Environment, Biodiversity & Soil Security
http://jenvbs.journals.ekb.eg/

Edible Mushroom of *Pleurotus* spp.: A Case Study of Oyster Mushroom (*Pleurotus ostreatus* L.)

Gréta Törős [1], Hassan El-Ramady [1,2] and **József Prokisch [1]**

[1] *Institute of Animal Science, Biotechnology and Nature Conservation, Faculty of Agricultural and Food Sciences and Environmental Management, University of Debrecen, 138 Böszörményi Street, 4032 Debrecen, Hungary*
[2] *Soil and Water Dept., Faculty of Agriculture, Kafrelsheikh University, 33516 Kafr El-Sheikh, Egypt*

THE HUMANITY tries to find alternative sources for everyday nutrition beside the traditional ones, which include meats, fruits and vegetables. The edible mushrooms are considered a promising non-traditional source for human diet. Among mushroom species, the genus of *Pleurotus* is commercially essential mushrooms, which produces alone about 25% of total cultivated throughout the world. *Pleurotus* mushrooms are rich in several nutritional compounds like dietary fibers, proteins, carbohydrates, essential amino acids, water-soluble vitamins, and minerals as well as many functional bioactive molecules including polyphenols, polysaccharides, lipids, and terpenoids. The current review focuses on the genus of *Pleurotus* and its different mushroom species. This mushroom has a great attraction from consumers due to its desirable flavor and aroma. This mushroom has also several applications because of its antifungal, anti-inflammatory, antibacterial, antiviral, antidiabetic, hepatoprotective, hypolipidemic, hypotensive and cytotoxic attributes. Like any scientific theme, more and further open questions concerning the mushroom of *Pleurotus ostreatus* and its handling should be answered.

Keywords: Anticancer, Steroids, Ergosterol, Anti-inflammatory, Active ingredients**.**

1. Pleurotus genus and its common species

Beside fruits and vegetables, edible mushrooms are considered an important source for human diet around the world. An increase interest on the mushrooms due to their desirable flavor and aroma, as well as their enormous applications as anti-inflammatory, antifungal, antibacterial, antiviral, hepatoprotective, antidiabetic, hypolipidemic, hypotensive and cytotoxic properties (Zawadzka et al. 2022). Edible mushrooms are a large and fascinating group of fungi, which include 3283 mushroom species as edible or conditionally edible, accounting for about 20% of all mushroom taxa recorded in the global sources (Zhang et al. 2021). Pleurotus (Jacq.: Fr.) Kumm. is the second most distributed edible mushroom worldwide (Sekan et al. 2019). Among many species of edible mushrooms, Pleurotus species, which belongs the Kingdom of Fungi, Phylum of Basidiomycota, Class of Agaricomycetes, Order of Agaricales, Family of Pleurotaceae, and the Genus is Pleurotus **(Table 1**).

China alone produces 87% of the global production of Pleurotus spp. (Barh et al. 2019). Pleurotus species are well known commercial and essential mushrooms, which widely cultivated throughout all over the world and due to their exceptional ligninolytic properties (Bellettini et al. 2019). It is an edible mushroom and it also has several biological effects, as it contains important bioactive molecules. The global production of Pleurotus mushrooms alone may account for around 25% of the total cultivated mushrooms. Pleurotus species could be found in several places including tropical forests and often grow on dead and decaying tree stumps, fallen branches, and wet logs particularly in Asia (Barh et al. 2019). The handling of *Pleurotus* spp. mushroom

*Corresponding author e-mail: ramady2000@gmail.com
Received: 21/01/2022; Accepted: 02/02/2022
DOI: 10.21608/jenvbs.2022.117554.1161

requires depth understanding of the extrinsic and intrinsic factors that are needed for a suitable and efficient production based on their chemical, biological, physical, and enzymatic properties (Bellettini et al. 2019). The mushrooms of Pleurotus are rich in dietary fiber, proteins, carbohydrates, essential amino acids, water-soluble vitamins, and minerals (Raman et al. 2021). Pleurotus has a huge diversity in its species and strains like Pleurotus ostreatus, Pleurotus citrinopileatus var cornucopiae, Pleurotus eryngii, Pleurotus pulmonarius, and Pleurotus djamor (Barh et al. 2019). Many Pleurotus species (e.g., P. citrinopileatus, P. djamor, and P. pulmonarius) could be used as a potential functional food due to their rich in Mg and Zn salts (Włodarczyk et al., 2021).

