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Evaluation the Weekly Intake of Some Wild Edible Indigenous Mushrooms Collected in Different Regions in Tunceli, Turkey

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Abstract

The quantity of some essential and non-essential elements of wild edible mushroom samples collected from Tunceli Province of Turkey was determined by using flame and electrothermal atomic absorption spectrometer after microwave digestion. The method accuracy was corrected using standard reference material (NIST SRM 1547-Peach Leaves). The essential element concentrations of analyzed mushroom samples were determined in the range of 0.036–0.563 mg kg^{-1} for calcium, 1.28–2.55 mg kg^{-1} for magnesium, 0.054–0.188 mg kg^{-1} for sodium, 1.00–4.57 mg kg^{-1} for copper, 212–480 mg kg^{-1} for iron, and 75–151 mg kg^{-1} for zinc but cobalt and chromium were not detected. Based on results, there were statistically significant differences between the element contents of analyzed mushroom species. Consequently, according to this study results, the weekly intake and target hazard quotient values of the elements show that the consumption of these mushrooms does not threaten human health.

Keywords Mushroom · Essential and non-essential elements · Weekly intake · Target hazard quotient

Introduction

Humans have used edible mushrooms as food since ancient times due to their unique and elegant taste. Nowadays, mushrooms are one of the most widely used food sources, and in pharmacy also [1]. These products have been evidenced to be effective as antioxidant, antimicrobial, immunomodulatory, antiviral, anti-inflammatory, antitumor, antiaromatase, cytotoxic, and anticholesterole agents [2–7]. Therefore, mushrooms that can be eaten are important food sources which have an important place in balanced nutrition. They contain a wide variety of biomolecules with nutritional and bioactive properties [8, 9]. Edible mushrooms contain many biologically active materials, such as vitamins, nutritive compounds, proteins, polysaccharides, and mineral contents and in contrast, they are poor in calories and fat so they are evaluated as nutritious food all over the world [10–15].

Mushrooms are known to be a good mineral source containing Ca, Fe, K, Mg, Mn, Na, P, and Zn in particular. Living organisms require varying amounts of elements such as Ca, Co, Cr, Cu, Fe, K, Mg, Na, and Zn that are essential because they have important roles in biological systems. However, they can also be toxic if taken excessive quantities. Heavy metals including Cd, Ni, and Pb are non-essential; they are toxic and their accumulation in progress of time could cause serious illnesses in human bodies. To estimate the adequacy intake of essential metals and assessing exposure risks from intake of toxic non-essential metals, accurate data that include food composition have vital importance [16, 17].

Wild mushroom species that accumulate high amounts of heavy metals, as Cd, Co, Cu, Hg, Mn, Ni, Pb, and Zn, are important indicators for environmental pollution [18]. Researchers reported that the heavy metal content in edible mushrooms is higher than the other agricultural crops [19]. Among mushroom species, metal analysis is important in white rot fungi due to the ability of accumulate air and soil contaminants. Heavy metals accumulated with edible

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mushrooms are potentially hazard for human health. In wild edible mushrooms, therefore, determining essential and toxic element levels is very important.

The climate during the year is suitable for the growth of mushrooms in Tunceli region, exclusively in spring and autumn. For this reason, this area has a large mushroom diversity in these months and many people collect and consume edible mushrooms.

In this study, seven indigenous edible mushroom species which are *Agaricus campestris*, *Morchella esculenta*, *Morchella vulgaris*, *Amanita vaginata*, *Langermannia gigantea*, *Pleurotus eryngii* var. *ferulae*, and *Pleurotus eryngii* var. *eryngii* collected from three different regions of Tunceli were analyzed. Thus, the first aim of the present study was to determine the essential (Ca, Co, Cr, Cu, Fe, Mg, Na, and Zn) and non-essential elements (Cd, Ni, and Pb) concentrations using flame atomic absorption spectrometer (FAAS) and electrothermal atomic absorption spectrometer (ETAAS) in these mushroom species. For this reason, it was also aimed that there is a correlation between the metal components the mushroom species and the collected region. The second aim of the current study was to evaluate essential and non-essential element concentrations of analyzed mushrooms and their risk to human health. In the light of the above, these concentrations were then compared against the recommended maximum levels allowed in food. In addition, the quality of the mushroom for human consumption was assessed.

Materials and Methods

Sample Collection and Preparation

The wild edible mushroom species [14, 20–29] used in this study (*A. campestris*, *M. esculenta*, *M. vulgaris*, *A. vaginata*, *L. gigantea*, *P. eryngii* var. *ferulae*, and *P. eryngii* var. *eryngii*) were collected from Tunceli region between the 2017 and 2018 years (Fig. 1). Each species of mushrooms were collected from three different regions for determining the correlation between the element components of species and the regions. Photos of mushroom species were taken in their natural habitats (Photo 1). The mushroom samples were first cleaned manually with soft brushes from forest and soil debris, then they were transported to the laboratory within 3 h of collection. Firstly, they were cleaned by tap water and then by ultrapure water. The mushroom fruit bodies were divided into several parts with plastic knife and then dried in an oven for 5 days at 70 °C to reach a constant weight before analysis. Then, the dried samples were powdered in mortar. Powdered mushroom samples were stored until they were analyzed in glass jars. Table 1 summarizes analyzed mushroom information including habitat, localization, harvest date, and the families.

Apparatus and Reagents

The measurements were performed using a PerkinElmer AAnalyst™ 800 model with deuterium background correction. Cd, Cr, Co, Cu, Ni, and Pb were determined by ETAAS using argon as inert gas. For Ca, Fe, Mg, Na, and Zn, measurements using air acetylene flame were carried out.

