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# Nutritional, Therapeutic, and Environmental Effect of Oyster Mushrooms: An Editorial

**Mishra S***

Department of Biotechnology, SR Institute of Management & Technology, India

***Corresponding author:** Sanjay Mishra, Professor, Department of Biotechnology, SR Institute of Management & Technology, Lucknow-226201, Uttar Pradesh, India, Emails: research@srgi.in; sanjaymishra66@gmail.com

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## Editorial

Oyster mushrooms (*Pleurotus species*) are recognized as a largely consumed and nutritionally rich variety, originating from Asia but nowadays cultivated globally. Primarily it was used as substitute food source particularly during First World War. Afterward, it has risen to develop the third most commercially produced mushroom wide-reaching due to its nutritional status. Oyster mushrooms, frequently overlooked despite their nutritional prosperity, represent a veritable treasure trove of essential nutrients. While their significance may have been underappreciated in some parts of the world, particularly in Western cultures, the eastern hemisphere has long documented the therapeutic potential of several mushroom species, including oyster mushrooms, in traditional medicine practices straddling millennia. Rich in riboflavin, pantothenic acid, niacin, selenium, copper, potassium, and vitamin D, these fungi propose a wide-ranging arrangement of vital nutrients essential for human health serve as admirable health supplements [1].

*Pleurotus species*, specifically, flourish on various agricultural wastes, owing to their greater wood disintegrating capabilities compared to other mushroom varieties. The nutritional conformation of *Pleurotus* species is influenced by numerous factors including genetic makeup, disparities in the physical and chemical characteristics of the growth medium, substrate type, pileus size, and harvesting period. Medicinally advantageous *Pleurotus species* are characteristically capable with high levels of protein, minerals (like sodium, potassium, iron, calcium and phosphorus), and vitamins (including folic acid, niacin, riboflavin and thiamine) [2,3], as well as proximate composition constituents, namely, protein, fat, ash, carbohydrates, and energy. Moreover, sugars such as fructose, mannitol, sucrose, trehalose, and fatty acids principally palmitic, oleic, stearic, linoleic, and linolenic acids have been recognized in *Pleurotus species*. *Pleurotus species* symbolizes a rich source of nutraceutical compounds, with lectins evolving as prominent glycoproteins having many-sided bioactivities like antitumor, immune modulator, and antiproliferative features [4,5].

In addition, polysaccharides, namely, β-glucan, polysaccharopeptides, and polysaccharide proteins derived from *Pleurotus* display pharmaceutical potential, demonstrating hepatoprotective, anti-inflammatory, immune-enhancing, and anticancer features. Particularly, heteroglycans from *Pleurotus* species have been noticed to excite macrophages whereas exerting anti-proliferative and proapoptotic effects on carcinoma cells, underlining their therapeutic potential in oncology. Researchers purified a homogeneous, branched β-1, 6-glucan (APEP-A-b) from the fruiting bodies of *P. eryngii* and determined its effects on immunity and gut microbiota in mice. They found that APEP-A-b suggestively increases splenic lymphocyte proliferation, NK cell activity, and phagocytic capacity of peritoneal cavity phagocytes. Besides, the amount of CD4+ and CD8+ T cells in lamina propria were significantly increased upon treatment with APEP-A-b. APEP-A-b also increases the amount of SCFAs produced in bacteria to promote production of acetic and butyric acid.

Overall, our results suggest that β-1, 6-glucan from *P. eryngii* improves immunity might by modulating the gut microbiota. Also, the phytochemical repertoire of *Pleurotus* includes varied compounds, together with alkaloids, saponins, steroids, flavonoids, anthraquinones and phlobatannins, each being contributory to its pharmacological arsenal. Phenolic compounds, observed as crucial secondary metabolites within *Pleurotus species*, display a range of physiological aids ranging from anti-inflammatory and antiallergenic features to cardioprotective, antiatherogenic, antimicrobial, antithrombotic, and antioxidant functions. Such multi-functional features position *Pleurotus* as a promising means for emerging therapeutic agents encounter several deteriorating disorders, symbolizing the latent synergy between natural products and modern pharmacotherapy [6,7].

