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# COMPARATIVE NUTRITIONAL ANALYSIS OF FRESH AND CANNED *AGARICUS BISPORUS*

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***Abstract***

*Mushrooms, although they have a low energy value, contain antioxidants, vitamins, and minerals and are an important source of proteins and fibers. The aim of this study was to analyze the nutritional value of fresh and canned Agaricus bisporus using XRF analysis, completed with data from different scientific articles and databases. Fresh Agaricus bisporus generally have a slight nutritional advantage over the canned form, offering lower sodium content and higher levels of certain vitamins. Some protein content may decrease during canning. It is known that during thermal processing, some minerals (such as potassium, phosphorus, copper, selenium, and zinc) leach into the canning liquid (brine), while others may increase if added during processing (e.g., sodium, calcium). Our results show that, in canned mushrooms, compared with the fresh ones, the potassium content decreases and the calcium content increases. Canned Agaricus bisporus have a longer shelf life and provide a better source of fiber and certain minerals, but they also contain significantly higher amounts of sodium, which might be a concern for individuals with cardiovascular conditions.*

***Key words****: XRF, minerals, thermal processing, health implications.*

## INTRODUCTION

*Agaricus bisporus,* being of high nutritional value, ranks among the most and consumed mushrooms in the world (El-Sebaaly, 2021).

In accordance with the USDA Food Database, 100 g of fresh *Agaricus bisporus* contain 2.89 g protein, 0.37 g fat, 0.83 g ash, 1.7 g fiber, 0.75 beta-glucan, 0.065 mg thiamin, 0.444 mg riboflavin, 0.077 mg vitamin B6, 9.07 µg biotin, 3.88 mg niacin, 35 µg folate, 0.9 IU vitamin D, 4.3 mg glutathione, 56 mg ergosterol, and the following amino acids: 0.477 g tryptophan, 1.88 g leucine, 1.15 g isoleucine, 1.41 g threonine, 1.7 g lysine, 0.37 g methionine, 1.12 g phenylalanine, 2.48 g valine, 0.655 g histidine, and 4 mg ergothioneine (USDA Food Databes).

The main component in *Agaricus bisporus* mushrooms (champignons) that is indigestible in the raw state but becomes more digestible through thermal (heat) treatment, is chitin. The canning process is the treatment that provides long product shelf-life **(**Cağlarirmak et al., 2001).

During thermal processing, some minerals (such as potassium, phosphorus, copper, selenium, and zinc) leach into the canning liquid (brine), while others may increase if added during processing (e.g., sodium, calcium).

Caglarirmark et al. (2001) show that levels of vitamins for freshly *Agaricus bisporus* and canned and stored products (for six month) are: B1 (0.094 mg/100 g - 0.028 mg/100 g), B2 (0.396 mg/100 g - 0.176 mg/100 g), vitamin C(5.72 mg/100 g - 2.31 mg/100 g), folic acid (0.078 mg/100 g - 0.020 mg/100 g), pantothenic acid (2.29 mg/100 g - 1.22 mg/100 g) and niacin (5.35 mg/100 g - 4.29 mg/100 g). In the same study, the values registered for another parameters for fresh and canned *Agaricus* are: protein (3.43-2.24%), fat (0.35- 0.30%), total carbohydrate (3.78-3.84%) and ash (0.71-1.60%) (Cağlarirmak et al., 2001).

Falandysz et al. (2013), report the following values for sodium (mg/kg dry weight) for *A. bisporus:*

- 700 mg/kg dry weight (fresh caps);
- 860 mg/kg dry weight (fresh and whole);
- 16.000-25.000 mg/kg dry weight (conserved).

So, do canned *Agaricus bisporus* provide a better source of fiber and certain minerals? However, they also contain significantly higher

amounts of sodium, which might be a concern for individuals with cardiovascular conditions (Falandysz et al., 2013).

After storage of canned mushrooms, significant decreases in asparagine, alanine, methionine, and glutamine had been registered. Although the canning and storage process of mushrooms caused decreases in the levels of amino acids, the protein quality was not significantly lower than in fresh *Agaricus bisporus* (Jaworska et al., 2012).

