BEHIND THE LABEL - CHEMICAL AND BIOACTIVE CHARACTERIZATION OF WHITE BUTTON AND OYSTER MUSHROOMS FROM RETAIL SOURCE

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ABSTRACT

This study aimed to comparatively analyze the chemical composition and antioxidant capacity of white button mushrooms (*Agaricus bisporus*) and oyster mushrooms (*Pleurotus ostreatus*) from the Croatian market. The two species differed significantly in total titratable acidity, with oyster mushrooms showing slightly higher values (0.147%), while dry matter content (average 8.61%) and pH (5.2) did not differ significantly. Significant differences were observed in ascorbic acid content, with oyster mushrooms (11.60 mg·100 g^{-1} fresh weight) containing significantly more than white button mushrooms. In contrast, white button mushrooms exhibited significantly higher total phenolic content (91.85 mg GAE·100 g^{-1} fresh weight) and non-flavonoid phenols (35.28 mg GAE·100 g^{-1} fresh weight), whereas total flavonoid content was higher in oyster mushrooms (61.31 mg GAE·100 g^{-1} fresh weight). Antioxidant capacity was assessed using ABTS and FRAP assays. FRAP measurements indicated significantly higher antioxidant capacity in white button mushrooms, whereas no significant differences were observed with the ABTS assay. Overall, these results highlight species-specific differences in the chemical composition and bioactive properties of white button and oyster mushrooms, providing valuable information regarding their nutritional and functional characteristics.

Keywords: cultivated mushrooms, chemical composition, ascorbic acid content, total phenol content, antioxidant capacity

INTRODUCTION

Mushrooms have long fascinated scientists and researchers, and they continue to be intensively studied in the context of their chemical composition, nutritional and functional potential, and ultimately their benefits for human health. The number of mushroom species described to date varies considerably depending on the literature source. Thus, Senila et al. (2024) report that more than 2,000 mushroom species have been described so far, of which approximately 350 are classified as edible, while only about 25 are commercially available. In contrast, Procházka et al. (2021) report significantly higher numbers, indicating that approximately 10,000 mushroom species have been described in Europe, with around 700 edible species reported in the literature for the Central European region, and approximately 70 species considered commercially available.

From a nutritional perspective, mushrooms are increasingly attracting attention due to their high protein content, with reported values ranging from 20 to 25 g·100 g^{-1} dry weight (Nasiri et al., 2012; Ayimbila and Keawsompong, 2023; Senila et al., 2024). The major nutritional value of mushroom proteins lies in their high biological value, reflected in the presence of all essential amino acids (Yu et al., 2020), as well as their high digestibility, which ranges from 60 to 70% (González et al., 2021). Despite the increasing interest in mushrooms as a protein source and as a high-quality alternative to proteins of animal origin, mushrooms are also highly distinctive due to their content of numerous antioxidants, particularly polyphenolic compounds with emphasis on flavonoids (Abdelshafy et al., 2022; Tel-Çayan et al., 2025). Owing to this composition, mushrooms have been shown to exhibit a wide range of biological activities, including anti-inflammatory,

antitumour, antibacterial, antioxidant, and antiviral effects (Palacios et al., 2011; Silva et al., 2024; Yu et al., 2025). In addition, several studies report their potential antiallergic, antiatherogenic, hypoglycaemic, and haematological effects (Palacios et al., 2011; Shamim et al., 2023; Yu et al., 2025). Beyond these functions, bioactive compounds derived from mushrooms are increasingly recognized for their role in modulating immune responses and their potential application in immunomodulatory strategies.

When considering mushrooms available on the market, button mushrooms (*Agaricus bisporus*) and oyster mushrooms (*Pleurotus ostreatus*) are among the most well-known and widely consumed species (Kumari et al., 2025; Gupta et al., 2025). These mushrooms are also popular in cultivation, as their production technologies are well established, standardized, and relatively uniform. Although both species are widely recognized for their nutritional value, differences in their chemical composition may arise due to species-specific characteristics and production conditions. Therefore, the aim of this study was to perform a comparative analysis of the chemical composition of white button mushrooms (*Agaricus bisporus*) and oyster mushrooms (*Pleurotus ostreatus*) available on the Croatian market.

MATERIALS AND METHODS

Mushroom material

For the purposes of the study, two mushroom species were purchased from a retail market in Croatia: white button mushrooms (*Agaricus bisporus*) and oyster mushrooms (*Pleurotus ostreatus*). Both species were purchased on the same day (22 January 2026). The mushrooms were packaged in polyethylene containers covered with plastic film. According to the product labels, information on the producer was available, indicating that both mushroom species were of Croatian origin and cultivated in the Republic of Croatia.

