AUCTORES
Globalize your Research

Journal of Pharmaceutics and Pharmacology Research
Waill A. Elkhateeb *

Open Access

Research Article

Mycotherapy of the good and the tasty medicinal mushrooms *Lentinus, Pleurotus,* and *Tremella*

Waill A. Elkhateeb[1*] and Ghoson M. Daba[1]
[1] Chemistry of Natural and Microbial Products Department, Pharmaceutical Industries Division, National Research Centre, Dokki, Giza, 12622, Egypt.
***Corresponding Author:** Waill A. Elkhateeb, Chemistry of Natural and Microbial Products Department, Pharmaceutical Industries Division, National Research Centre, Dokki, Giza, 12622, Egypt.

Received date: February 13, 2021; Accepted date: February 26, 2021; Published date: March 06, 2021
Citation: Waill A. Elkhateeb and Ghoson M. Daba (2021) Mycotherapy of the good and the tasty medicinal mushrooms Lentinus, Pleurotus, and Tremella *J. Pharmaceutics and Pharmacology Research*. 4(2); DOI: 10.31579/2693-7247/029
Copyright: © 2021, Waill A. Elkhateeb, This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Abstract

Fungi generally and mushrooms secondary metabolites specifically represent future factories and potent biotechnological tools for the production of bioactive natural substances, which could extend the healthy life of humanity. The application of microbial secondary metabolites in general and mushrooms metabolites in particular in various fields of biotechnology has attracted the interests of many researchers. This review focused on Lentinus, Pleurotus, and Tremella as a model of edible mushrooms rich in therapeutic agents that have known medicinal applications.

Keyword: lentinus; pleurotus; tremella; biological activities

Introduction

Mushrooms have been used as a traditional medicine for the last few eras. Mushrooms as higher Basidiomycetes and Ascomycetes contain secondary metabolites in their fruit bodies, cultured mycelium, and cultured broth. Mushrooms have been used in many sides of human activity for many years [1]. Some of these mushrooms have been called medicinal mushrooms due to their various morphological, physiological, and ecological characteristics that are also responsible for their diversity. Medicinal mushrooms produce a wide range of bioactive compounds [1]. Medicinal mushrooms possess medicinal properties such as anti-tumor, immunomodulating, antioxidant, cardiovascular, anti-hypercholesterolemic, anti-viral, anti-bacterial, anti-parasitic, antifungal, detoxification, hepatoprotective, and anti-diabetic effects [2-8]. Hence, mushrooms have gained a lot of attention as a functional food and for the development of drugs and nutraceuticals. [9-12]. Medicinal mushrooms exhibit many biological activities as anti-diabetic potential and Antihyperglycemic agents. The bioactive compound like polysaccharide, protein, lipids, fiber, and some low molecular weight compounds like alkaloids, terpenoids, lactones, lectins, and phenolic substances are involved in many diseases as a therapeutic mediators and also have been shown a major landmark for the cure of diabetes. [13]. The fungi belonging to the genus *Ganoderma* have been used since ancient times in Eastern traditional medicine in the treatment and prevention of several diseases such as cancer, hypertension, and diabetes, among many other conditions. More than 140 biologically active triterpenoids and 200 polysaccharides, as well as proteins and various metabolites, have been isolated from the fruiting bodies, mycelium and spores of different species of *Ganoderma*. Species belonging to the genus *Ganoderma* have been used since ancient times in Eastern traditional medicine, until modern days in the treatment, and prevention of several diseases such as cancer, hypertension, chronic bronchitis, asthma, and others [14, 15]. More recently, different preparations made from mycelium, fruiting bodies, and spores of *Ganoderma lucidum* have been marketed as dietary supplements due to their antitumor, immunomodulatory, and free radical scavenging abilities [15, 16]. Also, some other species belonging to *Ganoderma* have various beneficial effects on human health, including *Ganoderma tsugae, Ganoderma applanatum, Ganoderma colossum, Ganoderma concinna, Ganoderma pfeifferi,* and *Ganoderma neo–japonicum* [17-19].