Table 1. Selected list of some mushroom of *Pleurotus* species that belong Kingdom of Fungi, Phylum *Basidiomycota*, Class *Agaricomycetes*, Order *Agaricales*, Family *Pleurotaceae*, and the *Pleurotus* Genus.

Mushroom species name	Location or occurrence
Pleurotus abalonus Y.H. Han, K.M. Chen & S. Cheng	No occurrences listed
Pleurotus abieticola R.H. Petersen & K.W. Hughes	Russia, China, Japan
Pleurotus albidus (Berk.) Pegler	Caribbean, South America
Pleurotus australis Sacc.	Australia; New Zealand
Pleurotus calyptratus (Lindblad ex Fr.) Sacc.	Europe
Pleurotus citrinopileatus Singer	Eastern Asia
Pleurotus columbinus Quél.	Europe
Pleurotus cornucopiae (Paulet) Quél.	Europe
Pleurotus cystidiosus O. K. Mill.	USA, Japan
Pleurotus djamor (Rumph. ex Fr.) Boedijn	Tropical countries
Pleurotus dryinus (Pers.) P. Kumm.	North America, Europe
Pleurotus eryngii (DC.) Quél.	Europe; the Middle East
Pleurotus euosmus (Berk.) Sacc.	Great Britain
Pleurotus giganteus (Berk.) Karun. & K.D. Hyde	China, Thailand, Australia
Pleurotus flabellatus Sacc.	Congo, Brazil, Costa Rica
Pleurotus ferulae (Lanzi) X. L. Mao, 2000	No occurrences listed
Pleurotus fossulatus Cooke	Afghanistan
Pleurotus florida Eger	No occurrences listed
Pleurotus fuscosquamulosus D.A. Reid & Eicker	Africa, Europe
Pleurotus limpidus (Fr.) Sacc.	Australia; the USA
Pleurotus ostreatus (Jacq. ex Fr.) P. Kumm	North America, Europe
Pleurotus opuntiae (Durieu & Lév.) Sacc.	North America
Pleurotus placentodes (Berk.) Sacc.	China
Pleurotus populinus O. Hilber & O. K. Mill.	North America
Pleurotus pulmonarius (Fr.) Quél.	North America, Australasia
Pleurotus purpureo-olivaceus (G. Stev.) Segedin, P.K. Buchanan & J.P. Wilkie	Australia; New Zealand
Pleurotus nebrodensis (Inzenga) Quél.	Spain, France, India
Pleurotus rattenburyi Segedin	Australia; New Zealand
Pleurotus sajor-caju (Fr.) Singer	Russia and New Zealand
Pleurotus sapidus Sacc.	USA, India, China
Pleurotus salmoneostramineus Lj.N. Vassiljeva	Japan
Pleurotus smithii Guzmán	Mexico
Pleurotus spiculifer (Berk.) Sacc.	No occurrences listed
Pleurotus spodoleucus (Fr.) Quél.	Switzerland, Japan
Pleurotus tuber-regium (Fr.) Singer	Africa, Asia, Australasia
Pleurotus tuoliensis (C.J. Mou) M.R. Zhao & Jin X. Zhang	China

Source: from this website: https://www.gbif.org/species/ and https://www.britmycolsoc.org.uk/library/english-names on 12.01.2022.

Fig. 1. Some photos of mushrooms of *Pleurotus ostreatus* in a fresh form. All photos were taken by Gréta Törős in Nano-Food Lab, Debrecen and from Magyar Gomba Kertész Kft.

Fig. 2. Cultivating bag of oyster (*Pleurotus ostreatus*), which makes from wheat straw material as in Photo 1 (Magyar Gomba Kertész Kft., Demjén), whereas Photo 2 represents the cultivated oyster at Nanofood lab, which made from food industrial wastes (all photos were taken by Gréta Törős in Nano-Food Lab, Debrecen).

