Food and Health, 5(1), 12-18 (2019) • https://doi.org/10.3153/FH19002 E-ISSN: 2602-2834

Research Article

ANTIBACTERIAL AND ANTIOXIDANT ACTIVITY OF MYCELIAL EXTRACTS OF DIFFERENT PLEUROTUS SPECIES

Murat Özdal, Özlem Gülmez, Özlem Gür Özdal, Ömer Faruk Algur

Cite this article as:

Özdal, M., Gülmez, Ö., Gür Özdal, Ö., Algur, Ö.F. (2019). Antibacterial and Antioxidant Activity of Mycelial Extracts of Different Pleurotus Species. Food and Health, 5(1), 12-18. https://doi.org/10.3153/FH19002

Department of Biology, Science Faculty, Ataturk University, 25240, Erzurum, Turkey

Submitted: 19.01.2018

Accepted: 04.03.2018

Published online: 04.08.2018

Correspondence:

Murat ÖZDAL

E-mail: murat.ozdal@yahoo.com

Available online at
http://jfhs.scientificwebjournals.com

ABSTRACT

Mushrooms could be used as a potential means of producing natural antioxidants and antimicrobials. To obtain fungal biomass in submerged culture is an easy and rapid method. For this reason, biomasses of *Pleurotus* species which grown on liquid media were used to prepare hot water extracts and their antioxidant and antibacterial properties were determined. The highest total phenolic content was determined in *P. ostreatus* extract (9.14 $mg.g^{-1}$ dry weight of extract) whereas *Pleurotus sajor-caju* gave highest reading of total flavonoid content (3.10 $mg.g^{-1}$ dry weight of extract). In the scavenging effect of DPPH radical test, *P. sajor-caju* showed the highest activity potential (69.67%). Mycelia extracts from *Pleurotus* species showed the antibacterial activity against the Gram negative and Gram positive bacteria (plant and human pathogens). Based on the results obtained, each extract from the five species *Pleurotus* (*P. florida*, *P. citrinopileatus, P. sajor-caju*, *P. ostreatus* and *P. eryngii*) showed antioxidant and antibacterial properties, and could be used in the formulation of nutraceuticals. Furthermore, the results presented in this work demonstrated that extracts were capable of inhibiting the *in vitro* growth of *Helicobacter pylori*.

Keywords: Antioxidant, Antibacterial, Mycelial extract, *Pleurotus*

Introduction

Mushrooms synthesis a range of secondary bioactive molecules (phenols, polysaccharides, pigments, tocopherols, terpenes and steroids) with high therapeutic value. These molecules have pharmacological activities such as antimicrobial, antiviral, antioxidant, antiinflammatory, antitumor, antiallergic, antiaging, antidiabetic, anti-Alzheimer and hypocholesterolemic (De Silva et al., 2013, Canli et al., 2016). Among the metabolites, phenolic and flavonoid compounds show excellent antioxidant capacity (Barros et al., 2007, De Silva et al., 2013, Yildiz et al., 2015). These metabolites can be extractable (with water or different organic solvents) from both mycelial biomass and fruit body of mushrooms (Lee et al., 2007, Han et al., 2015) and they are sold as a capsule or tablet for diseases prevention (De Silva et al., 2013).

Pleurotus species are found throughout world and are among the most widely-cultivated. It well known that *Pleurotus* species produce bioactive molecules such as phenolic, pigment, polysaccharide, and terpenoid (Dündar et al., 2013, Corrêa et al., 2016). Bioactive metabolites are usually produced with little efficiency and productions of these metabolites depend on the species and growth parameters. These metabolites, obtained from *Pleurotus*, shows antioxidant and antimicrobial activities (Carvajal et al., 2012, Reis et al., 2012, Younis et al., 2015). *Pleurotus* species are mostly grown on solid substrates to obtain fruit body. It is known that the production of fruiting bodies take several months. However, mushroom mycelia/biomass can be produced in a short-time (a few weeks) using submerged fermentation.