In the retail market, the mushrooms were stored in refrigerated display cabinets at temperatures ranging from +2 to +7 °C. Immediately after purchase, the samples were transported to the Laboratory for the Analysis of the Quality of Plant-Based Agricultural Products at the Department of Sustainable Technologies and Renewable Energy Sources, Faculty of Agriculture, University of Zagreb.

Upon arrival at the laboratory, the mushrooms were gently wiped and cleaned of visible soil residues using a soft brush and paper towels. After cleaning, the mushrooms were chopped using a stainless-steel knife. For chemical analyses, a total sample mass of 250 g was used for each mushroom species. The prepared samples were immediately subjected to chemical analyses.

Chemical analysis

The following chemical analyses were performed to determine selected chemical properties of the mushroom samples: i) determination of dry matter, pH value and total acidity; total dry matter content (DM, %) was determined by oven drying at 105 °C to constant mass, according to the AOAC (1995) method. The pH value was measured using a digital pH meter (Mettler Toledo, SevenMulti S40, Switzerland), while total titratable acidity (TA, %) was determined by potentiometric titration with NaOH in accordance with AOAC (1995); ii) ascorbic acid content (AsA, mg/100 g fresh weight, fw) was determined by titration with 2,6-dichlorophenolindophenol (DCPIP) according to the AOAC (2002) method. The AsA content was calculated using equation (1):

$$AsA\ (mg/100\ g) = \frac{V \times F}{m} \times 100$$

where V represents the volume of DCPIP solution (ml), F is the DCPIP factor (mg·ml^{-1}), and m is the sample mass in the filtrate (g); iii) total phenolic compounds (TPC), including total non-flavonoid compounds (TNFC) and total flavonoid compounds (TFC), were determined spectrophotometrically using a UV–Vis spectrophotometer (Shimadzu UV-1900i, Kyoto, Japan). The analyses were carried out using the Folin–

Ciocalteu reagent according to the method described by Ough and Amerine (1988); iv) the antioxidant capacity of the samples was assessed using radical scavenging and reducing power assays. Specifically, the ABTS [2,2′-azinobis(3-ethylbenzothiazoline-6-sulfonic acid)] assay and the FRAP (ferric reducing antioxidant power) assay were applied following the procedure previously described by Miller et al. (1993) and Repajić et al. (2020). Both methods are based on spectrophotometric measurements and provide an evaluation of the ability of bioactive compounds present in the samples to neutralize free radicals or reduce ferric ions. Antioxidant capacity was quantified using Trolox as a reference standard, and the results were expressed as mmol Trolox equivalents (TE) per liter of sample.

Statistical analysis

Statistical analysis was performed using the SAS software package, version 9.3 (SAS Institute Inc., Cary, NC, USA). The experimental data were subjected to one-way analysis of variance (ANOVA) to evaluate the effect of mushroom species on the analyzed parameters. All laboratory analyses were conducted in triplicate. When significant differences were detected, mean values were compared using Duncan's multiple range test at a significance level of 1% ($p \leq 0.01$). Results are presented as mean values, and differences between samples are indicated in tables by different superscript letters, denoting statistically homogeneous groups.

RESULTS AND DISCUSSION

Some of the analyzed chemical properties of button and oyster mushrooms obtained from the market are presented in Table 1.

Table 1: Dry matter content (%), total titratable acidity (%) and pH-value of white button and oyster mushroom from market

	DM [%] ($\bar{x}$ ± SD)	**TA [%] ($\bar{x}$ ± SD)**	**pH ($\bar{x}$ ± SD)**
White button mushroom	8.35 ± 0.13^{a}	0.11 ± 0.01^{b}	5.20 ± 0.01^{a}
Oyster mushroom	8.86 ± 0.17^{a}	0.15 ± 0.03^{a}	5.20 ± 0.01^{a}
ANOVA	$p = 0.0153$	$p \leq 0.0001$	NS

Notes: Different superscript letters within the same column indicate statistically significant differences ($p < 0.01$); NS – not significant

The two analyzed mushroom species differed significantly only in total titratable acidity (TA), while the other two analyzed properties, total dry matter content (DM) and pH, did not differ significantly between the species. The average DM content was 8.61%, which is in agreement with literature data. Nasiri et al. (2012) reported an average moisture content of 91.5% for button mushrooms, while Djamila and Bahariawan (2020) reported moisture content for oyster mushrooms in the range of 90–95%. Both the results of the present study and literature data confirm the high-water content of button and oyster mushrooms, suggesting that this type of fresh material is highly sensitive to handling, prone to damage, difficult to store over extended periods, and very sensitive in terms of preserving its nutritional composition. This is one of the reasons why mushrooms on the market are typically sold as packaged products with a relatively short shelf life. Generally, fresh edible mushrooms are considered a low-acid food of a weak acidic to neutral pH, with an average value typically ranging between 6.0 and 6.7 (Jiang et al., 2018). According to the pH value, total titrable acidity (TA) of selected two mushroom species, is low with, in range from 0.107–0.147%. The obtained value is in accordance with other literature data which report an average TA value from 0.1–0.5% (expressed as citric acid) (Kumar and Barman Ray, 2016; Çelik and Öncül, 2024). Also, button and oyster mushroom from this study significantly differ in the TA, while slightly higher TA value was obtauend for oyster mushroom. From the available literature data, button mushrooms generally have slightly lower TA, approx. 0.31–0.48% (Kumar and Barman Ray, 2016), compared to the oyster mushrooms (approx. 0.41–0.62%)

