ISSN impresa 0717-3644
ISSN online 0718-221X

Maderas. Ciencia y tecnología 2024 (26): 20, 1-10

DOI: 10.22320/s0718221x/2024.20

# TOTAL PHENOLICS, TANNIN CONTENTS, ANTIOXIDANT PROPERTIES, PROTEIN AND SENSORY ANALYSIS OF *Pleurotus ostreatus*, *Pleurotus citrinopileatus* AND *Pleurotus djamor* CULTIVATED ON DIFFERENT SAWDUSTS

***Ceyhun Kılıç*[1,♠]**

https://orcid.org/0000-0003-4722-0177

***Ayşenur Gürgen*[2]**

https://orcid.org/0000-0002-2263-7323

***Sibel Yıldız*[3]**

https://orcid.org/0000-0001-8448-4628

***Zehra Can*[4]**

https://orcid.org/0000-0002-7156-4941

***Atiye Değirmenci*[5]**

https://orcid.org/0000-0003-4767-2667

## ABSTRACT

In mushroom cultivation, it is important to be aware of the impact of the growing substrate. This study investigated the cultivation of various oyster mushrooms, including *Pleurotus ostreatus*, *Pleurotus citrinopileatus*, and *Pleurotus djamor*, on different types of wood sawdust. Total phenolic content, condensed tannins, antioxidant activity by ferric reducing antioxidant power assay, protein and sensory evaluations were performed in cultivated oyster mushrooms. Wood sawdust of *Fagus orientalis* (oriental beech)*, Alnus glutinosa* (alder)*, Castanea sativa* (chestnut), and *Juglans regia* (walnut) were used as substrate for studied mushroom type, separately. Because champignon (*Agaricus bisporus*) was the most consumed mushroom, it was used as control sample. Methanolic extracts of dried mushrooms were used to measure bioactive characteristics. *Pleurotus ostreatus* samples cultivated in *Alnus glutinosa* (alder) sawdust substrate had the highest antioxidant activity. The lowest antioxidant activity values were found in *Pleurotus djamor* cultivated in *Juglans regia* (walnut) wood sawdust substrate. The highest protein content was measured in *Agaricus bisporus* as 13,84 %. The other highest protein concentration was found in *Pleurotus ostreatus* cultivated in *Alnus glutinosa* (alder) sawdust substrate, at 13,75 %. The lowest protein concentration belonged to *Pleurotus citrinopileatus* cultivated in *Fagus orientalis* (oriental beech) sawdust substrate as 9,86 %. While *Agaricus bisporus* and *Pleurotus ostreatus* had the highest overall appreciation score, *Pleurotus citrinopileatus* had the lowest. It has been observed that the substrate content has an important impact on chemical and sensory properties of the oyster mushrooms. This study provides knowledge on the chemical and sensory characteristics of three different *Pleurotus* mushroom species cultivated on different composts.

**Keywords:** Chemical properties, condensed tannins, *Pleurotus ostreatus, Pleurotus citrinopileatus*, *Pleurotus djamor,* mushrooms, protein content, sensory analysis.

[1]General Directorate of Forestry, Trabzon, Türkiye.
[2]Osmaniye Korkut Ata University. Faculty of Engineering. Industrial Engineering. Osmaniye, Türkiye.
[3]Karadeniz Technical University. Faculty of Forestry. Forest Industrial Engineering. Trabzon, Türkiye.
[4]Bayburt University. Faculty of Applied Sciences. Emergency Aid and Disaster Management. Bayburt, Türkiye.
[5]Karadeniz Technical University. Maçka Vocational School. Food Processing Department. Trabzon, Türkiye.
♠Corresponding author: ceyhunkilic@ogm.gov.tr
Received: 16.01.2023 Accepted: 05.01.2024

## INTRODUCTION

Global food production is currently confronted with a number of challenges, including rising population, the impact of climate change on agricultural productivity, the clear environmental impact of the agricultural-food system, and the uneven economic situation generated by global financing (Ray *et al.* 2019). As cardiovascular diseases, type 2 diabetes mellitus, and cancer become more widespread, there is a growing need to develop new dietary techniques and foodstuffs that can help prevent these diseases (Masri *et al.* 2017). So, in this context, *Pleurotus* spp. mushrooms can provide a valuable contribution as they can support growth and the production of value-added foods by very few uses of biological resources (Sekan *et al.* 2019, Xiao *et al.* 2022). Edible mushrooms may be an important alternative to conventional protein sources as they contain high amounts of protein (González *et al.* 2021). *P. ostreatus,* in particular, is an edible mushroom with a wealth of functional compounds (Espinosa-Páez *et al.* 2021), such as, high protein, zinc, chitin, fiber, and vitamins (C, D, and B complex) and amino acids (Sassine *et al.* 2021). *Pleurotus* spp. with around 40 known species is also known as one of the most valuable non-wood forest products (Raman *et al.* 2021). It has an increasing growth rate in the global marketplace compared to other forest products (Keča *et al.* 2017). It usually grows spontaneously on the bottom roots of heartwoods. For centuries, those mushroom species have served mankind as a source of health and food (Manzi *et al.* 1999). However, as in other natural products, the growing period of oyster mushrooms is limited by certain parameters. Therefore, the production of such a valuable non-wood forest product is increased by imitating the growing conditions and ensuring that it is grown in an artificial production environment (Josiane *et al.* 2018). It has been reported that there are some differences in terms of bioactive compounds content of cultivated mushrooms depending on growing substrate and growing conditions (Aghajani *et al.* 2018). Studies reported that the antioxidant properties, protein contents, and sensory attributes of oyster mushrooms, which can be easily grown using various lignocellulosic wastes, vary according to the compost they grow on (Yıldız *et al.* 2017a).