Moreover, submerged fermentation facilitates compounds extraction and purification, higher production of biomass by reducing growth time and contamination. These species are quite easily cultivated artificially in submerged medium (Reis et al., 2012, Mukhopadhyay and Guha, 2015). Thus mycelial is a cheap alternative and constant source to fruit bodies. *Because of their potential benefits of health to human body, mushrooms products (mushrooms extracts and tablets) are available in market.* There are growing demands for natural antioxidants and antimicrobials due to restriction in the use of synthetic ones. Because of these reasons, the aim of this work is to investigate and compare the antibacterial and antioxidant properties of the hot water extracts obtained from mycelia of *Pleurotus* species.

Materials and Methods

Fungal Cultures and Storage Conditions

The *Pleurotus citrinopileatus*, *P. eryngii,* and *P. ostreatus* were obtained from Erkel Gıda A.Ş., İzmir, Turkey. *P. sajor-caju* and *P. florida* were obtained from Dr. Abdurrahman Dündar, Mardin Artuklu University. The mushrooms are stored on potato dextrose agar (PDA) at 4°C.

Media Preparation and Fermentation Conditions

The *Pleurotus* mushrooms were firstly grown on PDA petri plates for at 25°C 10 days. Submerged fermentation was carried out in 250 mL Erlenmeyer flasks, containing 100 mL of liquid medium (Glucose 20 $g.L^{-1}$, peptone 2 $g.L^{-1}$, yeast extract 3 $g.L^{-1}$, KH_2PO_4 1 $g.L^{-1}$, $MgSO_4$ 0.5 $g.L^{-1}$). Each flask was inoculated with five 5-mm agar plugs. Each flask was maintained at 25°C and 150 rpm for 15 days. After growth, the fungal biomasses were obtained from the aqueous medium by filtration. The obtained biomasses were washed 4 times with sterilized distilled water, and then dried in the oven.

Preparation of Pleurotus Extracts

To obtain hot water extraction, 5 g dry and powdered mycelial biomass was boiled with 100 mL deionized water for 30 min. and then cooled. The cooled solution was filtered through Whatman filter paper (No. 4). To obtain dried extract, filtered solution evaporated in the oven (55 °C). The dried extracts were dissolved in sterilized distilled water as 100 $mg.mL^{-1}$ and kept at 4°C for further studies (Figure 1).

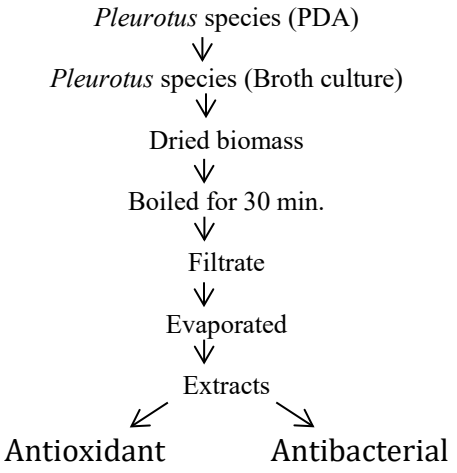

Figure 1. Obtaining the fungal extracts

Determination of Total Phenolic and Flavonoid Content

Total phenolic and flavonoid amounts of hot water extracts were estimated with using gallic acid (GAE) (Vamanu, 2012) and quercetin (QE) (Turkoglu et al., 2007) as standards, respectively.