In the preservation of mushrooms, mineral levels undergo changes caused mainly by the processes of scalding (blanching) and diffusion into the coating liquid.

According to the mushroom species, age, and the kind of substrate, different mineral contents were reported (Sinha et al., 2019).

The use of calcium-rich substrates (e.g., in casing soil or supplemented with calcium chloride/sulfate) can lead to higher levels in mushrooms (Tang et al., 2023).

Calcium chloride applied to irrigation of *Agaricus bisporus* crops increases the calcium content of the mushrooms and improves their post-harvest quality and shelf life (Miklus et al., 1996).

Shbeeb et al. found 3769 $mgkg^{-1}$ DW of calcium in whole canned *Agaricus bisporus* (Shbeeb et al., 2020).

Although several potentially toxic elements (Cu, Zn, Fe, Ni) are essential for the human body, they can cause allergic reactions, fatal neurological disorders, nephrotic effects, and hemolysis when ingested at high concentrations (Sinha et al., 2019).

Taking this into consideration, several countries and commissions, such as the USEPA, WHO, and FAO/WHO Codex, have specified maximum limits of potentially toxic elements in mushrooms (Siric et al., 2020; USEPA). Potentially toxic elements are non-degradable and can accumulate, posing high risks to human health when present in high levels in the food chain (Kumar et al., 2022).

Maximum limits for heavy metals such as cadmium, lead, and mercury in mushrooms are strictly regulated in the European Union (including Romania) to ensure food safety by Regulation (EU) 2023/915.

The content of micronutrients varies depending on whether the canned mushrooms are whole or cut. Dawadi et al., 2022 in their research on *Agaricus bisporus* reached the conclusion that micronutrient contents are higher in whole canned than in cut canned and the fresh type. (Dawadi et al.; 2022).

In their study, Dobrinas et al. found higher values for chromium, copper, and iron in canned mushrooms than in fresh mushrooms (Dobrinas et al., 2013).

## MATERIALS AND METHODS

Six commercial samples of fresh *Agaricus bisporus* and six samples of sliced and canned *Agaricus bisporus* mushrooms were collected from Romanian supermarket chains (Timișoara). The origin of the samples is Romania.

Immediately after collection, fresh and canned mushrooms were transported to the laboratory under refrigerated conditions.

We used a portable Hitachi XMET8000 device to determine the minerals by X-ray fluorescence, and we analyzed each sample in triplicate.

The moisture of the samples was determined using a Sartorius thermobalance.

The sterilized containers have the following ingredients: champignon mushrooms (*Agaricus bisporus*), water, salt, citric acid (acidity corrector) and ascorbic acid (antioxidant).

The samples are as follows:

- 1F - 6F = fresh mushroom samples,
- 7C - 10 C = canned in glass packaging,
- 11C - 12C = canned in metal packaging.

The nutritional parameters of canned mushrooms (100g), as indicated on the labels, are as follows: energetic value (15-20 kcal), fat (0.3-0.5 g), carbohydrates (0.2-0.5 g), fibre (2-2.8 g), protein (2.07-2.8 g) and salt (0.45-1 g).

For data analysis, we used PAST version 2.17c and MVSP version 3.22 softwares, in order to explore multivariate relationships among samples of the same mushroom variety in fresh and canned forms. Descriptive statistics (mean ± standard deviation) were first calculated, followed by multivariate techniques including principal component analysis (PCA) and hierarchical cluster analysis (HCA).

PCA was applied to diminish the dimensionality of the dataset and to categorize the main sources of variability in mineral composition among

fresh and processed (canned) mushrooms. PCA has the role of converting correlated variables into a smaller number of orthogonal components, permitting the visualization of patterns, separation between sample types, and identification of the variables contributing most to these differences. HCA was performed to complement PCA by grouping samples based on their general similarity. The combined use of PCA and HCA is widely recommended in food composition studies because it increases the robustness and interpretability of multivariate patterns (Matwijczuk et al., 2022).

