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Valorization of Agricultural Residues through Oyster Mushroom Cultivation: A Practical Approach for Small-Scale Farms in India

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Abstract

Oyster mushroom cultivation offers a practical route for converting low-value lignocellulosic residues into a marketable food product while reducing dependence on conventional crop-based resources. *Pleurotus ostreatus* is particularly suitable for small-scale production because it can colonize diverse agricultural and agro-industrial residues after appropriate moisture conditioning and pasteurization. This article synthesizes recent evidence with a field-oriented cultivation protocol relevant to residue-rich farming systems in India. Key operational points include substrate moisture of about 60–65%, hot-water pasteurization near 80°C for approximately 2 hours, spawn rates commonly around 2–5% of wet substrate, controlled spawn running near 22–28°C, and high relative humidity during fruiting. Because yield depends strongly on substrate composition and strain, these values should be treated as practical reference ranges rather than universal optima. Good hygiene, ventilation, moisture management and timely harvesting are critical for minimizing contamination and maintaining quality. Spent mushroom substrate can subsequently be directed toward composting; soil amendment or other validated agricultural applications, strengthening the circularity of the production system.

Introduction

Crop residues such as rice and wheat straw, maize residues, sugarcane by-products and other lignocellulosic materials are produced in large quantities but are frequently underutilized. Open burning, uncontrolled decomposition or low-value disposal can represent lost biomass resources and contribute to local environmental burdens. Oyster mushrooms provide a biological conversion pathway because *Pleurotus* species

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secrete lignocellulose-degrading enzymes and can use a broad range of plant-derived materials as growth substrates (Sánchez, 2010; Doroški et al., 2022; Addy et al., 2024). Recent studies continue to demonstrate that substrate composition affects colonization, fruiting time, biological efficiency and mushroom quality, meaning that residue availability alone is not sufficient; physical structure, moisture and nutrient balance must also be considered (Gebru et al., 2024; Miśkiewicz et al., 2025).

For Indian smallholders, the attraction is the short production cycle and the possibility of using locally available residues rather than purchasing a highly specialized growing medium. However, practical success depends on disciplined substrate preparation and microclimate management. The objective of this article is therefore not to propose a single universal recipe, but to translate current evidence into a concise field protocol that can be adapted to local residue availability, strain characteristics and climate.

Core Findings

Selecting and preparing the substrate

Clean, dry and non-mouldy straw should be preferred. Paddy and wheat straw are established substrates, while maize residues, bamboo or wood residues, tea waste, coffee waste and selected agro-industrial by-products can also support *Pleurotus* growth when their physical and nutritional properties are suitable (Zhang et al., 2002; Girmay et al., 2016; Yamauchi et al., 2019; Yang et al., 2016; Akçay et al., 2023). Recent work further shows that blending residues can outperform individual materials; for example, mixed agricultural-residue systems have produced substantially different colonization and yield responses compared with single residues (Gebru et al., 2024; Miśkiewicz et al., 2025). For farm use, straw may be chopped to roughly 3–5 cm to improve handling and packing. Hydration should continue until the substrate is uniformly moist without free water; around 60–65% moisture is a useful practical target, although published protocols vary. Where a simple low-cost method is required, ICAR-IIHR recommends hot-water pasteurization at about 80°C for 2 hours; steam pasteurization is another option, while pressure sterilization is more appropriate for controlled commercial systems (ICAR-IIHR; Doroški et al., 2022).

Practical cultivation protocol

After pasteurization, the substrate should be drained and cooled below approximately 30°C before inoculation to protect the spawn. A practical spawn rate is commonly 2–5% of wet substrate, with about 3% providing a reasonable starting point for small-scale trials; higher rates may shorten colonization but increase spawn cost. For example, 10 kg of prepared wet substrate at 3% requires approximately 300 g of spawn. Spawn can be distributed through several alternating substrate layers, avoiding excessive compression and maintaining enough pore space for gas exchange. The bags are then kept in a clean incubation area. Many *P. ostreatus* systems perform well around 22–28°C, with approximately 24–25°C often used as a practical target; complete colonization commonly occurs

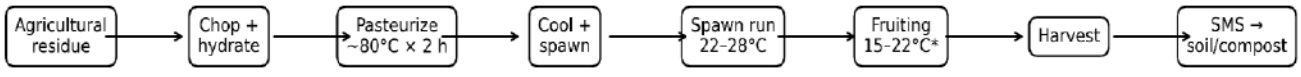


Figure 1. Field-oriented cultivation pathway for oyster mushroom production from agricultural residues.
**Fruiting temperature is strain-dependent*

within roughly 12–21 days depending on strain and substrate (Dhanalakshmi and Ambethgar, 2021; Silva et al., 2024). During spawn running, unnecessary spraying or opening of bags should be avoided because the substrate itself is the main water reservoir and repeated handling increases contamination risk.