Scavenging Activity of DPPH Radical

The *radical scavenging activity* of mycelia extracts was *calculated* using 2,2-diphenyl-1-picryhydrazyl (*DPPH*) assay (Reis et al., 2012; Barros et al., 2008). An aliquot of 270 µL of 6×10^{-5} mol.L^{-1} DPPH radical in methanol was added to a test tube with 30 µL of mycelia extract of various concentrations. The solution was mixed at room temperature and after incubated for 30 min. in dark conditions. The *absorbance* of the mixture was performed at 515 nm using Micro plate Reader. The antioxidant *capacity* was calculated in following way:

$$\text{Antioxidant activity} = [(Abs_{sample} - A_{control})/Abs_{sample}] \times 100$$

Microorganisms

Bacillus cereus BC-On (Ozdal et al., 2016a), *Arthrobacter agilis* A17 (Ozdal et al., 2017), *Pseudomonas aeruginosa* OG1 (Ozdal et al., 2016b), *Xanthomonas campestris* MO-03 (Genbank accession number KF939142), *Klebsiella oxycota* (clinical isolate), *Helicobacter pylori* (ATCC 43629) were used in the study.

Antimicrobial Activity

The antimicrobial properties of the extracts were determined by disk diffusion technique. One hundred milliliters (10^8 cfu.mL^{-1}) of the tested bacterial suspensions were spread on agar plates. Mueller–Hinton agar containing 5% sheep blood plates for *H. pylori*, and Tryptic Soy Agar (TSA) for other bacteria were used for antibacterial activities. *H. pylori* plates were incubated under microaerophilic conditions in anaerobic jars (Oxoid). Sterile paper disks (6 mm diameter) impregnated with 2 mg, 4 mg and 6 mg of each extract (60, 120 and 180 µL of stock solutions) were placed onto agar medium, and then incubated at 37°C for 48 hours. The discs were dried for 24 hours before use. At the end of the time, the diameter of the inhibition zone formed around each disc was measured in millimeters.

Results and Discussion

Yield of Dried Mycelial Biomass and Crude Extracts

Maximum biomass yields were obtained from the species of *P. ostreatus* (11.2 g.L^{-1}) and *P. citrinopileatus* (9.8 g.L^{-1}). The lowest biomass production was observed by *P. eryngii* with 6.1 g.L^{-1} (Table 1). Rosado et al. (2003) showed that production of mycelia biomass for *P. ostreatoroseus* was 16.8 g.L^{-1} and for *P. florida* was 22.8 g.L^{-1} in polysaccharide production medium, after a 9-day incubation. Confortin et al. (2008) obtained 8.18 g.L^{-1} of mycelial biomass when cultivating *P. sajor-caju* PS-2001. Sartori et al. (2015) reported that the production of mycelial biomass for *Pleurotus sajor-caju, P. ostreatus, P. albidus* and *P. flabellatus* were 12.73 g.L^{-1}, 13.27 g.L^{-1}, 16.27 g.L^{-1} and 8.20 g.L^{-1} in vinasse for 15 days, respectively. As seen in Table 1, *P. citrinopileatus* provided a higher extract yield (340 mg.g^{-1}) and *P. eryngii* provided a lower extract yield (180 mg.g^{-1}).

Table 1. Dry weight of mycelia biomass and hot water extraction yield of *Pleurotus* species

Pleurotus species	Mycelial biomass (g.L^{-1})	Yield of extract (mg.g^{-1})	Appearance
P. eryngii	6.1±1.5	180±5	Dark brown
P. sajor-caju	8.8±1.6	260±3	Dark orange/brown
P. citrinopileatus	9.8±1.9	340±4	Dark brown
P. ostreatus	11.2±2.1	300±4	Dark brown
P. florida	7.6±2.4	210±3	Dark orange/brown

The appearance/consistency of the five extracts was similar for *P. sajor-caju*, *P. ostreatus* and *P. eryngii* (dark brown powder), however for *P. florida* and *P. citrinopileatus*, the extracts were dark brown to orange powder.