## RESULTS AND DISCUSSIONS

The moisture content in fresh samples ranged between 87% ÷ 90.2% and in canned samples between 90.6% ÷ 91.8%, respectively.

Tables 1 and 2 show the intervals of the analyzed mineral contents for fresh and canned *Agaricus bisporus* detected in the laboratory using the XRF method or reported in the scientific literature.

Our results are similar to literature data, except calcium content in fresh *Agaricus bisporus,* which showed higher values (1946.4 mg/kg dry weight) compared with 1472.66 mg/kg dry weight reported by other researchers (Popescu et al., 2017).

We note that, for each element, there are large variations, a fact explained by the importance of the nature of the substrate and by the fact that *Agaricus bisporus* is a very good accumulator of heavy metals.

Table 1. Mineral's content of fresh *Agaricus bisporus* (mg/kg dry weight)

| Element | Literature Data Ranges | Fresh mushroom samples (1F to 6F) |
|---|---|---|
| K | 31029÷45200 (Shbeeb et al., 2020) (Bernas et al., 2006) | 35747÷ 40463 |
| Ca | 360÷1472.66 (Shbeeb et al., 2020) (Popescu et al., 2017) | 983.2 ÷1946.4 |
| Fe | 49.9÷1596 (Vetter et al., 2003) (Gebrelibanos et al., 2016) | 202.2 ÷ 417.6 |
| Zn | 46.8÷124.84 (Gebrelibanos et al., 2016) (Sinha et al., 2019) | 67.8 ÷ 187.2 |
| Cu | 7.4÷125 (Gebrelibanos et al., 2016) (Muszyńska et al., 2017) | 17.4 ÷51.6 |

Table 2. Mineral's content of canned *Agaricus bisporus* (mg/kg dry weight)

| Element | Literature Data Ranges | *Agaricus bisporus* canned in glass and metal packaging (7C to 12C) |
|---|---|---|
| K | 1287÷35396 (Vetter et al., 2003) | 1366.4÷24303 |
| Ca | 2563÷2937 (Vetter et al., 2003) (Shbeeb et al.,2020) | 2172÷4132 |
| Fe | 116÷485 (Vetter et al., 2003) (Shbeeb et al.,2020) | 186.6÷250.2 |
| Zn | 60.1 (Vetter et al., 2003) | 40.2÷115.8 |
| Cu | 15.4 ÷165.2 (Vetter et al., 2003) (Dobrinas et al., 2013) | 30.6÷58.2 |

In Figure 1 we observe that in preserved mushrooms potassium recorded lower values than in fresh mushrooms, while calcium recorded higher values, a fact confirmed by other researchers (Tables 1 and 2).

The highest calcium values for calcium were registered in samples 8C and 11C and the lowest in samples 2F-6F.

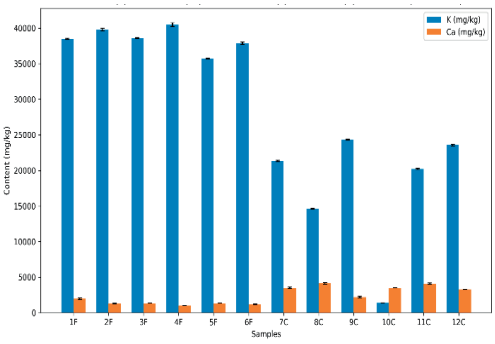


Figure 1. K and Ca contents in fresh (F) and canned (C) samples (Mean±SD) (mg/kg dry weight)
Legend: 1F-6F=fresh mushroom samples; 7C-10C= canned mushrooms in glass packaging; 11C-12 C= canned mushrooms in metal packaging

Analyzing Figure 2, we observe that the iron content in fresh mushrooms varies greatly from one sample to another. The highest iron values were recorded in fresh mushroom samples 1F, 3F and 5F and the lowest in following canned samples: 7C, 8C and 10C.

Regarding the zinc content, we observe that the highest values were found in fresh mushrooms samples 2F and 3F.