Several studies have been published on different *Pleurotus* spp. including study the genetic diversity among these species in many countries like Jordan (Hasan et al. 2018), the bioactive compounds and their and medicinal properties (Paul et al. 2017; Golak-Siwulska et al. 2018; Sarma et al. 2018; Krakowska et al. 2020; Cateni et al. 2021; Elhusseiny et al. 2021a), cultivating on agricultural and agro-industrial by-products (Tagkouli et al. 2021), the green potential of these mushrooms in biotechnology and myco-remediation (Sekan et al. 2019; Ydav et al. 2021), the nutritional values of species of *Pleurotus* (Raman et al. 2021), study the toxic and essential elements in some edible species (Mleczek et al. 2021), and the content of sterols and fatty acids comparing to some other edible mushrooms (Saini et al. 2021).

2. Nutritional value of *Pleurotus ostreatus* L.

Pleurotus mushrooms are rich in several nutritional compounds including proteins, dietary fiber, carbohydrates, vitamins, essential amino acids, and minerals. As well as functional bioactive molecules (Raman et al. 2021). The mushrooms *Pleurotus* have unique applications for flavoring,

excellent preservation quality, aroma, and high nutritional and medicinal values (Raman et al. 2021). *Pleurotus ostreatus,* well known as hiratake and a traditional edible, is considered the most popular among *Pleurotus* species, highly nutritious mushroom with a nutrient-rich dietary composition (Sekan et al. 2019). This mushroom has many applications such as producing lignocellulolytic enzymes (e.g., laccases) for bioethanol production, pulp bleaching, bioremediation, foods, and textiles (Duran-Aranguren et al. 2020). *Pleurotus ostreatus* has a distinguished capacity in the myco-remediation, which could apply to remediate the agro-industrial wastes through the degradation or deterioration a huge variety of compounds/substances in processes as myco-degradation and myco-deterioration (**Table 2**). This mushroom can also modify the structure of biosolids by enhancing their bio-separation, filterability, and dewaterability as highly tolerant to alkaline or acidic environments (Ahmed et al. 2020).

Table 2. The main applied environmental technologies of *Pleurotus* species like organic solid waste recycling, the degradation of pollutants, and bioethanol production.

Pleurotus species	The main applications of *Pleurotus* species	Reference
Bioremediation and organic solid waste recycling		
Pleurotus mutilus	Removing of hexavalent chromium and Congo red dye from aqueous solutions by mushroom biosorption	Alouache et al. (2021)
Pleurotus eryngii	Myco-remediation of sulfonamides by degradation to simpler organic compounds like sugar groups, formyl, acyl, and amino acid-derived compounds	Baran et al. (2021)
Pleurotus ostreatus L.	Mushrooms displayed high potential to degrade the organic micropollutants through bioremediation	Golovko et al. (2021)
Pleurotus ostreatus	Removing sulfonamides from real wastewater	Mayans et al. (2021)
Pleurotus ostreatus	Biodegradation of polycyclic aromatic hydrocarbons like naphthalene by white rot fungus	Elhusseiny et al. (2019)
Pleurotus ostreatus	Bioremediation of soils polluted with petroleum solid wastes and drill cuttings by enzymatic processes for mobilization of carbon from both studied pollutants	Romero-Silva et al. (2019)
Production of bioactive compounds		
Pleurotus floridanus	Extraction of bioactive components (ascorbic acid, flavonoid content, β-carotene, and lycopene) for antimicrobial and anti-inflammatory attributes	Bains et al. (2021)
Pleurotus ostreatus, P. eryngii, and *p. cornucopiae*	Study fatty acids, polysaccharides (glucans), phenolic compounds, triterpenoids (e.g., ergosterol), proteins, peptides and lectins in studied mushrooms	Cateni et al. (2021)
Pleurotus ostreatus, Pleurotus djamor	Extraction of some bioactive compounds from studied mushrooms to synthetize of silver nanoparticles	Martínez-Flores et al. (2021)
Pleurotus pulmonarius	Production of bioactive compounds like exopoly-saccharides using different agro-waste residues (Peels of plantain, mango, pineapple, groundnut shell, coconut coir and walnut husk)	Ogidi et al. (2020)
Pleurotus ostreatus	Production of bioactive compounds like laccase	Duran-Aranguren et al. (2020)
Bioethanol production		
Pleurotus florida	Lignin in cotton spinning wastes was degraded (60 %) and 80–85% of cellulose crystallinity reduced the cellulose after 14 days of pretreatment by mushrooms	Ranjithkumar et al. (2022)
Pleurotus eryngii; P. Florida P. ostreatus; P. pulmonarius; P. salignus	Strong ligninolytic enzymes produced by *Pleurotus* spp. for agro-forestry wastes (wheat straw, maize stalks and sawdust of blackberry, oak, grapevine, raspberry, plum and apple) to produce bioethanol	Galić et al. (2021)
Pleurotus pulmonarius	Producing biofuel from sawdust-based mushroom substrates of soft-wood spruce or hard-wood alder	Chen et al. (2020)
Pleurotus cornucopiae, P. ostreatus	Sustainable digestate management for some crops residues like maize, and sorghum for high cultivation efficiency	Fornito et al. (2020)
Pleurotus sapidus	Solid-state fermentation of rice straw and husks and sunflower seed hulls myco-employed to biomass and enzyme production	Postemsky et al. (2019)