In all experiments, nitric acid, hydrogen peroxide, and metal standard solutions were of analytical grade, and they were obtained from Merck (Darmstadt, Germany) and all solutions were prepared using ultrapure water (Elga, PURELAB). For cleaning the glass and plastic wares, diluted nitric acid and then ultrapure water were used. The element standard solutions used for calibration were prepared by diluting a stock solution of 1000 mg L^{-1} for Ca, Fe, Mg, Na and Zn and 1000 μg L^{-1} for Cd, Cr, Co, Cu, Ni, and Pb.

Microwave Digestion Procedure

A microwave digestion system (Berghof, Germany) was used for mushroom samples digestion. About 0.2 g of mushroom samples was taken into the digestion vessel and 2 mL of concentrated nitric acid and 3 mL hydrogen peroxide were added. Mixture was shaken carefully and at least 20 min was waited before the vessel was closed and digestion program applied. After centrifugation, clear solutions were diluted to 30 mL with ultrapure water. Blanks were carried out in the same way. Table 2 represents the microwave digestion system conditions.

Analytical Procedure for Element Analysis and Accuracy

Cd, Co, Cr, Cu, Ni, and Pb concentrations were measured using ETAAS and others were measured using FAAS. The Cd, Cr, Co, Cu, Ni, and Pb in mushroom samples were determined by ETAAS using argon as inert gas. For Ca, Fe, Mg, Na, and Zn, measurements using air acetylene flame were carried out. Analyses were repeated triplicate. The analytical method accuracy was checked using the certified reference material (NIST SRM 1547-Peach Leaves).

Statistical Analysis

Results of analyses were evaluated statistically by using IBM SPSS Statistics 24 (USA). The one-way analysis of variance (ANOVA) was used for data analysis. Moreover, the correlation between the element components in the mushroom species and the collected regions were analyzed using a two-way ANOVA. The results of element contents were expressed as mean value ± standard error (SE) of triplicate measurements.

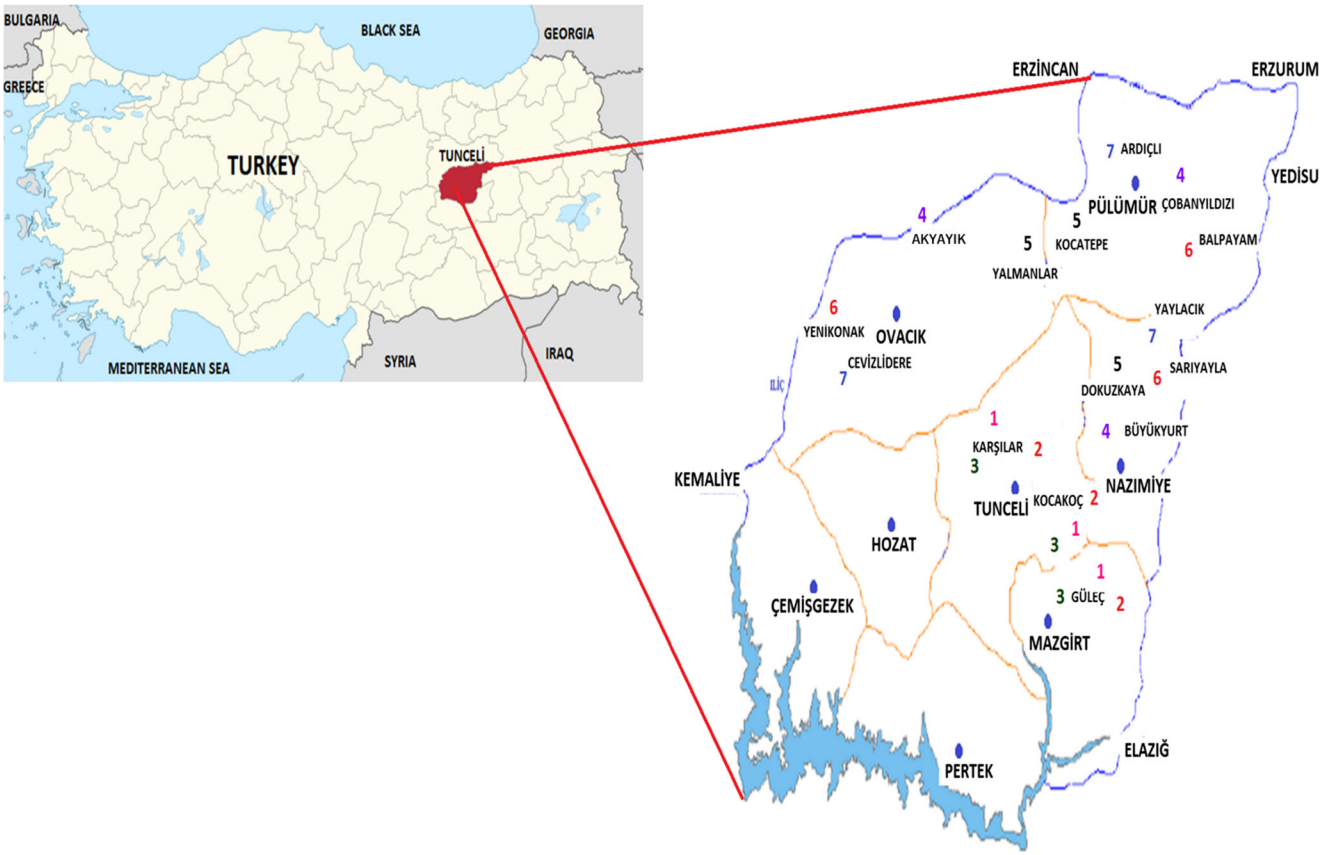

Fig. 1 Location of wild edible indigenous mushroom species collected between the years 2017 and 2018 (1, *Morchella esculenta*; 2, *Morchella vulgaris*; 3, *Amanita vaginata*; 4, *Agaricus campestris*; 5, *Langermannia gigantea*; 6, *Pleurotus eryngii* var. *ferulae*; 7, *Pleurotus eryngii* var. *eryngii*)

