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RESEARCH ARTICLE

Wild mushrooms from Ilgaz Mountain National Park (Western Black Sea, Turkey): element concentrations and their health risk assessment

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Abstract
The purpose of this study was to determine Fe, Cd, Cr, Se, P, Cu, Mn, Zn, Al, Ca, Mg, and K contents of some edible (*Chlorophyllum rhacodes*, *Clavariadelphus truncatus*, *Clitocybe nebularis*, *Hydnum repandum*, *Hygrophorus pudorinus*, *Infundibulicybe gibba*, *Lactarius deliciosus*, *L. piperatus*, *L. salmonicolor*, *Macrolepiota mastoidea*, *Russula grata*, *Suillus granulatus*, and *Tricholoma imbricatum*), inedible (*Amanita pantherina*, *Geastrum triplex*, *Gloeophyllum sepiarium*, *Hypholoma fasciculare*, *Phellinus vorax*, *Pholiota limonella*, *Russula anthracina*, and *Tapinella atrotomentosa*), and poisonous mushroom species (*Amanita pantherina* and *Hypholoma fasciculare*) collected from Ilgaz Mountain National Park (Western Black Sea, Turkey). The element contents of the mushrooms were determined to be 18.0–1239.1, 0.2–4.6, 0.1–3.4, 0.2–3.2, 1.0–8.9, 3.3–59.9, 3.7–220.4, 21.3–154.1, 6.4–754.3, 15.8–17,473.0, 413.0–5943.0, and 2803.0–24,490.0 mg·kg^{-1}, respectively. In addition to metal contents, the daily intakes of metal (DIM) and Health Risk Index (HRI) values of edible mushrooms were also calculated. Both DIM and HRI values of mushroom species except *L. salmanicolor*, *M. mastoidea*, and *R. grata* were within the legal limits. However, it was determined that the Fe content of *L. salmanicolor* and *M. mastoidea* and Cd content of *R. grata* were above the legal limits.

Keywords Ilgaz Mountain · Edible mushrooms · Metal concentration · DIM · HRI

Introduction

Mushrooms are organisms that can grow both in uncontaminated rural ecosystems and in urban areas with high industrial pollution (Karaman et al. 2012; Rakic et al. 2014). They are important in terms of pharmaceuticals as well as their ecological values (Siric et al. 2016). Both wild and cultivated mushrooms have many beneficial compounds for human health. Since mushrooms are low-calorie foods, they are particularly preferred in diets. In addition, they are rich in vitamins, elements (both macro and microelements), and proteins (Gargano et al. 2017). Some mushroom species have therapeutic value due to their primary (e.g., polysaccharides and polysaccharide–protein complexes, etc.) and secondary metabolites (e.g., alkaloids, terpenoids, phenolic compounds, etc.) and are also known as medicinal mushrooms in the literature (De Silva et al. 2013; Duru and Cayan 2015; Gargano et al. 2017). Studies have shown that mushrooms have many biological/pharmacological activities (such as neuroprotective, cardiovascular, antioxidant, antimicrobial, antitumor, etc.). These activities are thought to be due to compounds that they contain (Gargano et al. 2017; Paterson and Lima 2014; Phan et al. 2015; Plassard et al. 2011). Therefore, it is thought that mushrooms have a high potential to be used in the treatment of some diseases such as cancer, obesity, hypertension, and hyperglycemia, which threaten human beings and have a high prevalence (Guggenheim et al. 2014; Guillamon et al. 2010).

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In addition to the benefits mentioned above, fungi are also responsible for the cycle of elements in nature, as they also fulfill the functions of breaking down organic materials (Sesli et al. 2008). With the increasing interest of humans in wild mushroom species due to their nutritional properties, researchers have started to focus on whether the concentrations of elements accumulated in these organisms pose a risk to human health (Abdel-Azeem et al. 2007; Campos et al. 2009; Isildak et al. 2004; Joshi et al. 2011; Kalac and Svoboda 2000; Mleczek et al. 2016a; Severoglu et al. 2013; Siric et al. 2016). Some mushroom species can accumulate certain metals at higher concentrations than other organisms living in the same ecosystem (Dogan et al. 2006; Falandysz et al. 2008; Huang et al. 2015; Kalac 2010; Rakic et al. 2014; Sesli et al. 2008; Severoglu et al. 2013; Siric et al. 2016). The biosorption of elements by mushroom species is a well-known mechanism studied by many researchers (Mleczek et al. 2016a; Sesli and Dalman 2006; Sesli et al. 2008). When toxic metals and metalloids such as Hg, Pb, Cd, As, etc. accumulate in fruiting bodies of mushrooms at high concentrations, people who feed on these mushrooms can also accumulate them in their bodies. In this way, these metals can cause various adverse effects on human metabolism (Falandysz and Borovicka 2013; Mleczek et al. 2016b; Rubio et al. 2018; Rzymski et al. 2016). This makes controlling the toxic element content of wild mushroom species a priority issue (Agrawal and Dhanasekaran 2019; Rashid et al. 2018). High metal accumulation in mushrooms is also under the scrutiny of researchers as they are indicators of metal pollution in the ecosystem as well as their negative effects on human health (Li et al. 2017).

Wild mushroom species can be classified as edible, inedible (poisonous), soil-grown, wood-grown, parasitic or saprophytic, etc.. These differences in the way of life of mushrooms have a major impact on their metal accumulation capacity (Kalac 2010; Mleczek et al. 2016a). In addition, areas where mushroom species grow provide important clues in environmental researches in terms of metal accumulation (Kalac 2001; Rakic et al. 2014; Siric et al. 2016).

The purpose of this study was to determine Fe, Cd, Cr, Se, P, Cu, Mn, Zn, Al, Ca, Mg, and K contents of some edible (*Chlorophyllum rhacodes*, *Clavariadelphus truncatus*, *Clitocybe nebularis*, *Hydnum repandum*, *Hygrophorus pudorinus*, *Infundibulicybe gibba*, *Lactarius deliciosus*, *L. piperatus*, *L. salmonicolor*, *Macrolepiota mastoidea*, *Russula grata*, *Suillus granulatus*, and *Tricholoma imbricatum*), inedible (*Amanita pantherina*, *Geastrum triplex*, *Gloeophyllum sepiarium*, *Hypholoma fasciculare*, *Phellinus vorax*, *Pholiota limonella*, *Russula anthracina*, and *Tapinella atrotomentosa*), and poisonous mushroom species (*Amanita pantherina* and *Hypholoma fasciculare*) collected from Ilgaz Mountain National Park (Western Black Sea, Turkey). In addition, the daily intakes of metal (DIM) and Health Risk Index (HRI) values of edible mushroom species were also calculated, and their potential effects on human health were discussed.

Materials and methods

Collection, identification, digestion, and elemental analysis of mushroom species

Fully matured fruiting bodies of mushrooms were collected between October 20 and 21, 2019 from Ilgaz Mountain National Park, Western Black Sea, Turkey (1730 m., 11° 04' N 33° 42' E).

Information on the habitats and taxonomic records of mushroom species are given in Table 1. Experimental details on the digestion processes of mushroom species and determination of metal content can be found in the supplementary file (Sarikurkcu et al. 2020, 2011, 2015, 2012).

