

## Review Article

# Potentiality of Oyster Mushroom (*Pleurotus* Spp.) in Medicine- A Review

Chandana Paul, Tina Roy, and Nirmalendu Das\*

Department of Botany, Barasat Govt. College, India

## \*Corresponding author

Nirmalendu Das, Department of Botany, Barasat Govt. College, Barasat, Kolkata 700124, West Bengal, India, Tel: 91 9433451166; Email: nirmalendus@yahoo.co.uk

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## Abstract

The members of the genus *Pleurotus* generally known as oyster mushroom positioned second among the commercially cultivated edible mushrooms. Different *Pleurotus* species not only contained a large amount of polysaccharides, proteins and vitamins but also phenolics, flavonoids, steroids, glycosides, tannins, terpenoids, alkaloids, glucans and other antioxidants. Presence of these nutraceuticals enable them to exhibit different therapeutic activities such as antitumor, immunomodulatory, genoprotective, anti-inflammatory, hypocholesterolaemic, antihypertensive, antiplatelets, antihyperglycaemic, antimicrobial and antiviral activities. Some of these properties of oyster mushroom are discussed in the present review.

## INTRODUCTION

Mushrooms are the fruiting bodies of edible macrofungi and commonly belonging to Basidiomycotina and rarely to Ascomycotina. Chang and Miles defined mushroom as “a macrofungus with distinctive fruiting body which can be either hypogeous or epigeous and large enough to be seen with naked eye and to be picked by hand” [1]. They were known by the ancient Egyptians since long back, probably from three thousand years ago. Mushrooms were described as “food for the god” by the ancient Greeks and Romans and considered as luxury food and were eaten only by the nobility for culinary purposes [2]. Mushrooms constitutes about 14000-22000 species while the exact number might be much higher [3].

Exploitation of mushroom as an alternative source of protein has been emphasized to be of great enthusiasm to the researchers for last few decades [4]. After yeast fermentation, mushroom production has been considered as second most amongst the esteemed commercial microbial technologies. Cultivation of mushroom does not require fertile soil as they can grow inside the shady rooms degrading altogether various agro-residues. Due to their inherent tendency to grow upon a variety of substrates, mushrooms are considered to recycle organic wastes which unless are problematic for disposal [5]. A number of mushrooms are considered not only as nutritionally rich food but also beneficial from the standpoint of medicinal purposes. Button mushroom (*Agaricus* spp) and shitake (*Lentinus* spp) are widely accepted for commercial production but recently oyster mushroom (*Pleurotus* spp.) cultivation has stepped up in second position after the button mushroom as per its consumption around the globe [6].

The genus *Pleurotus* (oyster mushroom) constitute about 40 species and all are edible. About ten species are commercially cultivated. Oyster mushroom has been regarded as a popular edible mushroom essentially owing to its easy cultivation procedures within a wide range of temperatures (15-30°C). They can be cultivated on different varieties of substrates like agro-forest residues even on weeds for the production of food, feed, enzymes and a number of nutraceuticals in addition to their bioremedial properties [7,8]. A number of nutraceuticals like polysaccharide, protein, polysaccharide-protein complexes, proteoglycans, phenolics, flavonoids etc. can be derived from culture media, mycelium or fruiting body extracts of oyster mushroom which show an array of medicinal properties [9-12]. The therapeutic activities of different *Pleurotus* species are discussed in this review.

## DISCUSSION

Oyster mushrooms (*Pleurotus* spp.) are not only nutritionally rich but also medicinally important. They are the rich sources of antioxidants and possess antitumor, immunomodulatory, genoprotective, anti-inflammatory, hypocholesterolaemic, antihypertensive, antiplatelets, antihyperglycaemic, antimicrobial and antiviral activities. Some of these activities are summarized (Table 1).

