THE SCIENCE WORLD
A Monthly e Magazine
ISSN:2583-2212
May 2024 Vol.4(5), 1868-1875

Popular Article

Waste Valorization Through Oyster Mushroom Cultivation

Aditya[1*], Neeraj[2*], J.N. Bhatia[3]
[1,2]Department of Agriculture and Environmental Sciences, National Institute of Food Technology Entrepreneurship and Management, Kundli-131028 (NIFTEM-K), Sonipat, Haryana (*An Institute of National Importance of India*).
[3]Retired Professor (Plant Pathology), CCS HAU, Hisar, Haryana.
[*]Address all correspondence: Department of Agriculture and Environmental Sciences, National Institute of Food Technology Entrepreneurship and Management, Kundli 131028, Haryana, India (*An Institute of National Importance of India*)
https://doi.org/10.5281/zenodo.11365016

Introduction

The world population on the planet earth is increasing day by day and is estimated now at over 7 billion. According to some studies, there will be 9 billion people on the planet by 2050 and by 2100, there may be 20 billion of population. Due to urbanization and population growth, there will be a shortage of food and a decline in human health, along with a corresponding decrease in fertile land. One of the most commercially successful and environmentally friendly biotechnology processes is the conversion of lignocellulosic agricultural and forest leftovers into protein-rich mushrooms, which helps meet the world's food demand, particularly for protein and overall nutrition. Waste management is another pressing global issue, exacerbated by the rapid growth of urban populations and industrial activities. Traditional waste disposal methods, such as landfilling and incineration, pose significant environmental hazards, including greenhouse gas emissions, soil and water contamination and loss of valuable materials. Consequently, innovative and sustainable waste management strategies are essential. Waste valorization, the process of converting waste materials into valuable products, offers a promising solution. One such approach involves the cultivation of oyster mushrooms (*Pleurotus* spp.), which not only reduces waste but also produces nutritious food and other valuable by-products (Adebayo et al., 2014). Oyster mushrooms are known for their ability to grow on a wide range of organic substrates, including agricultural and industrial wastes such as agricultural crops straw, sawdust, coffee grounds, vegetable wastes (Aditya & Jarial, 2023). This adaptability allows for the efficient conversion of waste materials into a valuable protein source. Addressing waste management challenges, the cultivation of oyster mushrooms has several environmental benefits, including reducing landfill use, lowering greenhouse gas emissions and promoting the recycling of organic matter. Economically, this practice can provide additional income streams for farmers and entrepreneurs, while socially, it can contribute to food security and create employment opportunities. Thus, oyster mushroom cultivation represents a sustainable and multifaceted approach to waste valorization, offering significant advantages for environmental health, economic development and community well-being (Aditya et al., 2024a).

The Potential of Oyster Mushrooms

Oyster mushrooms, belonging to the genus *Pleurotus*, are a diverse group of fungi known for their broad and oyster-shaped basidiocarps (Fig. 1). They are widely cultivated for their culinary and medicinal properties. Oyster mushrooms are known for their adaptability to various substrates, rapid growth and high nutritional value. They are rich in proteins, vitamins, minerals and antioxidants, making them a popular food source worldwide. Additionally, oyster mushrooms possess medicinal properties, including anti-inflammatory, anti-tumor and immune-boosting effects (Bhamberi et al., 2022). The cultivation of oyster mushrooms can utilize agricultural and industrial wastes, such as straw, sawdust, coffee grounds, vegetable wastes etc. These substrates provide the necessary nutrients for mushroom growth, transforming waste materials into a valuable food source. This not only mitigates the environmental impact of waste disposal but also contributes to food security and economic development. Common substrates include agricultural residues (straw, corn cobs, sugarcane bagasse), wood industry by-products (sawdust, wood chips) and food industry wastes (coffee grounds, vegetable wastes). These substrates are rich in cellulose, hemicellulose and lignin, which are complex carbohydrates that can be broken down by mushroom enzymes (Aditya et al., 2022a). Oyster mushrooms convert waste into valuable protein through a series of processes involving the enzymatic breakdown of complex organic materials, mycelial colonization and the formation of fruiting bodies. This bioconversion not only reduces waste but also produces a nutritious food source and valuable by-products, contributing to sustainable waste management and resource utilization (Aditya et al., 2024a).