Risk Assessment

In this study, estimated weekly intake (EWI, mg kg^{-1} body weight $week^{-1}$) of elements were calculated and the results were presented in Table 7. When calculating the EWI, concentrations of the studied heavy metals, for a standardized person weighing 70 kg with a consumption of 210 g of dried edible wild mushrooms per week, were considered. FAO/WHO (1993) and USEPA defined Cd, Cr, and Pb values as 7 μg kg^{-1}, 9 μg kg^{-1}, and 25 μg kg^{-1}, respectively, for body weight of a consumer [30, 31]. On the other hand, for some elements, oral reference doses (RfDs) of Cu 40 mg kg^{-1} body weight/day, Ni 20 mg kg^{-1} body weight/day, and Zn 300 mg kg^{-1} body weight/day have been published by the Joint FAO/WHO Expert Committee on Food Additives [32].

The EWI of elements were calculated using the following equation:

$$\text{EWI} = \frac{(\text{weight of consumed mushroom} \times \text{mushroom element concentration})}{\text{Average body weight}}$$

Target Hazard Quotient

The target hazard quotient (THQ) has been used as marker because it connects the element concentrations in food with their toxicity, quantity and quality of food consumption, and consumers' body mass. The combination of many complex parameters provides more comprehensive information to assess the potential health risk of elements in various foods.

An equation used by Ihugba et al. (2018) was preferred to evaluate THQ and it was presented at below [33]:

$$\text{THQ} = \frac{E_F\, E_D F_{IR} C}{\text{RfD}_o W_{AB} T_A} \times 10^{-3}$$

Exposure frequency (365 days $year^{-1}$), exposure duration (equivalent to the average lifetime, 70 years), and ingestion rate of mushrooms (g/person/day), assuming 0.5 g and 1.0 g for an average-level consumer and a high-level consumer, are represented by E_F, E_D, and F_{IR}, respectively. Also, C represents mushroom element concentration as mg kg^{-1} dry weight. While RfDo is the oral reference dose (mg/kg/day), W_{AB} and T_A represented average body weight and averaged exposure time for non-carcinogens (365 days $year^{-1}$ × ED),

Photo 1 Photos of investigated wild edible indigenous mushroom species samples (*-Morchella esculenta, 2-Morchella vulgaris, 3-Pleurotus eryngii var. eryngii, 4-Pleurotus eryngii var. ferulae, 5-Langermannia gigantea, 6-Amanita vaginata, 7-Agaricus campestris"*) in collected region

respectively. The US EPA stated that an index more than 1 is considered as not safe for human health. Also, for some elements including Cu, Ni, Pb, and Zn, RfDo values were 0.04, 0.02, 0.0035, and 0.3, as mg kg^{-1} body weight day^{-1} [33, 34].

Table 1 Natural ecosystem information of collected and analyzed seven wild edible indigenous mushroom species such as species number (SN), mushrooms, localization, collection period, habitat, and family

SN	Mushroom	Localization	Collection period	Habitat	Family
1	*Morchella esculenta*	Kocakoç village (city center)	18.04.2017 22.04.2017 14.04.2017	On the edge of the river, between the grass, in the sandy region	*Morchellaceae*
2	*Morchella vulgaris*	Karşılar village (Munzur valley-city center)	18.04.2017 20.04.2017 16.04.2017	On the edge of the river, between the grass, in the sandy region	*Morchellaceae*
3	*Amanita vaginata*	Güleç village (vity center)	28.05.2018 18.05.2018 22.05.2018	Forests of oak and stone floors	*Amanitaceae*
4	*Agaricus campestris*	Çobanyıldız village (Pülümür) Akyayık village (Ovacık) Büyükyurt village (Nazımiye)	27.05.2017 26.05.2017 24.05.2017	Among the grasses and stones in high regions, steppe	*Agaricaceae*
5	*Langermannia gigantea*	Kocatepe village (Pülümür) Yalmanlar village (Ovacık) Dokuzkaya village (Nazımiye)	18.05.2017 20.05.2017 22.05.2017	On a sloping ground, stepe, in high regions	*Lycoperdaceae*
6	*Pleurotus eryngii* var. *ferulae*	Balpayam village (Pülümür) Yenikonak village (Ovacık) Sarıyayla village (Nazımiye)	05.06.2017 30.05.2017 19.05.2017	In high regions, on a sloping ground, between stones	*Pleurotaceae*
7	*Pleurotus eryngii* var. *eryngii*	Ardıçlı village (Pülümür) Cevizlidere village (Ovacık) Yaylacık village (Nazımiye)	17.05.2018 29.05.2018 19.05.2018	In high regions, on a sloping ground, between stones	*Pleurotaceae*