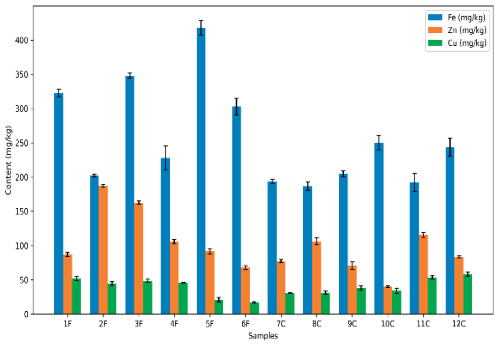


Figure 2. Iron, zinc and copper contents in fresh (F) and canned (C) (Mean±SD) samples (mg/kg dry weight) Legend: 1F-6F=fresh mushroom samples; 7C-10C= canned mushrooms in glass packaging; 11C-12 C= canned mushrooms in metal packaging.

The copper content varies as follows: in fresh mushroom samples between 17.4 mg/kg DW (6F) and 51.6 mg/kg DW (1F), in samples preserved in glass packaging between 30.6 mg/kg DW and 38.4 mg/kg DW and in samples preserved in metal packaging recorded the highest values, of 53.44 mg/kg DW (11C) and 58.2 mg/kg DW (12C). The copper level in mushrooms preserved in metal packaging may increase due to the presence of citric acid and ascorbic acid in the coating liquid, since these acids, especially in humid environments and during sterilization processes, may favor the migration (or leaching) of copper from the metal packaging into the product.

The hierarchical cluster analysis was performed using the paired group algorithm (UPGMA – Unweighted Pair Group Method with Arithmetic Mean) in combination with the Euclidean distance as the similarity measure. Before analysis, the data were standardized (z-score normalization) to eliminate the influence of differing variable scales, due to the high sensitivity of Euclidean distance to magnitude differences. To assess the quality of the clustering, the Cophenetic Correlation Coefficient (CCC) was calculated, yielding a value of 0.90**.** A CCC value of 0.90 indicates an exceptional level of representation, signifying that the dendrogram offers a highly reliable approximation of the underlying data structure, with minimal distortion of the original similarities. Therefore, the clustering results can be considered robust and appropriate for interpretation in terms of grouping patterns and processing effects (fresh vs. canned samples) (Figure 3). The Cluster Analysis reveals two clusters, separating the fresh samples, colored in green, from the canned samples, colored in red. The sample 10C appears separately from both groups due to the presence of low potassium and zinc contents.

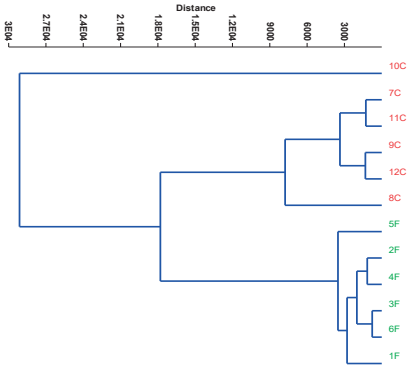


Figure 3. Cluster analysis legend: 1F-6F=fresh mushroom samples; 7C-10C= canned mushroomC= canned mushrooms in metal packaging

The fresh samples (1F–6F) are grouped more closely, indicating higher compositional similarity compared with canned samples.

In contrast, canned samples showed more distinct sub-clustering, with pairs such as 7C-11C and 9C-12C exhibiting high similarity, while samples such as 10C and 8C presented greater divergence. These patterns suggest that processing conditions and preservation media contribute to increased variability among canned mushroom products.

Applying PCA using a correlation matrix, a Jolliffe cut-off of 0.7 as well as the broken stick method (Figure 4) shows that we can take in consideration two principal components, PC1 and PC2 (Figures 5 and 6).