## Antioxidant activities

Mushrooms are rich sources of antioxidant that defense the body against free radicals which cause oxidative damage [13-16]. Oxidative damage is related to aging and a number of diseases such as atherosclerosis, cirrhosis, diabetes and even cancer are prevented by antioxidants. Sporophores of oyster mushrooms are rich in antioxidants [17-19]. Oyster mushrooms are the

**Table 1:** Bioactive Compounds and Therapeutic Uses of Some Oyster Mushroom (*Pleurotus* spp.).

NAME OF THE SPECIES	ACTIVE COMPOUND (S)/ EXTRACT	PROPERTIES	REFERENCES
<i>P. ostreatus</i> (oyster mushroom)	Protein polysaccharide	Inhibited the growth of a solid sarcoma 180 tumor implanted in mice.	Facchini et al., 2014 [89]
	Polysaccharide (2.4x10 <sup>4</sup> )Da	Enhanced concanavalin A (con A) or induced lymphocyte proliferation on male mice.	Sun et al., 2009 [90]
	β- glucan with (1,3) and (1,6) linkage	Exhibited strong anti-respiratory tract infection and anti-allergic effect.	Sapena et al., 2015 [91] Jesenak et al., 2013, 2014 [92, 93]
	Protein extract	Showed efficiency against human monocytic leukemia cell and human colorectal adenocarcinoma cells.	Wu et al., 2011 [94]
	Ribonuclease (17.7 K.Da)	Efficient to degrade genetic material of HIV.	Nomura et al., 1994 [81]
	Dimeric lectin	Exhibited anti-tumor activity in mice bearing hepatoma and sarcoma.	Wang et al., 2000 [52]
	Proteoglycan fraction (water soluble)	Exhibited immunomodulator and anticancer activity.	Sarangi et al., 2006 [55]
	Crude extract	Inhibited the growth of Gram-positive, Gram- negative bacteria and <i>A. niger</i> .	Gerasimenya et al., 2002 [84]
	Hexane-dichloro-methane extracts containing anisaldehyde.	Possessed inhibitory activity on growth of <i>A. niger</i> , <i>F. oxysporum</i> , <i>B. subtilis</i> and <i>P. aeruginosa</i> .	Okamoto et al., 2005 [85]
	Acetone extract	Exhibited anticancer potential.	Akanni et al., 2010 [95]
	Methanolic extract	Possessed antioxidant, reducing power, iron chelating and radical scavenging properties.	Yang et al., 2002 [22]
Mevinolin, a polysaccharide	Showed antihypercholesterolemic activity in rat.	Hossain et al., 2003 [63].	
<i>P. ostreatus var florida</i>	Methanolic extract	Inhibited mutagenicity elicited through mutagens requiring activities.	Lakshmi et al., 2004 [96]
<i>P. pulmonarius</i> (The lung oyster/phoenix mushroom)	Polysaccharide extract	Exhibited antiproliferative effect on cancer cell.	Lavi et al., 2010 [97]
	polysaccharide with both α - and β - linkages	Showed potent anti- inflammatory activities against formalin-induced paw edema and carrageenan in rats.	Jose et al., 2002 [24] Adebayo et al., 2012 [98]
	β- glucan	Inhibited colitis-association carcinogenesis in mice.	Lavi et al., 2012 [99]
	protein in hot water extracts	Inhibited HIV 1 reverse transcriptase activity	Wang and Ng, 2007 [79]
	Acetone extract	Exhibited anticancer and tumor suppressor activities.	Akanni et al., 2010 [95]
	Hot water extract	Inhibited the reverse transcriptase activity of HIV-1	Patel et al., 2012 [100]
<i>P. citrinopileatus</i> (Golden oyster mushroom)	Functional protein(PCP-3A)	Inhibited the proliferation of human leukemia cell U 937.	Chen et al., 2009 [101]
	Water soluble polysaccharide	Reduced the number of metastatic tumor nodule. Exhibited antihyperglycaemic activity and lowers the blood glucose level in diabetic rats.	Wang et al., 2005 [41]. Hu et al., 2006 [41]
	Lectin	Exhibited antitumor activity in mice bearing sarcoma 180.	Li et al., 2008 [103]
<i>P. florida</i> (The florida oyster)	Glucans	Activated the phagocytic activity of mouse macrophages in vitro.	Rout et al., 2005 [57]
	Protein fraction	Stimulated thymocytes, spleenocytes, and bone marrow cells and cytotoxicity of mouse natural killer cells. It also exhibited the antiproliferative activity.	Maiti et al., 2008 [104]
	Lectin	Showed capability of modulating arsenic mediated toxic effects.	Rana et al., 2012 [105].
	Methanolic extract	Inhibited platelet aggregation, decreased induced paw oedema in mice and inhibits inflammation.	Jose et al, 2004 [70].
<i>P. sajor-caju</i>	Protein- polysaccharide	Inhibited the solid sarcoma 180 tumor implanted in mice.	Facchini et al., 2014 [89]
	Ribonuclease	Exhibited antimicrobial activities; and antiproliferative effect on murine spleenocytes.	Nagi and Ng, 2004 [83]
	Hot water extract	Inhibited HIV 1 reverse transcriptase activity.	Patel et al., 2012 [100]
<i>P. eryngii</i> (King oyster mushroom)	Ubiquinone-9	Inhibited the activity of mammalian topoisomerase 1 and induced the apoptosis of cancer cells.	Bae et al., 2009 [106]
	Pleurone	Exhibited inhibitory activity on human neutrophil elastase (HNE) and also beneficial for the prevention of skin aging.	Lee et al., 2011 [107]
	Erynginolysin- a heamolysin	Inhibited the stimulated mitogenic response of murine spleenocytes and exhibited antibacterial activity against <i>Bacillus</i> sp.	Nagi and Ng, 2006 [108]
	Eryngin	Exhibited antibacterial activity.	Wang et al., 2004 [86]
	Ethanol extract	Suppressed hypersensitive immune responses such as inflammation and exhibited antiallergic activity.	Sano et al., 2002 (74)