The present review focuses on various edible medicinal species of mushrooms belong to genera: *Lentinus, Pleurotus*, and *Tremella*, along with their chemical composition, biologically active compounds isolated, and their pharmacological potential.

The genus *Lentinus*

The most cultivated mushroom worldwide is *Agaricus*, followed by *Lentinus, Pleurotus*, and *Tremella*. Mushrooms production continuously increases, China being the biggest producer around the world [20-22]. However, wild mushrooms are becoming more important for their nutritional, sensory, and especially pharmacological characteristics [23-25]. *Lentinus* species are normally wood-decaying basidiomycetes and have currently lamellae and domestic tissues in the basidiome, and hyaline, ellipsoid to cylindric spores. Species in the subgenus *Lentinus* have hyphal pegs. Commonly, the basidiomes are xeromorphic with a tough, firm texture when dry and have a long life is some country like Spain, but in Thailand, their fruits only formatted early in the summer duo to rain season (Figure, 1). Traditionally, *Lentinus* has been placed in the agaric family Tricholomataceae because species possess a lamellate hymenophore and white spore print [26-28]. *Lentinus* genus belonging to Class; Agaricomycetes, Order; Polyporales, Family;

Polyporaceae. *Lentinus* species are widespread in tropical Africa, Europe, South America, South East Asia, the Pacific Islands, and Australia [29].

Some species belonging to Lentinus and their biological activities

Mushrooms could be an alternative source of new antimicrobial compounds, mainly secondary metabolites, such as terpenes, steroids, anthraquinones, benzoic acid derivatives, and quinolones, but also of some primary metabolites like oxalic acid, peptides, and proteins. *Lentinus* edodes is the most studied species and seems to have an antimicrobial action against both gram-positive and gram-negative bacteria [30]. Finimundy et al. [31] have provided experimental information about the aqueous extracts of *Lentinus edodes* as potential sources of antioxidant and anticancer compounds. These extracts significantly decreased cell proliferation on tumors as well.

Species of *Lentinus* are best known for the commercially important. *Lentinus edodes* or "shiitake mushroom" has been used for many years to investigate functional properties and to isolate compounds for pharmaceutical use; this is because of its positive effects on human health. It has been utilized to alleviate the common cold for hundreds of years and some scientific evidence has supported this belief [32]. Sevindik, [33], determined that *Lentinus tigrinus* possessed antioxidant potential, and it was recommended to limit the consumption of this mushroom due to high oxidant values. It was determined that *L. tigrinus* mushroom collected in regions with adequate oxidative stress levels may be consumed as a natural antioxidant source. Also demonstrated that *Lentinus tigrinus* has antimicrobial activities against 9 different bacteria and fungi; *Staphylococcus aureus*, *Staphylococcus aureus*, *Enterococcus faecalis*, *Escherichia coli*, *Pseudomonas aeruginosa*, *Acinetobacter baumannii*, *Candida albicans*, *Candida krusei*, and *Candida glabrata*.

