Novel Research in Microbiology Journal (2020), 4(2): 688-695
Review Article

(Print) (ISSN 2537-0286)
(Online) (ISSN 2537-0294)
www.nrmj.journals.ekb.eg
DOI: 10.21608/nrmj.2020.84017

Pharmacological activities of Oyster mushroom *(Pleurotus ostreatus)*

Girma Waktola[1]; Tasisa Temesgen[2*]

[1]Department of Biology, Ambo University, Ethiopia; [2]School of Natural Resource Management and Environmental Sciences, Haramaya University, Ethiopia

[*]Corresponding author E-mail: tasisatemesgen@gmail.com

Received: 24 January, 2020; Accepted: 16 March, 2020; Published online: 19 April, 2020

Abstract

In this review paper, different characteristics especially medicinal values of Oyster mushroom were described. As a mycological expression, mushrooms are a fruiting body of macro fungi i.e. Basidiomycota that represents only a short reproductive stage in their life cycle. They have a long association with humankind, and provide profound biological and economic impacts. Starting from ancient times, mushrooms are consumed by man with delicacy, due to their good taste and pleasing flavor. *Pleurotus ostreatus* is an edible mushroom with high nutritional values and biomedical importance's, since it contains a large number of bioactive components that cause development of its therapeutic functions. The bioactive components that are present in *Pleurotus ostreatus* mushroom comprise: polysaccharides, lipopolysaccharides, proteins, peptides, glycoproteins, nucleosides, tri-terpenoids, lectins, lipids and their derivatives, in addition of its vital medicinal components beneficial for the human health. Moreover, *Pleurotus ostreatus* possess several medicinal properties including; anti-arthritic, antitumor, immune-modulatory, antioxidant, anticancer, anti-inflammatory, antigenotoxic, hypo cholesterolaemic, anti-hyperglycaemic, anti-hypertensive, antiplatelet aggregating, antiviral and antimicrobial activities.

Keywords: Oyster mushroom, *Pleurotus ostreatus*, medicinal value

1. Introduction

The word mushroom is a general term used mainly for the fruiting body of macro fungi (i.e. Basidiomycota), and represents only a short reproductive stage in their life cycle (Das, 2010). Maria *et al*., (2015) documented that mushrooms have been consumed since earliest history; ancient Greeks believed that they provided strength for warriors in battle, and the Romans perceived them as the food of the Gods.

Based on their chemical composition and benefits, mushroom can be classified as poisonous and edible, where edible mushroom can also be categorized into wild and cultivated edible mushrooms. Krishnamoorthy, (2014) added that mushrooms constitute an integral part of the normal human diet, and recently the amounts of consumption have been raised greatly. According to the report of Krishnamoorthy, (2014), mushrooms have rich

nutritional values with high contents of proteins, vitamins, minerals, fibers, trace elements, and cholesterol.

Dipan *et al*., (2018) reported that mushrooms are expressed as essential food, which can provide health benefits beyond the traditional nutrients they contain. Later, Marshall and Nair, (2009) added that edible mushrooms give high quality of protein, which can be produced with greater biological efficiency than animal protein.

Among several species of this genus, *P. ostreatus* is well known and is consumed by people all over the world, due to its taste, flavor, high nutritional values and medicinal properties. According to Isai *et al*., (2009); De-Silva *et al*., (2012); Krishnamoorthy, (2014), the presence of numerous nutritional compositions and various active ingredients in *P. ostreatus*, led to its pronounced potentialities such as of being antidiabetic, antibacterial, anticholestrolic, antiarthritic, antioxidant, anticancer, and antiviral as clear in Table (1). Moreover, Krishnamoorthy, (2014) added that due to its high nutritional values; *P. ostreatus* can provide significant support to human against malnutrition and diseases.

2. Medicinal values of Oyster mushroom

Garcia-Lafuente *et al*., (2011) demonstrated that mushrooms have been used in health care for treating simple and age-old common diseases like skin diseases, and to prevent day complex and pandemic disease such as AIDS. Later, Oyetayo and Ariyo, (2013); Dipan *et al*., (2018) reported that the high nutritional values of *P. ostreatus* in relation to its potential medicinal usage, suggest that *P. ostreatus* mushroom is the most known functional food for human health.