Depending on the mushroom species, the proximate composition and nutritional characteristics of mushrooms may have 84.1–61.3% of carbohydrates, 28.6–15.4% of proteins, and 3–33.3% of dietary fiber (Valverde et al. 2015). The protein content in mushrooms in general is higher compared to other vegetables, but less compared to meat and milk. These species are rich sources of proteins and minerals (Ca, Fe, Na, P, and K) and vitamins (B complex and C) (Lee et al. 2018). Additionally, the food quality may increase due to the richness of umami-taste in *Pleurotus* mushrooms (Lavelli et al. 2018). These mushrooms contain all the essential amino acids, including S-containing amino acids like methionine, and cysteine. *Pleurotus* mushrooms are considered a functional food due to their higher food value, mainly because of the high content of protein, carbohydrate, minerals, and vitamins (Raman et al. 2021). By many researchers, extensive research on *Pleurotus* species and their nutritional and medicinal attributes has been investigated as mentioned before. The most cultivated species of *Pleurotus* genus are *P. ostreatus* (black oyster), *P. sajor-caju* (gray oyster), *P. florida* (white oyster) and *P. eous* (pink or red oyster), and, particularly, *P. florida* and *P. sajor-caju* are the most popular (Raman et al. 2021). The main information about the *Pleurotus ostreatus* can present in **Table 3** including the basic information about this mushroom.

Table 3. The main nutritional and bioactive compounds of *Pleurotus ostreatus*.

Main item	Characterization					Ref.
Scientific and English name						
	Pleurotus ostreatus (Jacq. ex Fr.) P. Kumm and its English name is black oyster					[2]
Yield and harvesting	First harvest (19 d), yield (845.66 g kg^{-1}), biological efficiency (84.5 %)					[1]
Optimum temp. and growing media	21–24 °C, cultivated on straw of paddy rice, cereals including wheat, barley, maize, sugarcane bagasse, and crop residues					[2]
Occurrences	Cultivated in Africa, Australasia, and China, Korea, India, Japan, Europe, USA					[2]
Contents of vitamins						
	Thiamin (B_1)	Riboflavin (B_2)	Niacin (B_3)	Folic acid (B_9)	Ascorbic acid (C)	
Content (%) dw	0.32	0.58	8.72	0.052	12.52	[3]
Content, g/100 g fw	0.15	0.22	3.23	0.009	6.8-20	[4]
Contents of micronutrients (on basis dry weight)						
	Ca (mg kg^{-1})	Zn (mg kg^{-1})	Fe (mg kg^{-1})	Mg (mg kg^{-1})	K (mg kg^{-1})	
	260	38	15.8	900	1,950	[5]
	730	110.41	130	2,800	Not referred	[6]
	110	0.3	3.7	17.7	319.1	[7]
	1,200	61	48	1,700	30,000	[8]
	3,360	86.9	148.3	2,177	14,243	[9]

List of refs. [1] Jafarpour and Eghbalsaeed (2012), [2] Raman et al. (2021), [3] Patil et al. (2010), [4] Podkowa et al. (2021), [5] Raman et al. (2021), [6] Koutrotsios et al. (2020), [7] Kortei et al. (2017), [8] Golian et al. (2022), [9] Hoa et al. (2015)