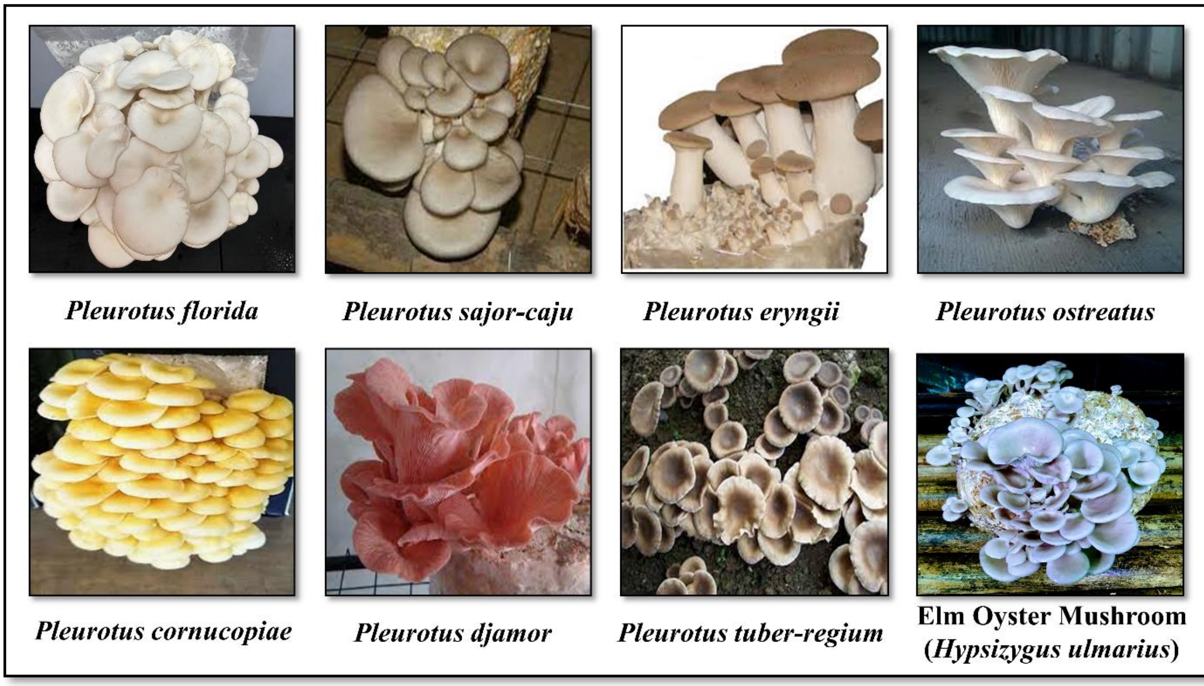

Figure 1. Basidiocarps of different oyster mushroom species.

Substrate Preparation and Mushroom Cultivation

1. Selection and Preparation of Growing Substrates

The first step in oyster mushroom cultivation is the selection of appropriate substrates. These substrates are generally abundant and inexpensive, making them ideal for mushroom cultivation. The preparation of substrates typically involves chopping, soaking and pasteurizing to eliminate contaminants and enhance nutrient availability (Aditya et al., 2022b).

2. Spawn and Spawning

Spawn in oyster mushroom cultivation refers to the material that contains mycelium, the vegetative part of the fungus, used to inoculate the growing substrate and can be prepared on different types of grain substrates. Spawning is the process of introducing this spawn to the substrate, initiating the colonization that will eventually produce mushrooms. The rate of spawning usually varies from 2-5 percent (Abdullah et al., 2013; Aditya et al., 2024b).

3. Inoculation and Incubation

After substrate preparation, the next step is inoculation, where the substrate is mixed with mushroom spawn. This process can be done in various containers, such as plastic bags, bottles or trays. Following inoculation, the substrates are incubated in a controlled environment with optimal temperature, humidity and ventilation. The mycelium colonizes the substrate over several weeks, forming a dense network that will eventually produce mushrooms (Aditya et al., 2023).