According to Finimundy *et al*., (2013); Chang and Wasser, (2012); Zhang *et al*., (2012), more than 100 medicinal functions and uses are attributed to mushrooms including; antioxidant, anticancer, anti-diabetic, anti-allergic, immunomodulating, cardiovascular protector, anti-cholesterolemic, antiviral, antibacterial, anti-parasitic, antifungal, have detoxification, and hepatoprotective effects (Fig. 1). Adebayo and Oloke, (2017) added that they also protect human against tumor development and inflammatory processes.

3. Antitumor activities of *P. ostreatus*

The study of Facchini *et al*., (2014) demonstrated that *P. ostreatus* mycelium extracts alone and in combination with cyclophosphamide (chemotherapeutic agent) inhibited the in vivo growth of tumor in mice. A previous study of Meerovich *et al*., (2005), reported that the combined administration of the mushroom extract with cyclophosphamide decreased the degree of leukopenia, compared to administration of cyclophosphamide alone.

According to Sarangi *et al*., (2006); Saat *et al*., (2019), water extract of *P. ostreatus* mycelium exhibited the most significant cytotoxic potential by inducing apoptosis of human carcinoma cells, when compared to many other types of mushroom extracts. A novel glucan from *P. ostreatus* mycelium induced in vitro apoptosis of colon cancer cells (Lavi *et al*., 2006). A previous study of Wang *et al*., (2000) stated that a lectin isolated from *P. ostreatus* potently inhibited the growth of sarcoma and hepatoma cells in mice, and prolonged their lifespan. Later, Ngai and Ng, (2004); reported that two ribonucleases were isolated from *P. ostreatus* fruiting bodies, which exhibited anti-proliferative effects on tumor and leukemia cell lines. Sarangi *et al*., (2006) added that water-soluble proteoglycans were isolated from *P. ostreatus* mycelium, which exerted antitumor activity in sarcoma-bearing mice. Proteoglycans injected into mice reduced the number of tumor cells by cell cycle arrest.

4. *Pleurotus ostreatus* extracts as antioxidants

Methanol extracts from *P. ostreatus* fruiting bodies were used as; antioxidant, reducing power, radical scavenging and iron chelating activities, which were higher than the other commercial mushrooms (Yang *et al*., 2002).

Table 1. Medicinal importance of *P. ostreatus*

No	Pharmacological Effect	Extracted Substances	References
1	Antifungal	Hexane-dichloromethane	Okamoto *et al*., 2002
2	Antibacterial	β-D Glucan (pleuran)	Vamanu, 2012
3	Hepatitis C virus	Laccase	El-Fakharany *et al*., 2010
2	Antiviral	Ubiquitin-like protein	El-Fakharany *et al*., 2010
4	Anticancer	Water soluble protein (or) polysaccharidees	De-Silva *et al*., 2012
5	Anti-diabetic	α- amylase α-glucosidase	Bello *et al*., 2017
6	Anti-tumor	β-D Glucan (pleuran) Glycopeptides Proteoglycans	Devi *et al*., 2013
7	Anti-hypercholesterolic	Lovastatin	Weng *et al*., 2010
8	Anti-arthritic	β-(1,3/1,6)Dglucan	Bauerova *et al*., 2009
9	Inhibit HIV-1 reverse transcriptase	novel ubiquitin protein	Wang and Ng, 2000
10	Eye health	Unspecified bioactive	Isai *et al*., 2009
11	Immune modulatory	polysaccharides-peptides, and polysaccharide-protein complex	Wang *et al*., 2000
12	Inhibition of protein synthesis, proteolytic enzymes	Phenolic and tannin	Cowan, 1999
13	Anti-hyperlipidemic	Ethanol	Mohamad *et al*., 2017