3. Therapeutic applications of *Pleurotus ostreatus* L.

The medicinal using of several edible mushrooms have been confirmed by many studies due to the existence of many organic compounds and antioxidants (Podkowa et al. 2020). *Pleurotus* species has been successfully applied as a food supplement for cardiac patients to reduce the blood cholesterol level due to their content of nicotinic acid, mevinolin, and a higher level of β-glucans (Raman et al. 2014). Several myco-chemicals could be found in *Pleurotus* mushrooms including polysaccharides, phenolic compounds, proteins, lipids, and, terpenoids, which have beneficial effects for human nutrition and health (Cateni et al. 2021). The bioactive compounds and therapeutic uses of many *Pleurotus* spp. (oyster mushrooms) have been discussed in many distinguished reports such as Paul et al. (2017), Golak-Siwulska et al. (2018), Sarma et al. (2018), Duran-Aranguren et al. (2020), Bains et al. (2021), Cateni et al. (2021), Elhusseiny et al. (2021a, b), Martínez-Flores et al. (2021), Podkowa e al. (2021), and Raman et al. (2021).

This is a call by the journal of Environment, Biodiversity and soil Security (EBSS) to publish all kinds on articles about the *Pleurouts* species especially *P. ostreatus* including complete or mini-review articles, original articles, and short communications. The studied mushroom has a great nutritional and medicinal attributes, which attracted several researchers for more investigations about this mushroom and their different applications. Further studies concerning this mushroom are still needed to open new windows of research on it particularly its potential against new pandemic like COVID-19.

Ethics approval and consent to participate: This article does not contain any studies with human participants or animals performed by any of the authors.

Consent for publication: All authors declare their consent for publication.

Funding: This research received no external funding.

Conflicts of Interest: The author declares no conflict of interest.

Acknowledgments: The authors thank the support of the **2020-1.1.2-PIACI-KFI-2020-00100 Project** "Development of innovative food raw materials based on Maillard reaction by functional transformation of traditional and exotic mushrooms for food and medicinal purposes".

4. References

Ahmed PM, de Figueroa LIC, Pajot HF (2020). Dual Purpose of ligninolytic- basidiomycetes: mycoremediation of bioethanol distillation vinasse coupled to sustainable bio-based compounds production, Fungal Biology Reviews, https://doi.org/10.1016/j.fbr.2019.12.001.

Alouache A, Selatnia A, Sayah HE, Khodja M, Moussous S, Daoud N (2021). Biosorption of hexavalent chromium and Congo red dye onto *Pleurotus mutilus* biomass in aqueous solutions. International Journal of Environmental Science and Technology https://doi.org/10.1007/s13762-021-03313-2.

Bains A, Chawla P, Tripathi A, Sadh PK (2021). A comparative study of antimicrobial and anti-inflammatory efficiency of modified solvent evaporated and vacuum oven dried bioactive components of *Pleurotus floridanus*. J Food Sci Technol 58(9), 3328–3337. https://doi.org/10.1007/s13197-020-04891-8.

Baran W, Adamek E, Waodarczyk A, Lazur J, Opoka W, Muszyaska B (2021). The remediation of sulfonamides from the environment by Pleurotus eryngii mycelium. Efficiency, products and mechanisms of mycodegradation. Chemosphere, 262, 128026–. doi:10.1016/j.chemosphere.2020.128026

Barh A, Sharma VP, Annepu SK, Kamal S, Sharma S, Bhatt P (2019). Genetic improvement in *Pleurotus* (oyster mushroom): a review. 3 Biotech 9, 322. https://doi.org/10.1007/s13205-019-1854-x

Bellettini MB, Fiorda FA, Maieves HA, Teixeira GL, Ávila S, Hornung PS, Júnior AM, Ribani RH (2019). Factors affecting mushroom *Pleurotus* spp. Saudi J Biol Sci. 26(4): 633–646. doi: 10.1016/j.sjbs.2016.12.005

Cateni F, Gargano ML, Procida G, Venturella G, Cirlincione F, Ferraro V (2021). Mycochemicals in wild and cultivated mushrooms: nutrition and health. Phytochem Rev https://doi.org/10.1007/s11101-021-09748-2