The production parameters of some *Pleurotus* species (*P. ostreatus*, *P. citrinopileatus*, and *P. djamor*) in different substrates composed different wooden sawdust by beech oriental beech (*Fagus orientalis* Lipsky), alder (*Alnus glutinosa* subsp. barbata (C.A.Mey.) Yalt.), chestnut (*Castanea sativa* Mill.), and walnut (*Juglans regia* L.) was investigated. The effect of compost material on chemical properties, total phenolic content, condensed tannin content, antioxidant activity, and protein concentration of mushrooms was revealed. Since *Pleurotus* species are considered to be new and different for Turkey, sensory analysis was also performed to evaluate consumer perception.

## MATERIALS AND METHODS

Preparation and cultivation of the oyster mushrooms were carried out in the Laboratories of the Eastern Karadeniz Forestry Research Institute and Forest Biology and Wood Protection Technology Department at Karadeniz Technical University. Extraction, total phenolic content, condensed tannin content, antioxidant activity assays of the cultivated oyster mushrooms were performed in the chemistry laboratories of the same university. Protein content determination was studied in the Central Research Laboratories at Giresun University. Sensory analysis was carried out by panelists from the Food Processing Department of Karadeniz Technical University.

### Material

The mycelium of *P. ostreatus*, *P. citrinopileatus* and *P. djamor* were purchased from commercial firms in Turkey (Gürsu Mushroom, Bursa). Waste wood sawdusts were obtained from the workshop of the Furniture Department at Karadeniz Technical University. As a reference to these mushrooms (control), champignon mushroom (*Agaricus bisporus*) was also included in the study. The champignon mushroom was not produced within the scope of the study and was purchased from a commercial company (Afacan Mushroom, Trabzon).

### Compost content, preparation, inoculation and harvesting

Wood sawdust was sterilized in an autoclave at 121 °C for 30 minutes to inactive detrimental organisms. After the cooling period (25 °C), the composts were prepared with 96 % wood sawdust, 3 % mycelium, and 1 % calcitic lime for pH balance in 29 cm x 45 cm bags - 4 as 1 kg for each variation as seen Figure 1 (Estrada *et al.* 2009, Yılmaz *et al.* 2017b).

**Figure 1:** Compost materials and bags.

Only one type of wood sawdust was used in each bag to easily compare the impact and performance of wood on oyster mushrooms. The pouches are kept in the mushroom cultivation room which has adequate light, ventilation, 25 °C ± 2 °C, and 70 % - 80 % humidity conditions. After the mycelium growing was completed, both side surfaces of the pouches were perforated to encourage mushroom development. The oyster mushrooms were harvested with a knife when they reached the same size (Figure 2).

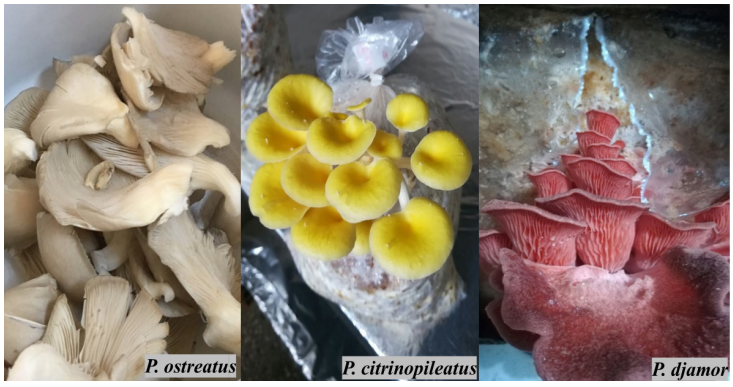


**Figure 2:** Cultivated mushrooms.

## Method

### Extraction procedure

Oyster mushroom and sawdust samples were dried in a laboratory type dryer at 60 °C for 8 hours. After the drying period, the samples were powdered using a blender. 5 g of oyster mushroom powder samples were placed in a falcon tube, with 50 mL of methanol (99 %). The final mixture was stirred using a shaker (Heidolph Promax 2020, Schwabach, Germany) at room temperature for 24 hours. Following extraction, particles were removed using coarse filter paper.

### Total phenolic content

Total phenolic content of studied samples was measured using Folin-Ciocalteu method as given by Slinkard and Singleton (1977). 400 µL of 0,5 N Folin-Ciocalteu reagent, 20 µL of sample, and 680 µL of distilled water were mixed. After 3 minutes, 400 µL of sodium carbonate solution (10 %) was added. The mixture was then incubated for 2 hours at 20 °C with vigorous shaking. Gallic acid was used as standard to construct the calibration curve. At the end of the incubation period, absorbance was measured at 760 nm. Total phenolic content of the samples was expressed as mg GAE (gallic acid equivalent)/g sample.

**Total condensed tannins**

The total condensed tannins were determined according to the Julkunen-Titto method (Julkunen-Tiitto 1985). Varied concentrations of 25 µL oyster mushroom extracts were mixed up with 750 µl of 4 % vanillin and were added 375 µL of concentrated HCl. The absorbance values were read at 500 nm. A graph was drawn with the absorbance values corresponding to the concentration. According to the drawn graph, the condensed tannins of the oyster mushroom samples were calculated. The condensed tannins content of the samples was expressed as mg CAE (catechin equivalent)/g sample.

**Antioxidant capacity by ferric reducing antioxidant power (FRAP) assay**

Antioxidant activity of the samples was measured using the ferric-reducing antioxidant power (FRAP) method of Benzie and Strain (1996) with minor modifications. The FRAP method is based on the reduction of the Fe(III)- 2,4,6-tris(2-pyridly)-S-triazine (TPTZ) complex to form a blue complex Fe(II)-TPTZ in the presence of antioxidants. Varying concentrations of $FeSO_4.7H_2O$ were prepared for standard curve. 50 µL of the sample was mixed with FRAP reagent and incubated for 4 minutes. The results were expressed as µmol $FeSO_4 \cdot 7H_2O$ per g of the sample (Benzie and Strain 1996).

