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Study on the mineral content of *Agaricus bisporus*

Simion ALDA[1], Despina Maria BORDEAN[2], Claudia SIRBULESCU[3], Laura RĂDULESCU[4], Mihaela LĂCĂTUȘ[2], Patricia TARKANYI[2], Marcel DANCI[1], Teodor CRISTEA[1], Dumitru SPĂTARIUC[4], Liana ALDA[4*]

[1]University of Life Sciences "King Mihai I" from Timișoara, Faculty of Engineering and Applied Technologies, Department of Forestry, e-mail: simion_alda@usvt.ro, marceldanci@usvt.ro, teodorcristea@usvt.ro
[2]University of Life Sciences "King Michael I" from Timisoara, Faculty of Food Engineering, Department of Food Control and Expertise, e-mail: despina_bordean@gmail.com, mihaela.lacatus.fia@usvt.com, patricia-cristina.tarkanyi.fia@usvt.ro
[3]University of Life Sciences "King Mihai I" from Timișoara, Faculty of Management and Rural Tourism, Department of Economy and Firm Financing, e-mail: claudiasirbulescu@usvt.ro
[4]University of Life Sciences "King Mihai I" from Timișoara, Faculty of Food Engineering, Department of Food Science, e-mail: lianaalda@usvt.ro, laura.radulescu@usvt.ro,spatariucdumitru_sfia@usvt.ro

*Corresponding author: lianaalda@usvt.ro

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Abstract
Agaricus bisporus, the most widely consumed mushroom species globally, was the focus of this study. Mushrooms are widely recognized as important sources of dietary fiber, proteins, carbohydrates, lipids, vitamins and minerals. However, they also have the capacity to accumulate toxic metals such as lead, cadmium, and mercury. Due to the presence of polysaccharides, peptides, essential amino acids, glycoproteins, nucleosides, triterpenoids, fatty acids and lectins, *Agaricus bisporus* has been reported to have antioxidant, antimicrobial, anti-hyper-cholesterolemic, antidiabetic, antihypertensive and hepatoprotective activities. We aimed to determine the mineral profile of *Agaricus bisporus* samples available on the Romanian market using X-ray fluorescence (XRF) spectrometry. The results regarding the mushrooms samples minerals content (mg/kg dry weight), obtained by using X-ray fluorescence spectrometry, are ranging between: K (31443-50579), Ca (1229-4838), Fe (337-580), Mn (105-130), Zn (113-312), Cu (25-86), Se (0-11). The analysis of obtained data was made using Excel, Statistica 11 and MVSP programs. These findings are consistent with previous studies indicating that potassium is the predominant mineral in mushrooms, followed by calcium. Therefore, regular mushroom consumption can contribute to meeting the daily requirements for these essential elements, alongside other nutritional benefits.

Keywords: X-ray spectrometry with fluorescence, health benefits, nutritional value

Introduction

Mushrooms are rich in nutrients such as proteins, carbohydrates, lipids, fibers, vitamins and minerals. The most abundant vitamin in *Agaricus* is niacin, riboflavin, vitamin B1, vitamin B3, L-ascorbic acid, α-tocopherol and folic acid [2,7].

Mushrooms have high moisture percentage depending on many factors such as growth and storage conditions [8]**.** Reis et al. (2012) found the following values for *Agaricus bisporus* samples: moisture (91–92 g/100 g) and energy (29–31 kcal/100 g) [13].

Due to the presence of polysaccharides, peptides, essential amino acids, glycoproteins, nucleosides, triterpenoids, fatty acids and lectins, *Agaricus bisporus* has been reported to have antioxidant, antimicrobial, antihypercholesterolemic, antidiabetic, antihypertensive and hepatoprotective activities [8,14,15].

Although the mineral content varies depending on the soil in which they are grown, mushrooms are an excellent source of minerals such as potassium, selenium, zinc, iron, copper and phosphorus [1]. An example with high selenium content is *Boletus edulis* (~ 20 µg Se/g dw with maximum up to 70 µg/g dw) [6]. These elements are essential for the health of the immune system, fertility, bones, circulation and cognitive functions [1].