Lentinus strigellus was cultivated in three different media and the secondary metabolites produced under different culture conditions were isolated and identified by Barros-Filho et al., [34], when cultivated in a liquid medium with peptone, *Lentinus strigellus* produced benzopyrans, 2,2-dimethyl-6-methoxychroman-4-one, 4-hydroxy-2,2-dimethyl-6-methoxychromane and (3R,4S)-3,4-dihydroxy-2,2-dimethyl-6-methoxychromane. When *Lentinus strigellus* cultured in Czapek medium enriched with potato broth, the fungus produced the same benzopyrans except (3S,4S)-3,4-dihydroxy-2,2-dimethyl-6-methoxychromane. Panepoxydone and isopanepoxydone were also isolated when *Lentinus strigellus* was grown in Czapek medium. Extracts and pure compounds of *Lentinus edodes* exhibit antibacterial, antifungal, cytostatic, antioxidant, anticancer, and immunomodulatory activity. Because of these attributes, different products derived from shiitake are on the market and are sold as dietary supplements [35]. A polysaccharide (LVP) was purified from the fruiting body of *Lentinus velutinus* by ethanol precipitation fractionation and Sephadex G-100 column chromatography. Udchumpisai and Bangyeekhun, [36], results revealed that the extracted polysaccharide exhibits both cytotoxic and antioxidant activity, and this polysaccharide showed specific cytotoxicity against cancer cells (HeLa and HepG2 cells), and alterations in cancer cell morphology were found after polysaccharide treatment [36]. Catechin is a major group of phenolic compounds found in 3 species of mushroom, *Lentinus squarrosulus*, *Lentinus polychrous*, and *Lentinus edodes*. The percentage of inhibition of free radical scavenging activity by DPPH assay was higher than 70% in ethanolic extract of *Lentinus squarrosulus* and *Lentinus polychrous*, while in *Lentinus edodes* it was lower as 30%. An anticancer protein, polysaccharide peptide (PSP), was also detected [37].

Figure 1. Lentinus spp., Collected by Linnea Gillman, Locality: United States, Colorado, Douglas, South of Chatfield State Park. Hosted by http://mycoportal.org).

The genus *Pleurotus*

Pleurotus genus, also known as oyster mushrooms, has approximately 40 species and all are commonly edible. In addition to their nutritional value, they possess medicinal properties and other beneficial effects and health-promoting effects. *Pleurotus* genus belonging to Class; Agaricomycetes, Order; Agaricales, Family; Pleurotaceae. *Pleurotus* species widespread in Europe and China, *Pleurotus* mushroom production is responsible for over 70% of the global market. The *Pleurotus* genus is found naturally in forests grouped to scattered, where they are responsible for the decomposition of wood (Figure, 2). *Pleurotus* species are valuable to cultivate and eat, as they are the source of valuable nutrients and healing

ingredients. Mycelium of white rot is known for its bioremediation abilities, including the accumulation of heavy metals and chlorinated aromatic hydrocarbons. *Pleurotus* genus has also been found applicable in the biotransformation of unsaturated terpenoid compounds [38, 39]. In Africa, oyster mushrooms are grown mainly on sawdust, with the addition of rice straw [40, 41].

Some species belonging to Pleurotus and their biological activities

Pleurotus species have been used by humans all over the world for many years [42, 43]. *Pleurotus* species have been used as medicinal mushrooms for a long time since they contain several compounds with important pharmacological and nutraceutical activities. Some of these substances are lectins with immunomodulatory, antiproliferative, and antitumor activities; phenolic compounds with antioxidant activities; and polysaccharides (polysaccharopeptides and polysaccharide proteins) with immunoenhancing and anticancer activities [44-46].

Exopolysaccharides and internal polysaccharides obtained from the *Pleurotus ostreatus* M2191 and PBS281009 cultivated using the batch system. The carbohydrate analysis revealed that the polysaccharides comprised 87–89% EPS and 68–74% IPS. The investigation of antioxidant activity in vitro revealed a good antioxidant potential, particularly for Exopolysaccharides and internal polysaccharides isolated from *Pleurotus ostreatus* [47].

Many researches have indicated that oyster mushrooms contain phenolic compounds with antioxidative effects [48-50]. The fruiting bodies of mushrooms of the *Pleurotus* genus contain lovastatin, which belongs to the group of statins affecting the metabolism of cholesterol. These compounds inhibit LDL cholesterol oxidation and positively affect the coagulation system and fibrinolysis. They have anti-inflammatory, anticoagulation, and antioxidative properties [51].

Extracts from some *Pleurotus* species are a good source of prebiotics due to the high soluble fiber content [52]. Research has proved that when an aqueous extract from *Pleurotus ostreatus* is added to yogurt, it stimulates the growth of useful microorganisms *Streptococcus thermophilus* and *Lactobacillus bulgaricus* [53].