4. Fruiting and Harvesting

Once the mycelium fully colonizes the substrate, the conditions are adjusted to initiate fruiting. This typically involves lowering the temperature, increasing humidity and providing light. Within a few days to weeks, the mushrooms begin to appear and can be harvested once they reach the desired size. Oyster mushrooms are typically harvested in multiple flushes over several weeks, providing a continuous supply of fresh mushrooms (Aditya et al., 2023; Aditya et al., 2024a). These harvested mushrooms are nutritionally rich and contain a number of bioactive compounds (Table 1). These mushrooms are rich in bioactive compounds such as polysaccharides, proteins and phenolic compounds, which exhibit antioxidant, anti-inflammatory, and immune-boosting properties, making them a valuable functional ingredient in health-promoting foods (Kour et al., 2022; Ritota, 2023). The spent substrate, now partially decomposed by the mushrooms, can be used as a nutrient-rich compost for soil amendment, completing the waste valorization cycle.

Table 1. Nutritional and Medicinal Importance of Oyster Mushrooms

Nutritional Importance of Oyster Mushrooms		
Sr. No.	**Macronutrient**	**Uses**
1.	Protein	Oyster mushrooms are an excellent source of high-quality protein, containing all essential amino acids. They typically provide about 15-35 percent of their dry weight as protein, making them a valuable protein source, especially for vegetarians and vegans.
2.	Carbohydrates	They are rich in dietary fiber, including both soluble and insoluble fiber, which aids in digestion and promotes gut health. The fiber content helps regulate blood sugar levels and lower cholesterol.
3.	Fats	Oyster mushrooms have a low-fat content, with the majority being unsaturated fatty acids, including linoleic acid. This makes them a heart-healthy food option.
Micronutrients		**Uses**
4.	Vitamins B complex	Oyster mushrooms are rich in B-complex vitamins, including B1 (thiamine), B2 (riboflavin), B3 (niacin), B5 (pantothenic acid), B6 (pyridoxine), and B9 (folate). These vitamins play crucial roles in energy metabolism, brain function, and the production of red blood cells.
5.	Vitamin D	They contain ergosterol, a precursor to vitamin D2, which is converted into vitamin D2 when exposed to UV light. Vitamin D is essential for bone health and immune function.
6.	Vitamin C	Present in moderate amounts, contributing to immune health and antioxidant protection.
7.	Minerals	Oyster mushrooms provide significant amounts of minerals such as potassium, phosphorus, magnesium, iron, zinc and selenium. These

		minerals are vital for various physiological functions, including muscle and nerve function, bone health and antioxidant defence.
Medicinal Importance of Oyster Mushrooms		
Bioactive Compounds		**Uses**
8.	Flavonoids	These compounds have strong antioxidant properties, protecting cells from oxidative stress and reducing the risk of chronic diseases such as heart disease, diabetes and cancer. They help neutralize free radicals, thus preventing cellular damage.
9.	β-glucans	β-glucans are polysaccharides with potent immune-modulating properties. They enhance the body's immune response by activating macrophages, natural killer cells, and other components of the immune system.
10.	Phenolic compounds	Oyster mushrooms are rich in phenolic compounds, which have strong antioxidant and anti-inflammatory properties. These compounds can help reduce the risk of inflammatory diseases and oxidative stress-related conditions
11.	Polysaccharides	The polysaccharides in oyster mushrooms, particularly β-glucans have been shown to possess anti-tumour activity. They can inhibit the growth of cancer cells and stimulate the immune system to attack tumour cells.
12.	Fiber	The high fiber content in oyster mushrooms helps reduce cholesterol levels and improve heart health by promoting the excretion of bile acids.
13.	Lectins	Lectins from oyster mushrooms have shown potential anti-cancer properties by binding to cancer cell membranes and inducing apoptosis (programmed cell death).
14.	Sterols	Oyster mushrooms contain ergosterol, which can be converted into vitamin D2. Additionally, sterols in these mushrooms help lower cholesterol levels by inhibiting cholesterol absorption in the intestines.
15.	Terpenoids	These compounds possess strong anti-inflammatory properties, helping to reduce inflammation and associated symptoms in chronic conditions such as arthritis and inflammatory bowel disease.
16.	Antimicrobial compounds	Oyster mushrooms produce various antimicrobial compounds that can inhibit the growth of harmful bacteria, fungi and viruses, thereby supporting overall immune health.
17.	Ergothioneine	This is a unique antioxidant found in significant amounts in oyster mushrooms. Ergothioneine accumulates in tissues prone to oxidative stress and helps protect cells from damage.