Table 2 Mushroom digestion method using a microwave system

Step	1	2	3
Temperature (°C)	145	180	100
Power (%)	75	90	40
Time (min)	5	10	10

Results and Discussion

In the current study, the contents of the essential elements (the macroelements Ca, Mg, and Na and the microelements Cu, Co, Cr, Fe, and Zn) and non-essential elements (Cd, Ni, and Pb) were determined and they were compared in terms of mushroom species in Table 3. In all tested species, the macroelement Mg (1.28 ± 0.03–2.55 ± 0.02 mg kg^{-1} dw) had the highest concentration; the microelements Fe and Zn were in the range between 212 ± 8 mg kg^{-1} dw–480 ± 25 mg kg^{-1} dw and 75 ± 2 mg kg^{-1} dw–151 ± 7 mg kg^{-1} dw, respectively. From the data given in Table 3 describing the concentrations of essential elements, *M. esculenta* has the highest concentration of essential elements as Ca (0.563 ± 0.018 mg kg^{-1} dw), Fe (480 ± 25 mg kg^{-1} dw), and Na (0.172 ± 0.004 mg kg^{-1} dw). Also, *A. vaginata* is rich in terms of Cu (5.17 ± 0.11 mg kg^{-1} dw) and Fe (462 ± 10 mg kg^{-1} dw) contents.

It was detected that there is a close relationship between the amount of mineral content and the mushroom species statistically (Table 3). The macroelement Ca content of across all the tested mushroom species were in the following order: *M. esculenta* > *M. vulgaris* > *A. vaginata* > *P. eryngii* var. *eryngii* ≥ *P. eryngii* var. *ferulae* ≥ *A. campestris* ≥ *L. gigantea*; the amounts of Na were in the following order: *P. eryngii* var. *eryngii* ≥ *M. esculenta* > *M. vulgaris* > *P. eryngii* var. *ferulae* ≥ *A. vaginata* ≥ *A. campestris* ≥ *L. gigantea*; and the amounts of Mg were, respectively, *P. eryngii* var. *eryngii* > *P. eryngii* var. *ferulae* > *A. campestris* > *A. vaginata* > *L. gigantean* ≥ *M. esculenta* ≥ *M. vulgaris* ($p < 0.05$).

On the other hand, the microelement contents of all mushroom species were examined. According to Table 3, there were statistically significant differences between the analyzed mushroom species as regards content of Cu, Fe, and Zn in their fruit bodies ($p < 0.05$). The microelement contents of all the mushroom studied were in following the order: for the amount of Cu content, *A. vaginata* > *A. campestris* > *L. gigantea* > *M. vulgaris* ≥ *M. esculenta* > *P. eryngii* var. *eryngii* ≥ *P. eryngii* var. *ferulae*; for the amount of Fe content, *M. esculenta* ≥ *A. vaginata* ≥ *M. vulgaris* > *A. campestris* ≥

Table 3 Comparison of element contents of seven edible indigenous mushroom samples in terms of mushroom species using a one-way analysis of variance (ANOVA) (mg kg^{-1}, dw).

Macrofungal species	Essential element								Non-essential element		
	Macroelements			Microelements							
	Ca	Mg	Na	Cu	Fe	Zn	Co	Cr	Cd	Ni	Pb
Agaricus campestris	0.068 ± 0.004 ^{ef}	1.78 ± 0.08 ^{c}	0.072 ± 0.004 ^{cd}	4.57 ± 0.20 ^{b}	378 ± 6 ^{b}	96 ± 2 ^{c}	ND	ND	ND		
Morchella esculenta	0.563 ± 0.018 ^{a}	1.28 ± 0.03 ^{e}	0.172 ± 0.004 ^{a}	2.77 ± 0.03 ^{d}	480 ± 25 ^{a}	98 ± 2 ^{bc}					
Morchella vulgaris	0.502 ± 0.028 ^{b}	1.28 ± 0.05 ^{e}	0.135 ± 0.018 ^{b}	2.81 ± 0.07 ^{d}	436 ± 16 ^{a}	108 ± 3 ^{b}					
Langermannia gigantea	0.036 ± 0.006 ^{f}	1.40 ± 0.05 ^{e}	0.054 ± 0.011 ^{d}	3.23 ± 0.26 ^{c}	212 ± 8 ^{d}	151 ± 7 ^{a}					
Amanita vaginata	0.382 ± 0.017 ^{c}	1.59 ± 0.06 ^{d}	0.077 ± 0.003 ^{cd}	5.17 ± 0.11 ^{a}	462 ± 10 ^{a}	104 ± 4 ^{bc}					
Pleurotus eryngii var. *eryngii*	0.134 ± 0.024 ^{d}	2.55 ± 0.02 ^{a}	0.188 ± 0.011 ^{a}	1.04 ± 0.04 ^{e}	277 ± 28 ^{c}	77 ± 3 ^{d}					
Pleurotus eryngii var. *ferulae*	0.104 ± 0.006 ^{de}	2.01 ± 0.08 ^{b}	0.094 ± 0.008 ^{c}	1.00 ± 0.09 ^{e}	337 ± 16 ^{b}	75 ± 2 ^{d}					
SRM*	1.559%	0.432%	23.8	3.75	219.8	17.97	0.07		0.0261	0.689	0.869
SRM**	1.522 ± 0.021%	0.420 ± 0.005%	23.2 ± 1.1	3.66 ± 0.4	212.8 ± 5.6	17.80 ± 0.44	0.068 ± 0.004	3.66 ± 0.4	0.0251 ± 0.0022		0.872 ± 0.022
% recovery SRM	97.6	97	97.5	97.8	96.8	99.1	97.8		96.8		100%
LOD (μg kg^{-1})	0.09	0.006	0.008	0.21	0.33	0.07	0.033	0.12	0.018	0.234	2.22
LOQ (μg kg^{-1})	0.3	0.02	0.03	0.7	1.1	0.23	0.11	0.4	0.06	0.78	7.4