	Water soluble polysaccharide	Removes free radical and increase the activity of antioxidant enzyme in liver injury mouse model.	Chen et al., 2012 [31]
<i>P. tuber-regium</i> (King tuber)	Sulphated $\beta$ - Glucans	Exhibited antiviral activities against herpes simplex virus type 1, type 2 and also exhibited antitumor activity.	Zhang et al., 2003, 2004 [76, 77]
	Polysaccharide	Inhibited solid tumor proliferation in mice. Showed antitumor effect on different human tumor cell lines.	Zhang et al., 2001 [47] Zhang et al., 2004 [48]
<i>P. cornucopiae</i> (Branched oyster mushroom)	Laccase ( mol wt. 66 KDa)	Inhibited the proliferation of murine leukemia and human hepatoma cell line ; also reduced the HIV- 1 reverse transcriptase activity.	Wong et al., 2010 [109]
	Acetone extract	Inhibited growth and induced apoptosis of HL60 cells.	Takei et al., 2005 [110]
<i>P. ferulae</i>	Ethanol extract	Reduced the total cholesterol in plasma, low density lipoprotein, triglyceride etc.	Alam et al., 2011 [64]
<i>P. geesteranus</i>	Polysaccharide from hot water extract	Exhibited cytotoxicity in human breast cancer cell line MCF-7.	Zhang et al., 2011 [111]
<i>P. nebrodensis</i>	Hemolysin	Exhibited strong cytotoxicity against various types of cancer cells and exhibited anti-HIV-1 activity.	Lv et al., 2009 [82]
	Aqueous extract and dried fine particles	Prevented hypertension.	Miyazawa et al., 2003 [61]
<i>P. cystidiosus</i> (Abalone or tree mushroom)	Methanolic extract	Exhibited antioxidant, radical scavenging, reducing power and iron chelating activities.	Yang et al., 2002 [22]
	Protein fractions	Lowered the blood pressure by the activity of angiotensin-1 converting enzyme.	Ching et al., 2011 [59]
<i>P. salmoneostramineus</i>	Mushroom powder	Reduced total phospholipids, lipid and LDL/HDL ratio.	Yoon et al., 2012 [65]
<i>P. eous</i>	Methanolic extract	Exhibited antioxidant activity.	Ramkumar et al., 2010 [112]
	Lectin	Exhibited antiproliferative effects on human tumor cell lines.	Mahajan et al., 2002 [51]
<i>P. abalonus</i>	Polysaccharide- peptide	Prolonged the lifespan of senescence- accelerated mice.	Li et al., 2007 [32]
<i>P. djamor</i>	Polysaccharide precipitate	Exhibited antitumor activity.	Borges et al., 2013 [113]
<i>P. floridanus</i>	70% ethanolic and aqueous extract.	Exhibited antibacterial activity effective against <i>E. coli</i> , <i>B. subtilis</i> , <i>B. megaterium</i> and <i>S. aureus</i> .	Das et al., 2012 [88]