Benefits of Waste Valorization through Mushroom Cultivation

1. **Environmental benefits**

Official Website
www.thescienceworld.net
thescienceworldmagazine@gmail.com

Published 25.05.2024

A. Waste reduction: Utilizing agricultural and industrial wastes for mushroom cultivation significantly reduces the volume of waste destined for landfills and incineration.
B. Resource conservation: Converting waste into valuable products conserves natural resources by reducing the need for synthetic fertilizers and soil amendments.
C. Carbon sequestration: Oyster mushrooms contribute to carbon sequestration by decomposing organic matter and incorporating carbon into their biomass and the soil.

2. Economic benefits

A. Income generation: Mushroom cultivation provides a source of income for small-scale farmers, entrepreneurs and rural communities.
B. Cost savings: Using waste materials as substrates reduces the cost of mushroom production compared to conventional methods that rely on commercial substrates.
C. Value addition: The production of mushrooms from waste materials adds value to otherwise discarded resources, enhancing their economic potential.

3. Social benefits

A. Food security: Oyster mushrooms are a nutritious food source that can help improve dietary diversity and combat malnutrition.
B. Employment opportunities: Mushroom cultivation creates jobs in rural and urban areas, contributing to economic development and poverty alleviation.
C. Community engagement: The process of waste valorization through mushroom cultivation can foster community involvement and awareness of sustainable practices.

Challenges and Solutions

1. Technical challenges

A. Substrate contamination: Contamination by unwanted microorganisms can hinder mushroom growth. Solutions include proper pasteurization, maintaining hygienic conditions and using quality spawn.
B. Climate control: Maintaining optimal environmental conditions for mushroom growth can be challenging, especially in regions with extreme climates. The use of simple, low-cost climate control systems can mitigate this issue.

2. Economic challenges

A. Initial investment: The cost of setting up mushroom cultivation facilities can be a barrier for small-scale farmers. Providing microloans and subsidies can help overcome this hurdle.
B. Market access: Farmers may face difficulties accessing markets for their mushrooms. Establishing cooperatives and linking farmers with buyers can improve market access and ensure fair prices.

3. Social challenges

A. Awareness and training: Lack of knowledge and skills in mushroom cultivation can limit adoption. Conducting training programs and extension services can address this gap.
B. Cultural acceptance: In some regions, mushrooms may not be traditionally consumed. Promoting the nutritional and culinary benefits of mushrooms can enhance their acceptance.

Future Prospects

The potential for waste valorization through oyster mushroom cultivation is vast. As awareness

Official Website
www.thescienceworld.net
thescienceworldmagazine@gmail.com
Published 25.05.2024

of sustainable practices grows, more communities and industries are likely to adopt this approach. Future research and innovation can further optimize substrate utilization, improve yield and enhance the nutritional and medicinal properties of mushrooms. Advances in biotechnology and agricultural sciences can enhance substrate utilization, ensuring that mushrooms can grow more efficiently on a wider range of waste materials. Improvements in cultivation techniques can lead to higher yields, making mushroom farming more economically viable and accessible. Moreover, future research should also aim to boost the nutritional and medicinal properties of oyster mushrooms, potentially increasing their value as a health food. Enhanced mushroom cultivation can play a significant role in reducing waste, mitigating environmental impact and supporting public health. The synergy of waste valorization and mushroom farming exemplifies a circular economy approach, promising a more sustainable and resilient future.

Technological Innovations

A. Advanced substrate formulations: Developing new substrate formulations that maximize nutrient availability and mushroom yield.
B. Automation and monitoring: Implementing automated systems for climate control, substrate preparation and harvesting to increase efficiency and reduce labour costs.
C. Genetic improvement: Breeding and selecting oyster mushroom strains with enhanced growth rates, disease resistance and nutritional profiles.

Conclusion

Waste valorization through oyster mushroom cultivation presents a sustainable and multifaceted solution to the global waste management crisis. Transforming agricultural and industrial wastes into valuable food products, this approach offers significant environmental, economic and social benefits. While challenges exist, targeted solutions and collaborative efforts can unlock the full potential of this innovative practice. As we move towards a more sustainable future, the integration of waste valorization and mushroom cultivation stands as a testament to the power of nature-based solutions in addressing complex global issues. Oyster mushrooms are a remarkable resource for their nutritional, bioactive and medicinal properties, as well as their contribution to sustainability. Rich in proteins, vitamins, minerals and fibers, they offer significant health benefits, including enhanced immune function, reduced inflammation, improved cardiovascular health and potential anti-cancer effects. Medicinally, they contain β-glucans and polysaccharides that boost the immune system, while ergothioneine and phenolic compounds provide strong antioxidant and anti-inflammatory benefits, aiding in the prevention of chronic and neurodegenerative diseases. Environmentally, their cultivation utilizes agricultural and industrial wastes, reducing landfill use, conserving resources and promoting sustainable farming through spent mushroom substrate as a soil amendment. Economically, oyster

Official Website
www.thescienceworld.net
thescienceworldmagazine@gmail.com
Published 25.05.2024

mushroom farming provides additional income and supports food security, particularly in resource-limited settings. Integrating their cultivation into waste management practices offers a holistic solution for health, sustainability, and economic development, aligning with global sustainability goals and fostering a healthier future.