Total Phenol and Total Flavonoids Contents

The maximum phenol content was obtained from *P. ostreatus* (7.1 mg.g^{-1} extract) and this was followed by *P. sajor-caju* (7 mg.g^{-1} extract) , *P. citrinopileatus* (5 mg.g^{-1} extract), *P. florida* (4.5 mg.g^{-1} extract) and *P. eryngii* (3.6 mg.g^{-1} extract). The maximum flavonoid content was obtained from *P. sajor-caju* and this was followed by *P. florida, P. eryngii*, *P. citrinopileatus, P. ostreatus* (Figure 2).In this study, total phenols of various *Pleurotus* species varied from 3.6 to 7.1 mg GAE.g^{-1} compared to the reported amounts in other *Pleurotus* species such as *P. eryngii* (21.67 mg tannic acid g^{-1}), *P. djamor* (18.88 mg tannic acid g^{-1} of mycelium) (Mishra et al. 2013), *P. eryngii* (4.45 mg GAE.g^{-1}), *P. ostreatus* (4.37 mg GAE.g^{-1}), *P. florida* (4.56 mg GAE.g^{-1}), *P. sajor caju* (3.97 mg GAE.g^{-1}) (Dundar et al. 2013). González-Palma et al. (2016) reported in aqueous mycelium extracts (obtained by boiling) of *P. ostreatus* 4.09 mg GAE.g^{-1} and 0.192 mg QE.g^{-1}. Lee et al. (2007) showed that hot water extract from mycelia of *P. citrinopileatus* as 7.85 mg GAE.g^{-1}. The production of extractable metabolites produced by *Pleurotus* species may alter due to different

growth media, different strains of mushroom and extraction solvents.

Antioxidant Activity of Extracts

The hot water extracts were screened for antioxidant activity. For this purpose, DPPH free radical scavenging technique was applied (Figure 3). In the presence of 10 mg.mL^{-1} extract, *P. sajor-caju* (69.67%) showed the highest radical scavenging effect and this followed by *P. ostreatus* (66.12%), *P. citrinopileatus* (64.12%), *P. florida* (56.42%) and *P. eryngii* (48.85%), respectively. As the extract concentration increased, the scavenging activity was also increased. This means that there is a dose dependent DPPH scavenging efficiency of the mycelium extract. Similar results have been reported in previous studies. The obtained results have been reported similarly in previous studies. Dundar et al. (2013) mentioned that the ethanolic extracts (obtained from mycelia) from *P. eryngii, P. ostreatus, P. florida* and *P. sajor-caju* scavenged DPPH radicals with 68.01%, 71.29%, 61.97% and 62.82% at 10 mg.mL^{-1}, respectively. Antioxidant activity of the hot water mycelial extract of *P. salmoneo-stramineus*, *P. ostreatus*, *P. eryngii* and *P. citrinopileatus* was determined between 22% and 75% at 10 mg.mL^{-1} (Smith 2014).