**Dumas protein analysis**

The method is based on determining the amount of protein from the volume of nitrogen gas formed by burning the food at a high temperature. The oyster mushroom powder samples were analyzed using the Costech ECS 4010 Elemental Analyzer after they were completely pulverized. This device determines the element percentages by burning solid or liquid organic compounds at a temperature of 1020 °C - 1050 °C. Helium gas is used as carrier gas and oxygen gas is used as combustible gas in the device. For elemental analysis, the powders of the samples were weighed 0,500 to 0,700 mg, poured into 5 mm x 9 mm tin capsules and turned into a prism. Carbon (C), Hydrogen (H), Nitrogen (N) and Sulfur (S) ratios were measured simultaneously by placing the capsules in the device and burning the samples. The peaks of the samples were read in the Costech 4010 program. The amount of protein was calculated by multiplying the amount of nitrogen found by a factor of 4,38 (Crisan and Sands 1978).

**Sensory analysis**

Sensory analysis of the studied samples was performed by a group of 25 semi-trained panelists. The age of the panelists was between 20 and 50 old of both sexes. Mushroom samples were encoded with non-consecutive three-digit numbers. Before microwave cooking, the mushroom samples were divided into four equal parts, and equal amount of salt and oil was added to each sample. The mushrooms were heat-treated in a household microwave oven at 600 W for 4 minutes. All samples were served on the same white plastic plates. Appearance, smell, color, hardness, taste, and overall appreciation for the mushroom samples were evaluated by using the hedonic scale within the range of 1 (bad), 2 (medium), 3 (good), and 4 (very good) points (Figure 3). This method has been preferred due to the fact that it is a technique that gives a fairly fast results, as well as allows the comparison of a large number of samples. Sufficient amount of the mushroom samples to try 3-4 times was served to each panelist. Water was also served to the panelists to rinse their mouths between tasting the consecutive mushroom samples. Because it is the best time for sensory analysis and daylight saving, the panels were performed at 10,00 - 13,00 o'clock (Altug-Onogur and Elmaci 2011).

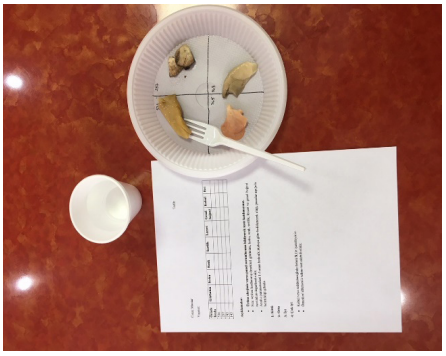

**Figure 3:** Sensory analysis.

### Statistical analysis

All assays were performed in triplicate. The data were recorded as means ± standard deviations and analyzed in a completely randomized design by using Statistical Package for Social Sciences (SPSS) version 23,0 (2016). Statistically significant differences ($p < 0,05$) among means of experimental results were analyzed by ANOVA and tests of significance were carried out using Duncan's multiple range tests.

## RESULTS AND DISCUSSION

### Total phenolic content

Total phenolic and condensed tannins contents and FRAP values of mushroom samples were given at Table 1. The highest and the lowest total phenolic contents were found in (in *P. ostreatus* mushroom cultivated on alder (*Alnus glutinosa*) sawdust (1,298 ± 0,060 mg GAE/g) and *in P. djamor* mushroom cultivated on walnut (*Juglans regia*) sawdust (0,364 ± 0,024 mg GAE/g) (Table 1). In a previous study, it was reported that different growing conditions affect the vitamin and mineral content as well as the polyphenols content of cultivated mushrooms (Muszyńska *et al.* 2015). *P. djamor* mushrooms has less total phenolic content in all growing substrates than other mushrooms. Although the total phenolics contents of *P. ostreatus* and *P. citrinopileatus* were almost similar, it was found that *P. ostreatus* had a little higher value than *P. citrinopileatus*. Yılmaz *et al.* (2017b) reported that the total polyphenolic content of *P. ostreatus* samples cultivated on sterilized tea wastes, non-sterilized tea wastes, and espresso wastes were 1,460 ± 0,012, 1,393 ± 0,060 and 1,075± 0,004 mg GAE/g, respectively. It was also reported that *P. ostreatus* cultivated on tea wastes, alder (*Alnus glutinosa*), *oriental beech* (*Fagus orientalis*), and chestnut (*Castanea sativa*) had similar total polyphenolic content, as *P. ostreatus* cultivated on espresso wastes and walnut (*Juglans regia* L.) (Yılmaz *et al.* 2017a). Phenolic contents of the samples in our study are higher than some salad greens such as *Chicory* sp. and *Lepidium sativum* (1,091 and 1,261 mg GAE/g, respectively) (Uyar *et al.* 2013). Vo and Ariyo (2013) found that, total phenolic contents of *P. ostreatus* grown on three different tropical wooden substrates (*Cananium* sp., african nutmeg (*Pycnanthus angolensis* (Welw.) Warb.) and kapok (*Ceiba pentandra* (L.) Gaertn.) were ranged from 0,89 to 2,63 mg GAE/g. This was found between 1,072 ± 0,027 and 1,298 ± 0,060 mg GAE/g for the studied *P. ostreatus* grown on four different (oriental beech (*Fagus orientalis* Lipsky), alder (*Alnus glutinosa* (L.) Gaertn.), chestnut (*Castanea sativa Mill.*), walnut (*Juglans regia* L.)) wooden substrates. A study with *P. djamor* mushroom from Mexico stated that total phenolic content was between 0,95 ± 0,02 and 0,36 ± 0,01 mg GAE/g (Oropeza-Guerrero *et al.* 2018). It can be stated that the difference in the growing substrate and the species of mushroom influence the total phenolic content of the mushroom.