Oyster mushrooms play a pivotal role of nutritional powerhouse, boasting a rich conformation that enables them a valued addition to any diet. Plentiful in protein, carbohydrates, and vitamins, their nutrient profile fluctuates somewhat depending on the specific species. However, across the panel, oyster mushrooms are prominent for their remarkable protein content, reflecting them an exceptional choice for those seeking alternative sources of this essential macronutrient, predominantly for vegetarians. Besides, their low-fat content further augments their dietary demand, placing them as an extremely desirable food for individuals targeting to maintain a balanced and healthy diet. Whether incorporated into savoury dishes or utilized as a meat auxiliary, the nutritional density of oyster mushrooms underscores their potential to contribute to overall health and well-being, offering a justifiable and wholesome option for those seeking to heighten their nutritional intake.

The fruiting body of mushrooms aids as the primary reservoir for carbohydrates, encompassing a substantial portion of the total carbohydrate content within the organism. Studies conducted in last decade sought to elucidate the carbohydrate conformation of many Oyster mushroom species, including *Pleurotus florida*, *Pleurotus ostreatus*, and *Pleurotussajor-caju* [8].

The findings revealed noteworthy disparities in carbohydrate content among these species, with *Pleurotus eryngii* emerging as the front-runner, boasting a remarkable carbohydrate concentration of about 40g per 100g of mushroom. Following closely behind, *Pleurotussajor-caju* showed a considerable carbohydrate presence, comprising 38g per 100g of mushroom biomass. These annotations underscore the changeability in carbohydrate conformation among different Oyster mushroom strains, highlighting the potential for targeted cultivation strategies to improve carbohydrate yield for several applications in nutrition, biotechnology, and pharmaceuticals. Besides, the studies along these notions and objectives provide clues to design new formulae for commercial supplementation [9].

Protein constitutes a vital constituent of mushroom dry weight, incomparable protein content characteristically found in vegetable sources. Edible mushroom proteins are high in quality, low in cost, widely available, and meet environmental and social requirements, making them suitable as sustainable alternative proteins [10]. Remarkably, mushrooms emerge as a significant protein source, offering a worthwhile alternative to animal-derived meat products because of their provision of essential amino acids, a symbolic feature shared with animal protein sources. Indeed, mushrooms have gathered attention as a treasured dietary supplement, predominantly for individuals adhering to vegetarian diets [10]. Fascinatingly, the total nitrogen content of mushrooms predominantly derives from proteinaceous amino acids, constituting around 80% of the crude protein value relative to the ideal protein standard of 100% [11]. Such insights underscore the nutritional worth of mushrooms as protein pools, strengthening their appeal as justifiable and nutritious dietary components in the pursuit for heightened health and dietary diversity.

Mushrooms, well-known for their nutritional prosperity, display a distinguishing lipid profile branded by a lower fat concentration relative to their protein and carbohydrate content. Though, the fats they do contain are principally comprised of unsaturated fatty acids, stressing their potential health-promoting possessions. In spite of their modest fat content, Oyster mushrooms, a prominent species within the fungal kingdom, feature linoleic acid as their prime fatty acid. The lipid profile across mushroom species can vary meaningfully, ranging from 0.2 to 8 grams per 100 grams of dry fruit bodies. A seminal study focused on three species of *Pleurotus* mushrooms, revealing intriguing insights into their lipid content. Among the species examined, *Pleurotus sajor-caju* emerged with the highest lipid content, at 0.61 grams per 100 grams of the fruiting body, followed by *Pleurotus ostreatus* (0.53 grams) and *Pleurotus florida* (0.46 grams) [12].

Mushrooms stand renowned for their remarkable vitamin content, standing as exemplary sources of essential nutrients, particularly Vitamin B [13]. Remarkably, while mushrooms commonly contain modest amounts of Vitamin C, their significance is further underscored by the exposure that wild varieties boast considerably higher levels of Vitamin D2 compared to their commercially cultivated counterparts, such as the commonly consumed *A. bisporus* [14]. This revelation underscores the potential of mushrooms as a natural source of Vitamin D, mostly crucial for individuals with restricted exposure to sunlight or dietary sources of this essential nutrient. As such, mushrooms arise as crucial constituents of a balanced diet, offering a rich source of vitamins essential for human health and well-being.