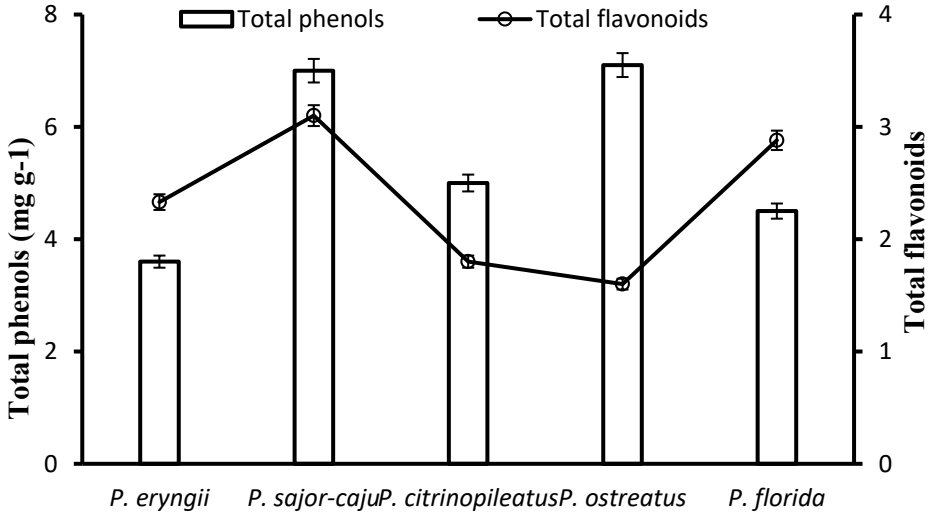

Figure 2. The total phenolic and flavonoids content in mushroom extracts

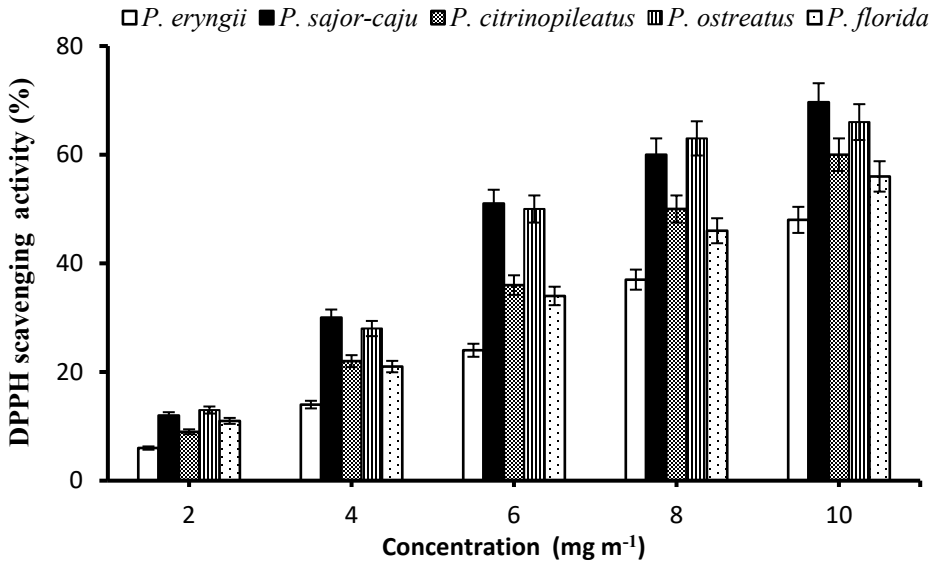

Figure 3. DPPH• scavenging capacity of *Pleurotus* species mycelial extracts

Antimicrobial Activity

The hot water extracts (2 mg.disc^{-1}, 4 mg.disc^{-1} and 6 mg.disc^{-1}) of the mycelia cells of five different *Pleurotus* species were performed against two Gram positive (*B. cereus* and *A. agilis*) and four Gram-negative (*P. aeruginosa*, *X. campestris, K. oxycota* and *H. pylori*) bacteria by the disc diffusion technique. As shown in Table 2, the concentration of the extracts changes the antibacterial effect. Among all bacteria, *Xanthomonas campestris* was the most sensitive to extracts. The extracts of *P. ostreatus* and *P. florida* were highly antibacterial against *A. agilis* and *H. pylori*. The extract of *P. eryngii* was highly antibacterial against *K. oxycota* and *X. campestris.*

Mushrooms contain different natural antimicrobial compounds such as anthraquinones, aromatic organic compounds, benzoic acid derivatives, fatty acids, organic acids, ribonuclease, peptides, polysaccharides, proteins, quinolines, steroids, terpenes, (Alves et al. 2012). Antibacterial effects of mushroom extracts largely dependent on the mushroom species, their strains and vegetative forms, cultivation conditions, method of extract preparation, methods of evaluation and interpretation of the results (Yamaç and Bilgili, 2006, Vamanu, 2012, Heleno et al., 2013, Dogan et al., 2013, Canli et al., 2015). *Pleurotus* species have a variety of compounds at different concentrations, and this explains the difference of antibacterial activity. Many researchers reported that extracts from the fruiting body or mycelial biomass of *Pleurotus* species exhibited antibacterial activity against different microorganisms (Table 3).

