ProEnvironment **Original article**
ProEnvironment 17/60 (2024) 260 - 264

Testing Heavy Metal Content of *Boletus* spp. Mushrooms in Relation with Their Origin Soil

MUREȘAN Alexandra-Cristina, Antonia ODAGIU*, Claudia BALINT

University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca, Faculty of Agriculture, Calea Mănăștur 3-5, 400372 Cluj-Napoca, Romania

* Corresponding author e-mail: antonia.odagiu@usamvcluj.ro

Received 4 October 2024; received and revised form 17 October 2024; accepted 9 December 2024; Available online 30 December 2024

Abstract

Mushrooms, particularly those of the Boletus genus, are efficient bioindicators of soil contamination due to their capacity to accumulate heavy metals. However, this raises safety concerns when toxic metals like cadmium (Cd) and silver (Ag) are present. Factors influencing metal uptake include species-specific physiology, environmental conditions, and soil composition.This study investigates the bioaccumulation of heavy metals in *Boletus* sp. mushrooms and their corresponding soils, focusing on the variability, environmental influences, and potential health risks associated with their consumption. The study emphasizes the importance of monitoring heavy metal concentrations in both soil and mushrooms, especially for toxic metals like cadmium and silver. Understanding the soil-mushroom relationship provides valuable insights into bioaccumulation patterns, which are crucial for ensuring food safety and ecological health.

Keywords: bioaccumulation, cluster analysis, environment, interelations.

1. Introduction

Mushrooms, particularly those belonging to the *Boletus* genus, are renowned for their ability to bioaccumulate heavy metals from their environment, making them valuable bioindicators of soil contamination [3]. This characteristic, however, raises concerns regarding their safety for human consumption, especially when they accumulate toxic metals such as cadmium (Cd) sharma [2]. The bioaccumulation process in mushrooms is influenced by various factors, including species-specific physiology, environmental conditions, and soil composition. Studies have shown that certain species can accumulate heavy metals to levels that may pose health risks [2] For instance, research on wild-grown edible mushrooms has highlighted their potential to concentrate elements like zinc (Zn), copper (Cu), and tin (Sn) in their fruiting bodies, with concentrations ranging from 6.98–20.10 mg/kg for Zn, 16.13–144.94 mg/kg for Cu, and 24.36–150.85 mg/kg for Sn [2] The variability in heavy metal content among mushroom species and even within the same species collected from different locations underscores the complexity of factors influencing metal uptake [6, 7]. Environmental pollution, soil pH, organic matter content, and the presence of other elements can significantly affect the levels of heavy metals in mushrooms [1, 4]

Given the potential health implications of consuming mushrooms with elevated heavy metal concentrations, it is crucial to monitor and assess the levels of these metals in both mushrooms and their corresponding soils. Understanding the relationships between soil contamination and mushroom bioaccumulation can inform safe foraging practices and contribute to environmental monitoring efforts [3, 6].

This study aims to analyze the concentrations of various heavy metals in *Boletus sp.* mushrooms and their soils of origin, evaluate the variability and potential health risks associated with their consumption, and explore the correlations between soil and mushroom metal contents to better understand the bioaccumulation patterns in these fungi.

2. Material and Method

Mushrooms and soil samples were collected fromm spontaneous vegetation from Bistrița-Năsăud County. Mushroom samples were air-dried in a laboratory environment at room temperature and then ground into a fine powder using a mechanical grinder. Soil samples were air-dried, sieved through a 2-mm mesh to remove large debris, and homogenized. For metal analysis, both mushroom and soil samples were subjected to uninvasove XRF determination usin an Xray equipment.

Basic descriptive statistics, including mean (X), minimum (Min.), maximum (Max.), standard deviation (s), and coefficient of variation (CV%), were calculated for each metal in both mushroom and soil samples. Simple Pearson correlation coefficients were computed to assess the relationships between metal concentrations in mushrooms and their corresponding soils. Hierarchical cluster analysis was performed using the Ward method and Euclidean distance to identify patterns of similarity among the metals in both matrices. All statistical analyses were conducted using Statistica for windows v.8.0 statistical software.

3. Results and Discussions

The variability and concentration of heavy metals in *Boletus* mushrooms show insights into both the consistency and potential biological or environmental influences on their accumulation. Zinc, an essential micronutrient, exhibits low variability, suggesting stable uptake by the mushrooms across the samples, while manganese shows the highest coefficient of variation, indicating considerable inconsistency, potentially linked to environmental factors or soil composition. The values for toxic metals such as cadmium and silver are of particular concern, as their presence, even in small amounts, can pose health risks if consumed. The inclusion of selenium, which has a dual role as an essential element and a potential toxin at higher concentrations, underscores the importance of evaluating its levels carefully. Chromium, tin, and other metals show moderate variability, suggesting some environmental or biological variability in their uptake (Table 1).

