SO_3	0.526	0.761	0.586	0.699	0.475	0.904	**0.919**	0.751	0.353	0.368	0.508	0.836	%
K_2O	4.626	17.909	11.537	**27.885**	23.165	23.533	21.113	2.067	21.242	2.189	20.071	25.107	%
CaO	1.823	0.426	0.846	0.647	1.182	0.361	0.361	1.074	0.487	**7.496**	ND	0.611	%
TiO_2	1280.882	266.888	575	967.023	463	538.369	1034.726	237.798	**1701.732**	214	34.826	88.261	mg/kg
V_2O_5	47.160	ND	**146.655**	21.089	99.515	2.931	26.9	140.645	21.332	40.614	ND	ND	mg/kg
Cr_2O_3	33.650	ND	99.539	36.444	75.062	28.348	61.16	**1149.588**	41.554	159.206	ND	ND	mg/kg
MnO	194.014	103.096	818.148	247.733	**851.086**	105.791	314.168	4.477	211.33	365.021	74.206	39.918	mg/kg
Fe_2O_3	0.816	0.186	**2.501**	0.347	1.93	0.339	0.602	0.39036	1.007	1.18	0.903	0.71	%
NiO	8.595	ND	29.094	ND	15.56	ND	ND	**227.428**	10.292	10.154	ND	ND	mg/kg
CuO	56.063	228.816	169.759	395.885	257.882	**500.625**	96.727	446.223	296.259	82.43	181.513	ND	mg/kg
ZnO	698.665	645.627	797.279	958.316	**1004.349**	670.715	519.577	39.884	859.227	800.572	659.509	301.04	mg/kg
As_2O_3	ND	ND	6.469	**302.824**	ND	ND	ND	ND	ND	2.267	ND	ND	mg/kg
SeO_2	ND	ND	9.184	12.833	ND	ND	ND	10.923	**35.804**	ND	ND	ND	mg/kg
Rb	131.382	25.979	98.836	**1649.439**	0.294	104.022	162.673	180.221	123.571	48.737	22.927	18.253	mg/kg
SrO	109.925	24.265	171.525	31.005	97.876	23.074	36.777	ND	47.718	**212.715**	ND	21.806	mg/kg
Y_2O_3	195.600	ND	195.8	ND	ND	ND	168.1	**315.616**	ND	ND	ND	ND	mg/kg
ZrO_2	28.887	ND	**167.895**	ND	132.433	14.87	30.565	32.165	41.613	36.555	ND	ND	mg/kg
I	25.279	26.166	ND	**34.674**	ND	25.411	25.819	ND	ND	ND	20.117	16.198	mg/kg
HfO_2	**72.077**	59.429	39.595	ND	16.866	ND	45.459	ND	24.266	66.38	47.949	52.064	mg/kg
HgO	ND	ND	**1075.876**	ND	ND	ND	ND	39.969	ND	ND	ND	ND	mg/kg
PbO	20.555	18.406	55.077	55.077	**79.918**	20.555	ND	ND	31.073	21.77	11.897	ND	mg/kg

*ND: Not Detected. The highest metal contents have been darkened.

Magnesium (Mg) content of mushrooms was ranged 551.217- 2400 mg/kg. The highest Mg was determined in *C. comatus.* Mg was not detected in *H. sinapizans*, *H. ligatus*, *P. candolleana* and *R. torulosa.* In a previous study, Mg content of some edible mushooms 641.36-2185.62 mg/kg (Bulam et al., 2019). It was seen that the mg values of this study are parallel to the literature data.

Aluminium (Al) was not detected only in *C. comatus* among the studied mushrooms. The highest Al was determined in *L. deliciosus* with 3.608 % while the lowest Al was determined in *Armillaria mellea* with 0.335 %. It was reported that Al concentrations of collected from West Macedonia and Epirus, Greece were under the detection limit of the used method (Ouzouni et al., 2009).