Determination of DIM and HRI values

DIM and HRI analyses of mushrooms were performed following the method given in the literature (Cui et al. 2004; Liu et al. 2015). While calculating DIM values of which details were also given in the supplementary file, R_fD^o values set by USEPA (2002) were taken into consideration.

Statistical analyses

Detailed information on the statistical analysis applied on the data obtained from this study was given in the supplementary file.

Results and discussion

Information about the taxonomic details, substrates, and edibility of the mushroom species analyzed in this study are given in Table 1. The concentrations of Fe, Cd, Cr, Se, P, Cu, Mn, Zn, Al, Ca, Mg, and K of mushrooms are presented in Tables 2 and 3 (in mg·kg^{-1} dry weight). Additionally, DIM and HRI values of edible mushrooms were calculated and documented in Table 4. In order to make comparison with the data obtained from the present study, a literature table containing the metal contents of the analyzed mushroom species was also created (Table 5).

No reports on the elemental contents of *G. triplex*, *G. separium*, *H. repandum*, *H. pudorinus*, *P. vorax*, *P. limonella*, *R. anthracina*, and *R. grata* could be found on the literature search. In addition, P content of *A. pantherina*; P and K contents of *C. rhacodes*; Cr and Se contents of *C. truncatus*; Fe, Cr, Se, P, Mn, Al, Ca, Mg, and K contents

Table 1 Families, habitats, substrates, edibility, and herbarium numbers of wild mushroom species

No	Mushrooms	Family	Herbarium No	Habitat	Substrat	Edibility
1	*A. pantherina* (DC.) Krombh	Amanitaceae	Akata 7254	Fir forest	On soil	Poisonous
2	*C. rhacodes* (Vittad.) Vellinga	Agaricaceae	Akata 7241	Fir forest	On soil	Edible
3	*C. truncatus* Donk	Clavariadelphaceae	Akata 7229	Fir forest	On soil	Edible
4	*C. nebularis* (Batsch) P. Kumm	Tricholomataceae	Akata 7231	Fir forest	On soil	Edible
5	*G. triplex* Jungh	Geastraceae	Akata 7230	Fir forest	On soil	Inedible
6	*G. sepiarium* (Wulfen) P. Karst	Gloeophyllaceae	Akata 7234	Fir forest	On fir stump	Inedible
7	*H. repandum* L	Hydnaceae	Akata 7242	Fir forest	On soil	Edible
8	*H. pudorinus* (Fr.) Fr	Hygrophoraceae	Akata 7249	Fir forest	On soil	Edible
9	*H. fasciculare* (Huds.) P. Kumm	Strophariaceae	Akata 7243	Fir forest	On fir stump	Poisonous
10	*I. gibba* (Pers.) Harmaja	Tricholomataceae	Akata 7248	Oak forest	On soil	Edible
11	*L. deliciosus* (L.) Gray	Russulaceae	Akata 7238	Pine forest	On soil	Edible
12	*L. piperatus* (L.) Pers	Russulaceae	Akata 7233	Oak forest	On soil	Edible
13	*L. salmonicolor* R. Heim & Leclair	Russulaceae	Akata 7235	Fir forest	On soil	Edible
14	*M. mastoidea* (Fr.) Singer	Agaricaceae	Akata 7236	Fir forest	On soil	Edible
15	*P. vorax* Harkn. ex Černý	Hymenochaetaceae	Akata 7225	Fine forest	On pine trunk	Inedible
16	*P. limonella* (Peck) Sacc	Strophariaceae	Akata 7246	Fir forest	On fir stump	Inedible
17	*R. anthracina* Romagn	Russulaceae	Akata 7226	Fir forest	On soil	Inedible
18	*R. grata* Britzelm	Russulaceae	Akata 7239	Oak forest	On soil	Edible
19	*S. granulatus* (L.) Roussel	Suillaceae	Akata 7244	Pine forest	On soil	Edible
20	*T. atrotomentosa* (Batsch) Šutara	Tapinellaceae	Akata 7227	Fir forest	On fir stump	Inedible
21	*T. imbricatum* (Fr.) P. Kumm	Tricholomataceae	Akata 7232	Pine forest	On soil	Edible

Table 2 Fe, Cd, Cr, Se, P, and Cu concentrations of wild mushroom species (mg·kg^{-1} dry weight)

No	Mushrooms	Fe	Cd	Cr	Se	P	Cu
1	*A. pantherina*	57.3 ± 0.6^{d}	0.74 ± 0.04^{c}	nd	0.37 ± 0.16^{a}	4.93 ± 0.04^{k}	13.27 ± 0.09^{g}
2	*C. rhacodes*	215.9 ± 1.0^{l}	0.28 ± 0.08^{a}	0.16 ± 0.07^{ab}	3.22 ± 0.42^{c}	8.90 ± 0.01^{p}	59.87 ± 0.33^{u}
3	*C. truncatus*	75.3 ± 0.2^{f}	0.53 ± 0.05^{b}	nd	0.29 ± 0.01^{a}	2.22 ± 0.02^{c}	33.67 ± 0.28^{s}
4	*C. nebularis*	133.1 ± 0.3^{k}	0.89 ± 0.11^{cde}	0.05 ± 0.03^{a}	0.75 ± 0.25^{a}	8.22 ± 0.05^{n}	32.44 ± 0.24^{r}
5	*G. triplex*	81.2 ± 0.3^{g}	2.55 ± 0.07^{f}	0.05 ± 0.03^{a}	1.91 ± 0.16^{b}	6.71 ± 0.06^{l}	44.29 ± 0.27^{t}
6	*G. sepiarium*	363.0 ± 1.5^{n}	0.17 ± 0.05^{a}	0.68 ± 0.21^{cd}	0.81 ± 0.11^{a}	1.04 ± 0.02^{a}	10.46 ± 0.06^{f}
7	*H. repandum*	42.1 ± 0.3^{c}	nd	0.22 ± 0.04^{ab}	0.65 ± 0.34^{a}	3.71 ± 0.03^{h}	14.37 ± 0.09^{h}
8	*H. pudorinus*	64.4 ± 0.5^{e}	nd	0.93 ± 0.09^{de}	0.58 ± 0.10^{a}	3.96 ± 0.04^{i}	3.27 ± 0.02^{a}
9	*H. fasciculare*	112.9 ± 0.7^{i}	0.95 ± 0.06^{de}	nd	0.28 ± 0.15^{a}	3.51 ± 0.04^{g}	17.87 ± 0.05^{k}
10	*I. gibba*	83.0 ± 0.2^{g}	0.76 ± 0.02^{cd}	0.25 ± 0.12^{ab}	0.41 ± 0.17^{a}	7.99 ± 0.10^{m}	30.99 ± 0.21^{p}
11	*L. deliciosus*	44.2 ± 0.3^{c}	0.91 ± 0.05^{cde}	nd	0.90 ± 0.19^{a}	4.04 ± 0.02^{i}	6.04 ± 0.10^{d}
12	*L. piperatus*	36.2 ± 0.2^{b}	0.92 ± 0.06^{cde}	nd	1.06 ± 0.01^{ab}	2.63 ± 0.01^{d}	27.05 ± 0.15^{o}
13	*L. salmonicolor*	862.6 ± 2.6^{r}	0.17 ± 0.04^{a}	3.36 ± 0.11^{g}	0.21 ± 0.10^{a}	3.12 ± 0.02^{f}	7.54 ± 0.07^{e}
14	*M. mastoidea*	811.1 ± 2.7^{p}	0.82 ± 0.07^{cde}	1.23 ± 0.10^{e}	1.06 ± 0.32^{ab}	8.48 ± 0.08^{o}	25.57 ± 0.11^{m}
15	*P. vorax*	1239.1 ± 2.8^{s}	3.52 ± 0.03^{g}	1.79 ± 0.07^{f}	0.46 ± 0.17^{a}	nd	21.09 ± 0.08^{l}
16	*P. limonella*	18.0 ± 0.1^{a}	0.31 ± 0.03^{a}	nd	0.34 ± 0.08^{a}	2.23 ± 0.04^{c}	6.02 ± 0.08^{d}
17	*R. anthracina*	66.0 ± 0.1^{e}	1.00 ± 0.04^{e}	nd	0.36 ± 0.23^{a}	1.48 ± 0.03^{b}	16.22 ± 0.10^{i}
18	*R. grata*	664.7 ± 1.1^{o}	4.56 ± 0.14^{h}	0.65 ± 0.03^{cd}	0.33 ± 0.04^{a}	4.09 ± 0.07^{i}	26.51 ± 0.16^{n}
19	*S. granulatus*	246.2 ± 0.8^{m}	nd	0.21 ± 0.04^{ab}	0.61 ± 0.10^{a}	2.55 ± 0.03^{d}	7.22 ± 0.04^{e}
20	*T. atrotomentosa*	20.5 ± 0.2^{a}	nd	0.44 ± 0.11^{bc}	0.82 ± 0.67^{a}	3.05 ± 0.02^{f}	4.32 ± 0.03^{c}
21	*T. imbricatum*	102.7 ± 0.3^{h}	0.15 ± 0.01^{a}	0.11 ± 0.06^{a}	0.74 ± 0.03^{a}	2.83 ± 0.01^{e}	3.79 ± 0.07^{b}