Figure 2. Pleurotus spp., Collected by Dan Molter, Locality: United States, Pennsylvania, Ryerson Station State Park. Hosted by http://mycoportal.org).

The genus *Tremella*

Tremella is a genus of fungi belonging to Division; Basidiomycota, Class; Termellomycetes, Order; Termellales, Family; Tremellaceae. Basidiocarps (fruit bodies), when produced, are gelatinous and described as the jelly fungi. *Tremella* species are mainly parasitic on wood-rotting fungi in the two phyla Ascomycota and Basidiomycota, particularly on species that occur on dead attached branches (Figure, 3). Some *Tremella* species parasitize the fruit bodies of their hosts and sometimes joining host hyphae, and some others parasitize the mycelium within the wood. *Tremella* species occur worldwide as a group. Over 100 species of *Tremella* are currently recognized worldwide. Two species, *Tremella fuciformis*, and *Tremella aurantialba* are commercially cultivated for food and medicinal activities [54, 55].

Some species belonging to Tremella and their biological activities

Tremella fuciformis, an edible medicinal mushroom, is commonly known as snow fungus, snow ear, silver ear fungus, and white jelly mushroom. *Tremella fuciformis* belonging to the order of Tremellales and the family of Tremellaceae, which has been traditionally used for health promotion in China and other East Asian countries for many years [56, 57]. Plenty of bioactive substances are discovered in *Tremella fuciformis*, including fatty acids, proteins, enzymes, polysaccharides, phenols, flavonoids, dietary fiber, and trace elements [58, 59]. Polysaccharides in *Tremella fuciformis*, widely existed in the fruiting bodies, spores, mycelia and ferment liquor. *Tremella fuciformis* polysaccharide shows multiple physiological, and healthy promoting effects, such as enhancing immune function, antitumor, anti-oxidation, anti-aging, hypoglycemic, hypolipidemic, neuroprotection, and other effects [60, 61]. *Tremella fuciformis* polysaccharide has been identified as a major bioactive component. The monosaccharides detected in polysaccharide were mannose, xylose, glucuronic acid, glucose, and galactose. *Tremella fuciformis* polysaccharides shows multiple physiological and healthy promoting effects including

immunomodulation, antitumor, anti-oxidation, anti-aging, hypoglycemic, hypolipidemic, neuroprotection, and other effects [57, 62].

Li, [63], measured the antioxidant activities of various subfractions of the methanol extract of *Tremella fuciformis* and the major phenolic components of the chloroform subfraction, which showed the highest antioxidant. *Tremella fuciformis* chloroform subfraction displayed the highest antioxidant activity in all experimental settings and 3 phenolic acids (4-hydroxybenzoic acid, gentisic acid, and 4-coumaric acid) were identified in the chloroform and ethyl acetate subfractions. The chloroform subfraction also exhibited anti-inflammatory activity in LPS-induced RAW 264.7 cells by inhibiting the expression of inducible nitric oxide synthase and thereby suppressing nitric oxide production [64-66].

Figure 3. Tremella spp., Collected by Gena Bentall, Locality: United States, California, McGuffie Rd, Salinas. Hosted by http://mycoportal.org).