### Condensed tannin content

The highest condensed tannin content (0,673 ± 0,012 CE mg/g) was measured in *P. ostreatus* cultivated on alder (*Alnus glutinosa*) sawdust, while the lowest (0,192 ± 0,053 CE mg/g) was in *P. djamor* cultivated on walnut (*Juglans regia*) sawdust (Table 1). In a previous study, condensed tannins of *P. ostreatus* cultivated on tea waste were given as 0,774 ± 0,001 mg CE/g (Yılmaz *et al.* 2017a). In addition, Yıldız *et al.* (2017b) reported that *P. ostreatus* cultivated on 50 % chestnut (*Castanea sativa*) and 50 % black pine (*Punus nigra*) sawdust had the lowest condensed tannin content as 0,618 ± 0,062 CE mg/g. The obtained condensed tannin results were also higher than some reported wild mushrooms such as *Lentinus ciliatus* (0,343 ± 0,030 CE mg/g), *Schizophyllum commune* (0,280 ± 0,024 CE mg/g), *Hygrocybe conica* (0,251 ± 0,011 CE mg/g), and *P. ostreatus* (cultivated) (0,326 ± 0,025 CE mg/g) (Hip *et al.* 2009).

### Antioxidant activity

While *P. djamor* cultivated on alder (*Alnus glutinosa*) sawdust exhibited the highest antioxidant activity as (16,960 ± 0,021 µmol $FeSO_4.7H_2O$/g, *P. ostreatus* cultivated on walnut (*Juglans regia*) sawdust was the lowest as 11,596 ± 0,032 µmol $FeSO_4.7H_2O$/g (Table 1). A study performed by Yıldız *et al.* (2017a) found that FRAP values of *P. ostreatus* cultivated on 50 % chestnut (*Castanea sativa*) and 50 % oriental beech (*Fagus orientalis*) sawdust and *P. citrinopileatus* cultivated on chestnut (*Castanea sativa*) sawdust were 11,761 ± 0,020 µmol $FeSO_4.7H_2O$/g and 10,130 ± 0,165 µmol $FeSO_4.7H_2O$/g, respectively. Another study by Arbaayah and Umi (2013) was revealed that the greatest ability for reducing the ferricyanide complex to ferrous form was observed in *P. djamor* extracts. Some studies also suggested that consumption of *P. djamor* may provide health benefits due to its antioxidant properties (Sudha *et al.* 2016).

**Table 1:** Total phenolic and condensed tannins contents, and FRAP values of mushroom samples.

| Mushroom Type | Grown Substrate | Total Phenolic Content (mg GAE/g) | Condansed Tannins (CE mg/g) | FRAP (µmol $FeSO4·7H_2O$/g) |
|---|---|---|---|---|
| | | X ± SD | X ± SD | X ± SD |
| *P. ostreatus* | *A. glutinosa* | 1,298 ± 0,060$^{fg}$ | 0,673 ± 0,012$^{i}$ | 14,478 ± 0,048$^{abc}$ |
| | *J. regia* | 1,072 ± 0,027$^{e}$ | 0,421 ± 0,003$^{de}$ | 11,596 ± 0,032$^{abc}$ |
| | *F. orientalis* | 1,284 ± 0,064$^{f}$ | 0,601 ± 0,052$^{h}$ | 13,922 ± 0,041$^{ab}$ |
| | *C. sativa* | 1,291 ± 0,078$^{f}$ | 0,437 ± 0,031$^{e}$ | 11,671 ± 0,030$^{abc}$ |
| *P. citrinopileatus* | *A. glutinosa* | 1,288 ± 0,006$^{f}$ | 0,354 ± 0,050$^{c}$ | 14,600 ± 0,024$^{bc}$ |
| | *J. regia* | 1,073 ± 0,007$^{e}$ | 0,503 ± 0,040$^{fg}$ | 12,100 ± 0,043$^{abc}$ |
| | *F. orientalis* | 1,039 ± 0,089$^{e}$ | 0,472 ± 0,017$^{ef}$ | 11,980 ± 0,022$^{abc}$ |
| | *C. sativa* | 1,059 ± 0,063$^{e}$ | 0,592 ± 0,011$^{h}$ | 12,640 ± 0,033$^{abc}$ |
| *P. djamor* | *A. glutinosa* | 0,939 ± 0,085$^{d}$ | 0,556 ± 0,094$^{gh}$ | 16,960 ± 0,021$^{c}$ |
| | *J. regia* | 0,364 ± 0,024$^{a}$ | 0,192 ± 0,053$^{b}$ | 13,800 ± 0,011$^{abc}$ |
| | *F. orientalis* | 0,475 ± 0,031$^{b}$ | 0,226 ± 0,021$^{b}$ | 13,740 ± 0,021$^{abc}$ |
| | *C. sativa* | 0,875 ± 0,001$^{d}$ | 0,365 ± 0,057$^{cd}$ | 16,660 ± 0,012$^{c}$ |
| *A. bisporus* | | 0,618 ± 0,048$^{c}$ | 0,536 ± 0,024$^{fgh}$ | 14,820 ± 0,034$^{bc}$ |
| No mushroom | *A. glutinosa* | 1,396 ± 0,010$^{g}$ | 0,195 ± 0,003$^{b}$ | 20,711 ± 0,076$^{abc}$ |
| | *J. regia* | 2,381 ± 0,022$^{h}$ | 0,717 ± 0,003$^{i}$ | 31,467 ± 0,055$^{d}$ |
| | *F. orientalis* | 0,368 ± 0,031$^{a}$ | 0,006 ± 0,004$^{a}$ | 7,845 ± 0,009$^{a}$ |
| | *C. sativa* | 2,533 ± 0,045$^{i}$ | 0,945 ± 0,006$^{j}$ | 33,600 ± 0,046$^{d}$ |