Environmental management during fruiting

Once the substrate is fully colonized, fruiting conditions should be established according to the strain. For many cool-fruiting *P. ostreatus* strains, approximately 15–22°C is a useful reference range, while other commercial strains can fruit at warmer temperatures. Relative humidity is generally maintained around 85–95% without persistent condensation. Fresh-air exchange is particularly important during fruiting; carbon dioxide is preferably kept below about 1,000 ppm when monitoring is available. Diffuse light in the approximate range of 1,000–1,500 lux has been reported for fruit-body development, but illumination requirements vary among production systems (Silva et al., 2024). Primordia may appear within several days after fruiting conditions are established, followed by harvestable basidiomata over the next several days. Rather than following a fixed misting schedule, water should be applied according to room humidity and the condition of the blocks. Fine misting may be required during dry weather, but standing water and direct saturation of developing mushrooms should be avoided.

Yield, contamination and harvest decisions

Yield should be evaluated against dry substrate input rather than bag weight alone. Biological efficiency (BE) can be expressed as: BE (%) = fresh mushroom yield (kg) / dry substrate weight (kg) × 100. Substrate trials show large differences in performance, confirming that local optimization is more informative than assuming that one residue is universally superior. For example, recent studies have reported high biological efficiencies from mixed-residue systems, while other residues produced substantially lower responses (Gebru et al., 2024; Subedi et al., 2023). Contamination remains a major practical constraint. Green moulds, bacterial growth, insects and poor hygiene can rapidly reduce productive bags. Contaminated units should be isolated promptly and handled

Table 1: Practical reference ranges for small-scale oyster mushroom cultivation

Parameter	Practical reference	Field interpretation
Straw particle size	~3–5 cm	Adequate structure and handling
Substrate moisture	~60–65%	Moist but without free drainage
Hot-water pasteurization	~80°C × 2 h	Low-cost small-scale option
Spawn rate	2–5% wet substrate	~3% is a useful starting point
Spawn running	22–28°C	~24–25°C often practical
Spawn-running RH	~85–95%	Avoid excessive condensation
Spawn-run duration	~12–21 days	Strain/substrate dependent
Fruiting temperature	~15–22°C*	Cool-fruiting strains; strain dependent
Fruiting RH	~85–95%	Maintain humid air, avoid waterlogging
CO_2	Preferably <1,000 ppm	Ventilate as fruiting develops
Light	~1,000–1,500 lux	Diffuse rather than intense light

**Reference range for many cool-fruiting strains; production temperature must be adjusted to the cultivar. Values are synthesis of published cultivation guidance and should not be treated as universal optima.*

according to farm biosecurity and waste-management procedures; cutting open contaminated bags inside the production room can spread spores. Clean tools, dedicated footwear, hand hygiene, clean water and good ventilation are inexpensive but important control measures.

Harvesting should occur when the caps are well developed and the margins are expanded but before excessive flattening and spore release. Clusters should be removed cleanly without unnecessary disturbance of the block. After each flush, visible debris should be removed and moisture maintained appropriately so the block can recover for subsequent flushes. Postharvest cooling and clean packaging are important because oyster mushrooms are highly perishable. If longer storage is required, controlled drying to a stable low moisture content offers a practical preservation route, after which the dried product can be marketed whole or milled into powder.

From mushroom crop to circular farm system

The sustainability advantage does not end at harvest. Spent mushroom substrate (SMS) still contains partially degraded lignocellulosic matter and mineral nutrients, and its composition depends strongly on the original substrate and cultivation process. Recent research has demonstrated the potential of SMS for agricultural applications, including soil-related uses and plant-growth support, although the material should be evaluated for maturity, salinity, contaminants and crop suitability before large-scale application (Wan Mahari et al., 2020; Silva et al., 2024; Miśkiewicz et al., 2025). A practical circular pathway is therefore residue → mushroom food → SMS → compost/soil amendment or another validated value-added application. This approach improves biomass utilization while creating opportunities for integrated farm enterprises.

Conclusion & Takeaway

Oyster mushroom cultivation can convert locally available agricultural residues into food within a relatively short production cycle, but reliable results depend more on process discipline than on a single substrate formula. For small farms, clean straw, appropriate hydration, effective pasteurization, a moderate spawn rate, controlled temperature and humidity, adequate fresh-air exchange and strict hygiene form the core of a robust system. Farmers should begin with small comparative batches rather than immediately scaling an untested substrate recipe. Recording substrate type, moisture, spawn rate, colonization time, first-harvest date, yield by flush and contamination frequency will allow local optimization and improve economic decision-making. Future farm systems can combine low-cost environmental sensors with cultivation records to develop data-driven advisories, while SMS valorization can extend the production chain toward a circular bioeconomy.

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