References

1. Elkhateeb WA, Daba GM, Thomas PW, Wen TC. (2019). Medicinal mushrooms as a new source of natural therapeutic bioactive compounds. *Egypt Pharmaceu J*, 18(2): 88-101.
2. Sharma D, Singh VP, Singh NK. (2018). A Review on Phytochemistry and Pharmacology of Medicinal as well as Poisonous Mushrooms. *Mini reviews in medicinal chemistry*, 18(13): 1095-1109.
3. El-Hagrassi A, Daba G, Elkhateeb W, Ahmed E, El-Dein AN, Fayad W, Shaheen M, Shehata R, El-Manawaty M, Wen T. (2020). In vitro bioactive potential and chemical analysis of the n-hexane extract of the medicinal mushroom, *Cordyceps militaris*. *Malays J Microbiol*. 16(1) 40-48.
4. Elkhateeb WA, Daba GM, El-Dein AN, Sheir DH, Fayad W, Shaheen MN, Wen TC. (2020). Insights into the in-vitro hypocholesterolemic, antioxidant, antirotavirus, and anticolon cancer activities of the methanolic extracts of a Japanese lichen, *Candelariella vitellina*, and a Japanese mushroom, *Ganoderma applanatum*. *Egyptian Pharmaceutical Journal*, 19(1): 67.
5. Elkhateeb WA, Elnahas MO, Thomas PW and Daba GM. (2020b). *Trametes Versicolor* and *Dictyophora Indusiata* Champions of Medicinal Mushrooms. *Open Access Journal of Pharmaceutical Research*, 4(1): 1-7.
6. Elkhateeb WA, Daba G. (2020). The endless nutritional and pharmaceutical benefits of the Himalayan gold, *Cordyceps*; Current knowledge and prospective potentials. *Biofarmasi Journal of Natural Product Biochemistry*, 18(2): 1-10.
7. Daba GM, Elkhateeb W, ELDien AN, Fadl E, Elhagrasi A, Fayad W, Wen TC. (2020). Therapeutic potentials of n-hexane extracts of the three medicinal mushrooms regarding their anti-colon cancer, antioxidant, and hypocholesterolemic capabilities. *Biodiversitas Journal of Biological Diversity*, 21(6): 1-10.
8. Thomas PW, Elkhateeb WA, Daba GM. (2020). Chaga (*Inonotus obliquus*): a medical marvel but a conservation dilemma? S*ydowia*, 72: 123-130
9. Hobbs C. (2002). Medicinal mushrooms: an exploration of tradition, healing, and culture. Book Publishing Company.
10. Mau JL, Lin HC, Chen CC. (2002). Antioxidant properties of several medicinal mushrooms. *Journal of agricultural and food chemistry*, 50(21): 6072-6077.
11. Mau JL, Tsai SY, Tseng, YH, Huang SJ. (2005). Antioxidant properties of methanolic extracts from Ganoderma tsugae. *Food chemistry*, 93(4): 641-649.
12. Muszynska B, Sulkowska-Ziaja K, Wolkowska M, Ekiert H. (2011). Chemical, pharmacological, and biological characterization of the culinary-medicinal honey mushroom, *Armillaria mellea* (Vahl) P. Kumm. (Agaricomycetideae): a review. *International journal of medicinal mushrooms*, 13(2): 1-10.
13. Chaturvedi VK, Dubey SK, Singh M. (2019). Antidiabetic potential of medicinal mushrooms. Phytochemicals from Medicinal Plants: Scope, *Applications, and Potential Health Claims*, 137.
14. Lee S, Shim SH, Kim JS, Shin KH, Kang S. (2005). Aldose reductase inhibitors from the fruiting bodies of *Ganoderma applanatum*. *Biological and Pharmaceutical Bulletin*, 28(6): 1103-1105.
15. Elkhateeb WA, Daba GM, Elnahas MO, Thomas PW. (2019). Anticoagulant Capacities of Some Medicinal Mushrooms. *ARC Journal of Pharmaceutical Sciences* (AJPS), 5 (4):1-9.