Table 1. Basic statistics for heavy metals from *Boletus* sp. mushrooms, ppm

Heavy metal	N	X	Min.	Max.	s	CV%
Zn	5	35.52	34.00	37.00	1.12	3.15
Cr	5	13.94	12.00	15.20	1.29	9.26
Sn	5	9.14	8.00	10.20	0.95	10.37
Se	5	6.30	5.00	8.00	1.20	19.11
Cd	5	6.04	5.00	7.00	0.74	12.26
Ag	5	4.96	4.00	5.90	0.68	13.72
Mn	5	3.70	2.80	5.00	0.88	23.72

n-number of replicates; X-average; s-standard deviation; CV-coefficient of variation.

The zinc, an essential element, shows low variability with a coefficient of variation of 4.67%, reflecting relatively consistent levels in the soil. Chromium and tin, also present in moderate concentrations, exhibit slightly higher variability, indicating potential differences in soil composition across samples. Selenium displays the highest coefficient of variation at 26.31%, despite its very low mean concentration, suggesting sporadic distribution in the soil and limited bioavailability. Cadmium and silver, though present in small amounts, also show high variability, which may relate to localized contamination or natural heterogeneity in the soil. Manganese, with the highest mean concentration but the lowest variability, indicates a uniformly high presence, which could influence the uptake by mushrooms (Table 2).

All heavy metals identified in soil are under the admitted limits. The Pearson correlation coefficients presented in the table reflect the relationships between heavy metal concentrations in Boletus mushrooms and their soil of origin, providing insights into the bioaccumulation patterns and metal mobility. Zinc shows a strong positive correlation with its concentration in soil (r = 0.79), indicating that soil Zn levels significantly influence its uptake by mushrooms. Similarly, cadmium exhibits an even stronger correlation (r = 0.97), emphasizing its high bioavailability and transfer potential, which is a concern given its toxicity.

Table 2. Basic statistics for heavy metals from origin soil of *Boletus* sp. mushrooms, ppm

Heavy metal	N	X	Min.	Max.	s	CV%
Zn	5	11.78	11.00	12.50	0.55	4.67
Cr	5	21.44	20.00	23.00	1.13	5.25
Sn	5	12.84	12.00	13.70	0.69	5.36
Se	5	0.17	0.10	0.20	0.04	26.31
Cd	5	1.56	1.00	2.00	0.38	24.66
Ag	5	1.52	1.00	2.00	0.36	23.90
Mn	5	308.20	300.00	315.00	5.76	1.87

n-number of replicates; X-average; s-standard deviation; CV-coefficient of variation.

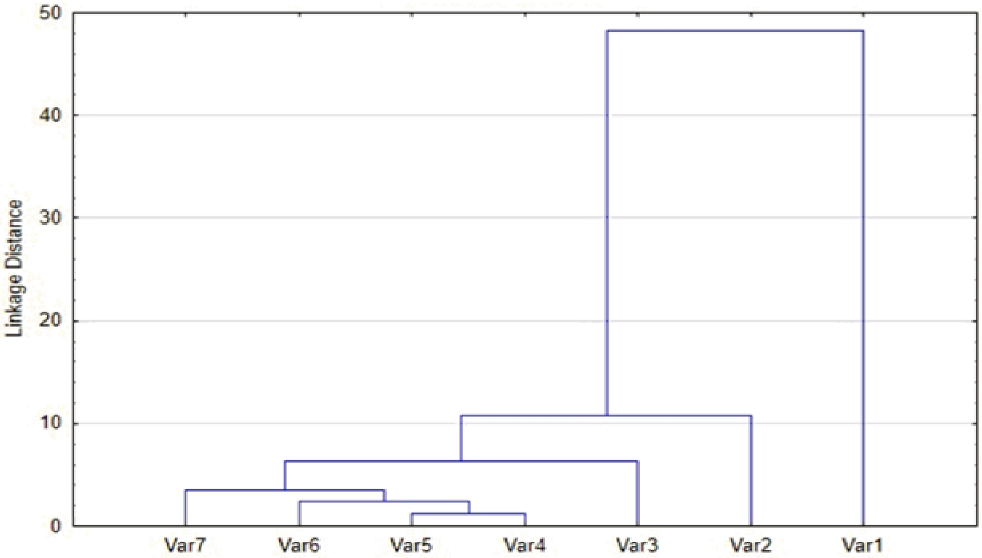
Silver also shows a robust correlation (r = 0.95), suggesting a consistent relationship between soil and mushroom concentrations. Conversely, selenium displays weaker and sometimes negative correlations with other metals, suggesting complex uptake mechanisms or limited bioavailability in soil. Chromium and manganese show weaker correlations with their counterparts in mushrooms, particularly manganese (r = 0.52), indicating that other environmental or biological factors may influence their levels in mushrooms beyond soil concentrations.