Different superscript letters within columns indicate significant differences between means ($p < 0.05$)

ND not detected

* Certified values

** Measured value

Table 4 Comparison of element contents (except Co and Cr)* of edible indigenous mushroom samples in terms of mushroom species using a two-way analysis of variance (ANOVA) (mg kg^{-1}, dw)

Essential element contents							
		Macroelements			Microelements		
		Ca	Mg	Na	Cu	Fe	Zn
Mushroom species	*A. campestris*	0.068 ^{c}	1.78 ^{c}	0.072 ^{c}	4.57 ^{a}	378 ^{a}	96 ^{b}
	L. gigantea	0.036 ^{d}	1.04 ^{d}	0.054 ^{d}	3.23 ^{b}	212 ^{c}	151 ^{a}
	P. eryngii var. *eryngii*	0.134 ^{a}	2.55 ^{a}	0.188 ^{a}	1.04 ^{c}	277 ^{b}	77 ^{c}
	P. eryngii var. *ferulae*	0.104 ^{b}	2.01 ^{b}	0.094 ^{b}	1.00 ^{c}	337 ^{a}	75 ^{c}
	SE	0.004	0.02	0.002	0.14	16	4
	p	$p < 0.01$	$p < 0.01$	$p < 0.01$	$p < 0.01$	$p < 0.01$	$p < 0.01$
Sample regions	Pülümür	0.069 ^{c}	2.04 ^{a}	0.096 ^{b}	2.54 ^{a}	282 ^{b}	101 ^{a}
	Ovacık	0.079 ^{b}	1.90 ^{b}	0.092 ^{b}	2.58 ^{a}	292 ^{ab}	941 ^{a}
	Nazımiye	0.110 ^{a}	1.87 ^{b}	0.118 ^{a}	2.26 ^{a}	329 ^{a}	104 ^{a}
	SE	0.003	0.02	0.001	0.12	14	0.12
	p	$p < 0.01$	$p < 0.01$	$p < 0.01$	$p > 0.05$	$p > 0.05$	$p > 0.05$

Different superscript letters within columns indicate significant differences between means ($p < 0.05$)

*Co and Cr concentrations were not detected

SE standard error, $n = 3$

P. eryngii var. *ferulae* > *P. eryngii* var. *eryngii* > *L. gigantean*; and for the amount of Zn content, *L. gigantea* > *M. vulgaris* ≥ *A. vaginata* ≥ *M. esculenta* ≥ *A. campestris* > *P. eryngii* var. *eryngii* ≥ *P. eryngii* var. *ferulae*. Besides, it was also found that these three mushroom species have the highest amount of Fe contents among all studied species. Also, essential elements Co and Cr and non-essential elements Pb, Cd, and Ni concentrations were found under the detection limit (Table 3).

As stated in several studies in the literature, the element contents are related to mushroom species and their ecosystems [35–37]. This study results revealed that there is a close relationship between the amount of essential element contents and their growing region of the examined edible mushroom species.

Table 5 Comparison of element contents (except Co and Cr)* of edible indigenous mushroom samples in terms of both species and collected area using a two-way analysis of variance (ANOVA) (mg kg^{-1} dw).

		Essential element contents					
		Macroelements			Microelements		
		Ca	Na	Mg	Cu	Zn	Fe
Mushroom species	*M. esculenta*	0.563 ^{a}	0.172 ^{a}	1.28 ^{b}	2.77 ^{b}	98 ^{b}	480 ^{a}
	M. vulgaris	0.502 ^{b}	0.135 ^{b}	1.28 ^{b}	2.81 ^{b}	108 ^{a}	436 ^{a}
	A. vaginata	0.382 ^{c}	0.077 ^{c}	1.59 ^{a}	5.17 ^{a}	104 ^{a}	462 ^{a}
	SE	0.009	0.004	0.02	0.06	2	17
	p	$p < 0.01$	$p < 0.01$	$p < 0.01$	$p < 0.01$	$p < 0.05$	$p < 0.05$
Sample regions	Kocakoç village	0.491 ^{a}	0.133 ^{a}	1.44 ^{a}	3.47 ^{a}	102 ^{a}	447 ^{a}
	Karşılar village	0.443 ^{b}	0.138 ^{a}	1.30 ^{b}	3.64 ^{a}	101 ^{a}	441 ^{a}
	Güleç village	0.514 ^{a}	0.113 ^{b}	1.41 ^{a}	3.64 ^{a}	107 ^{a}	490 ^{a}
	SE	0.009	0.004	0.02	0.06	2	17
	p	$p < 0.01$	$p < 0.01$	$p < 0.01$	$p > 0.05$	$p > 0.05$	$p > 0.05$

Different superscript letters within columns indicate significant differences between means ($p < 0.05$)