Table 2. Inhibition zones (mm) of crude extracts of *Pleurotus* species against bacteria

	Concentration of crude extracts of *Pleurotus* species (mg.disc^{-1})														
Bacteria	***P. eryngii***			***P. sajor-caju***			***P. citrinopileatus***			***P. ostreatus***			***P. florida***		
	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c
H. pylori	-	7.1	8.4	-	6.4	7.3	-	6.2	7.3	7.5	9.8	12.4	8.1	10	13
X. campestris	7.2	8.3	12.1	-	7.4	9.7	7.4	8.7	11.8	7	8.3	10.7	6.3	7.4	9.8
K. oxycota	11.2	13.4	15.2	-	8.2	10.3	-	7.8	9.8	-	8.2	10.8	-	8.6	11.6
P. aeruginosa	-	7	8.8	-	7.2	9	-	6.8	8.1	-	7.3	9.4	6.3	8	9.7
B. cereus	-	7.4	9.8	-	7.1	10.2	-	7.3	9.6	-	7	9.4	-	7.2	8.8
A. agilis	-	8	10.4	-	8.4	11.2	-	7.2	9.5	11	15	18	7.4	9.3	12.1

a. 2 mg.disc^{-1}, b. 4 mg.disc^{-1}, c. 6 mg.disc^{-1}; "-": no activity observed.

Table 3. Pleurotus extracts with antimicrobial activity against microorganisms

Pleurotus species	**Bacterial species**	**Extract-Solvent**	**References**
P. ostreatus *P. sajor-caju* *P. eryngii*	*B. megaterium, E. coli, K. pneumoniae,* *Candida glabrata, S. aureus* *B. megaterium, C. albicans,* *C. glabrata, E. coli, S. aureus,*	Fruit body- Methanol	Akyuz et al. 2010
P. ostreatus	*K. pneumoniae, S. aureus*, *S. pyogenes, S. dysenteriae,*	Mycelial biomass-water	Younis et al. 2015
	B. subtilis, K. pneumoniae, S. aureus, Shigella dysenteriae, Salmonella enterica, P. aeruginosa	Fruit body- water	
P. eryngii, *P. ostreatus*	*H. pylori*	Fruit body- Ethanol	Shang et al. 2013
P. eryngii *var. ferulae*	*B. megaterium, S. aureus, E. coli, K. pneumoniae,* *C. albicans, C. glabrata,* *Trichophyton spp., Epidermophyton spp.*	Fruit body- Methanol	Akyuz and Kirbag 2009

Conclusion

In conclusion, this study showed the presence of antimicrobial and antioxidant activities in different species of *Pleurotus*. The obtained mushroom extracts can be used in food supplement products and medicinal products for health promotion. The uses of antibiotics are known to be the main control method for diseases but they are detrimental to the human health and the ecosystem, and may contribute to the development of chemical-resistant microorganisms. It is well known that *H. pylori* which cause the ulceration of stomach and then cancer. In this study, we found that *P. sajor-caju* can be used as a medical food for recovering and treatment of ulcer.

Compliance with Ethical Standard

Conflict of interests: The authors declare that for this article they have no actual, potential or perceived conflict of interests.

Acknowledgment: We thank Erkel Gıda A.Ş. and Dr. Abdurrahman Dündar for the gift of the *Pleurotus* species.

References

Akyuz, M., Kirbag, S. (2009). Antimicrobial activity of *Pleurotus eryngii* var. *ferulae* grown on various agro-wastes. *EurAsian Journal of BioSciences*, 3, 58-63.

Akyuz, M., Onganer, A.N., Erecevit, P., Kirbag, S. (2010). Antimicrobial activity of some edible mushrooms in the eastern and southeast Anatolia region of Turkey. *Gazi University Journal of Science*, 23, 125-130.

Alves, J., Ferreira, C., Dias, J., Teixeira, V., Martins, A., Pintado, M. (2012). A review on antimicrobial activity of mushroom (Basidiomycetes) extracts and isolated compounds. *Planta Medica*, 78, 1707-1718.