In this study we aimed to determine the mineral profile of *Agaricus bisporus* samples available on the Romanian market using X-ray fluorescence spectrometry.

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Material and Method

Seven commercial samples of *Agaricus bisporus* mushrooms were collected from major Romanian supermarket chains. The mushrooms originated from Romanian producers, as indicated on the product labels. Samples were purchased from different retail locations in Timișoara**,** ensuring changeability across batches and producers. Immediately after collection, mushrooms were transported to the laboratory under refrigerated conditions and analysed to determine their mineral profile. The obtained mineral values were further compared with data available in the scientific literature to assess similarities, differences, and potential nutritional implications.

The moisture [%] of the samples were determined using a Sartorius thermobalance as described by Bordean, 2013 [4].

The method used to determine the mineral content is X-ray fluorescence (XRF), with a portable Hitachi XMET8000. Each element detected in the analysed mushroom's samples produces a set of characteristic fluorescent X-rays that is unique for that specific mineral. This technique is non-destructive and requires minimal sample preparation: the samples are ground, dried to constant weight and placed in small polyethylene bags. Each sample was analysed three times.

The analysis of obtained data was made using Excel, Statistica 11 and MVSP programs. Statistica 11 performed the cluster calculations, but we used a second program because it offers better visualization tools, and we prefer its graphical quality for publication.

Results and Discussion

The samples moisture content was ranged between 90.3%÷91% being in accord with literature data [13].

The results regarding the *Agaricus bisporus* minerals content (mg/kg dry weight), obtained by using X-ray fluorescence (XRF) spectrometry and the scientific literature data are presented in Table 1.

These findings are consistent with previous studies indicating that potassium is the predominant mineral in mushrooms, followed by calcium. Comparing our results with scientific literature data we observe that the results are similar, but the calcium content detected by X-ray fluorescence spectrometry, was found to be higher than the values obtained by classical method (atomic absorption spectrometry) [1,3,5,9,10,11,12]. This aspect must be analysed in future researches.

Table 1. Mineral concentration comparison of *Agaricus bisporus*

Element (mg/kg DW)	LabD	LitD [1,3,5,9,10,11,12]
K	31443÷50579	35000÷45200
Ca	1229÷4838	460÷990
Fe	337÷580	200÷400
Mn	105÷130	56.2÷91.1
Zn	113÷312	54.81÷112.75
Cu	25÷86	25÷125
Se	0÷11	0.053÷5

Legend: LabD-Laboratory data;LitD- Literature data; K-Potassium; Ca-Calcium; Fe-Iron;Mn-Manganese; Zn-Zinc; Cu-Copper; Se-Selenium;

The Principal Components Analysis (PCA) of mushroom mineral profiles is presented in Figure 1. In this figure, PC1 separates nutrient-rich versus nutrient poor mushrooms. So, as a result of principal components analysis, we obtained that:

- the samples 1M, 2M, 4M and 6M are mineral-dense;
- the samples 5M, 7M are moderately mineralized;
- the sample 3M is mineral-poor.

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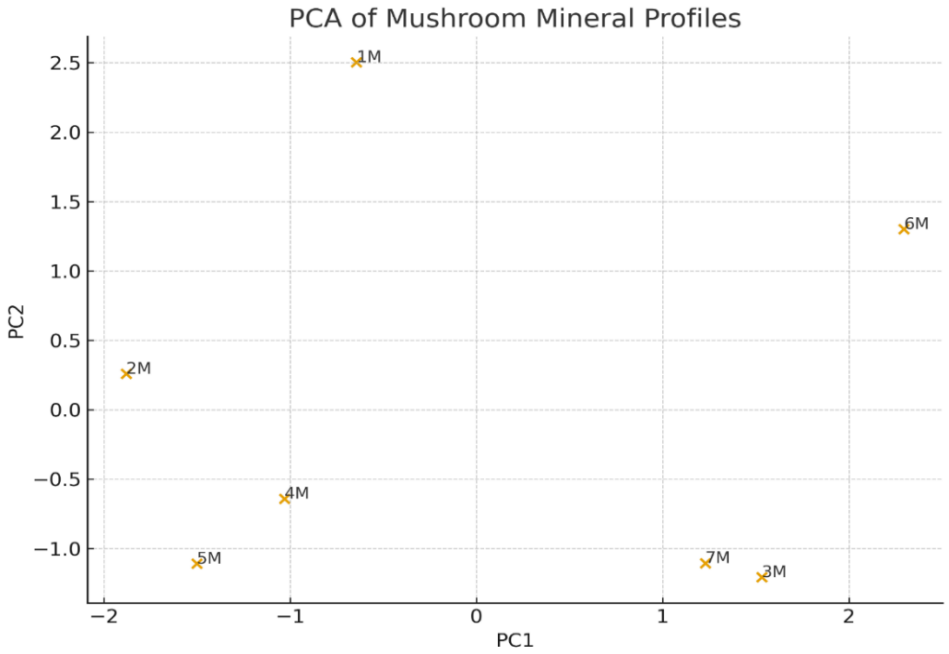