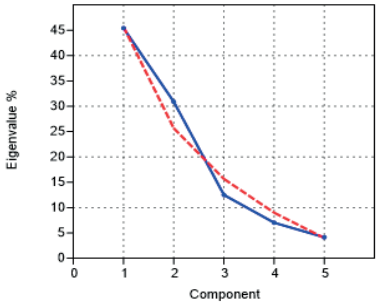


Figure 4. Broken stick

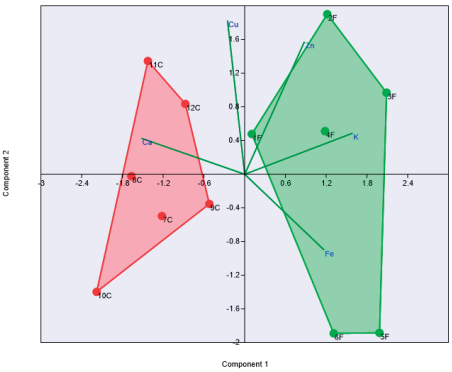


Figure 5. Graphical representation of data on principal components PC1 and PC2

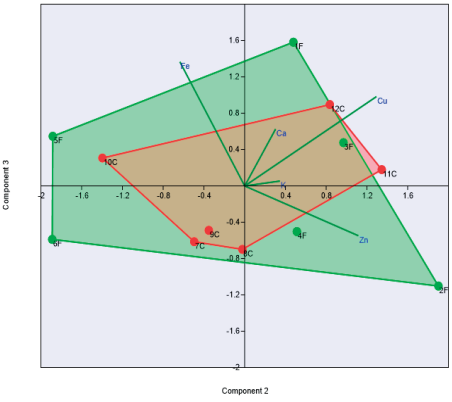


Figure 6. Graphical representation of data on principal components PC2 and PC3

The area of fresh samples is higher compared with that of canned samples, but at the same time it shows that both graphics present properties of the same mushroom assortment, with the difference that one is processed and the other is not processed.

Potassium, iron, and zinc are higher in the fresh samples, while calcium and copper show the highest values in the canned samples, as proven by PC1 and PC2. This indicates that Component 1 primarily reflects the effect of processing**,** separating fresh mushrooms from canned products**.** The results confirm the cluster analysis**,** where processing significantly alters the chemical profile of mushrooms. Fresh samples exhibited greater dispersion, reflecting natural variability, while canned mushrooms formed a more compact cluster, likely due to standardized processing conditions.

Table 3. The Partial Linear Correlation

| 0 | K | Ca | Fe | Zn | Cu |
|---|---|---|---|---|---|
| K | 0 | 0.10581 | 0.32241 | 0.24036 | 0.53427 |
| Ca | -0.57431 | 0 | **0.77448** | **0.86133** | 0.23775 |
| Fe | 0.37328 | -0.11186 | 0 | 0.49778 | **0.70394** |
| Zn | 0.43631 | -0.068337 | -0.26087 | 0 | 0.40252 |
| Cu | 0.23981 | 0.43849 | -0.148 | 0.31915 | 0 |

The Partial Linear Correlation (Table 3) shows:

- strong positive correlations between calcium and zinc, and between calcium and iron;
- a high correlation between copper and iron;
- a moderate positive correlation between potassium and copper ;
- moderate positive correlations between zinc and copper, and between iron and zinc;
- a moderate negative correlation between calcium and potassium;

While many studies report high concentrations of both copper and iron together (as they are essential nutrients for mushrooms), the exact Pearson correlation coefficient varies significantly by species and location. The positive or negative linear correlations are highly dependent on the growth medium (substrate) composition. (Shbeeb et al., 2020; Vetter et al., 2003).

## CONCLUSIONS

*Agaricus bisporus* mushrooms have a high nutritional value, regardless of whether they are fresh or canned.

Our results are similar to the literature data, except calcium content in fresh *Agaricus bisporus, which* registered higher values.

Our results show that, in canned mushrooms, compared with fresh ones, the potassium content decreases and the calcium content increases. Iron and zinc register decreases, and the copper content shows a slight increase. These conclusions are confirmed by other researchers (literature data from Tables 1 and 2).

The samples canned in metal packaging registered the highest values of copper content. Because minerals (especially zinc) can be found in large quantities in the canned liquid, discarding it reduces the final nutritional value of the meal.

Accordingly, canned *Agaricus bisporus* provide a better source of fiber and certain minerals, but they also contain significantly higher amounts of sodium, which might be a concern for individuals with cardiovascular conditions.

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