*Co and Cr concentrations were not detected

SE standard error, $n = 3$

Table 6 Element contents in fruiting body of various mushrooms in literature

Mushroom species	Element content in sporocarp (mg kg^{-1} dw)	References
Pleurotus tuber-regium	Ca ($0.34 \pm 0.01 \times 10^{-1}$), Cu ($0.04 \pm 7.07 \times 10^{-4}$), Fe ($2.40 \pm 7.07 \times 10^{-4}$), Mg ($0.90 \pm 0.01 \times 10^{-1}$), Na ($5.00 \pm 1.41 \times 10^{-4}$), Pb ($0.13 \pm 7.78 \times 10^{-4}$), Zn ($0.13 \pm 2.10 \times 10^{-3}$)	[16]
Termitomyces robustus	Ca ($0.40 \pm 1.40 \times 10^{-4}$), Cu ($0.05 \pm 1.41 \times 10^{-4}$), Fe ($2.24 \pm 0.02 \times 10^{-1}$), Mg ($0.72 \pm 7.78 \times 10^{-4}$), Na ($2.90 \pm 0.01$), Pb ($0.61 \pm 0.03 \times 10^{-1}$), Zn ($0.15 \pm 0.01$)	
Agaricus campestris	Cd (1.74), Pb (1.64)	[38]
Agaricus essettei	Cd (37.8), Pb (4.22)	
Amanita rubescens	Cd (4.24), Pb (0.70)	
Amanita vaginata	Cd (3.96), Pb (1.25)	
Morchella esculenta	Cd (0.55), Pb (0.74)	
Russula cyanoxantha	Cd (1.34), Pb (1.34)	
Russula olivacea	Cd (1.34), Pb (1.23)	
Amanita muscaria	Cd (2.4 ± 0.2), Fe (187 ± 17), Cu (33.6 ± 2.5), Zn (86.6 ± 7.1)	[39]
Amanita pantherina	Cd (1.6 ± 0.1), Fe (985 ± 69), Cu (19.7 ± 1.8), Zn (73.5 ± 6.5)	
Agaricus arvensis	Cd (2.5 ± 0.3), Fe (740 ± 60), Cu (44.8 ± 3.9), Zn (85.2 ± 6.1)	
Agaricus porphyrizon	Cd (1.8 ± 0.1), Fe (549 ± 46), Cu (19.3 ± 1.5), Zn (58.6 ± 4.6)	
Agaricus silvicola	Cd (2.4 ± 0.2), Fe (258 ± 23), Cu (36.8 ± 3.2), Zn (85.3 ± 5.2)	
M. esculenta var. *umbrina*	Cu (21.80 ± 0.18), Co (0.12 ± 0.00), Zn (153.00 ± 0.02), Fe (304 ± 2), Ca (2340 ± 18), Mg (1272 ± 1), Ni (6.40 ± 0.07), Pb (0.70 ± 0.37), Cd (0.72 ± 0.01), Cr (1.21 ± 0.09)	[40]
Morchella esculenta	Cu (ND), Cd (1.1 ± 0.1), Pb (3.5 ± 0.3), Zn (41.4 ± 2.4), Fe (243 ± 19.9), Cr (8.2 ± 0.6), Ni (2.5 ± 0.2)	[41]
Morchella elata	Cu (57.6 ± 4.4), Cd (1.4 ± 0.2), Pb (3.5 ± 0.3), Zn (56.5 ± 4.8), Fe (299 ± 21.5), Cr (22.0 ± 1.6), Ni (7.9 ± 0.5)	
Morchella vulgaris	Cu (32.6 ± 2.2), Cd (0.3 ± 0.03), Pb (2.1 ± 0.2), Zn (42.3 ± 3.9), Fe (174 ± 15.9), Cr (4.2 ± 0.3), Ni (2.8 ± 0.2)	
Morchella deliciosa Fr.	Ca (240 ± 84), Co (0.51 ± 0.22), Cr (5.9 ± 3.6), Cu (55 ± 23), Fe (42 ± 18), Mg (130 ± 35), Na (440 ± 160), Zn (58 ± 36)	[42]
Boletus tomentipes	Cd (0.23 ± 0.05), Cr (4.00 ± 0.43), Cu (13.6 ± 1.2), Fe (121 ± 10), Mg (248 ± 19), Ni (2.44 ± 0.39), Pb (2.60 ± 0.72), Zn (20.3 ± 1.43)	[43]
Morchella esculenta (L.) Pers.	Mg (1.81), Ca (0.85), Na (0.18), Fe (195), Zn (98.9), Cu (62.6)	[44]
Morchella vulgaris (Pers.) Boud.	Mg (1.92), Ca (0.87), Na (0.08), Fe (203), Zn (133), Cu (73.4)	
Agaricus campestris L., var. *campestris*	Mg (9.71), Ca (0.24), Na (0.11), Fe (50.3), Zn (58.6), Cu (35.5)	
Agaricus urinascens Sing. var. *urinascens*	Mg (0.90), Ca (0.35), Na (0.17), Fe (234), Zn (143), Cu (14.3)	
Pleurotus eryngii (DC.) Gillet	Mg (1.38), Ca (0.84), Na (0.03), Fe (355), Zn (43.2), Cu (16.7)	
Pleurotus ostreatus (Jacq.) P. Kumm.	Mg (1.70), Ca (1.26), Na (1.53), Fe (682), Zn (142), Cu (47.1)	
M. vulgaris	Pb (4.2 ± 0.1), Cd (0.89 ± 0.01), Zn (146 ± 0.5), Fe (1714 ± 10), Cu (28 ± 0.3), Cr (7.0 ± 0.03), Ni (4.0 ± 0.1), Co (3.62 ± 0.06)	[45]
Lactarius deliciosus	Fe (216.83 ± 1.38), Zn (123.57 ± 0.30), Cu (15.49 ± 0.12), Ni (1.58 ± 0.01), Cd (0.54 ± 0.00), Pb (0.44 ± 0.30), Cr (1.11 ± 0.01), Co (0.12 ± 0.00)	[46]
Pleurotus platypus	Cd (34.9), Pb (27.10)	[47]
Agaricus bisporus	Cd (29.67), Pb (33.78)	
Agaricus sp.	Cr (13.2), Mn (248), Fe (4906), Co (2.92), Ni (7.16), Cu (32.4), Zn (59.1), Cd (0.18), Pb (5.73)	[48]
T. biformel	Cr (1.32), Mn (18.91), Fe (365), Co (0.17), Ni (1.02), Cu (6.67), Zn (21.3), Cd (0.02), Pb (1.29)	
A. fulva		[49]
Sampling site 1		
Caps	Ca (110 ± 42), Cd (3.3 ± 2.1), Co (0.098 ± 0.061), Cu (72 ± 7), Fe (46 ± 27), Mg (1500 ± 200), Na (860 ± 460), Ni (0.29 ± 0.09), Pb (1.0 ± 0.7), Zn (230 ± 37)	
Stipes	Ca (460 ± 330), Cd (0.98 ± 0.62), Co (0.11 ± 0.08), Cu (32 ± 4), Fe (91 ± 100), Mg (730 ± 1100), Na (2000 ± 900), Ni (0.58 ± 0.26), Pb (< 0.03), Zn (140 ± 30)	
Sampling site 2		
Caps	Cd (0.48 ± 0.02), Co (0.043 ± 0.011), Cr (0.074 ± 0.005), Cu (59 ± 1), Ni (0.20 ± 0.01), Pb (2.9 ± 0.1), Zn (210 ± 5)	
Stipes	Cd (1.8 ± 0.1), Co (0.057 ± 0.002), Cr (0.14 ± 0.01), Cu (17 ± 0), Ni (0.26 ± 0.01), Pb (1.2 ± 0.0), Zn (60 ± 1)	