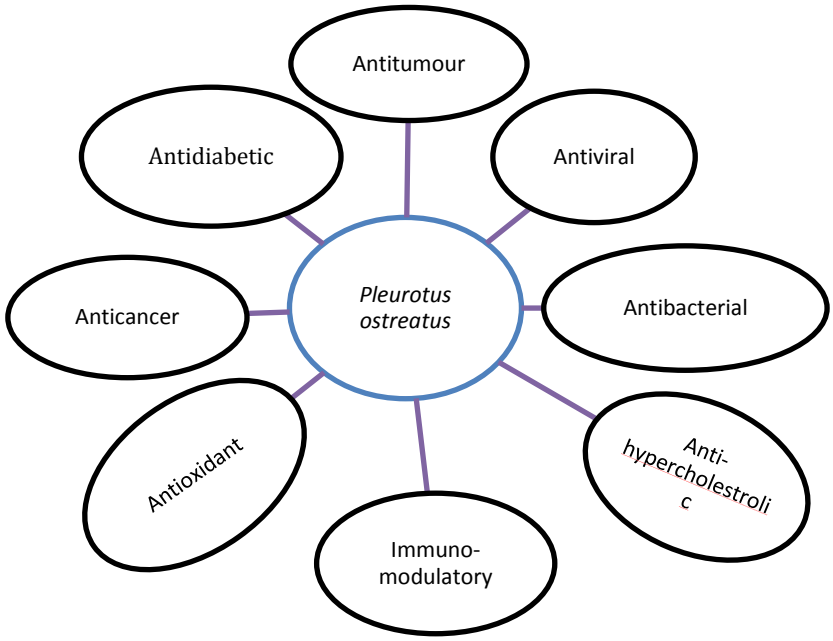

Fig. 1. Medicinal properties of *P. ostreatus* reported by Wang *et al*., (2000); Isai *et al*., (2009); El-Fakharany *et al*., (2010); Vamanu, (2012); Devi *et al*., (2013)

On the other hand, Elmastas *et al*., (2007) and Dubost *et al*., (2007) reported that Oyster mushroom extracts possessed only moderate antioxidant activities compared to the other edible mushrooms.

Adebayo *et al*., (2014b); Okafor *et al*., (2017) stated that oxidative stress has been implicated as a primary factor in the progression of many degenerative diseases like cancer and hepatotoxicity. Antioxidants compounds including phenols and flavonoids are delaying and inhibiting the different compounds causing oxidative stresses. As reported by Jayakumar *et al*., (2011), an extract of *P. ostreatus* enhanced the catalase gene expression and decreased the incidence of free radical-induced protein oxidation in aged rats, thereby protecting the occurrence of age-associated disorders that involve the formation of free radicals. Hapsari *et al*., (2012); Okafor *et al*., (2017) reported that the ethanolic extracts of the Oyster mushroom have potent in vitro and in vivo antioxidant activities. According to Lo, (2005); Zhang *et al*., (2012), two polysaccharide fractions i.e. PSPO-1a and PSPO-4a have been isolated from the fruiting bodies of *P. ostreatus*, they exhibited stronger DPPH and superoxide anion radical scavenging activity with increased concentration; however, they were less effective on scavenging hydroxyl radical. Zhang *et al*., (2012) added that among these two polysaccharides, PSPO-1a possess more effective free-radical scavenger potential than PSPO-4a. Later, Mitra *et al*., (2013) stated that the free radical scavenging activation properties of the water soluble polysaccharides from *P. ostreatus* showed superior antioxidant properties, which might be attributed to the presence of carbohydrate component mostly β-glucan. Consequently, *P. ostreatus* act as a good source for the development of antioxidant food additives.

5. Oyster mushroom extracts as antimicrobials

Pleurotus ostreatus extracts and its isolated compounds can be used as antibacterial and antifungal agents, presumably they act as defense mechanisms against the various microorganisms. According to Periasamy, (2005); Okamoto *et al*., (2002); Okafor *et al*., (2017), hexane-dichloromethane extract from *P. ostreatus* contain p-anisaldehyde that has inhibitory effects on *Bacillus subtilis*, *Pseudomonas aeruginosa*, *Aspergillus niger* and *Fusarium oxysporum*.

5.1. Antibacterial potential of *P. ostreatus*

An alkaline skeletal β-D Glucan (pleuran) can be extracted from the fruiting bodies of *P. ostreatus*. This β-D Glucan promoted the survival of mice susceptible to bacterial infections (Karacsonyi and Kuniak 1994). In a previous study, Cowan, (1999) documented that the phenolic and tannin constituents of *P. ostreatus* could elicit antibacterial activity with several mechanisms of action including; cell membrane lysis, inhibition of protein synthesis, proteolytic enzymes and microbial adhesions.