Chen F, Xiong S, Sundelin J, MartÃ-n C, Hultberg M (2020). Potential for combined production of food and biofuel: Cultivation of Pleurotus pulmonarius on soft- and hardwood sawdusts. Journal of Cleaner Production, 266, 122011–. doi:10.1016/j.jclepro.2020.122011

Duran-Aranguren D, Chiriva-Saloman JS, Anaya L, Duran-Sequeda D, Cruz LJ, Serrano JD, Sarmiento L, Restrepo S, Sanjuan T, Sierra R. (2020). Effect of bioactive compounds extracted from Cordyceps nidus ANDES-F1080 on laccase activity of *Pleurotus ostreatus* ANDES-F515. Biotechnology Reports, 26, e00466. doi:10.1016/j.btre.2020.e00466

Elhusseiny SM, Amin HM, Shebl RI (2019). Modulation of laccase transcriptome during biodegradation of naphthalene by white rot fungus *Pleurotus ostreatus*. International Microbiology 22, 217–225. https://doi.org/10.1007/s10123-018-00041-5

Elhusseiny SM, El-Mahdy TS, Awad MF, Elleboudy NS, Farag MMS, Aboshanab KM, Yassien MA (2021a). Antiviral, Cytotoxic, and Antioxidant Activities of Three Edible Agaricomycetes Mushrooms: *Pleurotus columbinus*, *Pleurotus sajor-caju*, and *Agaricus bisporus*. J. Fungi, 7, 645. https://doi.org/10.3390/jof7080645.

Elhusseiny SM, El-Mahdy TS, Awad MF, Elleboudy NS, Farag MMS, Yassein MA, Aboshanab KM (2021b). Proteome Analysis and *In Vitro* Antiviral, Anticancer and Antioxidant Capacities of the Aqueous Extracts of *Lentinula edodes* and *Pleurotus ostreatus* Edible Mushrooms. Molecules, 26, 4623. https://doi.org/10.3390/molecules 26154623.

Fornito S, Puliga F, Leonardi P, Di Foggia M, Zambonelli A, Francioso O (2020). Degradative Ability of Mushrooms Cultivated on Corn Silage Digestate. Molecules 25, 3020. doi:10.3390/molecules25133020

Galić M, Stajić M, Vukojević J, Ćilerdžić J (2021). Obtaining Cellulose Available Raw Materials by Pretreatment of Common Agro-Forestry Residues with *Pleurotus* spp. Front. Bioeng. Biotechnol. 9:720473. doi: 10.3389/fbioe.2021.720473

Golian M, Hegedusová A, Mezeyová I, Chlebová Z, Hegedus O, Urminská D, Vollmannová A, Chlebo P (2022). Accumulation of Selected Metal Elements in Fruiting Bodies of Oyster Mushroom. Foods, 11, 76. https://doi.org/10.3390/foods11010076

Golovko O, Kaczmarek M, Asp Hå, Bergstrand K-J, Ahrens L, Hultberg M (2021). Uptake of perfluoroalkyl substances, pharmaceuticals, and parabens by oyster mushrooms (*Pleurotus ostreatus*) and exposure risk in human consumption, Chemosphere, https://doi.org/10.1016/j.chemosphere.2021.132898

Hasan HA, Almomany AM, Hasan S, Al-Abdallat AM (2018). Assessment of Genetic Diversity among *Pleurotus* spp. Isolates from Jordan. J. Fungi, 4, 52; doi: 10.3390/jof4020052

Hoa HT, Wang C-L, Wang C-H (2015). The Effects of Different Substrates on the Growth, Yield, and Nutritional Composition of Two Oyster Mushrooms (*Pleurotus ostreatus* and *Pleurotus cystidiosus*). Mycobiology 43(4), 423-434. http://dx.doi.org/10.5941/MYCO.2015.43.4.423

Jafarpour M, Eghbalsaeed S (2012). High protein complementation with high fiber substrates for oyster mushroom cultures. Afr J Biotechnol. 11(14):3284–3289.