16. Wachtel-Galor S, Tomlinson B, Benzie IF. (2004). *Ganoderma lucidum* ('Lingzhi'), a Chinese medicinal mushroom: biomarker responses in a controlled human supplementation study. *British Journal of Nutrition*, 91(2): 263-269.
17. González AG, León F, Rivera A, Padrón JI, González-Plata J, Zuluaga JC, Bermejo, J. (2002). New Lanostanoids from the Fungus *Ganoderma* c oncinna. *Journal of natural products*, 65(3): 417-421.
18. Zjawiony JK. (2004). Biologically active compounds from Aphyllophorales (polypore) fungi. *Journal of natural products*, 67(2): 300-310.
19. Trigos Á. (2011). Biologically active metabolites of the genus *Ganoderma*: Three decades of myco-chemistry research. *Revista Mexicana de Micología*, 34: 63-83.
20. Chang S-T, Miles PG. (2008). Mushrooms: Cultivation, Nutritional Value, Medicinal Effect, and Environmental Impact. 2nd. Boca Raton, Fla, USA: CRC Press; 2008.
21. Aida FM, Shuhaimi M, Yazid M, Maaruf AG. (2009). Mushroom as a potential source of prebiotics: a review. *Trends in Food Science & Technology*, 20(11-12): 567–575.
22. Patel S, Goyal A. (2012). Recent developments in mushrooms as anticancer therapeutics: a review. *3 Biotech.* 2(1): 1–15.
23. Ergönül PG, Akata I, Kalyoncu F, Ergönül B. (2013) Fatty acid compositions of six wild edible mushroom species. *The Scientific World Journal*. 1-4.
24. Elkhateeb W, Daba G, Elnahas M, Thomas P, Emam M. (2020). Metabolic profile and skin-related bioactivities of *Cerioporus squamosus* hydromethanolic extract. *Biodiversitas Journal of Biological Diversity*, 21(10): 1-9.
25. Elkhateeb WA, Elnahas MO, Thomas PW, Daba GM. (2020). *Fomes fomentarius* and *Polyporus squamosus* Models of Marvel Medicinal Mushrooms. *Biomedical Research and Reviews*, 3(1): 1-4.
26. Sysouphanthong P, Thongkantha S, Zhao R, Soytong K, Hyde KD. (2010). Mushroom diversity in sustainable shade tea forest and the effect of fire damage. *Biodiversity and conservation*, 19(5): 1401-1415.
27. Karunarathna SC, Yang ZL, Zhao RL, Vellinga EC, Bahkali AH, Chukeatirote E, Hyde KD. (2011). Three new species of *Lentinus* from northern Thailand. *Mycological progress*, 10(4), 389-398.
28. Senthilarasu G. (2015). The lentinoid fungi (*Lentinus* and *Panus*) from Western ghats, India. *IMA fungus*, 6(1): 119-128.
29. Njouonkou AL, Mossebo DC, Akoa A. (2013). The genera *Lentinus* and *Panus* in the Dja Biosphere Reserve and its periphery, Cameroon. *Kew Bulletin*, 68(3): 517-521.
30. Alves M, Ferreira IF, Dias J, Teixeira V, Martins A, Pintado M. (2012) A review on antimicrobial activity of mushroom (*Basidiomycetes*) extracts and isolated compounds. *Planta Medica*. 78(16): 1707–1718.
31. Finimundy TC, Gambato G, Fontana R. (2013). Aqueous extracts of Lentinula edodes and Pleurotus sajor-caju exhibit high antioxidant capability and promising in vitro antitumor activity. Nutrition Research. 33(1): 76–84.
32. Mattila P, Könkö K, Eurola M. (2001). Contents of vitamins, mineral elements, and some phenolic compounds in cultivated mushrooms. Journal of Agricultural and Food Chemistry. 49(5): 2343–2348.
33. Sevindik M. (2018). Investigation of antioxidant/oxidant status and antimicrobial activities of *Lentinus tigrinus*. *Advances in pharmacological sciences*, 2018, 1-10.
34. Barros-Filho BA, de Oliveira MC, Mafezoli J, Barbosa FG, Rodrigues-Filho E. (2012). Secondary metabolite production by the basidiomycete, *Lentinus strigellus*, under different culture conditions. *Natural product communications*, 7(6): 1934578X1200700620.