Silicon (Si) content of studied mushrooms was ranged between 0.545 and 6.301 %. The highest Si content was determined in *L. deliciosus* mushroom. Si was not detected *P. ostreatus, T. pubescens, A. bisporus*. Koyyalamudi et al., (2013) reported that Si content of *A. bisporus* mushrooms obtained from two farms was ranged between 1.6 and 3.7 mg/100 g.

Phosphate (P) was detected in all the studied mushrooms. The highest and the lowest P were found in *A. bisporus* (4.385 %) and *C. comatus* (0.135 %), respectively. In a previous study, P content of *Ganoderma lucidum* collected from the nature and cultured on orange stump were determined as 4.270 % and 4.722 %, respectively (Turfan et al., 2016).

Sulphur (S) content of studied mushrooms was ranged 0.353-0.919 %. The highest S content was determined in *A. mellea* mushroom. Turfan et al., (2016) reported that S content of *G. lucidum* mushrooms were ranged between 1.006% and 1.174 %, respectively.

Potasium (K) was detected in all the studied mushrooms. K content of studied mushrooms was ranged between 2.189 and 27.885 %. The highest K content was determined in *H. sinapizans*. Li and Chang (1982) stated that the amount of K, P, Na and Mg in mushrooms is around 50-70% and only K covers 45% of the total mineral content.

Calcium (Ca) was detected in the entire studied mushroom expect *T. pubescens.* Ca content of studied mushrooms was ranged between 0.361 and 7.496%. The highest Ca content was seen in *Russula torulosa* mushroom. In a previous study, Ca content of *G. lucidum* collected from the nature and cultured on orange stump were 0.234 % and 0.170 %, respectively (Turfan et al., 2016).

Titanium (Ti) content of studied mushrooms was ranged between 34.826 and 1701.732 mg/kg. The highest Ti content was determined in *P. candolleana*. The data that is currently accessible in the research literature documenting the accumulation and content of and Ti in wild-growing mushroom species is insufficient (Mleczek et al., 2015).

Vanadium (V) is normally found in ultra-trace amounts in different food (Nielsen, 1998). V content of studied mushrooms was ranged between 2.931 and 146.45 mg/kg. The highest V content was determined in *L. deliciosus* mushroom.

Chromium (Cr) is essential for insulin action, but an accumulation of chromium in the human body can have the opposite effect, leading to issues with the male reproductive system as well as cancers of the lung, stomach, intestinal, and respiratory systems. Cr content of studied mushrooms was ranged between 28.348 and 1149.588 mg/kg. The highest Cr content was determined in *C. comatus* mushroom. Mleczek et al., (2015) determined that Cr content of *Boletus edulis*, *Leccinum scabrum*, *Boletus badius* were 2.059, 1.611 and 2.357 mg/kg, respectively.

Manganese (Mn) is an essential nutrient, but it can be toxic at high levels. Mn was detected in the entire studied mushroom. Mn content of studied mushrooms was ranged between 4.477 and 851.086 mg/kg. The highest Mn content was determined in *H. ligatus* mushroom. Bulam et al., (2019) reported that Mn content of some edible wild mushroom species collected from Giresun province of Eastern Black Sea Region were ranged between 12.26 and 74.07 mg/kg.

Iron (Fe) is an essential dietary element. Fe deficiency and heme Fe deficiency anemia are global health problems (Bjørklund et al., 2017). Fe content of studied mushrooms was ranged between 0.186 and 1.93 %. The highest Fe content was determined in *L. delicious* mushroom. In a previous study, Fe content of *G. lucidum* collected from the nature and cultivated on orange stump were determined as 0.056 % and 0.065 %, respectively (Turfan et al., 2016).

Nickel (Ni) is a healthy activator for certain enzyme species; yet, it can be extremely hazardous, especially at amounts that surpass the toxicity threshold (Mehri, 2020). Ni content of studied mushrooms was ranged between 8.595 and 227.428 mg/kg. The highest Ni content was determined in *C. comatus* mushroom. Baba et al. (2012) determined the Ni content of nine different macrofungi species were used as materials collected from Hatay 4.494-11.740 mg/kg.