Karaman *et al*., (2010) demonstrated that the methanol and chloroform organic extracts of *P. ostreatus* were manifested as effective against Gram-positive bacteria, and were considered as potential sources of antibacterial agents. In a later study of Mirunalini *et al*., (2012), the antibacterial potential of *P. ostreatus* and the biosynthesized silver nanoparticles (AgNPs) using *P. ostreatus* were evaluated against several Gram positive bacteria, through measuring the diameters of the inhibition zones. The AgNPs biosynthesized using *P. ostreatus* expressed maximum zones of inhibition against all the tested bacteria.

5.2. Antiviral properties of Oyster Mushroom

The antiviral chemotherapy involves the intervention of human with antiviral agents that are specific for the inhibition of viral multiplication, without affecting the normal cell division. Thus, it is very important to identify and develop new antiviral agents that have no adverse side effects on human, and also reduce the viral resistance. El-Fakharany *et al*., (2010) reported that a laccase purified from *P.*

ostreatus mushroom was capable of inhibiting the Hepatitis C virus entry into the peripheral blood cells and into the hepatoma HepG2 cells, and inhibited its replication. During the previous study of Wang and Ng, (2000), a novel ubiquitin-like protein was isolated from *P. ostreatus*, which manifested an inhibitory activity towards the HIV-1 reverse transcriptase.

6. Anti-diabetic activities of *P. ostreatus*

Krishna and Usha, (2009) reported that the combination of *P. ostreatus* with other mushrooms such as *Murraya Koenigii* produced synergistic effects on blood glucose-lowering effect in both insulin dependent and insulin-independent diabetic conditions. Adebayo and Oloke, (2017) added that *P. ostreatus* extract can reduce the high blood glucose levels in hyperglycemic rats, although lesser than treatment with amaryl.

7. Anti-hypercholesterolic characteristics of the Oyster mushroom

According to Mohamad *et al*., (2017), *P. ostreatus* is used for prevention and treatment of atherosclerosis, as it contains large amounts of anti-atherosclerotic agents including; ergothioneine, lovastatin, and chrysin. Previously, Avagyan *et al*., (2013); Facchini *et al*., (2014) reported that the ethanolic extract of *P. ostreatus* has an effective anti-hyperlipidemic activity to the diet of normal wistar male rat. Alam *et al*., (2009) study demonstrated the effect of feeding the hypercholesterolic rats with 5% powder of *P. ostreatus*, which reduced the total cholesterol (TC) level by 37%, and triglycerides (TG) level by 45%. This was attributed to the presence of an active substance called lovastatin in this mushroom.

8. Immune-modulatory efficacy of *P. ostreatus*

According to El-Enshasy and Hatti-Kaul, (2013), the immune-modulatory properties of Oyster mushroom with its low cytotoxicity raised the possibility that it could be effective in the treatment of cancer patients receiving radiation and conventional chemotherapy, as it builds up the immune resistance and decreases the toxicity. Wang *et al*., (2000) reported that large number of components including; lectins, polysaccharides, polysaccharides-peptides, and polysaccharide-protein complex, have been isolated from *P. ostreatus*, and recorded to have immune-modulatory effects. Shamtsyan *et al*., (2004); Deepalakshmi and Mirunalini, (2014) added that water extract from fruit bodies and mycelia of *P. ostreatus* has a role in increasing the production of reactive oxygen species (ROS) from the neutrophils, and has immune-modulatory properties involving all the immune competent cells.

Conclusion

There are qualitative and quantitative differences in the chemical composition of *P. ostreatus* products depending on the strain, origin, extraction process and cultivation conditions. Due to its several medicinal properties, *P. ostreatus* has a great significance on the human health and other organisms, depending on its cultivation conditions. *P. ostreatus* act as a good source for the development of antioxidant food additives. In addition, *P. ostreatus* is manifested as effective against Gram-positive bacteria, and as a potential source of antibacterial agents. The protein present in *P. ostreatus* fruiting bodies has anti-HIV activity, whereas Laccase extracted from this fruit body is capable of inhibiting the entry of Hepatitis C virus into the peripheral blood cells, in addition to inhibiting its replication.