35. Gaitán-Hernández R, López-Peña D, Esqueda M, Gutiérrez A. (2019). Review of bioactive molecules production, biomass, and basidiomata of shiitake culinary-medicinal mushrooms, *Lentinus edodes* (Agaricomycetes). *International Journal of Medicinal Mushrooms*, 21(9): 1-10.
36. Udchumpisai W, Bangyeekhun E. (2020). Purification, structural characterization, and biological activity of polysaccharides from *Lentinus velutinus*. *Mycobiology*, 48(1): 51-57.
37. Attarat J, Phermthai T. (2015). Bioactive compounds in three edible *Lentinus* mushrooms. *Walailak Journal of Science and Technology* (WJST), 12(6): 491-504.
38. Kalač P. (2016). Edible mushrooms: chemical composition and nutritional value. Academic Press.
39. Ali N, Khairudin H, Mohamed M, Hassan O. (2018). Cultivation of *Pleurotus ostreatus* on oil palm fronds mixed with rubber tree sawdust. *Chem Eng Trans*, 63:547-552.
40. Narh Mensah DL, Addo P, Dzomeku M, Obodai M. (2018). Bioprospecting of powdered pineapple rind as an organic supplement of composted sawdust for *Pleurotus ostreatus* mushroom cultivation. *Food Sci Nutr*, 6: 280-286.
41. Grabarczyk M, Mączka W, Wińska K, Uklańska-Pusz C. (2019). Mushrooms of the *Pleurotus* genus–properties and application. *Biotechnology and Food Science*, 83(1): 13-30.
42. Jayakumar T, Sakthivel M, Thomas PA, Geraldine P. (2008). Pleurotus ostreatus, an oyster mushroom, decreases the oxidative stress induced by carbon tetrachloride in rat kidneys, heart and brain. Chemico-Biological Interactions. 176(2-3): 108–120.
43. Mori K, Kobayashi C, Tomita T, Inatomi S, Ikeda M. (2008) Antiatherosclerotic effect of the edible mushrooms Pleurotus eryngii (Eringi), Grifola frondosa (Maitake), and Hypsizygus marmoreus (Bunashimeji) in apolipoprotein E-deficient mice. Nutrition Research. 28(5): 335–342.
44. Jedinak A, Sliva D. (2008). Pleurotus ostreatus inhibits proliferation of human breast and colon cancer cells through p53-dependent as well as p53-independent pathway. Inter J Oncol. 33(6): 1307–1313.
45. Jagadish LK, Shenbhagaraman R, Venkatakrishnan V, Kaviyarasan V. (2008). Studies on the phytochemical, antioxidant and antimicrobial properties of three indigenous Pleurotus species. J Molec Biol Biotechnol. 1: 20–29.
46. Smiderle FR, Olsen LM, Carbonero ER. (2008). Anti-inflammatory and analgesic properties in a rodent model of a (1→3),(1→6)-linked β-glucan isolated from Pleurotus pulmonarius . European J Pharmacol. 597(1–3): 86–91.
47. Vamanu E. (2012). Biological activities of the polysaccharides produced in submerged culture of two edible Pleurotus ostreatus mushrooms. *Journal of Biomedicine and Biotechnology*, 1-10.
48. Palacios I, Lozano M, Moro C, D'Arrigo M, Rostagno M, Martínez J. (2011). Antioxidant properties of phenolic compounds occurring in edible mushrooms. *Food Chem*. 128: 674-678.
49. Muszyńska B, Sułkowska-Ziaja K, Ekiert H. (2013). Phenolic acids in selected edible basidiomycota species: *Armillaria mellea, Boletus badius, Boletus edulis, Cantharellus cibarius, Lactarius deliciosus* and *Pleurotus ostreatus*. *Acta Sci. Pol., Hortorum Cultus* 12, 107-116.
50. Piska K, Sułkowksa-Ziaja K, Muszyńska B. (2017). Edible mushroom *Pleurotus ostreatus* (oyster mushroom) – its dietary significance and biological activity. *Acta Sci. Pol., Hortorum Cultus* 16(1): 151- 161.
51. Alarcon J, Aguila S, Arancibia-Avila P, Fuentes O, Zamorano-Ponce E, Hernandez M. (2003). Production and purification of