The values indicated by different superscripts within the same columns of Table 2 shows significant difference at $p<0.05$

Table 3 Mn, Zn, Al, Ca, Mg, and K concentrations of wild mushroom species (mg·kg^{-1} dry weight)

No	Mushrooms	Mn	Zn	Al	Ca	Mg	K
1	*A. pantherina*	11.13 ± 0.06^{e}	116.9 ± 1.9^{p}	59.8 ± 0.4^{gh}	45.8 ± 1.1^{b}	777 ± 4^{h}	$24{,}490\pm136^{s}$
2	*C. rhacodes*	33.16 ± 0.15^{n}	154.1 ± 0.8^{s}	148.0 ± 0.6^{l}	324.5 ± 0.7^{g}	1108 ± 3^{o}	$15{,}592\pm17^{i}$
3	*C. truncatus*	3.69 ± 0.03^{a}	120.9 ± 0.8^{r}	22.0 ± 0.2^{cd}	172.3 ± 1.8^{f}	567 ± 1^{d}	$22{,}614\pm46^{r}$
4	*C. nebularis*	19.20 ± 0.16^{l}	80.1 ± 0.5^{m}	58.6 ± 0.6^{gh}	93.1 ± 0.8^{c}	827 ± 3^{kl}	$13{,}058\pm41^{i}$
5	*G. triplex*	220.44 ± 0.82^{s}	102.7 ± 0.3^{n}	62.5 ± 0.7^{h}	1946.8 ± 9.6^{m}	1484 ± 7^{r}	7943 ± 46^{d}
6	*G. sepiarium*	65.99 ± 0.44^{p}	42.3 ± 0.6^{d}	296.5 ± 2.0^{m}	7180.2 ± 35.1^{n}	899 ± 4^{m}	2803 ± 9^{a}
7	*H. repandum*	10.44 ± 0.05^{e}	45.7 ± 0.3^{e}	18.9 ± 0.1^{c}	138.9 ± 0.9^{de}	524 ± 2^{c}	$20{,}504\pm12^{o}$
8	*H. pudorinus*	12.91 ± 0.11^{fg}	30.6 ± 0.2^{c}	54.5 ± 0.3^{g}	15.8 ± 1.5^{a}	833 ± 6^{l}	$15{,}690\pm87^{l}$
9	*H. fasciculare*	7.87 ± 0.06^{d}	59.9 ± 0.8^{h}	29.0 ± 0.3^{e}	165.5 ± 1.7^{ef}	639 ± 5^{e}	$15{,}535\pm91^{l}$
10	*I. gibba*	16.28 ± 0.09^{i}	74.3 ± 1.0^{l}	12.9 ± 0.1^{b}	52.6 ± 0.3^{b}	674 ± 1^{g}	9439 ± 8^{e}
11	*L. deliciosus*	14.75 ± 0.07^{h}	110.2 ± 1.0^{o}	23.5 ± 0.4^{cd}	92.5 ± 0.4^{c}	820 ± 3^{k}	9359 ± 23^{e}
12	*L. piperatus*	5.23 ± 0.04^{b}	71.7 ± 0.7^{k}	27.0 ± 0.3^{de}	38.8 ± 0.7^{ab}	427 ± 1^{b}	$11{,}335\pm38^{g}$
13	*L. salmonicolor*	17.56 ± 0.13^{k}	57.2 ± 0.3^{g}	505.8 ± 3.8^{n}	534.6 ± 1.3^{k}	1001 ± 2^{n}	$11{,}244\pm30^{g}$
14	*M. mastoidea*	31.12 ± 0.20^{m}	60.6 ± 0.3^{h}	636.8 ± 3.5^{p}	770.1 ± 3.8^{l}	1229 ± 7^{p}	$13{,}716\pm61^{k}$
15	*P. vorax*	45.25 ± 0.09^{o}	21.3 ± 0.1^{a}	754.3 ± 1.9^{r}	$17{,}472.9\pm20.1^{o}$	5943 ± 4^{s}	3760 ± 4^{b}
16	*P. limonella*	13.21 ± 0.08^{g}	30.5 ± 0.2^{c}	9.8 ± 0.1^{ab}	116.2 ± 1.2^{cd}	806 ± 1^{i}	$21{,}716\pm15^{p}$
17	*R. anthracina*	6.41 ± 0.03^{c}	30.4 ± 0.2^{c}	41.6 ± 0.4^{f}	112.0 ± 0.7^{cd}	562 ± 1^{d}	$12{,}289\pm18^{h}$
18	*R. grata*	82.50 ± 0.71^{r}	65.7 ± 0.7^{i}	602.3 ± 4.7^{o}	453.0 ± 0.1^{i}	887 ± 1^{m}	$17{,}680\pm6^{n}$
19	*S. granulatus*	12.07 ± 0.05^{f}	42.3 ± 0.1^{d}	123.9 ± 1.1^{k}	378.7 ± 2.0^{h}	413 ± 2^{a}	$10{,}286\pm39^{f}$
20	*T. atrotomentosa*	4.31 ± 0.04^{a}	23.4 ± 0.1^{b}	6.4 ± 0.2^{a}	110.2 ± 1.4^{c}	659 ± 2^{f}	4957 ± 12^{c}
21	*T. imbricatum*	12.67 ± 0.05^{fg}	48.1 ± 0.3^{f}	86.9 ± 0.3^{i}	110.3 ± 1.1^{c}	805 ± 2^{i}	$16{,}247\pm52^{m}$