Means followed by different letters in the same column differ significantly at $p < 0,05$ (Duncan's multiple range test)

**Protein content**

Protein content *of P. ostreatus, P. citrinopileatus, P. djamor and A. bisporus* were given in Table 2. *A. bisporus* had the highest protein concentration (13,84 %), in this study. Similar protein concentration (13,75 %) was measured in *P. ostreatus* cultivated on alder (*Alnus glutinosa*) sawdust (Table 2). This value was 13,67 % in *P. djamor* cultivated on walnut (*Juglans regia*) sawdust. The lowest protein concentration (9,86 %) was determined in *P. citrinopileatus* cultivated on oriental beech (*Fagus orientalis*) sawdust. Protein contents of *Pleurotus* species grown in selected wood sawdusts were determined between 9,86 - 13,75 %. It was 13,84 for the of commercially obtained *A. bisporus*. Therefore, it can be concluded that the protein content of both mushroom groups is close to each other. In another previous study, Khan and Tania (2012) determined the protein ratio in *P. eryngii* and *P. ostreatus* to be between 11 - 17 %. Jaworska *et al.* (2011) found that as a proportion of total amino acids in fresh form of *P. ostreatus* is 10 - 12 %, in frozen form 10 - 11 %, and in canned form 11 - 12 %. Bengü *et al.* (2019) performed Dumas protein method of cultivated *P. ostreatus* (22,04 %) and *A. bisporus* (22,22 %) samples, which values they were multiplied by the conversion factor of 6,25. In the current study, the protein percentage of *P. ostreatus* was, and of *A. bisporus* 13,84 %. In another study, protein percentage of *P. ostreatus* samples cultivated on tea and espresso wastes were 13,16 % and 13,05 % respectively (Yılmaz *et al.* 2017a). It has been determined that the content of protein found in mushrooms varies depending on what specie of mushroom. It was also determined that the protein ratio of the mushroom is influenced by the substrate in which it is cultivated, even if the mushroom is of the same species.

**Table 2:** Protein content of *P. ostreatus, P. citrinopileatus, P. djamor* and *A. bisporus.*

| Mushroom Type | Grown Substrate | Amount (g) | Nitrogen (%) | Carbon (%) | Hydrogen (%) | Protein (%) |
|---|---|---|---|---|---|---|
| *P. ostreatus* | *A. glutinosa* | 0,548 | 3,14 | 39,61 | 6,41 | 13,75 |
| | *J. regia* | 0,617 | 2,37 | 38,01 | 6,49 | 10,38 |
| | *F. orientalis* | 0,583 | 2,52 | 36,29 | 5,22 | 11,04 |
| | *C. sativa* | 0,647 | 2,63 | 44,29 | 6,30 | 11,52 |
| *P. citrinopileatus* | *A. glutinosa* | 0,702 | 3,01 | 41,63 | 6,45 | 13,18 |
| | *J. regia* | 0,698 | 2,81 | 43,04 | 6,42 | 12,31 |
| | *F. orientalis* | 0,562 | 2,25 | 37,64 | 5,40 | 9,86 |
| | *C. sativa* | 0,634 | 2,61 | 40,26 | 6,02 | 11,43 |
| *P. djamor* | *A. glutinosa* | 0,695 | 2,76 | 42,17 | 6,58 | 12,09 |
| | *J. regia* | 0,656 | 3,12 | 38,28 | 6,29 | 13,67 |
| | *F. orientalis* | 0,671 | 2,40 | 38,16 | 6,38 | 10,51 |
| | *C. sativa* | 0,567 | 2,36 | 38,06 | 5,98 | 10,34 |
| *A. bisporus* | | 0,617 | 3,16 | 38,99 | 6,61 | 13,84 |

**Sensory analysis**

Since oyster mushrooms are usually cultivated on oriental beech (*Fagus orientalis*) wood substrate, sensory analysis was performed only using mushrooms produced in oriental beech (*Fagus orientalis*) sawdust and also commercial *A. bisporus* (Table 3) (Akçay and Doğan 2019, Başyiğit and Sakaldaş 2021). Oyster mushrooms can absorb the flavor of the compost. Therefore, the mushrooms grown in an unusual compost such as walnut (*Juglans regia* L.), chestnut (*Castanea sativa*) and alder (*Alnus glutinosa*) wood substrates were not included (Omarini *et al.* 2010, Yokota *et al.* 2016). Mushrooms grown on oriental beech (*Fagus orientalis*) compost were used in the sensory analysis, since alder (*Alnus glutinosa*), walnut (*Juglans regia*) and chestnut (*Castanea sativa*) shavings could add a different flavor to the mushroom. *P. citrinopileatus* and *P. djamor* samples were scored lowest on all the evaluated sensory characteristics except color. The smell characteristics of *P. citrinopileatus* and *A. bisporus* mushrooms were found to be quite different by the panelists. The hardness, taste, and general appreciation scores of *A. bisporus*, *P. ostreatus* and *P. djamor* mushrooms were similar and statistically different from *P. citrinopileatus* mushrooms ($p < 0,05$). Although *P. ostreatus* had the highest score in general appreciation, no statistically significant difference was detected between the samples ($p > 0,05$). General appreciation scores showed that *A. bisporus* and *P. ostreatus* mushrooms gained more appreciation than *P. citrinopileatus* (Table 3). Previous findings demonstrated that *Pleurotus* species produced using plant wastes had the highest mushroom flavor and sour intensity ratings. (Omarini *et al.* 2010). Nayak *et al.* (2015) evaluated sensory attributes of 15 % (w/w) *A. bisporus* added fish meatball samples. They reported that the sensory evaluation scores of the mushroom-added samples were higher than the control (non-added) sample. El-Refai *et al.* (2014) were also found that sensory analysis of 8 % (w/w) *P. ostreatus* added beef meatballs had good sensory characteristics. Wu *et al.* (2022) reported that Sausage containing *P. ostreatus* had better sensory scores than sausage samples without *P. ostreatus* (Wu *et al.* 2022).