Barros, L., Calhelha, R.C., Vaz. J.A., Ferreira, I.C.F.R., Baptista, P., Estevinho, L.M. (2007). Antimicrobial activity and bioactive compounds of Portuguese wild edible mushrooms. *European Food Research and Technology*, 225, 151-156.

Barros, L., Ferreira, I.C., Baptista, P. (2008). Phenolics and antioxidant activity of mushroom *Leucopaxillus giganteus* mycelium at different carbon sources. *Food Science* and *Technology International*, 4, 47-55.

Canli, K., Altuner, E.M., Akata, I., Turkmen, Y., Uzek, U. (2016). In vitro antimicrobial screening of *Lycoperdon lividum* and determination of the ethanol extract composition by gas chromatography/mass spectrometry. *Bangladesh Journal of Pharmacology*, 11, 389-394.

Canli, K., Altuner, E.M., Akata, I. (2015). Antimicrobial screening of *Mnium stellare*. *Bangladesh Journal of Pharmacology*, 10, 321-325.

Carvajal, A.E.S., Koehnlein, E.A, Soares, A.A., Eler, G.J., Nakashima, A.T., Bracht, A., Peralta, R.M. (2012). Bioactives of fruiting bodies and submerged culture mycelia of *Agaricus brasiliensis* (*A. blazei*) and their antioxidant properties. *LWT - Food Science and Technology*, 46, 493-499.

Confortin, F.G., Marchetto, R., Bettin, F., Camassola, M., Salvador, M., Dillon, A.J.P. (2008). Production of Pleurotus sajor-caju strain PS-2001 biomass in submerged culture. *Journal of Industrial Microbiology and Biotechnology*, 35, 1149-1155.

Corrêa, R.C.G., Brugnari, T., Bracht, A., Peralta, R.M., Ferreira, I.C. (2016). Biotechnological, nutritional and therapeutic uses of *Pleurotus* spp. (Oyster mushroom) related with its chemical composition, a review on the past decade findings. *Trends in Food Science & Technology*, 50, 103-117.

De Silva, D.D., Rapior, S., Sudarman, E., Stadler, M., Xu, J., Alias, S.A., Hyde, K.D. (2013). Bioactive metabolites from macrofungi: ethnopharmacology, biological activities and chemistry. *Fungal Diversity*, 62, 1-40.

Doğan, H.H., Duman, R., Özkalp, B., Aydin, S. (2013). Antimicrobial activities of some mushrooms in Turkey. *Pharmaceutical Biology*, 51, 707-711.

Dundar, A., Okumus, V., Ozdemir, S., Yildiz, A. (2013). Antioxidant properties of cultured mycelia from four Pleurotus species produced in submerged medium. *International Journal of Food Properties*, 16, 1105-1116.

González-Palma, I., Escalona-Buendía, H.B., Ponce-Alquicira, E., Téllez-Téllez, M., Gupta, V.K., Díaz-Godínez, G., Soriano-Santos, J. (2016). Evaluation of the antioxidant activity of aqueous and methanol extracts of *Pleurotus ostreatus* in different growth stages. *Frontiers in Microbiology*, 7, 1-9.

Han, S.R., Kim, K.H., Lim, K.O., Oh, T.J. (2015). Biological activity analysis of different solvent extracts from

Pleurotus ostreatus. *Indian Journal of Science and Technology*, 8, 1-8.

Heleno, S.A., Stojković, D., Barros, L., Glamočlija, J., Soković, M., Martins, A., Queiroz, M.J.R.P., Ferreira, I.C.F.R. (2013). A comparative study of chemical composition, antioxidant and Antimicrobial properties of *Morchella esculenta* (L.) Pers. from Portugal and Serbia. *Food Research International*, 51, 236–243.

Lee, Y.L., Huang, G.W., Liang, Z.C., Mau, J.L. (2007). Antioxidant properties of three extracts from *Pleurotus citrinopileatus*. *LWT - Food Science and Technology*, 40, 823-833.