Funding source

This study was not funded by any profit or non-profit organization.

9. References

Adebayo, E.A. and Oloke, J.K. (2017). Oyster Mushroom (*Pleurotus* Species); A Natural Functional Food. Journal of Microbiology, Biotechnology and Food Sciences. 7(3): 254-264.

Adebayo, E.A.; Oloke, J.K.; Aina, D.A. and Bora, T.C. (2014b). Antioxidant and Nutritional Importance

of some *Pleurotus* species. Journal of Microbiology, Biotechnology and Food Sciences. 3(4): 289-294.

Alam, N.; Amin, R.; Khan, A.; Ara, I.; Shim, M. and Lee, M.W. (2009). Comparative effects of oyster mushroom on lipid profile, liver and kidney function in hyper cholesterolemic rats. Mycobiology. 37: 37-42.

Avagyan, I.A.; Nanagulyan, S.G. and Minasbekyan, L.A. (2013). Increasing of Fermentative and Anti-inflamatory Activity of the *Pleurotus ostreatus* (Jacq.:Fr.) Kumm. Culture by Modification of Growth Conditions by MM-waves. PIERS Proceedings, Stockholm, Sweden. 12-15.

Bauerova, K.; Paulouicova, E.; Mihalava, D.; Svik, K. and Ponist, S. (2009). Study of new ways of supplementary and combinatory therapy of rheumatoid arthritis with immunomodulators Glucomannan and Immunoglukan in adjuvant arthritis. Toxicology and Industrial Health. 25: 329-335.

Bello, M.; Oluwamukomi, M.O. and Ndigwe, V.N. (2017). Anti-Diabetic Activity Of Three Species Of Oyster Mushroom. Annals. Food Science and Technology. 18(2): 246-254.

Chang, S.T. and Wasser, S.P. (2012). The role of culinary-medicinal mushrooms on human welfare with a pyramid model for human health. International Journal of Medicinal Mushrooms. 14(2): 95-134.

Cowan, M.M. (1999). Plant products as antimicrobial agents. Clinical Microbiology Reviews. 12: 564-582.

Das, K. (2010). Diversity and conservation of wild mushrooms in Sikkim with special reference to Barsey Rhododendron Sanctuary. NeBIO. 1(2): 1-13.

Deepalakshmi, K. and Mirunalini, S. (2014). *Pleurotus ostreatus*: an oyster mushroom with nutritional and medicinal properties. Journal of Biochemical Technology. 5(2): 718-726.

De-Silva, D.D.; Rapior, S.; Fons, F.; Bahkali, A.H. and Hyde, K.D. (2012). Medicinal mushrooms in supportive cancer therapies: an approach to anti-cancer effects and putative mechanisms of action. Fungal Diversity. 55: 1-35.

Devi, K.S.P.; Roy, B.; Patra, P; Sahoo, B.; Islam, S.S. and Maiti, T.K. (2013). Characterization and lectin microarray of an immunomodulatory heteroglycan from *Pleurotus ostreatus* mycelia. Carbohydrate Polymers. 94(2): 857-865.

Dipan, S.; Ajay, K.S. and Badal, K.D. (2018). Bioactive compounds with special references to anticancer property of oyster mushroom *Pleurotus ostreatus*. Journal of Pharmacognosy and Phytochemistry. 7(4): 2694-2698.

Dubost, N.J.; Ou, B. and Beelman, R.B. (2007). Quantification of polyphenols and ergothioneine in cultivated mushrooms and correlation to total antioxidant capacity. Food Chemistry. 105: 727-735.

EI- Fakharany, E.M.; Haroun, B.M.; Ng, T.B. and Redwan, E.R. (2010). Oyster mushroom laccase inhibits hepatitis C virus entry into Peripheral blood cells and hepatoma cells. Protein & Peptide Letters. 17: 1031-1039

El-Enshasy, H.A. and Hatti-Kaul, R. (2013). Mushroom immunomodulators: unique molecules with unlimited applications. Trends in Biotechnology. 31(12): 668-677.