**Table 3:** Sensory analysis scores of *P. ostreatus, P. citrinopileatus, P. djamor* and *A. bisporus.*

| Mushroom Type | Appearance | Smell | Colour | Hardness | Taste | Overall Appreciation |
|---|---|---|---|---|---|---|
| *P. ostreatus* | $2,65 \pm 1,22^{b*}$ | $2,18 \pm 1,01^{ab}$ | $2,76 \pm 1,20^{a}$ | $2,82 \pm 1,07^{b}$ | $3,18 \pm 1,01^{b}$ | $2,94 \pm 0,83^{b}$ |
| *P. citrinopileatus* | $1,82 \pm 0,95^{a}$ | $1,53 \pm 0,87^{a}$ | $2,00 \pm 1,06^{a}$ | $1,88 \pm 0,99^{a}$ | $1,59 \pm 0,87^{a}$ | $1,65 \pm 1,11^{a}$ |
| *P. djamor* | $2,29 \pm 0,92^{ab}$ | $2,12 \pm 0,99^{ab}$ | $2,76 \pm 1,09^{a}$ | $2,59 \pm 1,00^{b}$ | $2,59 \pm 1,18^{b}$ | $2,47 \pm 1,12^{b}$ |
| *A. bisporus* | $2,65 \pm 0,93^{b}$ | $2,65 \pm 0,99^{b}$ | $2,59 \pm 1,12^{a}$ | $2,76 \pm 0,83^{b}$ | $2,94 \pm 0,97^{b}$ | $2,88 \pm 0,93^{b}$ |

Means followed by different letter(s) in the same column differ significantly at $p < 0,05$ (Duncan's multiple range test)

## CONCLUSIONS

Current study was provided important findings on chemical and sensory characteristics of three different *Pleurotus* mushroom species cultivated on the different composts.

*P. ostreatus* grown in *F. orientalis* compost can be proposed based on the results. This recommendation also applies to the manufacturers.

If it is to be consumed in terms of antioxidant and protein benefits, *P. ostreatus* grown in *A. glutinosa* sawdust compost or *P. djamor* grown in the same compost can be preferred. Although there is no statistical difference, if only the taste is important to the consumer, *P. ostreatus* is recommended.

If the color, hardness, appearance, smell and general appreciation are to be effective in addition to the flavor, *A. bisporus* and *P. ostreatus* are recommended.

In future studies, in vitro bio accessibility studies can be conducted for these mushrooms, and they can be used as source for different value-added products.

**Acknowledgements**

This study was performed within a research project of the General Directorate of Forestry, Head of Foreign Relations, Training and Research Department on behalf and funded by the General Directorate of Forestry of Türkiye.

**Authorship contributions**

C. K.: Investigation, methodology, writing – original draft. A. G.: Methodology, formal analysis, writing – review & editing. S. Y.: Supervision. Z. C.: Methodology. A. D.: Methodology, writing – review & editing

**REFERENCES**

**Aghajani, H.; Bari, E.; Bahmani, M.; Humar, M.; Ghanbary, M.A.T.; Nicholas, D.D.; Zahedian, E. 2018.** Influence of relative humidity and temperature on cultivation of *Pleurotus* species. *Maderas. Ciencia y Tecnología* 20(4): 571-578. https://doi.org/10.4067/S0718-221X2018005004501

**Akçay, B.C.; Doğan, H.H. 2019.** Cultivation and dissemination of *Pleurotus ostreatus* (Jacq.) P. Kumm. in Marmara Region. *The Journal of Fungus* 10(2): 92-102. https://dergipark.org.tr/tr/download/article-file/842155

**Altug-Onogur, T.; Elmaci, Y. 2011.** Sensory Evaluation on Foods. Sidas Publishing: Izmir, Turkey. https://www.gidakitaplari.com/KD/55/Gidalarda-Duyusal-Degerlendirme

**Arbaayah, H.; Umi, K. Y. 2013.** Antioxidant properties in the oyster mushrooms (*Pleurotus* spp.) and split gill mushroom (*Schizophyllum commune*) ethanolic extracts. *Mycosphere* 4(4): 661-673. https://doi.org/10.5943/mycosphere/4/4/2

**Başyiğit, S.; Sakaldaş, M., 2021.** The effects of modified atmosphere packaging at different storage temperatures on quality of oyster mushroom (*Pleurotus ostreatus*). *ÇOMÜ LJAR 2* (4): 48-55. https://dergipark.org.tr/tr/download/article-file/2135118

**Bengü, A.Ş.; Yılmaz, H.Ç.; Türkekul, İ.; Işık, H. 2019.** Determination of total protein, vitamin and fatty acid content of *Pleurotus ostreatus* and *Agaricus bisporus* mushrooms collected from nature and cultured. *Turkish Journal of Agricultural and Natural Sciences* 6(2): 222-229. https://doi.org/10.30910/turkjans.557099

**Benzie, I.F.; Strain, J.J. 1996.** The ferric reducing ability of plasma (FRAP) as a Measure of "antioxidant power": the FRAP assay. *Analytical Biochemistry* 239(1): 70-76. https://doi.org/10.1006/abio.1996.0292

**Crisan, E.; Sands, A. 1978.** Nutritional value. In: Biology and cultivation of Edibles Mushrooms. Chang, S.T.; Hayes W.A. (Eds.). New York: Academic Press