Table 6 (continued)

Mushroom species	Element content in sporocarp (mg kg^{-1} dw)	References
Sampling site 3		
Caps	Ca (19 ± 21), Cd (11 ± 0), Co (0.028 ± 0.001), Cr (0.064 ± 0.004), Cu (64 ± 2), Fe (24 ± 8), Mg (1100 ± 200), Na (120 ± 110), Ni (0.19 ± 0.01), Pb (5.5 ± 0.1), Zn (180 ± 4)	
Stipes	Ca (140 ± 60), Cd (4.3 ± 0.2), Co (0.050 ± 0.001), Cr (0.095 ± 0.006), Cu (34 ± 1), Fe (43 ± 23), Mg (600 ± 160), Na (280 ± 210), Ni (0.23 ± 0.01), Pb (2.9 ± 0.1), Zn (110 ± 2)	
Chlorophyllum rhacodes	Ca (264 ± 129), Cd (0.49 ± 0.21), Co (0.1 ± 0.03), Cr (0.08 ± 0.03), Cu (85.6 ± 22.9), Fe (33.7 ± 24.5), Mg (903 ± 53), Ni (0.65 ± 0.33), Pb (0.22 ± 0.11), Zn (127 ± 37)	[50]
Suillus grevillea	Ca (199 ± 68), Cd (3.13 ± 2.64), Co (0.57 ± 0.58), Cr (0.16 ± 0.09), Cu (23.3 ± 7), Fe (39.8 ± 15.5), Mg (837 ± 93), Ni (1.91 ± 0.68), Pb (0.15 ± 0.11), Zn (84.5 ± 22.9)	
Imleria badia	Ca (67.9 ± 22.6), Cd (0.26 ± 0.14), Co (0.09 ± 0.09), Cr (0.09 ± 0.07), Cu (33.3 ± 8.7), Fe (23.4 ± 12.7), Mg (690 ± 37), Ni (1.53 ± 1.30), Pb (0.05 ± 0.03), Zn (128 ± 39)	
Xerocomellus chrysenteron	Ca (105 ± 40), Cd (0.07 ± 0.06), Co (0.31 ± 0.08), Cr (0.17 ± 0.16), Cu (28.2 ± 6.7), Fe (16.6 ± 9.2), Mg (827 ± 101), Ni (1.29 ± 0.44), Pb (0.09 ± 0.06), Zn (88.1 ± 23.8)	

ND not detected

All analyzed mushroom species' element composition were compared in terms of both species and collected area. Their results were presented in Tables 4 and 5. It was found out that macroelement contents of four mushroom species and different regions where these are collected were statistically different. Each *P.erygii* var. *eryngii* sample has the highest Ca and Na content collected from Nazımiye. Moreover, this mushroom collected from Pülümür has the highest Mg content then other samples (Table 4).

Microelement amount of mushroom species were determined statistically different. In addition, it was also detected that the microelement concentration of these mushrooms changes correspondingly with their geographical habitat (Table 4). Concentration of Cu and Zn were statistically different in *A. campestris*, *L. gigantea*, *P. eryngii* var. *eryngi*, and *P. eryngii* var. *ferulae* species. However, there is no difference in terms of Cu and Zn concentrations for the each these mushroom species in three regions. Finally, *A. campestris* and *P. eryngii* var. *ferulae* Fe concentrations were the highest collected from Nazımiye and Ovacik.