Copper (Cu) was detected in all the studied mushroom expect *A. bisporus*. Cu contents of studied mushrooms were ranged between 82.43 and 500.625 mg/kg. The highest Cu content was determined in *S. luteus* mushroom. Akgül et al., (2016) determined Cu content of wild edible mushroom *Tricholoma terreum* and *Coprinus micaceus* as 9.59 and 16.50 mg/kg, respectively.

Zinc (Zn) is one of the most important trace elements that are required for the proper functioning of enzymes. As a metalloenzymatic cofactor, it is essential to the function of more than 300 different enzymes. Zn was detected in all the studied mushrooms. The highest and the lowest ZnO content were determined in *H. ligatus* and *C. comatus* with 1004.349 and 39.884 mg/kg, respectively. Bulam et al., (2019) reported that Zn content of some edible wild mushroom species collected from Giresun province of Eastern Black Sea Region were ranged 52.25-258.17 mg/kg.

Arsenic (As) is one of the elements that can be found at concentrations that cause concerns for chemistry and toxicology (Matta and Gjyli, 2016). Among the studied mushrooms As was detected only three mushroom species that *L. deliciosus*, *H. sinapizans*, *R. torulosa*. As content of studied mushrooms were ranged between 2.267 and 302.824 mg/kg. The highest As content was determined in *H. sinapizans*. Siwulski et al., (2017) reported that among the fruit bodies of six cultivated species of the genus *Pleurotus*, the highest and the lowest As content was determined in *P. ostreatus* and *P. eryngii* with 3.59 and 0.040 mg/kg, respectively.

Selenium (Se) is an essential micronutrient. Micronutrients are necessary for both human health and the health of lower plants (Mehri, 2020). Among the studied mushrooms Se was detected in *L. deliciosus*, *H. sinapizans, C. comatus, P. candolleana* mushrooms. Se content of studied mushrooms was ranged between 9.184 and 35.804 mg/kg. The highest Se content was determined in *P. candolleana* mushroom. Siwulski et al., (2020) reported that Se content of five strains of *P. ostreatus* ranged 0.09- 4.09 mg/kg.

Rubidium (Rb) has a biological role in mammal systems (Jorhem et al., 2008). Rb was detected in the entire studied mushroom and ranged between 0.294 and 1649.439 mg/kg. The highest Rb content was determined in *H. sinapizans*. Mleczek et al., (2021) investigated multi-elemental composition of 4 edible wild-growing mushroom species that commonly occur in Polish forests and 13 cultivated mushroom species. They reported that Rb content of cultivated mushroom and wild-growing varied 0.003–9.92 mg/kg and 0.450–2.67 mg/kg, respectively.

Strontium (Sr) is an element that could pose a risk to human health because of its tendency to operate as a calcium-substituting agent in bone, which could have an effect on the bone's overall density (Melnyk, 2019). Among the studied mushrooms, Sr was not detected only in *C. comatus* and *T. pubescens*. The highest Sr content was determined in *R. torulosa* mushroom with 212.715 mg/kg. Mleczek et al., (2021) reported that Sr content of 17 mushroom species were ranged 0.02-6.63 mg/kg.

Yttrium (Y) is a heavy rare earth element (Wu et al., 2022). Y was detected in *S. commune*, *L. deliciosus*, *A. mellea*, *C. comatus* mushrooms. The highest Y content was determined in *C. comatus* with 315.616 mg/kg. The lowest Y content was determined in *A. mellea* with 168.1 mg/kg.

Zirconium (Zr) and its effects on biological systems continue to be a mystery. It can be found in almost any environment and in concentrations that are far higher than those of most trace elements (Ghosh et al. 1992). Among the studied mushroom, Zr not detected in *P. ostreatus, H. sinapizans*, *T. pubescens* and *A. bisporus*. Zr content of studied mushrooms were ranged between 14.87 and 167.895 mg/kg. The highest Zr content was determined in Lactarius deliciosus mushroom. Siwulski et al., (2017) reported that among the fruit bodies of six cultivated species of the genus Pleurotus, the lowest and the highest Zr content was determined in *P. pulmonarius* and *P. ostreatus* H195 with 0.01 and 0.54 mg/kg, respectively.