Elmastas, M.; Isildak, O.; Turkekul, I. and Temur, N. (2007). Determination of antioxidant activity and antioxidant compounds in wild edible mushrooms. Journal of Food Composition and Analysis. 20: 337-345.

Facchini, J.M.; Alves, E.P.; Aguilera, C.; Gern, R.M.M.; Silveira, M.L.L.; Wisbeck, E. and Furlan, S.A. (2014). Antitumor activity of *Pleurotus ostreatus* polysaccharide fractions on Ehrlich tumor and Sarcoma 180. International Journal of Biological Macromolecules. 68: 72-77.

Finimundy, T.; Gambato, C. and 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.

Garcia-Lafuente, A.; Moro, C.; Villares, A.; Guillamón, E.; Rostagno, M.A.; D'Arrigo, M. and Martinez, J.A. (2011). Mushrooms as a source of anti-inflammatory agents. American Journal of Community Psychology. 48(1-2): 125-141.

Hapsari, R.; Elya, B. and Amin, J. (2012). Formulation and evaluation of antioxidant and tyrosinase inhibitory effect from gel containing the 70 % ethanolic *Pleurotus ostreatus* extract. International Journal of Medicinal and Aromatic Plants. 2(1): 135-140.

Isai, M.; Elanchezhian, R.; Sakthivel, M.; Chinnakkaruppan, A.; Rajamohan, M.; Jesudasan, C.N.; Thomas, P.A. and Geraldine, P. (2009). Anticataractogenic effect of an extract of the oyster mushroom, *Pleurotous ostreatus*, in an experimental model. Current Eye Research. 34: 264-273.

Jayakumar, T.; Thomas, P.A.; Sheu, J.R. and Geraldine, P. (2011). *In-vitro* and *in-vivo* antioxidant effects of the oyster mushroom *Pleurotus ostreatus*. Food Research International. 44: 851-861.

Karaman, M.; Jovin, E.; Malbasa, R.; Matavuly, M. and Popovie, M. (2010). Medicinal and edible lignicolous fungi as natural source of antioxidative and antibacterial agents. Phytotherapy Research. 24: 1473-1481.

Karacsonyi, S. and Kuniak, L. (1994). Polysaccharides of *Pleurotus ostreatus*: isolation and structure of pleuran, an alkali-insoluble beta-D-glucan. Carbohydrate Polymers. 24: 107-111.

Krishnamoorthy, D. and Sankaran, M. (2014). *Pleurotus ostreatus*: an oyster mushroom with nutritional and medicinal properties. Journal of Biochemical Technology. 5(2): 718-726.

Krishna, S. and Usha, P.T.A. (2009). Hyoglycaemic effect of a combination of *Pleurotus ostreatus*, Murray Koenigii and Aeglemarmelos in diabetic rats. Indian Journal of Animal Science. 79: 986-987.

Lavi, I.; Friesem, D.; Geresh, S.; Hadar, Y. and Schwartz, B. (2006). An aqueous polysaccharide extract from the edible mushroom *Pleurotus ostreatus* induces anti-proliferative and pro-apoptotic effects on HT-29 colon cancer cells. Cancer Letters. 244: 61-70.

Lo, S.H. (2005). Quality evaluation of *Agaricus bisporus*, *Pleurotus eryngii*, during postharvest storage. [Thesis]. National Chung-Hsing University, Taichung, Taiwan.

María, E.V.; Talía, H. and Octavio, P. (2015). Edible Mushrooms: Improving Human Health and Promoting Quality Life. International Journal of Microbiology. 1-14.

Marshall, E. and Nair, N.G. (2009). Make money by growing mushrooms. Food and Agriculture Organization of the United Nations, Rome.

Meerovich, I.G.; Yang, M.; Jiang, P.; Hoffman; R.M.; Gerasimenya, V.P. and Orlov, A.E. (2005). Study of action of cyclophosphamide and extract of mycelium of *Pleurotus ostreatus in vivo* on mice, bearing melanoma B16-F0- -GFP. Proceedings of the SPIE, Vol. 5704, Genetically Engineered and Optical Probes for Biomedical Applications III, San Hose, California, USA.

Mirunalini, S.; Arulmozhi, V.; Deepalakshmi, K. and Krishnaveni, M. (2012). Intracellular biosynthesis and antibacterial activity of silver nano particles using Edible mushrooms. Notulae Scientia Biologicae. 4(4): 55-61.