M. esculenta's, *M. vulgaris*', and *A. vaginata*'s macro- and microelement contents were compared and shown in Table 5. *M. esculenta* which collected from Kocakoç and Güleç village has the highest content in terms of Ca. Moreover, this mushrooms collected from Kocakoç and Karşılar village have the highest Na content. Lastly, the Mg amount of *A. vaginata* was the highest collected from Kocakoç and Güleç village. There is no difference when it was compared in terms of microelement concentration of mushrooms in the collected regions. Fe concentrations in *M. esculenta*, *M. vulgaris*, and *A. vaginata* were statistically similar ($p > 0.05$). When compared the regions, there were no difference in terms of Fe concentrations, too. It was observed that Zn concentrations in *M. vulgaris* and *A. vaginata* were statistically similar when assessed in terms

Table 7 Estimated weekly intake (EWI) and target hazard quotient (THQ) values of elements in case of consumption of mushroom samples

	EWI (mg kg^{-1} body weight/week)							THQ		
Macrofungal species	Ca	Fe	Cu	Mg	Na	Zn		Cu	Fe	Zn
Agaricus campestris	1.8E−4	1.1	1.4E−2	5.3E−3	2.2E−4	2.9E−1	ALC, HLC	5.7E−2, 1.1E−1	2.7E−1, 5.4E−1	1.6E−1, 3.2E−1
Morchella esculenta	1.7E−3	1.4	8.3E−3	3.8 E−3	5.2E−4	2.9E−1	ALC, HLC	3.5E−2, 6.9E−2	3.4E−1, 6.9E−1	1.6E−1, 3.3E−1
Morchella vulgaris	1.5E−3	1.3	8.4E−3	3.8 E−3	4.1E−4	3.2E−1	ALC, HLC	3.5E−2, 7.0E−2	3.1E−1, 6.2E−1	1.8E−1, 3.6E−1
Langermannia gigantea	1.1E−4	6.4E−1	9.7E−3	4.2 E−3	1.6E−4	4.5E−1	ALC, HLC	4.0E−2, 8.1E−2	1.5E−1, 3.0E−1	2.5E−1, 5.0E−1
Amanita vaginata	1.1E−3	1.4	1.6E−2	4.8 E−3	2.3E−4	3.1E−1	ALC, HLC	6.5E−2, 1.3E−1	3.3E−1, 6.0E−1	1.7E−1, 3.5E−1
Pleurotus eryngii var. *eryngii*	4.0E−4	8.3E−1	3.1E−3	7.7 E−3	5.6E−4	2.3E−1	ALC HLC	1.3E−2, 2.6E−2	2.0E−1, 4.0E−1	1.3E−1, 2.6E−1
Pleurotus eryngii var. *ferulae*	3.1E−4	1.0	3.0E−3	6.0 E−3	2.8E−4	2.3E−1	ALC, HLC	1.3E−2, 2.5E−2	2.4E−1, 4.8E−1	1.3E−1, 2.5E−1

of species. On the other hand, these species have the highest Zn content and there was no difference in Zn content among the samples collected from different areas. And, also, *A. vaginata* has the highest Cu content among these three species. In addition, it was detected that the Cu concentrations of the mushroom did not change correspondingly with their collected region.

Element concentrations of mushrooms have been reported from several studies in Table 6. Also, mushrooms were reported to be an accumulator for toxic metals [38, 51]; white rot fungus are especially good bioaccumulators because of the cell walls of these mushrooms. In white rot fungi, the existence of toxic metals is important because they affect the growth of the fungus and the biodegradation process [52]. Also, they constitute a risk for human health in the case of consumption. In the present study, concentration of non-essential elements as Cd, Ni, and Pb were under the detection limit.

Mushroom Consumption Safety

As consumption of wild edible mushroom is a possible source of metal accumulation in humans, there is great interest in estimation of the weekly intakes of elements through mushroom consumption. The EWI (mg/week/person) and THQs of elements through consumption of mushroom species by Turkish people in the Tunceli Province are illustrated in Table 7. The EWI of elements was calculated on the basis of the concentrations measured in mushroom and daily mushroom consumption rate. As can be seen in Table 7, the values of EWI of Ca, Cu, Fe, Mg, Na, and Zn in mushroom in this study are well below their corresponding permissible tolerable weekly intake for 70 kg person values.

Another evaluation factors for risk assessment of metal intake associated with food and foodstuff are values of THQ. In fact, the THQ values express estimated dose of a contaminant and the reference dose ratio. When it is below the reference dose, there will be no appreciable risk. Because the US EPA stated that an index lower than 1 is considered as safe for human health [34, 53]. Table 7 presents the THQ values on the consumption of meals prepared with analyzed mushroom. Here, ALC (average-level consumer) and HLC (high-level consumer) values represent consuming 0.5 g and 1 g of mushroom from a meal, respectively. In the present study, the range of ALC mean values of Cu, Fe, and Zn of analyzed mushroom is from 1.3E−2 to 6.5E−2, from 1.5E−1 to 3.4E−1, and from 1.3E−1 to 2.5E−1, respectively. Similarly, the range of HLC mean values of Cu, Fe, and Zn of analyzed mushroom is from 2.5E−2 to 1.3E−1, from 3.0E−1 to 6.9E−1, and from 2.5E−1 to 5.0E−1, respectively. When consuming habits are considered, it can be mentioned that the weekly intake of mushroom has no risk for average- and high-level mushroom consumption originating from the local area on Tunceli Province people's health. Therefore, consumption of mushroom collected from the areas does not constitute a toxicological risk to human health in terms of Cd, Ni, and Pb level.

Conclusion

Regarding the daily intake and safety aspects, the investigated mushroom species were safe for human consumption, because the EWI for an adult consuming 210 g of mushroom, having 70 kg of body weight, was found to be lower than provisional tolerable weekly intake (PTWI) for Ca, Cu, Fe, Mg, Na, and Zn. Also, the value of THQ was found to be below the RfDo and also less 1 (THQ < 1). When mushrooms are consumed at an average level, the concentrations of the other elements have no health risks. But a continuous monitoring of heavy metals in mushroom consumer in Tunceli Province is necessary to insure the prescribed worldwide limit.

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Conflict of interest The authors declare that they have no conflict of interest.

Compliance with ethical standards

This study does not involve human or animal subjects.

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