Iodine (I) is one of the necessary trace elements, and there has been a lot of research done on it recently because of its relevance to nutrition. It is necessary for the generation of hormones known as thyroxine and tri-iodothyronine, both of which are essential to the healthy growth and development of the human body (Lossow et al., 2019). I content of studied mushrooms were ranged between 16.198 and 34.674 mg/kg. The highest and the lowest I content was determined in *H. sinapizans* and *A. bisporus*, respectively.

Hafnium (Hf) was discovered 100 years ago. There is no evidence to support the claim that hafnium is an important nutrient for either animals or humans. (Curtis et al., 1954). Hf was not detected in *H. sinapizans*, *S. luteus*, *C. comatus*. Hf content of studied mushrooms was ranged between 16.866 and 72.077 mg/kg. The highest Hf content was determined in *S. commune*.

Mercury (Hg) is a widely recognized environmental persistent pollutant and a highly toxic element (Singh, et al., 2023). Among the studied mushrooms, Hg was detected only in *L. deliciosus* (1075.876 mg/kg) and *C. comatus* (39.969 mg/kg). The highest Hg content was determined in *L. deliciosus* mushrooms. Mleczek et al.,

(2021) reported that mean content of the Hg metals in wild-growing mushroom species 1.68 mg/kg and mean for all cultivated mushroom species 0.237 mg/kg.

Lead (Pb) is a hazardous element that can be found in the environment both naturally and as a result of anthropogenic activity. Lead's presence in the environment can result in the chemical contamination of products that are consumed by humans (Pandey and Madhuri, 2014). Among the studied mushrooms, Pb was not detected in *A. mellea*, *C. comatus, A.bisporus*. Pb content of studied mushrooms was ranged between 11.897 and 79.918 mg/kg. The highest lead (Pb) content was determined in *H. ligatus* mushroom.

In general, differences were detected between the research results and literature data in terms of element composition of mushrooms. These differences may occur depending on the mushroom specie, region, growing conditions, soil characteristics and the analytical procedure used in laboratory analysis.

4. Conclusion

In the study, among the studied mushrooms; the highest Al, Si, V, Zr, Fe and Hg were determined in *L. deliciosus*. The highest K, As, Rb, I determined in *H. sinapizans*. The highest Mn, Zn, Pb were determined in *H. ligatus*. The highest Mg, Cr, Ni, Y were determined in *C. comatus*. The highest Ti and Se were determined in *P. candolleana*. The highest Ca and Sr were determined in *R. torulosa*. The highest Hf was determined in *S. commune*. The highest P was determined in *A. bisporus*. The highest S was determined in *A. mellea*. The highest Cu was determined in *S. luteus.* No metal has been detected in *P. ostreatus* and *T. pubescens* mushroom species. The highest metal diversity was seen in *L. delicious* mushroom. This mushroom was followed by the *H. sinapizans* and *C. comatus* mushrooms with four different metal types. It is recommended to examine including these fungi in other studies more detail. In conclusion, it was deduced that elemental composition of mushrooms was affected especially by mushroom species. For more comprehensive research it must also be investigated the substrate media on which the mushrooms grown (wood, three, sawdust, wood chip, soil etc.). Finally, it should not be forgotten that fungi, which have a high ability to absorb heavy metals, can be evaluated as bio-indicators, especially in locations with high pollution.

Acknowledgement

This work was supported by Karadeniz Technical University Scientific Research Projects Unit (FBA-2017-5579). This study was also presented firstly as oral presentation at the 5th International Symposium on Non-Wood Forest Products, 2023.

Author Contributions

Sibel YILDIZ: Supervision, writing – review & editing

Hasan Hüseyin DOĞAN: Investigation, methodology

Ayşenur GÜRGEN: Methodology, writing – original draft

Uğur ÇEVİK: Methodology

Conflict of Interest

The authors declared no conflict of interest.