(Senuri et al., 2025). The TA and pH values of edible mushrooms are strongly influenced by cultivation conditions, particularly the substrate used, as its composition affects organic acid metabolism and nutrient availability during growth. Both button and oyster mushrooms are commonly cultivated on slightly acidic substrates (Muswati et al., 2021), a characteristic that is often reflected in the pH and titratable acidity of the harvested fruiting bodies and may partially explain the observed pH and TA values in the analyzed samples.

Table 2: Bioactive compounds content of white button and oyster mushroom from market

	AsA [mg·100 g^{-1} fresh weight] ($\bar{x}$ ± SD)	**TPC [mg GAE·100 g^{-1} fresh weight] ($\bar{x}$ ± SD)**	**TNFC [mg GAE·100 g^{-1} fresh weight] ($\bar{x}$ ± SD)**	**TFC [mg GAE·100 g^{-1} fresh weight] ($\bar{x}$ ± SD)**
White button mushroom	9.69 ± 0.20^{b}	91.85 ± 0.91^{a}	35.28 ± 0.54^{a}	56.57 ± 0.39^{b}
Oyster mushroom	11.60 ± 0.20^{a}	64.32 ± 0.59^{b}	3.04 ± 0.52^{b}	61.31 ± 0.92^{a}
ANOVA	$p \leq 0.0001$	$p \leq 0.0001$	$p \leq 0.0001$	$p = 0.0012$

Notes: Different superscript letters within the same column indicate statistically significant differences ($p < 0.01$). AsA – ascorbic acid content; TPC – total phenolic content; TNFC – total non-flavonoid content; TFC – total flavonoid content

Although fungi are heterotrophic and cannot fix carbon like plants, they can accumulate ascorbic acid (AsA) by metabolizing glucose and other sugars derived from lignocellulosic substrates during saprophytic growth (Mishra et al., 2025). In this study, button and oyster mushrooms differed significantly in AsA content, with oyster mushrooms showing approximately 20% higher AsA levels compared to button mushrooms. These results are in agreement with literature data, which also report that oyster mushrooms generally contain higher amounts of ascorbic acid (vitamin C) than white button mushrooms. For instance, literature indicates that the AsA content of oyster mushrooms ranges from 5.38 to 41.28 mg·100 g^{-1} fresh weight (Kaushal et al., 2025), whereas Goyal et al. (2020) report approximately 2.25 mg·100 g^{-1} fresh weight of AsA for button mushrooms. As previously mentioned, in addition to other bioactive compounds, mushrooms are particularly characterized by their polyphenolic compounds, which significantly contribute to antioxidant activity and, consequently, to numerous potential functional and biological properties. According to a comparative analysis of cultivated white button mushrooms and oyster mushrooms reported by Silva et al. (2024), white button mushrooms exhibited a significantly higher total phenolic content (TPC) compared to oyster mushrooms. In general, the same study reported that *Agaricus* varieties (white and brown) showed the highest TPC among the examined mushroom species (*Lentinula edodes, Pleurotus ostreatus,* and *Hericium erinaceus*), which is also consistent with the findings of Reis et al. (2012). The results of the present study (Table 2) are in agreement with these observations, whereby white button mushrooms exhibited approximately 42% higher TPC compared to oyster mushrooms. However, it should be emphasized that Silva et al. (2024) reported a TPC value of 46.2 mg GAE·100 g^{-1} fresh weight for white button mushrooms, which is considerably lower than the value obtained in the present study. Furthermore, other phenolic compounds analyzed in this research, particularly non-flavonoid compounds (TNFC), were also found to be significantly higher in white button mushrooms compared to oyster mushrooms, whereas, conversely, total flavonoid content (TFC) was higher in oyster mushrooms than in white button mushrooms. The higher total phenolic content observed in cultivated white button mushrooms in the present study, compared to literature data, may be attributed to specific cultivation and environmental conditions. Phenolic compounds in mushrooms are considered secondary metabolites involved in stress response mechanisms, and their biosynthesis may be enhanced under abiotic stress conditions (Fogarasi et al., 2024). Variations in substrate composition, microclimatic factors, and the developmental stage at harvest may have induced oxidative stress, thereby stimulating the accumulation of phenolic compounds.