Jeon SM, Bok SH, Jang MK et al (2001) Antioxidative activity of naringin and lovastatin in high cholesterol-fed rabbits. Life Sci 69(24), 2855–2866. https://doi.org/10.1016/s00243205(01)01363-7

Kortei NK, Odamtten GT, Obodai M, Wiafe-Kwagyan M, Addo EA (2017). Influence of low dose of gamma radiation and storage on some vitamins and mineral elements of dried oyster mushrooms (*Pleurotus ostreatus*). Food Sci Nutr. 5:570–578. DOI: 10.1002/fsn3.432.

Koutrotsios G, Danezis G, Georgiou C, Zervakis GI (2020). Elemental Content in *Pleurotus ostreatus* and *Cyclocybe cylindracea* Mushrooms: Correlations with Concentrations in Cultivation Substrates and Effects on the Production Process. Molecules, 25, 2179. doi:10.3390/molecules25092179.

Krakowska A, Zięba P, Włodarczyk, A., Kała, K., Sułkowska-Ziaja, K., Bernaś, E., Sękarab, A., Ostachowicz, B., Muszyńska, B. (2020). Selected edible medicinal mushrooms from *Pleurotus* genus as an answer for human civilization diseases. Food Chemistry, 127084. doi:10.1016/j.foodchem.2020.12708

Lavelli V, Proserpio C, Gallotti F, et al. (2018). Circular reuse of bio-resources: the role of Pleurotus spp. in the development of functional foods. Food Funct. 9(3):1353–1372.

Lee K, Sim U, Choi Y, et al. (2018). Nutritional compositions and antioxidant activities of frequently consumed mushrooms in Korea. J Kor Food Nutr Assoc. 47(11):1178–1184.

Martínez-Flores HE, Contreras-Chávez R, Garnica-Romo MG (2021). Effect of Extraction Processes on Bioactive Compounds from *Pleurotus ostreatus* and *Pleurotus djamor*: Their Applications in the Synthesis of Silver Nanoparticles. Journal of Inorganic and Organometallic Polymers and Materials 31, 1406–1418. https://doi.org/10.1007/s10904-020-01820-2

Mayans B, Camacho-Arévalo R, García-Delgado C, Antón-Herrero R, Escolástico C, Segura ML, Eymar E (2021). An assessment of *Pleurotus ostreatus* to remove sulfonamides, and its role as a biofilter based on its own spent mushroom substrate. Environmental Science and Pollution Research 28, 7032–7042. https://doi.org/10.1007/s11356-020-11078-3

Mleczek M, Budka A, Siwulski M, Mleczek P, Budzyńska S, Proch J, Gąsecka M, Niedzielski P, Rzymski P (2021). A comparison of toxic and essential elements in edible wild and cultivated mushroom species. European Food Research and Technology 247, 1249–1262. https://doi.org/10.1007/s00217-021-03706-0.

Ogidi CO, Ubaru AM, Ladi-Lawal T, Thonda OA, Aladejana OM, Malomo O (2020). Bioactivity assessment of exopolysaccharides produced by *Pleurotus pulmonarius* in submerged culture with different agro-waste residues. Heliyon, 6(12), e05685. doi:10.1016/j.heliyon.2020.e05685.

Patil SS, Ahmed SA, Telang SM, et al. (2010). The nutritional value of *Pleurotus ostreatus* (jacq.:fr.) Kumm cultivated on different lignocellulosic agrowastes. Innov Rom Food Biotechnol. 7: 66–76.

Paul C, Roy T, Das N (2017). Potentiality of Oyster Mushroom (*Pleurotus* Spp.) in Medicine- A Review. Ann Food Process Preserv 2(2), 1014.

Podkowa A, Kryczyk-Poprawa A, Opoka W, Muszyńska B (2021). Culinary–medicinal mushrooms: a review of organic compounds and bioelements with antioxidant

activity. European Food Research and Technology 247, 513–533. https://doi.org/10.1007/s00217-020-03646-1

Postemsky PD, Bidegain MA, Lluberas G, Lopretti MI, Bonifacino S, Inés LM, Zygadlo JA, Fernández-Lahore M, Omarini AB (2019). Biorefining via solid-state fermentation of rice and sunflower by-products employing novel monosporic strains from *Pleurotus sapidus*. Bioresource Technology, 121692, doi:10.10 16/j.biortech.2019.121692.