References

Akgül, H., Nur, A. D., Sevindik, M. and Doğan, M. (2016). *Tricholoma terreum* ve *Coprinus micaceus*' un bazı biyolojik aktivitelerinin belirlenmesi. *Artvin Çoruh Üniversitesi Orman Fakültesi Dergisi*, *17*(2), 158-162.

Anwar, S., Nawaz, M. F., Gul, S., Rizwan, M., Ali, S. and Kareem, A. (2016). Uptake and distribution of minerals and heavy metals in commonly grown leafy vegetable species irrigated with sewage water. *Environmental Monitoring and Assessment, 188* (9), 541-549.

Atamaleki, A., Yazdanbakhsh, A., Fakhri, Y., Mahdipour, F., Khodakarim, S. and Khaneghah, A. M. (2019). The concentration of potentially toxic elements (PTEs) in the onion and tomato irrigated by wastewater: a systematic review; meta-analysis and health risk assessment. *Food Research International*, *125*, 108518.

Baba, H., Ergün, N. and Özçubukçu, S. (2012). Determination of heavy metal accumulation and mineral contents of some macrofungi in Antakya (Hatay). *BİBAD, Biyoloji Bilimleri Araştırma Dergisi*, *5*(1), 5-6.

Bjørklund, G., Aaseth, J., Skalny, A. V., Suliburska, J., Skalnaya, M. G., Nikonorov, A. A. and Tinkov, A. A. (2017). Interactions of iron with manganese, zinc, chromium, and selenium as related to prophylaxis and treatment of iron deficiency. *Journal of Trace Elements in Medicine and Biology*, *41*, 41-53.

Bulam, S., Üstün, N. Ş. and Pekşen, A. (2019). Yenebilir doğa mantarlarının bazı fiziksel ve fizikokimyasal özellikleri ile mineral madde içeriklerinin belirlenmesi. *Mantar Dergisi*, *10*(3), 193-203.

Cocchi, L., Vescovi, L., Petrini, L. E. And Petrini, O. (2006). Heavy metals in edible mushrooms in Italy. *Food Chemistry*, *98*(2), 277-284.

Curtis, C. E., Doney, L. M. and Johnson, J. R. (1954). Some properties of hafnium oxide, hafnium silicate, calcium hafnate, and hafnium carbide. *Journal of the American Ceramic Society*, *37*(10), 458-465.

Demirbaş, A. (2000). Accumulation of heavy metals in some edible mushrooms from Turkey. *Food Chemistry*, *68*(4), 415-419.

Dowlati, M., Sobhi, H. R., Esrafili, A., FarzadKia, M. and Yeganeh, M. (2021). Heavy metals content in edible mushrooms: A systematic review, meta-analysis and health risk assessment. *Trends in Food Science & Technology*, *109*, 527-535.

Falandysz, J., Kawano, M., Świeczkowski, A., Brzostowski, A. and Dadej, M. (2003). Total mercury in wild-grown higher mushrooms and underlying soil from Wdzydze Landscape Park, Northern Poland. *Food Chemistry*, *81*(1), 21-26.

Fu, Z., Liu, G. and Wang, L. (2020). Assessment of potential human health risk of trace element in wild edible mushroom species collected from Yunnan Province, China. *Environmental Science and Pollution Research*, *27*, 29218-29227.

Gadd, G. M. (2007). Geomycology: biogeochemical transformations of rocks, minerals, metals and radionuclides by fungi, bioweathering and bioremediation. *Mycological Research*, *111*(1), 3-49.

Ghosh, S., Sharma, A. and Talukder, G. (1992). Zirconium: an abnormal trace element in biology. *Biological Trace Element Research*, *35*, 247-271.

Isildak, Ö., Turkekul, I., Elmastas, M. And Tuzen, M. (2004). Analysis of heavy metals in some wild-grown edible mushrooms from the middle black sea region, Turkey. *Food Chemistry*, *86*(4), 547-552.