Mitra, P.; Khatua, S. and Acharya, K. (2013). Free radical scavenging and NOS activation properties of water soluble crude polysaccharides from *Pleurotus ostreatus*. Asian Journal of Pharmaceutical and Clinical Research. 6(3): 67-70.

Mohamad, H.; Zainal, A.; Noorlidah, A. and Nurhayati, Z.A. (2017). Therapeutic Properties of *Pleurotus* species (Oyster mushrooms) for

Atherosclerosis: A Review. International Journal of Food Properties. 20(6): 1251-1261.

Ngai, P.H. and Ng, T.B. (2004). A ribonuclease with antimicrobial, antimitogenic and anti-prolife relative activities from the edible mushroom *Pleurotus sajor-caju*. Peptides. 25(1): 11-17.

Okafor, D.C.; Onuegbu, N.C.; Odimegwu, N.E.; Ibeabuchi, J.C.; Njoku, N.E; Agunwa, I.M.; Ofoedu, C.E. and Njoku, C.C. (2017). Antioxidant and Antimicrobial Activities of Oyster Mushroom. American Journal of Food Science and Technology. 5(2): 64-69.

Okamoto, K.; Narayama, S.; Katsuo, A.; Shigematsu, I. and Yanase, H. (2002). Biosynthesis of p-anisaldehyde by the white-rot basidiomycete *Pleurotus ostreatus*. Journal of Bioscience and Bioengineering. 93: 207-210.

Oyetayo, V.O. and Ariyo, O.O. (2013). Micro and macronutrient properties of *Pleurotus ostreatus* (Jacq: Fries) cultivated on different wood substrates. Jordan Journal of Biological Science. 6: 223-226.

Periasamy, K. (2005). Novel antibacterial compounds obtained from some edible mushrooms. International Journal of Medicinal Mushrooms. 7: 443-444.

Saat, E.; Irawan, W.K.; Enos, T.A. and Harlinda, K. (2019). The potential of white-oyster mushroom (*Pleurotus ostreatus*) as antimicrobial and natural antioxidant. Biofarmasi Journal of Natural Product Biochemistry. 17 (1): 17-23.

Sarangi, I.; Ghosh, D.; Bhutia, S.K.; Mallick, S.K. and Maiti, T.K. (2006). Antitumor and immunomodulating effects of *Pleurotus ostreatus* mycelia derived proteoglycans. International Immunopharmacology. 6: 1287-1297.

Shamtsyan, M.M.; Konusova, V.G.; Goloshchev, A.M.; Maksimova, Y.O.; Panchenko, A.V. and Petrishchev, N.N. (2004). Immunomodulating and anti-tumor effects of basidiomycetes *Pleurotus ostreatus* (Jacq. fr) *P. Kumm* and *P. conucopiae* (Pau. Ex Pers.) Rollan. Journal of Biological Physics and Chemistry. 4(3): 157-61

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

Wang, H. and Ng, T.B. (2000). Isolation of a novel ubiquitin-like protein from *Pleurotus ostreatus* mushroom with anti-human immune deficiency virus, translation-inhibitory and ribonuclease activities. Biochemical and Biophysical Research Communications. 276: 587-593.

Wang, H.; Gao, J. and Ng, T.B. (2000). A new lectin with highly potent anti-heptoma and antisarcoma activities from the oyster mushroom *Pleurotus ostreatus*. Biochemical and Biophysical Research Communications. 275: 810-816.

Weng, T.C.; Yang, Y.H.; Lin, S.J. and Tai, S.H. (2010). A systemic review and meta-analysis on the therapeutic equivalence of stains. Journal of Clinical Pharmacy and Therapeutics. 35:139-151.

Yang, J.H.; Lin, H.C. and Mau, J.L. (2002). Antioxidant properties of several commercial mushrooms. Food Chemistry. 77: 229-235.

Zhang, Y.X.; Dai, L.; Kong, X.W. and Chen, L. (2012). Characeterization and *in vitro* antioxidant activities of polysaccharides from *Pleurotus ostreatus*. International Journal of Biological Macromolecules. 51(3): 259-265.