source of important natural oxidants as these are rich in vitamin and selenium contents [20]. Pleuran, a polysaccharide has been isolated from *P. ostreatus* shows a good result in pre-cancerous lesions of colon in rats [21]. Methanolic extract from sporophores of *P. cystidiosus* and *P. ostreatus* possessed antioxidant, reducing power; iron chelating and radical scavenging properties that were better in comparison to other commercially produced mushrooms [22]. Methanolic extracts from sporophores of *P. pulmonarius* and *P. florida* also possessed similar activities [23, 24]. Mushrooms are very rich in phenolic compounds which are the source of their major antioxidant machinaries [25-27]. Jayakumar et al. [28], reported that the ethanolic extracts of the *P. ostreatus* exhibit antioxidant activity by scavenging hydroxyl and superoxide radical and inhibit the reducing power on ferric ions and lipid peroxidation. It also reduced the intensity of lipid peroxidation and enhanced the activities of enzymatic and non-enzymatic antioxidants. Ethanolic extract from *P. citrinopileatus* fruiting bodies showed antioxidant activities comparable to those from three other oyster mushrooms viz. *P. ostreatus*, *P. eryngii* and *P. ferulae* [29, 30]. Chen et al., found a polysaccharide from aqueous extract of *P. eryngii* capable of removing free radical and increase the antioxidant enzyme activity in liver injury in mouse model [31]. Li et al., isolated a polysaccharide-peptide complex from *P. abalonus* fruiting bodies which delayed the life span of senescence- accelerated mice [32]. Lakshmi et al., also observed the antioxidant activity in *P. sajor-caju* [33].

### Genoprotective activities

Oyster mushroom extract also exhibits DNA protecting

activities [34]. Filipic et al., tested 89 different mushroom species on *Escherichia coli* and *Salmonella typhimurium* within them *P. cornucopiae* showed the most efficient bio- antimutagenic and antigenotoxic activities [35]. Extracts of *P. cornucopiae* significantly reduced H<sub>2</sub>O<sub>2</sub>- induced DNA damage in lung cells of Chinese hamster [36]. Extract of *P. ostreatus* alleviated genotoxicity through DNA damage suppression in artificially mutated *Drosophila* [37].

### Anti-tumor activities

In the recent year a number of research have been carried out on oyster mushroom extracts and isolated bioactive compounds such as proteins, polysaccharide and other substances that possess antineoplastic activities. When compared to other mushroom extracts aqueous extract of *P. ostreatus* sporophore showed the most significant cytotoxicity through apoptosis of human carcinoma cells suggesting that the bioactive compounds were water soluble proteins or polysaccharide [38]. Aqueous extract of *P. sajor-caju* also exhibited antitumor activity in vitro [39]. Protein extracted from *P. sajor-caju* containing xyloglucan, polysaccharide and xylanprotein exhibits antitumor activity against sarcoma 180 cell line. Polysaccharides are well-documented as potent immune modulating and antitumor substances among all the bioactive compounds [40]. Water soluble polysaccharides extracted from fermentation broth of *P. citrinopileatus* reduced the metastatic tumor nodule numbers in tumor-bearing mice [41]. It is reported that polysaccharides extracted from *P. tuber-regium* exerts antitumor activity against