Işiloğlu, M., Merdivan, M. and Yilmaz, F. (2001). Heavy metal contents in some macrofungi collected in the northwestern part of Turkey. *Archives of Environmental Contamination and Toxicology*, *41*, 1-7.

Jorhem, L., Åstrand, C., Sundström, B., Baxter, M., Stokes, P., Lewis, J. and Grawé, K. P. (2008). Elements in rice on the Swedish market: Part 2. Chromium, copper, iron, manganese, platinum, rubidium, selenium and zinc. *Food Additives and Contaminants*, *25*(7), 841-850.

Kalač, P. and Stašková, I. (1991). Concentrations of lead, cadmium, mercury and copper in mushrooms in the vicinity of a lead smelter. *Science of the Total Environment*, *105*, 109-119.

Kalač, P. and Svoboda, L. (2000). A review of trace element concentrations in edible mushrooms. *Food Chemistry*, *69*(3), 273-281.

Kokkoris, V., Massas, I., Polemis, E., Koutrotsios, G. and Zervakis, G. I. (2019). Accumulation of heavy metals by wild edible mushrooms with respect to soil substrates in the Athens metropolitan area (Greece). *Science of The Total Environment*, *685*, 280-296.

Koyyalamudi, S. R., Jeong, S. C., Manavalan, S., Vysetti, B. and Pang, G. (2013). Micronutrient mineral content of the fruiting bodies of Australian cultivated *Agaricus bisporus* white button mushrooms. *Journal of Food Composition and Analysis*, *31*(1), 109-114.

Lasota, W., Florczak, J. and Karmańska, A. (1990). Effect of growing conditions on accumulation of some toxic substances in mushrooms: Part I. Studies on Hg, Cd, Pb and Zn absorption by *Agaricus bisporus* Lange and *Pleurotus ostreatus* Jacq. Fr. Kumm. *Bromatologia i Chemia Toksykologiczna*, *23*, 95-99.

Li, G.S.F. and Chang, S.T. (1982). The nucleic acid content of some edible mushrooms. *European Journal f Applied Microbiology and Biotechnology*, 15, 237-240.

Lossow, K., Schwerdtle, T., and Kipp, A. (2019). Selenium and iodine–essential trace elements for the thyroid. *Ernahrungs Umschau*, *66*, 175-180.

Matta, G., and Gjyli, L. (2016). Mercury, lead and arsenic: impact on environment and human health. *Journal of Chemical and Pharmaceutical Sciences*, *9*(2), 718-725.

Mehri, A. (2020). Trace elements in human nutrition (II)–an update. *International Journal of Preventive Medicine*, *11*(2), 1-17.

Melnyk, L. J., Donohue, M. J., Pham, M. and Donohue, J. (2019). Absorption of strontium by foods prepared in drinking water. *Journal of Trace Elements in Medicine and Biology*, *53*, 22-26.

Mleczek, M., Siwulski, M., Mikołajczak, P., Goliński, P., Gąsecka, M., Sobieralski, K., Dawidowicz L. and Szymańczyk, M. (2015). Bioaccumulation of elements in three selected mushroom species from southwest Poland. *Journal of Environmental Science and Health, Part B, 50*(3), 207-216.

Mleczek, M., Budka, A., Siwulski, M., Mleczek, P., Budzyńska, S., Proch, J., Gąsecka, M., Niedzielski, P. and Rzymski, P. (2021). A comparison of toxic and essential elements in edible wild and cultivated mushroom species. *European Food Research and Technology*, *247*, 1249-1262.

Mushtaq, W., Hayri, B., Akata, I. and Sevindik, M. (2020). Antioxidant potential and element contents of wild edible mushroom *Suillus granulatus*. *KSU J. Agric Nat*, *23*(3), 592-595.

Nielsen, F. H. (1998). Ultratrace elements in nutrition: current knowledge and speculation. *The Journal of Trace Elements in Experimental Medicine: The Official Publication of the International Society for Trace Element Research in Humans*, *11*(2-3), 251-274.