**El-Refai, A.; El-Zeiny A.R.; Rabo, E. 2014.** Quality attributes of mushroom-beef patties as a functional meat product. *Journal of Hygienic Engineering and Design* 6: 49-62. https://keypublishing.org/jhed/wp-content/uploads/2020/07/01.-Ahmed-El-Refai.pdf

**Espinosa-Páez, E.; Hernández-Luna, C.E.; Longoria-García, S.; Martínez-Silva, P.A.; Ortiz-Rodríguez, I.; Villarreal-Vera, M.T.; Cantú-Saldaña, C.M. 2021.** *Pleurotus ostreatus*: A potential concurrent biotransformation agent/ingredient on development of functional foods (cookies). *LWT - Food Science and Technology* 148: e111727. https://doi.org/10.1016/j.lwt.2021.111727

**Estrada, A.E.R.; Jimenez-Gasco, M.; Royse, D.J. 2009.** Improvement of yield of *Pleurotus eryngii* var. *eryngii* by substrate supplementation and use of a casing overlay. *Bioresource Technology* 100 (21): 5270-5276. https://doi.org/10.1016/j.biortech.2009.02.073

**González, A.; Nobre, C.; Simões, L.S.; Cruz, M.; Loredo, A.; Rodríguez-Jasso, R.M.; Contreras, J.; Texeira, J.; Belmares, R. 2021.** Evaluation of functional and nutritional potential of a protein concentrate from *Pleurotus ostreatus* mushroom. *Food Chemistry* 346: e128884. https://doi.org/10.1016/j.foodchem.2020.128884

**Hip, S.; Fook, Y.; Swee, K.; Chun, W. 2009.** Phenolic profiles of selected edible wild mushrooms as affected by extraction solvent, time and temperature. *Asian Journal of Food and Agro-Industry* 2 (3): 392-401. https://www.cabdirect.org/cabdirect/abstract/20103303373

**Jaworska, G.; Bernaś, E.; Mickowska, B. 2011.** Effect of production process on the amino acid content of frozen and canned *Pleurotus ostreatus* mushrooms. *Food Chemistry* 125(3): 936-943. https://doi.org/10.1016/j.foodchem.2010.09.084

**Josiane, M.; Estelle, M.; Francis, N.; Kamdem, S. 2018.** Effect of substrates on nutritional composition and functional properties of *Pleurotus ostreatus*. *Current Research in Agricultural Sciences* 5(1): 15-22. https://doi.org/10.18488/journal.68.2018.51.15.22

**Julkunen-Tiitto, R. 1985.** Phenolic constituents in the leaves of northern willows: methods for the analysis of certain phenolics. *Journal of Agricultural and Food Chemistry* 33(2): 213-217. https://doi.org/10.1021/jf00062a013

**Keča, L.; Marčeta, M.; Posavec, S.; Jelić, S.; Pezdevšek-Malovrh, Š. 2017.** Market characteristics and cluster analysis of non-wood forest products. *Šumarski List* 141(3-4): 151-162. https://doi.org/10.31298/sl.141.3-4.5

**Khan, M.A.; Tania, M. 2012.** Nutritional and medicinal importance of *Pleurotus* mushrooms: an overview. *Food Reviews International* 28(3): 313-329. https://doi.org/10.1080/87559129.2011.637267

**Manzi, P.; Gambelli, L.; Marconi, S.; Vivanti, V.; Pizzoferrato, L. 1999.** Nutrients in edible mushrooms: an inter-species comparative study. *Food Chemistry* 65(4): 477-482. https://doi.org/10.1016/S0308-8146(98)00212-X

**Masri, H.J.M.H.J.; Maftoun, P.M.P.; Abd Malek, R.; Boumehira, A.Z.; Pareek, A.; Hanapi, S.Z.; Ling, O.M.; El Enshasy, H. 2017.** The edible mushroom *Pleurotus* spp.: II. Medicinal values. *International Journal of Biotechnology for Wellness Industries* 6(1): 1-11. https://doi.org/10.6000/1927-3037.2017.06.01.1

**Muszyńska, B.; Kała, K.; Sułkowska-Ziaja, K.; Szewczyk, A.; Łojewski, M.; Rojowski, J. 2015.** Analysis of the content of phenolic compounds in in vitro culture of some edible mushrooms (Basidiomycota). *Medicina Internacia Revuo* 26(104): 146-152. https://interrev.com/mir/index.php/mir/article/view/48/30

**Nayak, P.C.; Raju, C.; Lakshmisha, I.; Singh, R.R.; Sofi, F.R. 2015.** Influence of Button mushroom (*Agaricus bisporus*) on quality and refrigerated storage stability of patties prepared from sutchi catfish (*Pangasius hypophthalmus*). *Journal of Food Science and Technology* 52(6): 3529-3538. https://doi.org/10.1007/s13197-014-1415-6

**Omarini, A.; Nepote, V.; Grosso, N.R.; Zygadlo, J.A.; Albertó, E. 2010.** Sensory analysis and fruiting bodies characterisation of the edible mushrooms *Pleurotus ostreatus* and *Polyporus tenuiculus* obtained on leaf waste from the essential oil production industry. *International Journal of Food Science & Technology* 45(3): 466-474. https://doi.org/10.1111/j.1365-2621.2009.02147.x

**Oropeza-Guerrero, M.P.; Santos-Sánchez, N.F.; Salas-Coronado, R.; Valadez-Blanco, R.; Hernández-Carlos, B.; Guadarrama-Mendoza, P.C. 2018.** Productivity and antioxidant activity of wild, reconstituted, and hybrid strains of the pink oyster mushroom, *Pleurotus djamor* (Agaricomycetes), from Mexico. *International Journal of Medicinal Mushrooms* 20(7): 607-621. https://doi.org/10.1615/IntJMedMushrooms.2018026382