Mishra, K.K., Pal, R.S., Arunkumar, R., Chandrashekara, C., Jain, S.K., Bhatt, J.C. (2013). Antioxidant properties of different edible mushroom species and increased bioconversion efficiency of *Pleurotus eryngii* using locally available casing materials. *Food Chemistry*, 138, 1557-1563.

Mukhopadhyay, R., Guha, A.K. (2015). A comprehensive analysis of the nutritional quality of edible mushroom *Pleurotus sajor-caju* grown in deproteinized whey medium. *LWT-Food Science and Technology*, 61, 339-345.

Ozdal, M., Ozdal. O.G., Sezen. A., Algur, O.F. (2016a). Biosynthesis of indole-3-acetic acid by *Bacillus cereus* immobilized cells. *Cumhuriyet Science Journal*, 37, 212-222.

Ozdal, M., Ozdal, O.G., Algur, O.F. (2016b) Isolation and characterization of α-endosulfan degrading bacteria from the microflora of cockroaches. *Polish Journal of Microbiology*, 65, 63-68.

Ozdal, M., Ozdal, O.G., Sezen, A., Algur, O.F., Kurbanoglu, E.B. (2017). Continuous production of indole-3-acetic acid by immobilized cells of *Arthrobacter agilis*. *3 Biotech*, 7, 23.

Reis, F.S., Martins, A., Barros, L., Ferreira, I.C. (2012). Antioxidant properties and phenolic profile of the most widely appreciated cultivated mushrooms: a comparative study between in vivo and in vitro samples. *Food* and *Chemical Toxicology*, 50, 1201-1207.

Rosado, F.R., Germano, S., Carbonero, E.R., da Costa, S.M.G., Iacomini, M., Kemmelmeier, C. (2003). Biomass and exopolysaccharide production in submerged cultures of *Pleurotus ostreatoroseus* Sing. and *Pleurotus ostreatus* "florida"(Jack.: Fr.) Kummer. *Journal of Basic Microbiology,* 43, 230-237.

Sartori, S.B., Ferreira, L.F.R., Messias, T.G., Souza, G., Pompeu, G.B., Monteiro, R.T.R. (2015). *Pleurotus* biomass production on vinasse and its potential use for aquaculture feed. *Mycology*, 6, 28-34.

Shang, X., Tan, Q., Liu, R., Yu, K., Li, P., Zhao, G.P. (2013). In vitro anti-*Helicobacter pylori* effects of medicinal mushroom extracts, with special emphasis on the Lion's Mane mushroom, *Hericium erinaceus* (higher Basidiomycetes). *International Journal of Medicinal Mushrooms*, 15, 165-174.

Smith, H.A. (2014). Production of antimicrobials and antioxidants from filamentous fungi. A thesis submitted to the National University of Ireland for the degree of Doctor of Philosophy.

Turkoglu, A., Duru, M.E., Mercan, N., Kivrak, I., Gezer, K. (2007). Antioxidant and antimicrobial activities of *Laetiporus sulphureus* (Bull.) Murrill. *Food Chemistry*, 101, 267-273.

Vamanu, E. (2012). In vitro antimicrobial and antioxidant activities of ethanolic extract of lyophilized mycelium of *Pleurotus ostreatus* PQMZ91109. *Molecules*, 17, 3653-3671.

Yamaç, M., Bilgili, F. (2006). Antimicrobial activities of fruit bodies and/or mycelial cultures of some mushroom isolates. *Pharmaceutical Biology*, 44, 660-667.

Yildiz, O., Can, Z., Laghari, A.Q., Şahin, H., Malkoç, M. (2015). Wild edible mushrooms as a natural source of phenolics and antioxidants. *Journal of Food Biochemistry*, 39, 148-154.

Younis, A.M., Wu, F.S., El Shikh, H.H. (2015). Antimicrobial activity of extracts of the oyster culinary medicinal mushroom *Pleurotus ostreatus* (higher basidiomycetes) and identification of a new antimicrobial compound. *International Journal of Medicinal Mushrooms*, 17, 579-590.