Nikkarinen, M. and Mertanen, E. (2004). Impact of geological origin on trace element composition of edible mushrooms. *Journal of Food Composition and Analysis*, *17*(3-4), 301-310.

Ouzouni, P. K., Petridis, D., Koller, W. D. and Riganakos, K. A. (2009). Nutritional value and metal content of wild edible mushrooms collected from West Macedonia and Epirus, Greece. *Food Chemistry*, *115*(4), 1575-1580.

Pandey, G. and Madhuri, S. (2014). Heavy metals causing toxicity in animals and fishes. *Research Journal of Animal, Veterinary and Fishery Sciences*, *2*(2), 17-23.

Rácz, L., Papp, L. and Fodor, P. (1995). Migration analysis of elements from compost and casing material to the fruit bodies in cultivated mushrooms (*Agaricus bisporus*). *Acta alimentaria (Budapest)*, *24*(2), 161-166.

Sanglimsuwan, S., Yoshida, N., Morinaga, T. and Murooka, Y. (1993). Resistance to and uptake of heavy metals in mushrooms. *Journal of Fermentation and Bioengineering*, *75*(2), 112-114.

Sarikurkcu, C., Yildiz, D., Akata, I. and Tepe, B. (2021). Evaluation of the metal concentrations of wild mushroom species with their health risk assessments. *Environmental Science and Pollution Research, 28,* 21437-21454.

Sesli, E. and Tüzen, M. (1999). Levels of trace elements in the fruiting bodies of macrofungi growing in the East Black Sea region of Turkey. *Food Chemistry*, *65*(4), 453-460.

Sevindik, M. (2018). Antioxidant activity of ethanol extract of *Daedaleopsis nitida* medicinal mushroom from Turkey. *Mycopath*, *16*(2), 47-49.

Singh, A. D., Khanna, K., Kour, J., Dhiman, S., Bhardwaj, T., Devi, K., Sharma, N., Kumar, P., Kapoor, N., Sharma, P., Arora, P., Sharma, A. and Bhardwaj, R. (2023). Critical review on biogeochemical dynamics of mercury (Hg) and its abatement strategies. *Chemosphere*, 137917.

Siwulski, M., Mleczek, M., Rzymski, P., Budka, A., Jasińska, A., Niedzielski, P., Kalač, P., Gąsecka, M., Budzyńska, S. and Mikołajczak, P. (2017). Screening the multi-element content of *Pleurotus* mushroom species using inductively coupled plasma optical emission spectrometer (ICP-OES). *Food Analytical Methods*, *10*, 487-496.

Siwulski, M., Budka, A., Rzymski, P., Gąsecka, M., Kalač, P., Budzyńska, S., Magdziak, Z., Niedzielski, P., Mleczek, P. and Mleczek, M. (2020). Worldwide basket survey of multielemental composition of white button mushroom *Agaricus bisporus*. *Chemosphere*, 239, 124718.

Turfan, N., Karadeniz, M., and Ünal, S. (2016). Comparison of some chemical contents of *Ganoderma lucidum* (Curtis) P. Karst collected from nature and cultured on orange stump. *Turkish Journal Of Agriculture-Food Science And Technology*, *4*(3), 158-162.

Tüzen, M., Özdemir, M. and Demirbaş, A. (1998). Study of heavy metals in some cultivated and uncultivated mushrooms of Turkish origin. *Food Chemistry*, *63*(2), 247-251.

Wu, S., Bie, C., Su, H., Gao, Y. and Sun, X. (2022). The effective separation of yttrium and other heavy rare earth elements with salicylic acid derivatives. *Minerals Engineering*, *178*, 107396.

Yamaç, M., Yıldız, D., Sarıkürkcü, C., Celikkollu, M. and Solak, M. H. (2007). Heavy metals in some edible mushrooms from the Central Anatolia, Turkey. *Food Chemistry*, *103*(2), 263-267.