References

Abdullah, N., Ismail, R., Johari, N.M.K., Annuar, M.S.M. (2013). Production of liquid spawn of an edible grey oyster mushroom, *Pleurotus pulmonarius* (Fr.) Quel by submerged fermentation and sporophore yield on rubber wood sawdust. *Scientia Horticulturae*, **161**, 65-69. https://doi.org/10.1016/j.scienta.2013.06.026

Adebayo, E.A., Alao, M.B., Olatunbosun, O.O., Omoleye, E.O., Omisakin, O.B. (2014). Yield evaluation of *Pleurotus pulmonarius* (oyster mushroom) on different agricultural wastes and various grains for spawn production. *Ife Journal of Science*, **16**(3), 475-480. https://www.ajol.info/index.php/ijs/article/view/131687

Aditya., & Jarial, R.S. (2023). Utilization of agro-industrial wastes and organic supplements for cultivation of blue oyster mushroom. *Bangladesh Journal of Botany*, **52**(1), 179-185. http://dx.doi.org/10.3329/bjb.v52i1.65249

Aditya., Jarial, R.S., & Bhatia, J.N. (2023). Performance of various agroforestry wastes for the cultivation of elm oyster mushroom *Hypsizygus ulmarius* (Agaricomycetes) in India and its biochemical constituents. *International Journal of Medicinal Mushrooms*, **25**(8), 55-62. http://dx.doi.org/10.1615/IntJMedMushrooms.2023049037

Aditya., Jarial, R.S., & Jarial, K. (2022a). Commercial cultivation of the elm oyster mushroom *Hypsizygus ulmarius* (Agricomycetes) on different substrates and its medicinal benefits. *International Journal of Medicinal Mushrooms*, **24**(12), 87-93. http://dx.doi.org/10.1615/IntJMedMushrooms.2022045380

Aditya., Jarial, R.S., & Jarial, K. (2022b). Performance evaluation of substrates for cultivation of blue oyster mushroom. *Indian Journal of Horticulture*, **79**(3), 323-329. http://dx.doi.org/10.5958/0974-0112.2022.00044.5

Aditya., Neeraj., Bhatia, J.N., & Yadav, A.N. (2024b). Characterization and yield performance of spawn prepared from *Hypsizygus ulmarius* (Bull.) Redhead and some *Pleurotus* species (Agaricomycetes). *Biocatalysis and Agricultural Biotechnology*, **56**(103047), 1-12. http://dx.doi.org/10.1016/j.bcab.2024.103047

Aditya., Neeraj., Jarial, R.S., Jarial, K., & Bhatia, J.N. (2024a). Comprehensive review on oyster mushroom species (Agaricomycetes): Morphology, nutrition, cultivation and future aspects. *Heliyon*, **10**(5), e26539. http://dx.doi.org/10.1016/j.heliyon.2024.e26539

Bhamberi, A., Srivastava, M., Mahale, V.G., Mahale, S., Karan, S.K. (2022). Mushroom as potential sources of active metabolites and medicines. *Frontiers in Microbiology*, **13**, 897266. https://doi.org/10.3389/fmicb.2022.837266

Kour, H., Kour, D., Kour, S., Singh, S., Hashmi, S.A.J., Yadav, A.N., Kumar, K., Sharma Y.P., Ahluwalia, A.S. (2022). Bioactive compounds from mushrooms: An emerging bioresources of food and nutraceuticals. *Food Bioscience*, 102124. https://doi.org/10.1016/j.fbio.2022.102124

Ritota, M. (2023). Edible mushrooms: Functional foods for functional ingredients? A focus on *Pleurotus* spp. *AIMS Agriculture and Food*, **8**(02), 391-439. https://doi.org/10.3934/agrfood.2023022