statins from *Pleurotus ostreatus* (Basidiomycetes) strains. Z. Naturforsch. C 58(1-2): 62-64.
52. Synytsya A, Mickova K, Synytsya A, Jablonsky I, Spevacek J, Erban V. (2009). Glucans from fruit bodies of cultivated mushroom *Pleurotus ostreatus* and *Pleurotus eryngii*: Structure and potential prebiotic activity. *Carbohyd. Polym*. 76: 548-556.
53. Pelaes Vital A, Goto P, Hanai L, Gomesda-Costa S, de Abreu Filho B, Nakamura C. (2015). Microbiological, functional and rheological properties of low fat yogurt supplemented with Pleurotus ostreatus aqueous extract. LWT – *Food Sci. Technol*. 64: 1028-1035.
54. Pippola E, Kotiranta H. (2008). The genus *Tremella* (Basidiomycota, Tremellales) in Finland. In Annales Botanici Fennici (Vol. 45, No. 6, pp. 401-434). *Finnish Zoological and Botanical Publishing Board.*
55. Malysheva VF, Malysheva EF, Bulakh EM. (2015). The genus *Tremella* Tremellales, Basidiomycota in Russia with description of two new species and proposal of one nomenclatural combination. *Phytotax*, 238(1): 40-70.
56. Park KJ, Lee S, Kim HS, Yamazaki M, Chiba K, Ha HC. (2007) The neuroprotective and neurotrophic effects of *Tremella fuciformis* in PC12h cells. *Mycobiology*, 35(1): 11-15.
57. Yang D, Liu Y, Zhang L. (2019). *Tremella* polysaccharide: The molecular mechanisms of its drug action. *Progress in molecular biology and translational science*, 163: 383-421.
58. Cheng HH, Hou WC, Lu ML. (2002). Interactions of lipid metabolism and intestinal physiology with *Tremella fuciformis* Berk edible mushroom in rats fed a high-cholesterol diet with or without Nebacitin. *J Agric Food Chem*. 50: 7438–7443.
59. Kimk A, Chang HY, Choi SW, Yoon JW, Lee C. (2006). Cytotoxic effects of extracts from *Tremella fuciformis* strain FB001 on the human colon adenocarcinoma cell line DLD-1. *Food Sci Biotechnol*. 15(6): 889–895.
60. Zhu H, Sun SJ. (2008). Inhibition of bacterial quorum sensing-regulated behaviours by *Tremella fuciformis* extract. *Curr Microbiol*. 57: 418–422.
61. Ma SY, He L, Yao LF. (2010) Research advances on structural characteristics and bioactivity of Tremella fuciformis polysaccharides. *Food Sci*. 23: 411–416.
62. Zhou F, Kong F, Wang B, McPhie K, Gilbert GL, Dwyer DE. (2011). Molecular characterization of enterovirus 71 and Coxsackievirus A16 using the 5' untranslated region and VP1 region. *J Med Microbiol*. 60(Pt 3): 349–358.
63. Wu YJ, Wei ZX, Zhang FM, Linhardt RJ, Sun PL, Zhang AQ. (2019). Structure, bioactivities and applications of the polysaccharides from *Tremella fuciformis* mushroom: a review. *International journal of biological macromolecules*, 121: 1005-1010.
64. Li H. (2015). Antioxidant and Anti-inflammatory Activities of Methanol Extracts of *Tremella fuciformis* and Its Major Phenolic Acids. , *Journal of Food Science*, 79(1): 1-10.
65. Li H, Lee HS, Kim SH, Moon B, Lee C. (2014). Antioxidant and anti-inflammatory activities of methanol extracts of *Tremella fuciformis* and its major phenolic acids. *Journal of food science*, 79(4): C460-C468.
66. Elkhateeb WA. (2020). What Medicinal Mushroom Can Do?. *Chem Res J*, *5*(1), 106-118.