Figure 1. The Principal Components Analysis (PCA) of Mushroom Mineral profiles
Legend: 1M -7 M= mushroom samples

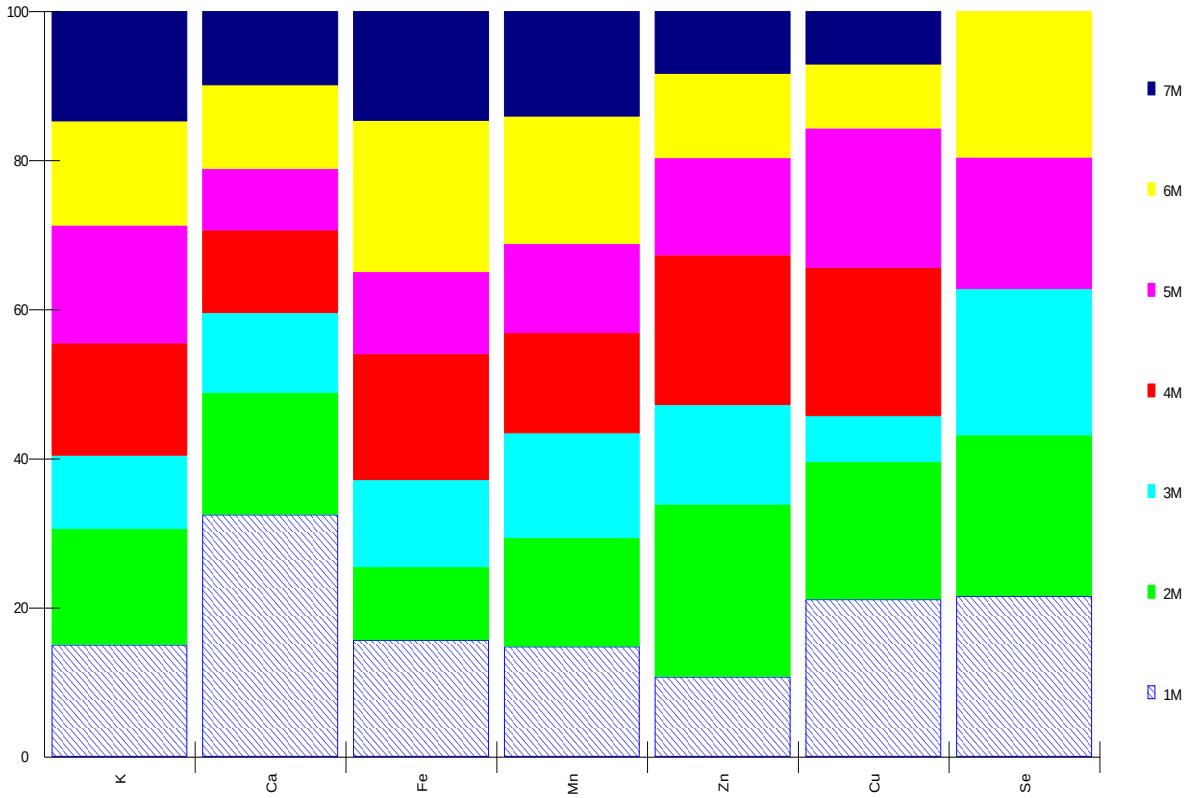

Figure 2. Fingerprint based on mineral content (%)
Legend: 1M-7M= mushrooms samples