The values indicated by different superscripts within the same columns of Table 3 shows significant difference at $p<0.05$

Table 4 DIM and HRI of wild edible mushroom species

Edible mushrooms	DIM (μg/kg body weight/serving)						HRI					
	Cd	Cr	Cu	Fe	Mn	Zn	Cd	Cr	Cu	Fe	Mn	Zn
C. rhacodes	0.12	0.07	25.66	92.52	14.21	66.04	0.12	0.02	0.64	0.31	0.10	0.22
C. truncatus	0.23	nd	14.43	32.26	1.58	51.83	0.23	nd	0.36	0.11	0.01	0.17
C. nebularis	0.38	0.02	13.90	57.06	8.23	34.33	0.38	0.01	0.35	0.19	0.06	0.11
H. repandum	nd[4]	0.10	6.16	18.05	4.47	19.59	nd	0.03	0.15	0.06	0.03	0.07
H. pudorinus	nd	0.40	1.40	27.60	5.53	13.11	nd	0.13	0.04	0.09	0.04	0.04
I. gibba	0.33	0.11	13.28	35.56	6.98	31.85	0.33	0.04	0.33	0.12	0.05	0.11
L. deliciosus	0.39	nd	2.59	18.95	6.32	47.24	0.39	nd	0.06	0.06	0.05	0.16
L. piperatus	0.39	nd	11.59	15.52	2.24	30.71	0.39	nd	0.29	0.05	0.02	0.10
L. salmonicolor	0.07	1.44	3.23	369.67	7.53	24.52	0.07	0.48	0.08	1.23	0.05	0.08
M. mastoidea	0.35	0.53	10.96	347.61	13.34	25.96	0.35	0.18	0.27	1.16	0.10	0.09
R. grata	1.95	0.28	11.36	284.85	35.36	28.15	1.95	0.09	0.28	0.95	0.25	0.09
S. granulatus	nd	0.09	3.09	105.50	5.17	18.11	nd	0.03	0.08	0.35	0.04	0.06
T. imbricatum	0.07	0.05	1.62	44.03	5.43	20.60	0.07	0.02	0.04	0.15	0.04	0.07
R_fD^o [1] (μg/kg body weight/day)	1.0[3]	3.0[3]	40[3]	300[2]	140[3]	300[3]						

[1] R_fD^o, reference dose

[2] JECFA (1993)

[3] USEPA (2002)

[4] *nd*, not determined

of *C. nebularis*; Se and P contents of *H. repandum*; P and Ca contents of *H. fasciculare*; Cr, Se, P, Al, Ca, Mg, and K contents of *I. gibba*; Ca content of *L. salmanicolor*; Se, P, Ca, Mg, and K contents of *M. mastoidea*; Se, Al, and Mg

Table 5 Literature data on metal content of mushrooms examined in this study

Metal	Concentration (mg·kg^{-1})	Reference
A. pantherina		
Fe	0.45	Rasalanavho et al. 2020
	95.00	Sesli 2007
	985.00	Tuzen et al. 2007
	3690.70	Murati et al. 2015
	9455.20	Murati et al. 2015
Cd	0.05	Murati et al. 2015
	0.17	Murati et al. 2015
	0.80	Rasalanavho et al. 2020
	1.60	Tuzen et al. 2007
	1.77	Rasalanavho et al. 2020
Cr	0.08	Rasalanavho et al. 2020
	2.48	Rasalanavho et al. 2020
Se	7.30	Rasalanavho et al. 2020
	10.80	Tuzen et al. 2007
	11.00	Rasalanavho et al. 2019
	12.00	Rasalanavho et al. 2020
P	-	-
Cu	3.00	Murati et al. 2015
	19.70	Tuzen et al. 2007
	23.70	Murati et al. 2015
	36.40	Sesli 2007
	48.62	Rasalanavho et al. 2020
	60.00	Rasalanavho et al. 2019
	70.65	Rasalanavho et al. 2020
Mn	14.42	Rasalanavho et al. 2020
	19.00	Rasalanavho et al. 2019
	19.50	Sesli 2007
	29.23	Rasalanavho et al. 2020
	53.50	Tuzen et al. 2007
	54.50	Murati et al. 2015
	177.40	Murati et al. 2015
Zn	10.00	Murati et al. 2015
	30.70	Sesli 2007
	43.20	Murati et al. 2015
	73.50	Tuzen et al. 2007
	94.45	Rasalanavho et al. 2020
	130.00	Rasalanavho et al. 2019
	212.53	Rasalanavho et al. 2020
Al	116.00	Sesli 2007
Ca	149.48	Rasalanavho et al. 2020
	334.11	Rasalanavho et al. 2020
Mg	0.98	Rasalanavho et al. 2020
	1.37	Rasalanavho et al. 2020
K	53.54	Rasalanavho et al. 2020
	71.08	Rasalanavho et al. 2020
C. rhacodes		
Fe	33.70	Šíma et al. 2019
Cd	0.49	Šíma et al. 2019
Cr	0.08	Šíma et al. 2019
Se	1.50	Šíma et al. 2019
P	-	-
Cu	85.60	Šíma et al. 2019
Mn	84.60	Šíma et al. 2019

Table 5 (continued)

Metal	Concentration (mg·kg^{-1})	Reference
Zn	127.00	Šíma et al. 2019
Al	27.40	Šíma et al. 2019
Ca	264.00	Šíma et al. 2019
Mg	903.00	Šíma et al. 2019
K	-	-
C. truncatus		
Fe	236.00	Gaso et al. 2007
	245.00	Gaso et al. 2007
	655.00	Sesli and Dalman 2006
Cd	2.00	Gaso et al. 2007
	2.20	Sesli and Dalman 2006
Cr	-	-
Se	-	-
P	3.00	Gaso et al. 2007
	4.00	Gaso et al. 2007
Cu	90.20	Sesli and Dalman 2006
	98.00	Gaso et al. 2007
	99.00	Gaso et al. 2007
Mn	10.00	Gaso et al. 2007
	20.00	Gaso et al. 2007
	60.90	Sesli and Dalman 2006
Zn	125.00	Sesli and Dalman 2006
	130.00	Gaso et al. 2007
	132.00	Gaso et al. 2007
Al	0.70	Gaso et al. 2007
	0.80	Gaso et al. 2007
Ca	1.00	Gaso et al. 2007
Mg	0.60	Gaso et al. 2007
	0.70	Gaso et al. 2007
K	35.00	Gaso et al. 2007
	38.00	Gaso et al. 2007
C. nebularis		
Fe	-	-
Cd	1.16	Jamnická et al. 2007
	2.19	Jamnická et al. 2007
Cr	-	-
Se	-	-
P	-	-
Cu	21.39	Jamnická et al. 2007
	34.10	Jamnická et al. 2007
Mn	-	-
Zn	60.05	Jamnická et al. 2007
	101.13	Jamnická et al. 2007
Al	-	-
Ca	-	-
Mg	-	-
K	-	-
G. triplex		