Overall, the correlations highlight significant variabilities in the transfer dynamics of different metals from soil to mushrooms. Strong correlations for toxic metals like cadmium and silver underline the importance of soil monitoring in areas where mushrooms are harvested for consumption (Table 3).

Table 3. The simple Pearson correlations between heavy metals identified in *Boletus* sp. mushroom and soil of origin

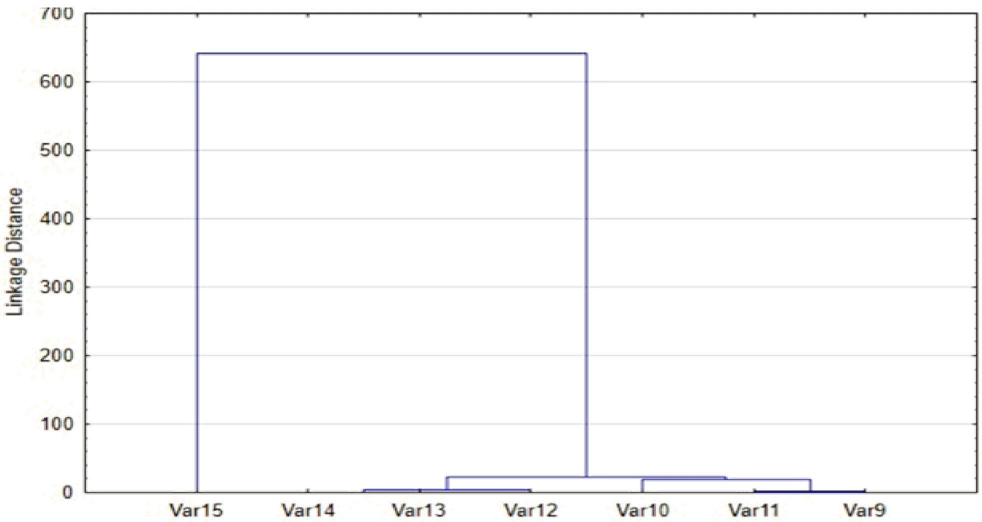
Heavy metal	Zn	Cr	Sn	Se	Cd	Ag	Mn
Zn	0.79	0.13	0.73	-0.11	0.87	0.67	0.31
Cr	0.96	0.24	0.88	-0.04	0.99	0.88	0.34
Sn	0.94	-0.02	0.88	0.12	0.97	0.82	0.09
Se	0.96	-0.05	0.90	0.21	0.95	0.87	0.01
Cd	0.97	0.27	0.83	-0.11	0.96	0.98	0.30
Ag	0.91	0.48	0.82	-0.05	0.85	0.95	0.44
Mn	0.52	-0.20	0.58	0.16	0.64	0.28	0.02

Cluster analysis was performed for heavy metals identified in both mushrooms and their origin soil (Figures 1 and 2). The dendrogram presented in Figure 1 shows the results of a cluster analysis applied to heavy metals identified in *Boletus* mushrooms, grouping them based on the similarity of their concentrations and relationships(Fig. 1). Zinc (Zn) and Tin (Sn) are closely grouped, suggesting they exhibit similar bioaccumulation patterns in the mushrooms, likely due to comparable soil mobility or similar physiological pathways in the fungal tissues. Chromium (Cr) and Cadmium (Cd) form another cluster, indicating a shared tendency in their uptake and distribution, possibly influenced by their availability in the soil or their chemical behavior. Silver (Ag) is grouped slightly farther from Cr and Cd, suggesting moderate similarity in uptake but with some distinct differences that may stem from its unique mobility or bioavailability. Selenium (Se) appears to cluster separately from most other metals, reflecting its distinct behavior. Its uptake is likely influenced by its low concentration in the soil and specific biological pathways in the mushrooms. Manganese (Mn) forms a standalone branch in the dendrogram, highlighting its unique behavior. This separation may result from its significantly higher concentrations compared to other metals and its essential role in fungal metabolism, which could lead to differing uptake dynamics. The clustering pattern suggests distinct groupings of heavy metals, likely to reflect their shared environmental or biological pathways, such as uptake mechanisms or soil availability. Metals that are closer on the dendrogram exhibit stronger similarities in their behavior, while those further apart are more distinct. The hierarchical structure provides insight into how these metals interact or are distributed in the mushrooms, potentially driven by factors like their chemical properties, mobility in the soil, or the mushrooms' physiological preferences. The largest cluster encompasses metals with the most significant differences in accumulation patterns, indicating variability in their uptake and environmental presence.