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/10.10 80/12298093.2020.1835142.

Raman J, Nanjian R, Lakshmanan H, et al. (2014). Hypolipidemic effect of *Pleurotus djamor* var. roseus in experimentally induced hyper-cholesteromic rats. Res J Pharm Biol Chem Sci. 5(2): 581–588.

Ranjithkumar M, Uthandi S, Kumar PS, Muniraj I, Thanabal V, Rajarathinam R (2022). Highly crystalline cotton spinning wastes utilization: Pretreatment, optimized hydrolysis and fermentation using *Pleurotus florida* for bioethanol production. Fuel 308, 122052. https://doi.org/10.1016/j.fuel.2021.122052

Romero-Silva R, Sánchez-Reyes A, Díaz-Rodríguez Y, Batista-García RA, Hernández-Hernández D, de Robles JT (2019). Bioremediation of soils contaminated with petroleum solid wastes and drill cuttings by *Pleurotus* sp. under different treatment scales. SN Applied Sciences 1, 1209. https://doi.org/10.1007/s42452-019-1236-3

Saini RK, Rauf A, Khalil AA, Ko E-Y, Keuma Y-S, Anwar S, Alamri A, Rengasamy KRR (2021). Edible mushrooms show significant differences in sterols and fatty acid compositions. South African Journal of Botany, 141, 344–356. doi:10.1016/j.sajb.2021.05.022

Sarma D, Saha AK, Datta BK (2018) Bioactive compounds with special references to anticancer property of oyster mushroom *Pleurotus ostreatus*. J Pharmacogn Phytochem 7(4):2694–2698.

Sekan AS, Myronycheva OS, Karlsson O, Gryganskyi AP, Blume Y (2019). Green potential of *Pleurotus* spp. in biotechnology. PeerJ.; 7: e6664. doi: 10.7717/peerj.6664.

Sharma J, Sharma D, Sharma A, Bansal S (2021). Thermo stable tyrosinase purified from *Pleurotus djamor* grown in biomimetic calcium carbonate: A biological strategy to industrial waste remediation. Environmental Technology & Innovation 21, 101294, https://doi.org/1 0.1016/j.eti.2020.101294.

Tagkouli D, Bekiaris, G.; Pantazi, S.; Anastasopoulou, M.E.; Koutrotsios, G.; Mallouchos, A.; Zervakis, G.I.; Kalogeropoulos, N (2021). Volatile Profiling of *Pleurotus eryngii* and *Pleurotus ostreatus* Mushrooms Cultivated on Agricultural and Agro-Industrial By-Products. Foods, 10, 1287. https://doi.org/10.3390/foo ds10061287.

Valverde ME, Hernandez-Perez T, Paredes-Lopez O (2015). Edible mushrooms: improving human health and promoting quality life. Int J Microbiol. 2015, 376387, 1-14.

Włodarczyk A, Krakowska A, Sułkowska-Ziaja K, Suchanek M, Zieba P, Opoka W, Muszynska B (2021). Pleurotus spp. Mycelia Enriched in Magnesium and Zinc Salts as a Potential Functional Food. Molecules, 26, 162. https://doi.org/10.3390/molecules26010162

Yadav P, Rai SN, Mishra V, Singh MP (2021). Mycoremediation of environmental pollutants: a review with special emphasis on mushrooms. Environmental Sustainability 4, 605–618. https://doi.org/10.1007/s42398-021-00197-3

Zawadzka A, Janczewska A, Kobus-Cisowska J, Dziedziński M, Siwulski M, Czarniecka-Skubina E, Stuper-Szablewska K (2022). The effect of light conditions on the content of selected active ingredients in anatomical parts of the oyster mushroom (*Pleurotus ostreatus* L.). PLoS One. 17(1), e0262279. doi: 10.1371/journal.pone.0262279.

Zhang Y, Mo M, Yang L, Mi F, Cao Y, Liu C, Tang X, Wang P, Xu J (2021). Exploring the Species Diversity of Edible Mushrooms in Yunnan, Southwestern China, by DNA Barcoding. J. Fungi, 7, 310. https://doi.org/10.3390/jof7040310.