**Raman, J.; Jang, K.Y.; Oh, Y.L.; Oh, M.; Im, J.H.; Lakshmanan, H.; Sabaratnam, V. 2021.** Cultivation and nutritional value of prominent Pleurotus spp.: an overview. *Mycobiology* 49(1): 1-14. https://doi.org/10.1080/12298093.2020.1835142

**Ray, D.K.; West, P.C.; Clark, M.; Gerber, J.S.; Prishchepov, A.V.; Chatterjee, S. 2019.** Climate change has likely already affected global food production. *PloS One* 14(5): e0217148. https://doi.org/10.1371/journal.pone.0217148

**Sassine, Y.N.; Naim, L.; El Sebaaly, Z.; Abou Fayssal, S.; Alsanad, M.A.; Yordanova, M.H. 2021.** Nano urea effects on *Pleurotus ostreatus* nutritional value depending on the dose and timing of application. *Scientific Reports* 11(1): 1-11. https://doi.org/10.1038/s41598-021-85191-9

**Sekan, A.S.; Myronycheva, O.S.; Karlsson, O.; Gryganskyi, A.P.; Blume, Y. 2019.** Green potential of *Pleurotus* spp. in biotechnology. *PeerJ* 7: e6664. https://doi.org/10.7717/peerj.6664

**Slinkard, K.; Singleton, V.L. 1977.** Total phenol analysis: automation and comparison with manual methods. *American Journal of Enology and Viticulture* 28(1): 49-55. https://www.ajevonline.org/content/28/1/49.short

**SPSS. 2016.** SPSS for Windows, version 23.0, IBM Corp. https://www.ibm.com/support/pages/downloading-ibm-spss-statistics-23

**Sudha, G.; Janardhanan, A.; Moorthy, A.; Chinnasamy, M.; Gunasekaran, S.; Thimmaraju, A.; Gopalan, J. 2016.** Comparative study on the antioxidant activity of methanolic and aqueous extracts from the fruiting bodies of an edible mushroom *Pleurotus djamor*. *Food Science and Biotechnology* 25(2): 371-377. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6049180/

**Uyar, B.; Gezmen-Karadağ, M.; Şanlıer, N.; Günyel, S. 2013.** Determining the amount of total phenolic compounds of some vegetables frequently used in our society. *Journal of Food* 38(1): 23-29. https://dergipark.org.tr/en/pub/gida/issue/6945/92658

**Vo, O.; Ariyo, O.O. 2013.** Antimicrobial and antioxidant properties of *Pleurotus ostreatus* (Jacq: Fries) cultivated on different tropical woody substrates. *Journal of Waste Conversion, Bioproducts and Biotechnology* 1(2): 28-32. https://www.researchgate.net/profile/Olusegun-Oyetayo/publication/274081430_Antimicrobial_and_Antioxidant_Properties_of_Pleurotus_ostreatus_Jacq_Fries_Cultivated_on_Different_Tropical_Woody_Substrates/links/551ba3fe0cf251c35b509fe3/Antimicrobial-and-Antioxidant-Properties-of-Pleurotus-ostreatus-Jacq-Fries-Cultivated-on-Different-Tropical-Woody-Substrates.pdf

**Wu, X.; Wang, P.; Xu, Q.; Jiang, B.; Li, L.; Ren, L.; Li, X.; Wang, L. 2022.** Effects of *Pleurotus ostreatus*on physicochemical properties and residual nitrite of the pork sausage. *Coatings* 12(4): e484. https://doi.org/10.3390/coatings12040484

**Xiao, P.; Wu, D.; Wang, J. 2022.** Bibliometric analysis of global research on white rot fungi biotechnology for environmental application. *Environmental Science and Pollution Research* 29(1): 1491-1507. https://doi.org/10.1007/s11356-021-15787-1

**Yıldız, S.; Yılmaz, A.; Can, Z.; Kılıç, C.; Yıldız Ü.C. 2017a.** Total phenolic, flavonoid, tannin contents and antioxidant properties of *Pleurotus ostreatus* and *Pleurotus citrinopileatus* cultivated on various sawdust. *The Journal of Food* 42(3): 315-323. https://dergipark.org.tr/en/pub/gida/issue/27486/298494

**Yıldız, S.; Yılmaz, A.; Kılıç, C. 2017b.** Utilization of pasteurisation liquid obtained from chestnut (*Castanea sativa*) sawdust as wood preservative. *Mugla Journal of Science Technology* 3(1): 16-19. https://doi.org/10.22531/muglajsci.259055

**Yılmaz, A.; Yıldız, S.; Kılıç, C.; Can, Z. 2017a.** Protein contents and antioxidant properties of *Pleurotus ostreatus* cultivated on tea and espresso wastes. *International Journal of Secondary Metabolite* 4 (3): 177-186. https://dergipark.org.tr/tr/pub/ijsm/issue/32131/370113

**Yılmaz, A.; Yıldız, S.; Kılıç, C.; Can, Z. 2017b.** Total phenolics, flavonoids, tannin contents and antioxidant properties of *Pleurotus ostreatus* cultivated on different wastes and sawdust. *International Journal of Secondary Metabolite* 4 (1): 1-9. https://doi.org/10.21448/ijsm.252052

**Yokota, M.; Frison, P.; Marcante, R.; Jorge, L.; Valle, J.; Dragunski, D.; Colauto, N.; Linde, G. 2016.** Iron translocation in *Pleurotus ostreatus* basidiocarps: production, bioavailability, and antioxidant activity. *Genetics and Molecular Research* 15(1): 1-10. http://dx.doi.org/10.4238/gmr.15017888