Table 5 (continued)

Metal	Concentration (mg·kg^{-1})	Reference
No literature data available		
G. sepiarium		
No literature data available		
H. repandum		
Fe	2.12	Jedidi et al. 2017
	33.50	Demirbaş 2001a
	50.00	Colak et al. 2009
	50.06	Severoglu et al. 2013
	72.50	Tüzen et al. 1998
	265.00	Sesli and Tuzen 2006
	317.00	Ouzouni et al. 2007
	700.00	Sesli and Dalman 2006
Cd	0.11	Severoglu et al. 2013
	0.21	Ouzouni et al. 2007
	0.25	Sesli and Tuzen 2006
	0.76	Demirbaş 2001a
	3.08	Demirbas 2000
	3.42	Tüzen et al. 1998
	7.50	Sesli and Dalman 2006
Cr	1.58	Ouzouni et al. 2007
	1.68	Demirbaş 2001a
Se	-	-
P	-	-
Cu	2.08	Severoglu et al. 2013
	2.76	Jedidi et al. 2017
	5.15	Tüzen et al. 1998
	6.84	Demirbaş 2001a
	18.09	Demirbas 2000
	20.00	Colak et al. 2009
	24.20	Sesli and Dalman 2006
	24.30	Ouzouni et al. 2007
	35.38	Alonso et al. 2003
	42.83	Alonso et al. 2003
	46.40	Sesli and Tuzen 2006
Mn	3.12	Demirbaş 2001a
	14.80	Sesli and Dalman 2006
	15.30	Sesli and Tuzen 2006
	21.60	Tüzen et al. 1998
	23.50	Colak et al. 2009
	26.30	Ouzouni et al. 2007
Zn	2.03	Severoglu et al. 2013
	3.82	Jedidi et al. 2017
	14.10	Demirbaş 2001a
	17.10	Tüzen et al. 1998
	30.00	Alonso et al. 2003
	35.90	Ouzouni et al. 2007
	52.50	Alonso et al. 2003
	55.00	Colak et al. 2009
	74.20	Sesli and Tuzen 2006
	103.00	Sesli and Dalman 2006
Al	12.50	Demirbaş 2001a
Ca	68.50	Demirbaş 2001a

Table 5 (continued)

Metal	Concentration (mg·kg^{-1})	Reference
Mg	1030.00	Demirbaş 2001a
K	36,000.00	Demirbaş 2001a
H. pudorinus		
No literature data available		
H. fasciculare		
Fe	55.60	Tüzen et al. 1998
	106.00	Gramss and Voigt 2013
	126.00	Gramss and Voigt 2013
	229.50	Radulescu et al. 2010
	241.01	Murati et al. 2019
	423.00	Demirbaş 2001a
	674.00	Sesli et al. 2008
	800.00	Sesli and Dalman 2006
Cd	0.14	Gramss and Voigt 2013
	0.21	Gramss and Voigt 2013
	0.35	Radulescu et al. 2010
	0.63	Murati et al. 2019
	1.28	Demirbaş 2001a
	1.34	Tüzen et al. 1998
	1.36	Demirbaş 2001b
	2.40	Sesli and Dalman 2006
Cr	0.06	Radulescu et al. 2010
	0.11	Gramss and Voigt 2013
	0.22	Gramss and Voigt 2013
	0.74	Demirbaş 2001a
Se	1.16	Radulescu et al. 2010
	12.00	Rasalanavho et al. 2019
P	-	-
Cu	5.56	Tüzen et al. 1998
	9.67	Radulescu et al. 2010
	11.50	Demirbaş 2001b
	21.40	Gramss and Voigt 2013
	22.18	Murati et al. 2019
	25.80	Sesli et al. 2008
	25.90	Sesli and Dalman 2006
	36.60	Gramss and Voigt 2013
	40.00	Rasalanavho et al. 2019
	72.60	Demirbaş 2001a
Mn	2.98	Radulescu et al. 2010
	6.00	Tüzen et al. 1998
	7.75	Gramss and Voigt 2013
	12.60	Demirbaş 2001b
	23.90	Gramss and Voigt 2013
	24.00	Rasalanavho et al. 2019
	33.61	Murati et al. 2019
	44.80	Demirbaş 2001a
	46.30	Sesli and Dalman 2006
	51.50	Sesli et al. 2008/

Table 5 (continued)

Metal	Concentration (mg·kg^{-1})	Reference
Zn	17.90	Tüzen et al. 1998
	19.60	Demirbaş 2001b
	33.30	Gramss and Voigt 2013
	34.12	Murati et al. 2019
	37.90	Gramss and Voigt 2013
	65.40	Demirbaş 2001a
	86.00	Rasalanavho et al. 2019
	86.40	Radulescu et al. 2010
	150.00	Sesli and Dalman 2006
	169.00	Sesli et al. 2008
Al	17.50	Demirbaş 2001a
	27.30	Sesli et al. 2008
	39.50	Gramss and Voigt 2013
	74.00	Gramss and Voigt 2013
Ca	-	-
Mg	162.20	Sesli et al. 2008
K	59,406.00	Sesli et al. 2008
I. gibba		
Fe	7769.00	Sarikurkcu et al. 2020
Cd	0.74	Sarikurkcu et al. 2020
Cr	-	-
Se	-	-
P	-	-
Cu	34.70	Sarikurkcu et al. 2020
Mn	673.00	Sarikurkcu et al. 2020
Zn	25.10	Sarikurkcu et al. 2020
Al	-	-
Ca	-	-
Mg	-	-
K	-	-
L. deliciosus		
Fe	0.04	Rasalanavho et al. 2020
	0.08	Rasalanavho et al. 2020
	2.39	Jedidi et al. 2017
	7.60	Konuk et al. 2007
	10.90	Rubio et al. 2018
	26.91	Severoglu et al. 2013
	29.80	Aloupi et al. 2012
	132.60	Mleczek et al. 2013b
	197.01	Xu et al. 2019
	216.83	Kosanic et al. 2016
	222.00	Carvalho et al. 2005
	253.00	Gezer and Kaygusuz 2014
	900.00	Sesli and Dalman 2006

Table 5 (continued)