human leukemia cells in vitro, through antiproliferative activity and cytotoxicity [42]. In comparison to native polysaccharides of *P. tuber-regium*, their corresponding sulphated or carboxymethylated derivatives showed higher antitumor activities [43-46]. Polysaccharides, isolated from both fruiting bodies and mycelia of *P. tuber-regium* successfully inhibits solid tumor proliferation in mice and antitumor activity have also been found against different tumor cell lines [47,48]. Mycelial extract of *P. ostreatus*, alone and in combination with chemotherapeutic agent (cyclophosphamide), inhibited the tumor growth of mice *in vivo* [49]. A novel  $\alpha$ -glucan has been isolated from mycelium of *P. ostreatus* which induces apoptosis of colon cancer cells in vitro [50]. A lectin isolated from *P. eous* exhibits antiproliferative effects on human tumor cell lines without any toxicity [51]. Another lectin from *P. ostreatus* suppressed the growth of hepatoma and sarcoma in mice and delayed their life span [52]. Eryngeolysin was extracted from the fruiting bodies of *P. eryngii*, shows cytotoxicity against leukemia cells [53].

### Immunomodulatory and antimitogenic activities

Different compounds isolated from a number of oyster mushrooms have immunostimulatory activities on humoral and cell mediated immunity. An immunomodulatory activity of *P. ostreatus* polysaccharide has been reported against infectious brusel disease (IBD) of broilers [54]. Water soluble polysaccharide isolated from fermentation broth of *P. citrinopileatus* showed an increasing number of CD4<sup>+</sup>, macrophages, CD8<sup>+</sup> and T cells in mice [41]. Proteoglycan isolated from mycelia of *P. ostreatus* shows immunomodulatory effect by stimulating macrophage and uplifting the cytotoxicity of mouse natural killer cell [55].  $\beta$ -glucan is a well-known biological response modifier and considered as an immunomodulator [56]. Glucans from *P. florida* sporophores also induced the phagocytosis of mouse macrophages [57].

*Pleurotus* sp. also exhibited antimitogenic effects. Eryngeolysin isolated from *P. eryngii* inhibits the accelerated mitogenic response of murine splenocytes [53]. A ribonuclease from fruiting bodies of *P. sajor-caju* exerted antiproliferative effect on murine splenocytes [58].

### Antihypertensive and antihypercholesterolemic and antihyperglycaemic activities

Oyster mushrooms exhibit anti-hypertensive properties. Protein fractions from *P. cystidiosus* inhibited the activity of angiotensin-1 converting enzyme (ACE) which lowers the blood pressure as comparable to captopril (an ACE inhibitor) used for the treatment of hypertension [59]. *P. cornucopiae* also showed the same effect by inhibiting ACE [60]. Miyazawa et al., (2003) showed that hot aqueous extracts of dried powder of *P. nebrodensis* fruiting bodies exhibit the antihypertensive activity [61].

Mevinolin, a polysaccharide present in *P. citrinopileatus* and *P. ostreatus* showed the antihypercholesterolemic activity [62, 63]. Sporophores of *P. ferulae* lowered the total plasma cholesterol, phospholipids, triglyceride, low density lipoprotein, etc. in hypercholesterolemic ratio [64]. Dried mushroom powder of *P. salmoneostramineus* also reduced phospholipids, total fats and LDL/HDL ratio [65].

Water soluble polysaccharide from *P. citrinopileatus*

fermentation broth exhibited the antihyperglycaemic activity and also lowers blood glucose level in diabetic rats [66]. Aqueous extract of *P. pulmonarius* reduced serum glucose level in alloxan treated diabetic mice when given orally [67]. Endo-polymer from *P. ostreatus* mycelia culture also showed hypoglycaemic effects [68].