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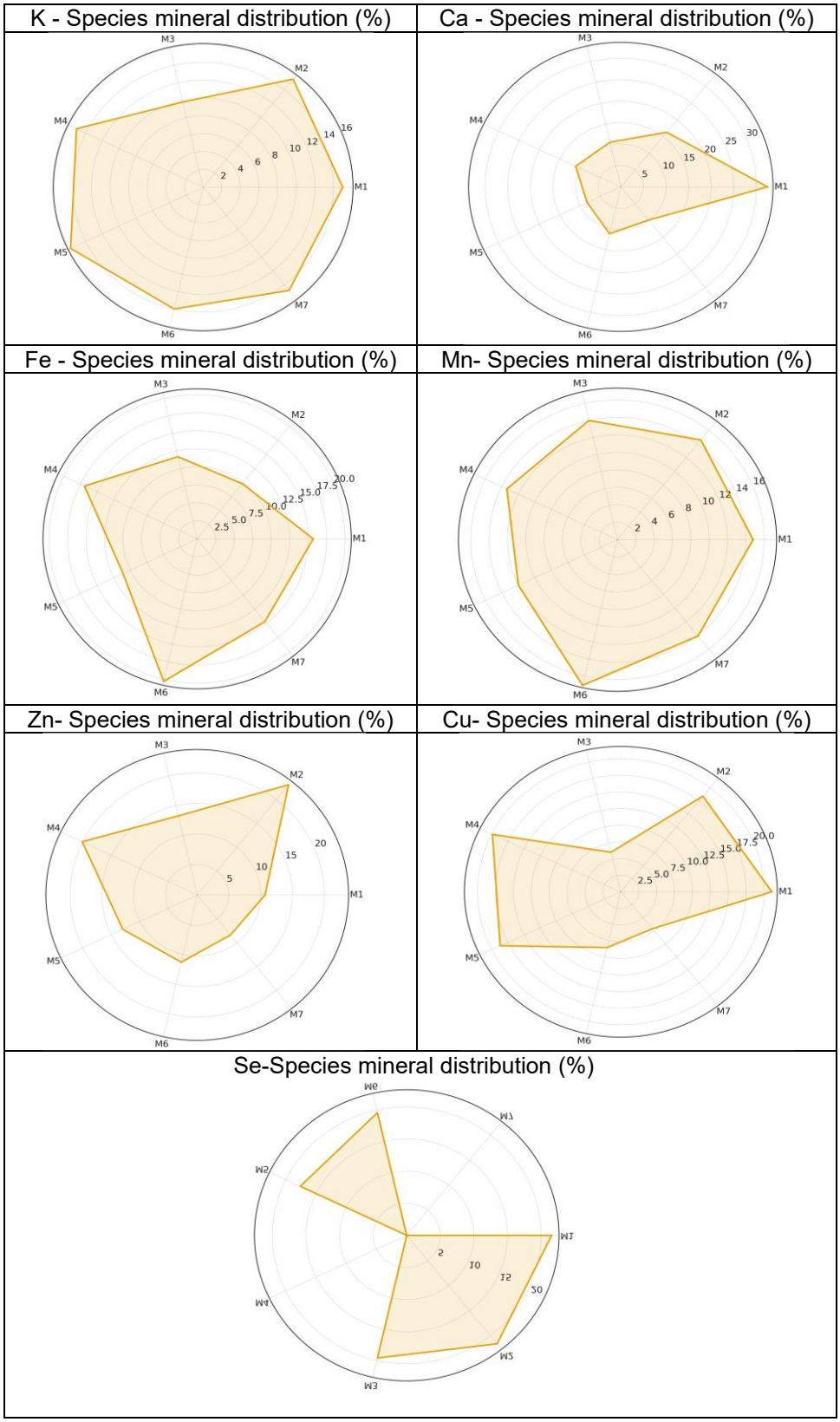