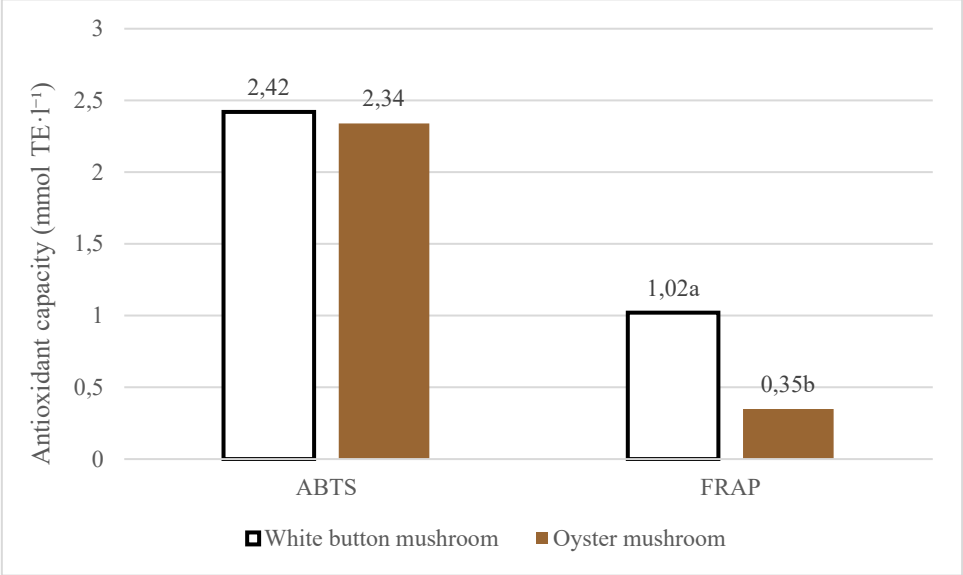

Figure 1: Antioxidant capacity (mmol TE·l^{-1}) of white button and oyster mushrooms measured by ABTS and FRAP assays

In Figure 1 are presented results of antioxidant capacity of analyzed mushroom species. According to the obtained results from ABTS assay, no significant differences of antioxidant capacity were determined between white button and oyster mushroom with approximate amount of 2.35 mmol TE·l^{-1}, while significant differences were determined in FRAP assay. According to the FRAP assay, white button mushroom have significantly higher antioxidant capacity compared to the oyster mushroom. These results are consistent with analyzed bioactive compounds, since white button mushrooms exhibited significantly higher TPC content which significantly contribute to antioxidant capacity compared to the oyster mushroom. Furthermore, these results are in agreement with Silva et al. (2024), who also reported a significantly higher antioxidant capacity of white button mushrooms by the FRAP assay compared to oyster mushrooms, whereas, conversely, the ABTS assay indicated a significantly higher antioxidant capacity for oyster mushrooms. This discrepancy can be explained by the specificity and sensitivity of the antioxidant assays. In general, polyphenolic compounds (flavonoids and non-flavonoids) are hydrophilic molecules that act by donating electrons or hydrogen atoms, which underlies the mechanisms of both methods. Consequently, samples with higher total phenols (TPC), flavonoids (TFC), and non-flavonoid phenols (TNFC) exhibit higher reducing capacity measured by FRAP, which primarily detects hydrophilic compounds. The ABTS method, on the other hand, is sensitive to both hydrophilic and lipophilic compounds. Mushrooms also contain fatty acids and other lipophilic constituents (Mishra et al., 2025) that contribute to the ABTS-measured antioxidant capacity, explaining the observed differences between the two assays. It should also be emphasized that besides used assay, obtained results of antioxidant capacity for white button and oyster mushroom are generally high confirming high potential of this species in numerous functional and health benefits (Fogarasi et al., 2024; Silva et al., 2024).

CONCLUSION

This study demonstrated species-specific differences in the chemical composition and antioxidant properties of white button mushrooms (*Agaricus bisporus*) and oyster mushrooms (*Pleurotus ostreatus*) available on the Croatian market. The two species differed significantly in total titratable acidity, with oyster mushrooms showing slightly higher values, while dry matter content and pH were similar. Oyster mushrooms contained significantly higher ascorbic acid, whereas white button mushrooms exhibited significantly higher total phenolic content and non-flavonoid phenols, with total flavonoid content being higher in oyster mushrooms. Antioxidant capacity measured by FRAP was significantly higher in white button mushrooms, whereas

no significant differences were observed with the ABTS assay. These results reflect the distinct bioactive compound profiles of the two species. Overall, the findings provide valuable information on the nutritional composition and functional properties of white button and oyster mushrooms, which may be useful for consumers, food producers, and further research on edible, cultivated mushrooms.

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