The term “therapeutics” encapsulates the multifaceted domain of medicine concerned with the treatment of diseases, while the concept of a drug’s therapeutic value delineates its efficacy in eliciting desired physiological responses upon administration [15]. In contemporary discourse, the paradigm of therapeutic interventions has expanded beyond conventional pharmaceuticals to encompass a diverse array of foods meticulously crafted to deliver therapeutic benefits. Among these, whole foods such as nuts, seeds, fruits, vegetables, whole grains, cruciferous vegetables like broccoli, cabbage, cauliflower, antioxidant-rich berries like cranberries, omega-3 fatty acid-rich fish, flaxseeds, garlic, adaptogenic herbs like ginseng, oats, poly-phenolrich red grapes and red wine in moderation, soybean, and lycopene spacked tomatoes have garnered particular attention for their potential therapeutic properties. However, amidst this burgeoning landscape of therapeutic foods, caution must be exercised, especially in the case of wild mushrooms [16]. While certain mushrooms hold esteemed positions in traditional medicine and culinary traditions, not all varieties found in the wild are safe for consumption. Indeed, some contain compounds that pose significant health risks if ingested. Hence, prudent consumption dictates adherence to the classification of safe-to-eat mushrooms. Oyster mushrooms stand out in this regard, characterized by their safety profile and ease of cultivation. Renowned for their versatility in culinary applications, Oyster mushrooms also harbour a plethora of therapeutic effects, making them an invaluable addition to the armamentarium of functional foods aimed at promoting health and well-being [17].

In a groundbreaking study, researchers investigated the antibiotic potential of extracts derived from various strains of Oyster mushrooms (*Pleurotus eryngii* var. eryngii, *P. eryngii* var. ferulae, *P. eryngii* var. elaeoselini, and *P. nebrodensis*) against a panel of reference bacterial strains including *Staphylococcus aureus*, *Staphylococcus epidermidis, Pseudomonas aeruginosa*, and *Escherichia coli* [18]. The results exposed varying degrees of antibacterial activity across the mushroom strains, highlighting their potential as natural antimicrobial agents. Moreover, another group of researchers explored the antibacterial efficacy of *P. florida* extracts against bacterial and fungal pathogens, demonstrating significant inhibitory effects, particularly with the ethanolic extract exhibiting promising minimum inhibitory concentrations against Escherichia coli and other pathogens. Further investigations into the bioactive constituents of Oyster mushrooms, such as phenolic and tannin compounds found in P. ostreatus, elucidated mechanisms of action including cell membrane lysis, inhibition of protein synthesis, and interference with microbial adhesion processes [19]. Remarkably, petroleum and acetone extract of *P. ostreatus* exhibited broad-spectrum antibacterial activity against both gram-positive and gram-negative bacteria, offering potential solutions to combat the rising threat of multidrug-resistant pathogens. These findings underscore the importance of exploring natural sources like Oyster mushrooms for novel antibiotic therapeutics in the face of intensifying antimicrobial resistance [19].

In the quest of effective antiviral chemotherapy, the supreme objective is to recognize agents that selectively obstruct viral replication. Fungi represent a vast source of bioactive molecules, which could potentially be used as antivirals in the future. Potential research study has made a significant pace in this endeavor through isolating and characterizing a purified laccase enzyme derived from the *P. ostreatus* mushroom. These efforts revealed the remarkable capability of this laccase in inhibiting the entry of the hepatitis C virus into both peripheral blood cells and hepatoma HepG2 cells, as well as suppressing its replication [20]. This innovative finding underscores the potential of natural compounds, such as those found in mushrooms, as promising candidates for antiviral therapeutics, offering a beacon of hope in the ongoing battle against viral contagions [20,21].

Antioxidants play a critical role in mitigating oxidative stress within cells, counteracting the harmful effects of reactive oxygen species (ROS) such as superoxides, peroxides, and hydroxyl radicals. Left unchecked, ROS can inflict oxidative damage on cellular structures, contributing to the development of degenerative diseases like cancer and hepatotoxicity [22,23]. *Pleurotus* species, commonly known as oyster mushrooms, emerges as a potent source of antioxidants, offering a natural solution for disease prevention and treatment [23]. Studies have demonstrated the longevity-promoting effects of *Pleurotus* species antioxidants in organisms like the Mexican fruit fly *Anastrepha ludens* [24]. The vitamin and selenium contents inherent in *Pleurotus species* further augment its antioxidant properties. Research by Jayakumar T, et al. [24] emphasized the ability of *Pleurotus ostreatus* extracts to upregulate catalase gene expression in aging rats, protection against age-linked oxidative stress. Additionally, water-soluble crude polysaccharide extracts from *P. ostreatus* have unveiled notable antioxidant abilities, as proved by their potent free radical scavenging and nitric oxide synthase activation possessions. Remarkably, an acidic polysaccharide isolated from *Pleurotus ostreatus* has demonstrated robust antioxidant effects, underscoring the potential of *Pleurotus species* as a treasured source of antioxidants for combating oxidative stress-related diseases [25,26].