Figure 3. Radar plots of mineral distribution in edible mushrooms samples

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Analysing the fingerprint based on mineral content (%)(Figure 2) and radar plots of mineral distribution in edible mushrooms samples (Figure 3), we obtained that the total amount of every mineral in the analyzed samples is distributed in %, in the following descending order:

- potassium: 5M>2M>4M>1M>7M>6M>3M;
- calcium: 1M>2M>6M>4M>7M>5M>3M;
- iron: 6M>4M>1M>7M>3M>5M>2M;
- manganese: 6M>1M>2M>7M>3M>4M>5M;
- zinc: 2M>4M>3M>5M>6M>1M>7M;
- copper: 1M>4M>5M>2M>6M>7M>3M;
- selenium: 1M(=2M)>3M(=6M)>5M>4M(=7M);

Figure 2 and Figure 3 present complementary views of the mineral data.

Figure 2 shows the contribution of each sample to each mineral (element-focused), while Figure 3 shows the overall mineral profile for each sample (sample-focused).

Using both improves clarity and provides a more complete understanding of distribution patterns.

In Figure 4 is shown the cluster analysis representation which was created with MVSP Software, using the “nearest neighbor” method.

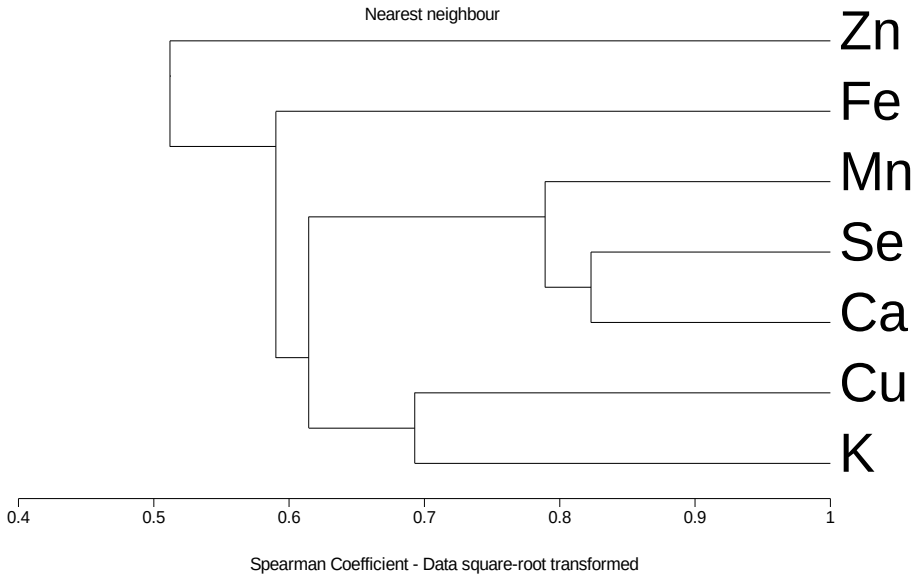

Figure 4. The cluster analyses of Zn, Fe, Mn, Se, Ca, Cu and K identified in mushroom samples

The analysis based on Spearman coefficient (data square-root transformed) using nearest neighbor equation revealed the presence of main minerals groups based on the similarities between them:

- Zn, Fe**,** cluster together → strong similarity;
- Se, Ca, cluster together → moderate similarity;
- Cu and K → most distinct (the highest variation between mushroom samples).

The clusters in Figure 4 (Zn–Fe, Se–Ca, and the distinct Cu and K) directly reproduce the visual patterns detected in Figures 2 and 3. The branch lengths specify the degree of similarity, confirming the relationships recommended by the graphical fingerprints.

Conclusions

Due to the presence of polysaccharides, peptides, essential amino acids, glycoproteins, nucleosides, triterpenoids, fatty acids and lectins, *Agaricus bisporus* has been reported to have antioxidant, antimicrobial, antihypercholesterolemic, antidiabetic, antihypertensive and hepatoprotective activities.

Although the mineral composition of the samples differs from one sample to another, our results reveals that the mushrooms are rich in potassium, calcium, iron, manganese, zinc, copper and some sample contains selenium. Therefore, regular mushroom consumption can contribute to meeting the daily requirements for these essential elements, alongside other nutritional benefits.

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