Metal	Concentration (mg·kg^{-1})	Reference
Cd	0.01	Rubio et al. 2018
	0.01	Severoglu et al. 2013
	0.15	Aloupi et al. 2012
	0.26	Cayir et al. 2010
	0.30	Konuk et al. 2007
	0.54	Kosanic et al. 2016
	0.78	Rasalanavho et al. 2020
	0.89	Cayir et al. 2010
	1.15	Rasalanavho et al. 2020
	1.91	Xu et al. 2019
	2.15	Gezer and Kaygusuz 2014
	2.37	Mleczek et al. 2013a
Cr	0.04	Aloupi et al. 2012
	0.12	Cayir et al. 2010
	0.15	Rasalanavho et al. 2020
	0.16	Rubio et al. 2018
	0.36	Konuk et al. 2007
	0.72	Gezer and Kaygusuz 2014
	0.80	Cayir et al. 2010
	1.00	Severoglu et al. 2013
	1.11	Kosanic et al. 2016
	2.35	Rasalanavho et al. 2020
	3.88	Vetter 1997
	4.02	Xu et al. 2019
	5.14	Vetter 1997
	13.20	Campos and Tejera 2011
Se	0.13	Konuk et al. 2007
	8.50	Rasalanavho et al. 2020
	11.00	Rasalanavho et al. 2019
	12.50	Rasalanavho et al. 2020
P	52.00	Konuk et al. 2007
Cu	0.02	Konuk et al. 2007
	1.28	Xu et al. 2019
	1.64	Rubio et al. 2018
	1.91	Severoglu et al. 2013
	5.40	Campos and Tejera 2011
	5.57	Cayir et al. 2010
	6.82	Cayir et al. 2010
	6.90	Aloupi et al. 2012
	11.00	Carvalho et al. 2005
	11.86	Jedidi et al. 2017
	14.30	Mleczek et al. 2013a
	14.85	Rasalanavho et al. 2020
	15.49	Kosanic et al. 2016
	20.00	Rasalanavho et al. 2019
	22.14	Rasalanavho et al. 2020
	56.10	Gezer and Kaygusuz 2014
	75.60	Sesli and Dalman 2006

Table 5 (continued)

Metal	Concentration (mg·kg^{-1})	Reference
Mn	0.36	Konuk et al. 2007
	3.85	Rasalanavho et al. 2020
	5.70	Aloupi et al. 2012
	5.98	Kosanic et al. 2016
	6.00	Rasalanavho et al. 2019
	11.91	Rasalanavho et al. 2020
	23.12	Xu et al. 2019
	24.00	Carvalho et al. 2005
	30.20	Mleczek et al. 2013b
	37.60	Gezer and Kaygusuz 2014
	46.60	Sesli and Dalman 2006
Zn	0.56	Konuk et al. 2007
	2.32	Rubio et al. 2018
	2.49	Severoglu et al. 2013
	7.40	Jedidi et al. 2017
	23.50	Sesli and Dalman 2006
	52.34	Xu et al. 2019
	59.37	Rasalanavho et al. 2020
	66.80	Campos and Tejera 2011
	74.92	Cayir et al. 2010
	81.10	Aloupi et al. 2012
	87.00	Carvalho et al. 2005
	88.71	Mleczek et al. 2013a
	93.22	Cayir et al. 2010
	100.00	Rasalanavho et al. 2019
	123.57	Kosanic et al. 2016
	142.20	Gezer and Kaygusuz 2014
	150.53	Rasalanavho et al. 2020
Al	13.58	Konuk et al. 2007
	18.20	Rubio et al. 2018
	36.70	Mleczek et al. 2013b
	70.10	Campos and Tejera 2011
Ca	78.37	Rasalanavho et al. 2020
	117.70	Mleczek et al. 2013b
	124.00	Konuk et al. 2007
	165.16	Rasalanavho et al. 2020
	247.07	Xu et al. 2019
	250.00	Carvalho et al. 2005
	262.17	Jedidi et al. 2017
Mg	0.78	Rasalanavho et al. 2020
	1.11	Rasalanavho et al. 2020
	13.20	Konuk et al. 2007
	179.70	Mleczek et al. 2013b
	1244.29	Xu et al. 2019/
	1624.68	Jedidi et al. 2017
K	16.29	Rasalanavho et al. 2020
	20.75	Rasalanavho et al. 2020
	75.60	Konuk et al. 2007
	6859.10	Jedidi et al. 2017
	24,987.50	Mleczek et al. 2013b
	26,000.00	Carvalho et al. 2005

Table 5 (continued)

Metal	Concentration (mg·kg^{-1})	Reference
L. piperatus		
Fe	3.47	Konuk et al. 2007
	78.80	Cvetkovic et al. 2015
	145.00	Demirbaş 2001a
	940.00	Ayaz et al. 2011
Cd	0.88	Demirbas 2003
	1.08	Demirbaş 2001a
	1.93	Ayaz et al. 2011
	2.93	Cvetkovic et al. 2015
Cr	0.10	Konuk et al. 2007
	1.08	Demirbaş 2001a
	4.29	Cvetkovic et al. 2015
	15.05	Demirbas 2003
Se	0.05	Konuk et al. 2007
P	5526.80	Cvetkovic et al. 2015
Cu	0.44	Konuk et al. 2007
	16.80	Demirbaş 2001a
	18.11	Demirbas 2003
	42.60	Cvetkovic et al. 2015
	53.50	Ayaz et al. 2011
Mn	0.45	Konuk et al. 2007
	7.60	Demirbaş 2001a
	14.50	Cvetkovic et al. 2015
	328.60	Ayaz et al. 2011
Zn	0.58	Konuk et al. 2007
	29.40	Demirbaş 2001a
	45.20	Cvetkovic et al. 2015
	88.70	Ayaz et al. 2011
Al	9.80	Demirbaş 2001a
	12.15	Konuk et al. 2007
	80.20	Cvetkovic et al. 2015
Ca	3.36	Konuk et al. 2007
	78.60	Demirbaş 2001a
	548.20	Cvetkovic et al. 2015
Mg	6.78	Konuk et al. 2007
	461.50	Cvetkovic et al. 2015
	850.00	Demirbaş 2001a
K	79.00	Konuk et al. 2007
	28,000.00	Demirbaş 2001a
	32,827.10	Cvetkovic et al. 2015
L. salmonicolor		
Fe	12.00	Konuk et al. 2007
	71.78	Niemiec et al. 2018
	137.87	Zavastin et al. 2015
	239.00	Ouzouni et al. 2007
	10,558.00	Niemiec et al. 2018
Cd	0.01	Konuk et al. 2007
	0.05	Zavastin et al. 2015
	0.09	Ouzouni et al. 2007
	0.52	Chowaniak et al. 2017
	6.00	Chowaniak et al. 2017

Table 5 (continued)

Metal	Concentration (mg·kg^{-1})	Reference
Cr	0.24	(Konuk et al. 2007)
	0.27	Niemiec et al. 2017
	0.41	Ouzouni et al. 2007
	1.91	Niemiec et al. 2017
Se	0.06	Konuk et al. 2007
	1.49	Zavastin et al. 2015
P	121.00	Konuk et al. 2007
Cu	0.05	Konuk et al. 2007
	6.15	Ouzouni et al. 2007
	6.73	Chowaniak et al. 2017
	14.61	Zavastin et al. 2015
	22.42	Chowaniak et al. 2017
Mn	0.74	Konuk et al. 2007
	8.52	Niemiec et al. 2018
	20.80	Ouzouni et al. 2007
	36.35	Zavastin et al. 2015
	714.00	Niemiec et al. 2018
Zn	0.52	Konuk et al. 2007
	39.08	Chowaniak et al. 2017
	94.50	Ouzouni et al. 2007
	98.16	Chowaniak et al. 2017
	152.53	Zavastin et al. 2015
Al	4.56	Konuk et al. 2007
	19.34	Niemiec et al. 2017
	107.50	Niemiec et al. 2017
Ca	-	-
Mg	11.60	Konuk et al. 2007
	855.00	Ouzouni et al. 2007
	934.67	Zavastin et al. 2015
K	112.00	Konuk et al. 2007
M. mastoidea		
Fe	15.60	(Colak et al. 2007)
	194.70	(Kaya and Bag 2010)
Cd	2.20	(Colak et al. 2007)
Cr	1127.00	(Kaya and Bag 2010)
Se	-	-
P	-	-
Cu	45.59	Kaya and Bag 2010
	8.20	Colak et al. 2007
Mn	16.49	Kaya and Bag 2010
	48.50	Colak et al. 2007
Zn	31.38	Kaya and Bag 2010
	34.40	Colak et al. 2007
Al	204.10	Kaya and Bag 2010
Ca	-	-
Mg	-	-
K	-	-
P. vorax		
No literature data available		