### Anti-inflammatory activity

Methanolic extracts of *P. pulmonarius* and *P. florida* fruiting bodies reduced both acute as well as chronic inflammation and decrease induced paw oedema in mice [24, 69, 70]. PCP 3-A, a non-lectin glycoprotein isolated from fruiting bodies of *P. citrinopileatus* down-regulated the pro-inflammatory mediators such as iNOS and NF-Kb in RAW 264.7 cells (mouse leukemic monocyte macrophage cell line) [71]. Pleuran, a polysaccharide isolated from sporophores of oyster mushrooms found to possess anti-inflammatory activity [72, 73]. Extract of *P. eryngii* fruiting bodies suppressed the inflammation in delayed type (type IV hypersensitivity) allergy response in mice [74].

### Antiviral activity

Oyster mushrooms showed antiviral effects directly or indirectly as a result of immunostimulation [75]. Zhang et al., isolated water soluble sulphated derivatives of  $\beta$ -glucans from sclerotia of *P. tuber-regium* that exerts antiviral activities against herpes simplex virus type-1 and type-2 [76,77]. An ubiquitin-like protein was extracted from fruiting bodies of *P. ostreatus* shows anti-HIV activities [78]. Aqueous extracts of *P. pulmonarius* and *P. sajor-caju* exert the inhibitory activity against HIV-1 reverse transcriptase [79]. Li et al., (2008) isolated a lectin from *P. citrinopileatus* fruiting bodies that inhibits HIV-1 reverse transcriptase [80]. Ribonucleases, isolated from *P. ostreatus* [81] have the capability to degrade the genetic material of HIV. From *P. nebrodensis* a monomeric protein, hemolysin was isolated which possesses the anti-HIV-1 activity in CEM cell culture [82].

### Antimicrobial activities

Antibacterial and antifungal activities have also been reported in *Pleurotus* spp. Nagi et al., reported a ribonuclease isolated from *P. sajor-caju* inhibited the growth of *Mycosphaerella arachidicola*, *Fusarium oxysporum*, *Pseudomonas aeruginosa* and *Staphylococcus aureus* [83]. Ethanolic extract of *P. florida* fruiting bodies showed antimicrobial activity against *Escherichia coli*, *Bacillus subtilis*, *B. megaterium* and *S. aureus*. Gerasimenya et al., (2002) reported antimicrobial activity of *P. ostreatus* crude extracts against gram-positive, gram-negative bacteria and *Aspergillus niger* [84]. Hexane-dichloromethane extracts containing anisaldehyde from *P. ostreatus* inhibited the growth of *A. niger*, *F. oxysporum*, *B. subtilis* and *P. aeruginosa* [85]. Eryngin, an antifungal peptide isolated from *P. eryngii* shows inhibitory activity on growth of *M. arachidicola* and *F. oxysporum* [86]. Eryngeolysin, a hemolysin, isolated from *P. eryngii* shows growth inhibition of *Bacillus spp.* [87]. Das et al., reported both ethanol and aqueous extract of fruiting bodies and mycelium of *P. floridanus* inhibit the growth of *E. coli*, *B. subtilis* and *S. aureus* [88].

### CONCLUSION

A large number of mushroom species are reported to produce pharmacologically important substances. Many of these species

are not edible within which *Ganoderma* is most important. Though a number of metabolites are isolated, purified and characterized (still the number is very less) from different medicinal mushroom including *Pleurotus* spp. but still there are many questions particularly for their safety profile and effective doses. Though different nutraceuticals are effective against certain physiological disorders but still there is lack of knowledge in respect to the mode of action of these substances. More extensive research is needed to solve the queries related to the therapeutic uses of different medicinal mushroom. As oyster mushroom (*Pleurotus* spp.) is delicious edible fungi, so, consumption of this mushroom not only prevents us from malnutrition but also from a number of diseases/ pharmacological disorders.

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