Var1- Zn, Var2 – Cr, Var3 – Sn, Var4 – Se, Var5 – Cd, Var6 – Ag, Var7 – Mn.

Figure 1. The cluster analysis applied to heavy metals identified in *Boletus* sp. mushrooms



Var9- Zn, Var10 – Cr, Var11 – Sn, Var12 – Se, Var13– Cd, Var14 – Ag, Var15 – Mn.

Figure 2. The cluster analysis applied to heavy metals identified in origin soil of *Boletus* sp. mushrooms

According to the dendrogram (Fig. 2), zinc (Zn) and tin (Sn) appear closely linked in the clustering, suggesting a strong similarity in their distribution within the soil, potentially reflecting similar sources or mobility. Chromium (Cr) and cadmium (Cd) are grouped together, indicating that these metals may share environmental pathways or be influenced by similar soil conditions. Silver (Ag) is situated closer to this group, showing some overlap in behavior, though it retains a distinct cluster due to its unique properties or distribution mechanisms in the soil. Selenium (Se) forms a distinct cluster, reflecting its lower concentration and specific behavior in soil environments, possibly due to limited mobility or unique chemical interactions. Manganese (Mn) is notably separated from other metals, likely due to its significantly higher concentration in the soil and its essential role in biological systems, which may lead to distinct dynamics in its distribution.

4. Conclusions

The results of our study indicate distinct patterns in metal accumulation and distribution, reflecting both environmental influences and biological uptake mechanisms. Zinc, an essential micronutrient, exhibits low variability in both mushrooms and soil, suggesting consistent uptake and distribution, linked to its stable presence in the environment. In contrast, manganese, despite being essential, shows the highest variability in mushrooms, emphasizing the potential influence of environmental heterogeneity or selective biological uptake. Toxic metals such as cadmium and silver are present in small but concerning amounts, with high bioavailability demonstrated by strong correlations between soil and mushroom concentrations. Selenium stands out due to its dual role as an essential element and potential toxin, showing unique variability and clustering patterns that reflect its limited mobility and specific physiological pathways.

Cluster analyses provide further insights, with zinc and tin consistently grouped together, suggesting similar behaviors in both mushrooms and soil. Chromium and cadmium form another distinct cluster, indicating shared environmental or chemical pathways. Manganese is consistently separated in both dendrograms, likely due to its significantly higher concentrations and unique role in biological systems. These patterns underline the importance of understanding heavy metal dynamics in the soil-mushroom system. Strong correlations for toxic metals like cadmium and silver emphasize the need for continuous monitoring of soil quality in regions where Boletus sp. mushrooms are harvested for consumption. The clustering results highlight distinct groupings of metals, reflecting shared environmental and biological pathways. Our study also emphasizes the critical role of soil composition in determining heavy metal content in mushrooms, with important implications for ecological health and food safety.

References

[1] Bucurica I.A., I.D. Dulama, C. Radulescu, A.L. Banica, S.G. Stanescu, 2024, Heavy Metals and Associated Risks of Wild Edible Mushrooms Consumption: Transfer Factor, Carcinogenic Risk, and Health Risk Index, Journal of Fungi, 10(12), 844, https://doi.org/10.3390/jof10120844.

[2] Isildak O., I. Turkekul, M. Elmastas, H.Y. Aboul-Enein, 2007, Bioaccumulation of Heavy Metals in Some Wild-Grown Edible Mushrooms', Analytical Letters, 40(6), 1099 – 1116.

[3] Mocek-Płóciniak A., J. Mencel, W. Zakrzewski, S. Roszkowski, 2023, Phytoremediation as an Effective Remedy, for Removing Trace Elements from Ecosystems, Plants, 12, 1653.

[4] Niedzielski P., M. Siwulski, M. Szostek A. Budka, S. Budzyńska, M. Krzesłowska, P.l Kalač, M. Mleczek, 2024, Mineral composition variation in *Boletales* mushrooms - indication of soil properties and taxonomic influence, Environ Sci Pollut Res, 31, 41137–41154.

[5] Sharma N., K.K. Sodhi, M. Kumar, D.K. Singh, 2020, Heavy metals eco-toxicity with major concern to chromium and recent advancement in remediation technologies, Environ. Nanotechnol. Monit. Manag., 15, 100388.

[6] Swislowski P., M. Rajfur, 2018, Mushrooms as biomonitors of heavy metals contamination in forest areas, Ecol. Chem. Eng., S., 25, 557–568.

[7] Zocher A.L., D. Kraemer, G. Merschel, M. Bau, 2018, Distribution of major and trace elements in the bolete Mushroom *Suillus luteus* and the bioavailability of rare earth elements, Chem. Geol., 483, 491–500.

ProEnvironment
Available online at: http://journals.usamvcluj.ro/index.php/promediu