Table 5 (continued)

Metal	Concentration (mg·kg^{-1})	Reference
P. limonella		
No literature data available		
R. anthracina		
No literature data available		
R. grata		
No literature data available		
S. granulatus		
Fe	193.38	Mushtaq et al. 2020
	458.00	Gençcelep et al. 2009
Cd	1.35	Mushtaq et al. 2020
Cr	48.82	Mushtaq et al. 2020
Se	-	-
P	4.49	Gençcelep et al. 2009
Cu	9.37	Mushtaq et al. 2020
	107.00	Gençcelep et al. 2009
Mn	30.30	Gençcelep et al. 2009
	94.01	Mushtaq et al. 2020
Zn	28.27	Mushtaq et al. 2020
	169.00	Gençcelep et al. 2009
Al	-	-
Ca	0.46	Gençcelep et al. 2009
Mg	-	-
K	29.10	Gençcelep et al. 2009
T. atrotomentosa		
Fe	137.00	Sarikurkcu et al. 2020
Cd	0.53	Sarikurkcu et al. 2020
Cr	-	-
Se	-	-
P	-	-
Cu	2.60	Elekes et al. 2010
	3.90	Sarikurkcu et al. 2020
Mn	7.80	Sarikurkcu et al. 2020
Zn	0.11	Elekes et al. 2010
	0.32	Elekes et al. 2010
	26.90	Sarikurkcu et al. 2020
Al	-	-
Ca	-	-
Mg	-	-
K	-	-
T. imbricatum		
Fe	68.90	Sesli 2007
	744.00	Doğan et al. 2012
Cd	-	-
Cr	-	-
Se	-	-
P	7755.00	Doğan et al. 2012
Cu	10.60	Sesli 2007
Mn	16.00	Doğan et al. 2012
	17.50	Sesli 2007
Zn	165.00	Sesli 2007
Al	330.00	Sesli 2007
Ca	-	-
Mg	-	-
K	24,217.00	Doğan et al. 2012

The metal contents of mushrooms were given in ascending order contents of *S. granulatus*; Cr, Se, P, Al, Ca, Mg, and K contents of *T. atrotomentosa*; and Cd, Cr, Se, Ca, and Mg contents of *T. imbricatum* have been studied for the first time.

Fe

Fe is found in the structure of hemoglobin, whose main function is to carry oxygen, and therefore is an important element. It is known that about 70% of the Fe in the human body is used for hemoglobin production. Fe is the main structural component of myoglobin, which is abundant in muscle cells, as well as hemoglobin. Fe deficiency causes anemia in organisms (Gupta 2014). The Fe contents of the mushrooms analyzed in the present study were found to range between 18.00 (*P. limonella*) and 1239.10 (*P. vorax*) $mg \cdot kg^{-1}$. According to the literature data, Fe concentrations of the mushroom samples were between 0.04 and 10,558.00 $mg \cdot kg^{-1}$ (Niemiec et al. 2018; Rasalanavho et al. 2020).

Cd

Cd is a toxic element to humans. It can accumulate in kidneys and proximal tubule cells under Cd-contaminated environmental conditions. Depending on the amount, it may cause bone damage/demineralization and kidney dysfunction. Exposure to Cd through inhalation, as a result of industrial activities, can also affect lung function and cause lung cancer (Bernard 2008). As can be seen from Table 1, the Cd content of mushroom species was between 0.15 and 4.56 $mg \cdot kg^{-1}$. It was determined that the mushroom with the lowest Cd content was *T. imbricatum*, while that with the highest was *R. grata*. According to the literature data, the Cd content of mushroom samples was between 0.01 and 7.50 $mg \cdot kg^{-1}$ (Rubio et al. 2018; Sesli and Dalman 2006).

Cr

Cr is one of the minerals the body needs in order to fulfill its normal physiological conditions. Therefore, it is necessary to have trace amounts of Cr in the body. Especially individuals who act actively in their daily life need more of this element to meet their increasing energy needs and to maintain their working performance. Cr also plays an important role in lipid and protein metabolism. In addition, Cr + 3 is known to help insulin function. However, Cr + 6 is toxic and can cause cancer (Achmad and Auerkari 2017). In the present study, the Cr concentrations of the mushrooms were between 0.05 (*C. nebularis*) and 3.36 (*L. salmonicolor*) $mg \cdot kg^{-1}$. Literature data showed that the Cr content of mushrooms in question ranged from 0.04 to 1127.0 $mg \cdot kg^{-1}$ (Aloupi et al. 2012; Kaya and Bag 2010).

Se

Se is an important element found in the body in fairly low concentrations but fulfills very important biological functions. Since Se supports the functions of enzymes, hormones, and vitamins, it plays a role in catalytic, structural, and regulatory processes. In addition, it helps many biochemical reactions to take place in a healthy way in organisms (Sobolev et al. 2018). As a result of the elemental analysis of the mushroom samples, it was determined that the Se contents were between 0.21 and 3.22 $mg \cdot kg^{-1}$. While *L. salmanicolor* had the lowest Se content, the species with the highest Se concentration was *C. rhacodes*. As understood from previous studies, the Se contents of the mushrooms analyzed in the present study were between 0.05 and 12.50 $mg \cdot kg^{-1}$ (Konuk et al. 2007; Rasalanavho et al. 2020).

P

P is an element that is vital to human life. Monomers of genetic material of organisms contain this element. Therefore, P is the structural component of DNA and RNA. P is also the structural component of phospholipids and key players in energy metabolism such as ATP and GTP. Excessive exposure to P is toxic to humans, and it has been reported that over 1 $mg \cdot kg^{-1}$ is an acute lethal dose (Anderson and Garner 1995). In the present study, P concentrations of mushroom species were between 1.04 (*G. sepiarium*) and 8.90 (*C. rhacodes*) $mg \cdot kg^{-1}$. Literature data showed that the concentration of this element in these mushrooms was between 3.0 and 7755.0 $mg \cdot kg^{-1}$ (Doğan et al. 2012; Gaso et al. 2007). In the literature, it was determined that the P contents of the mentioned mushrooms were quite variable (e.g., as in the P content of *T. imbricatum* (7755.0 $mg \cdot kg^{-1}$)). This may be due to the capacity of the mushroom to accumulate the relevant element or the ecosystem in which the mushroom grows or may be due to the errors that occur during elemental analysis.