*Pleurotus species* have gathered significant attention in the area of cancer research because of their inherent tumor-suppressing possessions, a phenomenon well-documented over a prolonged period. While several extracts from diverse *Pleurotus species* have confirmed anti-cancer activity in both cancer cell lines and experimental animal models, the translation of these findings into clinical practice through human trials remains lacking [27]. Remarkable annotations include the capability of hot water extracts of *Pleurotus* species to inhibit the spread of MCF-7 human breast cancer cells. Furthermore, treatment with *P. ostreatus* extracts has been shown to downregulate the expression of key biomarkers associated with colon cancer, such as cyclin D1 and Ki-67 [27].

Subsequent studies on antitumor potential of *Pleurotus species* by validated these findings, representing the efficacy of hot water and ethanol extracts from *Pleurotus* fruiting bodies against various human solid carcinomas, including lung and cervical carcinomas [27,28]. The immune-modulatory role of *Pleurotus ferulae* polysaccharides (PFPS) was further elucidated, enhancing the therapeutic effectiveness of dendritic cell-based vaccines targeting human papilloma virus. These altogether findings highlight the promising latent of *Pleurotus species* as treasured additions to the armamentarium of cancer therapeutics, necessitating further exploration and clinical validation.

Myco-remediation, the process through which fungal species are employed for bioremediation drives, has gathered substantial attention in environmental science and biotechnology. Fungi, owing to their flexible metabolic capabilities, have arisen as promising agents for combating environmental pollutants. Among these fungi, oyster mushrooms have demonstrated notable bioremediation capabilities [28]. *Pleurotus pulmonarius* is identified as an effective fungus in degrading crude oil, offering a natural solution to oil spill remediation efforts [29]. Moreover, the efficacy of *Pleurotus pulmonarius* is successfully confirmed in combating radioactive cellulose-based waste, signifying its worth in nuclear waste management [29]. Spent Mushroom Compost (SMC) has arisen as a treasured resource in myco-remediation, with studies by Law, et al. revealing the capacity of *Pleurotus pulmonarius* SMC to significantly reduce pentachlorophenol (PCP) levels [29,30].

Furthermore, myco-remediation encompasses to bioabsorption, with research representing the ability of several oyster mushroom species, together with *Pleurotus ostreatus*, *Pleurotus* sajor-caju, and *Pleurotus florida*, to absorb heavy metals such as cadmium, lead, copper, and chromium from contaminated substrates [31]. These findings highlight the multifaceted potential of oyster mushrooms in environmental remediation approaches, offering maintainable and eco-friendly solutions to various pollution challenges. The use of oyster mushrooms is considered a sustainable strategy in the bioremediation of polluted environments, the biodegradation of agro-wastes or agro-industrial wastes, and the bio-fermentation of ligninolytic wastes to produce enzymes.

## Conclusion and Future Perspectives

The exploration of *Pleurotus ostreatus*, a remarkable edible mushroom reflecting both nutritional and biomedical significance, reveals a rich reservoir of bioactive compounds with diverse therapeutic functions. These compounds hold enormous potential in addressing a myriad of health conditions. Furthermore, owing to its extraordinary nutritional profile, *Pleurotus ostreatus* stances as a potentially in the fight against malnutrition-related diseases, offering a natural and sustainable solution. However, the current focus of research predominantly revolves around extracts derived from the fruiting body, with comparatively fewer studies investigating extracts from cultivated fungi. Hence, there exists a compelling need to redirect research efforts towards exploring the therapeutic potential inherent in cultivated strains. Despite the wealth of *in vivo* and *in vitro* evidence supporting the therapeutic effects of *Pleurotus ostreatus*, the translation of these findings into clinical practice necessitates rigorous clinical trials. Furthermore, mushrooms may be safe as a vaccine adjuvant, but there is minor concern about using them to treat people with for example active SARS-CoV-2 infection since an immune-stimulating agent like mushroom might supercharge an individual's immune response, leading to a cytokine storm, posing the greater risk of COVID-19 mortality. Hence, future research endeavors should line up clinical investigations to copiously elucidate the therapeutic gamut and expose the vast possibilities of this remarkable mushroom species.

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