Cu

Cu is an extremely important element for human metabolism as it enables many critical enzymes to function properly. In addition, it has a positive effect on the skin, epithelium, and connective tissues. It plays a role in the production processes of critical molecules such as hemoglobin, myelin, and melanin and is essential for the normal functions of the thyroid gland. Cu is also an essential part of the body's antioxidant defense system (Osredkar and Sustar 2011). According to the data in Table 2, the Cu contents of the mushroom species were between 3.27 and 59.87 mg·kg^{-1}. Mushrooms with minimum and maximum Cu contents were *H. pudorinus* and *C. rhacodes*, respectively. According to the literature data, the Cu contents of the mushrooms were between 0.02 and 107.0 mg·kg^{-1} (Gençcelep et al. 2009; Konuk et al. 2007).

Mn

Mn is usually taken into the body with food and water. During digestion, it is absorbed through the gastrointestinal system and transported to the mitochondria in the cells of some organs such as the liver, pancreas, and pituitary gland (Deng et al. 2013). This element plays a critical role in both the synthesis and activation of a large number of enzymes, such as oxidoreductases, transferases, hydrolases, lyases, isomerases, and ligases. Mn is also needed for the synthesis of some vitamins (examples, B and C) and proteins and for the effective functioning of the immune system (Aschner and Aschner 2005). As a result of acute exposure to Mn, a disorder called manganism may occur (Koh et al. 2014). According to the literature data, the Mn contents of the mushrooms examined in the present study were between 0.36 and 714.0 mg·kg^{-1} (Konuk et al. 2007; Niemiec et al. 2018). The mushroom with the lowest Mn content was *C. truncatus* with 3.69 mg·kg^{-1}, while the mushroom with the highest Mn content was *G. triplex* with 220.44 mg·kg^{-1}.

Zn

Defined as a basic trace element or a micronutrient, Zn is of great importance in the growth and development of all high-structured plants and animals. In particular, it takes an active part in many physiological processes and helps the immune system. Zn is critical in the functioning of hundreds of different enzymes, DNA stabilization, and gene expression (Frassinetti et al. 2006). In the present study, the Zn contents of the mushrooms ranges between 21.3 and 154.1 mg·kg^{-1}. The mushroom species with the lowest and highest Zn contents were *P. vorax* and *C. rhacodes*, respectively. According to the literature data, the Zn contents of the mushroom species were between 0.11 and 212.53 mg·kg^{-1} (Elekes et al. 2010; Rasalanavho et al. 2020).

Al

Although organisms contain some Al, this element is not considered as an essential element for biological systems since it does not take part in any biological process in the human body. There is also no evidence that any organism used Al in the evolutionary period. Thus, although Al is abundant in the environment, it is characterized as a biochemical paradox due to its lack of biological function (Macdonald and Martin 1988). According to the data in Table 3, it was determined that the mushroom with the lowest Al content was *T. atrotomentosa* (6.4 mg·kg^{-1}). The mushroom species with the highest Al content was *P. vorax* (754.3 mg·kg^{-1}). According to the data in the literature, the Al content of mushrooms was between 0.7 and 330.0 mg·kg^{-1} (Gaso et al. 2007; Sesli 2007).

Ca

Ca in the form of Ca^{2+} is an important element for both the biochemistry and physiology of organisms. Its most distinctive feature is that it acts as secondary messenger in signal transmission paths. In this way, it plays critical roles in neurotransmitter release, contraction of muscle cells, and fertilization. In addition, many enzymes and coagulation factors that take part in normal metabolic functions use Ca as a cofactor. Ca also contributes to the formation of membrane potential across cell membranes and bone development (Peacock 2010). According to the literature data, the Ca content of the mushrooms in the present study were between 0.46 and 548.2 mg·kg^{-1} (Cvetkovic et al. 2015; Gençcelep et al. 2009). In the present study, Ca contents of mushroom species were between 15.8 and 17,473.0 mg·kg^{-1}. Ca contents of *G. triplex* (1946.8 mg·kg^{-1}), *G. sepiarium* (7180.2 mg·kg^{-1}), and *P. vorax* (17,472.9 mg·kg^{-1}) were higher than the literature data. This situation was thought to be due to the mineral composition of the soil on which these mushroom species grow.

Mg

Mg in the form of Mg^{2+} is an essential element for life and is present in every cell type. Mg, which is one of the elements that ATP needs to be active biologically, is an important part of energy metabolism. Therefore, it is possible to actually call the molecule known as ATP as Mg-ATP. Mg is the main player in the stability of all polyphosphate compounds in cells (Leroy 1926). Gaso et al. (2007) and Jedidi et al. (2017) reported that minimum and maximum Mg contents of the mushroom species analyzed in the present study were 0.6 and 1624.68 mg·kg^{-1}, respectively. Here, the Mg contents of mushrooms were found to be between 413.0 (*S. granulatus*) and 5943.0 mg·kg^{-1} (*P. vorax*).

K

K is the basic cation found in animal cells. The difference between Na, another cation, and the concentrations of this element enables the formation of the membrane potential (Santos et al. 2012). When not enough K is taken, there may be an increased risk of hypertension, stroke, and cardiovascular disease. In case of excessive intake, problems such as abdominal pain, nausea, vomiting, and diarrhea may occur (Aburto et al. 2013; D'Elia et al. 2011). K content data obtained from the present study were found to be compatible with the literature data. According to the literature data, the K content of the mushroom species in question was between 16.29 and 59,406.0 mg·kg^{-1} (Rasalanavho et al. 2020; Sesli et al. 2008). According to the data in Table 3, the K content of the mushroom species was between 2803.0 and 24,490.0 mg·kg^{-1}. The K content of *G. sepiarium* was the lowest, while that of *A. pantherina* was the highest.

DIM and HRI of the mushrooms

In addition to the elemental contents of the mushrooms collected from Ilgaz Mountain National Park, DIM and HRI values of edible ones were also calculated based on these data. According to the data presented in Table 4, it has been determined that both DIM and HRI values of mushroom species except *L. salmanicolor*, *M. mastoidea*, and *R. grata* were within the legal limits determined by JECFA (1993) and USEPA (2002). However, it was determined that the Fe content of *L. salmanicolor* and *M. mastoidea* was above the limits set by JECFA (1993). A similar situation is valid for the Cd content of *R. grata* (USEPA 2002). Although it is necessary to pay attention to the consumption of all three mushrooms, the Cd content of *R. grata* should be checked especially before consuming.

Conclusions

As a result of the data presented above, it was concluded that the Fe concentrations of *L. salmanicolor* and *M. mastoidea* and Cd content *R. grata* collected from Ilgaz Mountain National Park (Western Black Sea, Turkey) exceed the legal limits set by JECFA (1993) and USEPA (2002). It has been concluded that the Cd content of *R. grata* should be monitored carefully since this element causes acute and chronic toxicity due to biomagnification and can inhibit biosynthesis reactions if it accumulates in the human body.

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Declarations

Ethics approval and consent to participate Not applicable (this paper does not contain studies involving human participants, human data, or human tissue).

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