



Effect of Rice Husk Substitution in Sawdust Media on the Productivity of *Pleurotus ostreatus*

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Abstract

This study investigated the effect of rice husk supplementation in sawdust-based substrates on the growth and yield of oyster mushrooms (*Pleurotus ostreatus*). Five substrate formulations were tested, ranging from 100% sawdust to mixtures containing 15–60% rice husk. Growth parameters measured included the number of fruiting bodies, cap diameter, stipe diameter, stipe height, and fresh weight yield. Results revealed that moderate husk inclusion (15–30%) significantly enhanced yield components, while excessive supplementation ($\geq 45\%$) reduced growth due to increased silica content and poor degradability. Pure sawdust supported faster mycelial colonization and larger cap diameters, but overall productivity was higher in substrates containing small proportions of husk. The findings demonstrate that substrate optimization is critical not only for maximizing mushroom yield but also for promoting sustainable agriculture by valorizing rice husk, an abundant agro-industrial byproduct.

KEYWORDS

Pleurotus ostreatus; Oyster mushroom; Rice husk; Sawdust; Substrate optimization and Sustainable agriculture.

1 | INTRODUCTION

Mushroom cultivation has become an increasingly important component of sustainable agriculture and food systems, providing high-quality protein, essential amino acids, vitamins, and bioactive compounds that contribute to human nutrition and health. Among the cultivated mushrooms, the oyster mushroom (*Pleurotus ostreatus*) has gained global recognition due to its rapid growth, adaptability to a wide range of lignocellulosic substrates, high productivity, and consumer acceptability (Nandhini et al., 2023). As a species capable of bioconverting agricultural residues into valuable food products, *P. ostreatus* cultivation represents an effective strategy to improve food security while contributing to circular bioeconomy principles by reducing agricultural waste (Zhang et al., 2022).

Sawdust has traditionally served as the primary substrate for oyster mushroom cultivation. It provides a lignocellulosic matrix rich in cellulose, hemicellulose, and lignin, which are enzymatically degraded by the fungus to obtain nutrients for mycelial development and fruiting body formation (Haque et al., 2024).

However, dependence on sawdust has raised ecological and economic concerns. Sawmill residues are declining in availability due to increasing demand from wood-based industries and restrictions on deforestation. Furthermore, price fluctuations and transportation costs for sawdust limit the scalability of mushroom production, particularly for smallholder farmers in developing regions (Purnomo et al., 2025). These challenges highlight the need to explore alternative or complementary substrates that are abundant, inexpensive, and locally available.

Rice husk, a major byproduct of rice milling, offers significant potential as a supplementary or substitute material in mushroom substrates. Global rice production generates millions of tons of husk annually, much of which remains underutilized or disposed of through open burning, causing environmental pollution and greenhouse gas emissions (Mohan et al., 2023). Rice husk is structurally composed of cellulose, hemicellulose, lignin, and a high proportion of silica, providing a fibrous texture and porosity that may

improve aeration in mushroom substrates (Borah et al., 2024). While its nutrient content is lower than that of sawdust, combining rice husk with other organic amendments can create a balanced substrate that supports both vigorous mycelial colonization and productive fruiting.

The productivity of oyster mushrooms depends heavily on the physicochemical properties of the substrate. Parameters such as pH, carbon-to-nitrogen (C:N) ratio, water-holding capacity, and porosity influence both vegetative growth and yield performance (Riaz et al., 2022). Sawdust alone has favorable lignocellulosic content but may compact under high moisture, reducing aeration and slowing colonization. In contrast, rice husk increases bulk density and porosity but requires supplementation with nitrogen-rich amendments to support fruiting body development (Silva et al., 2023). Therefore, the substitution or partial replacement of sawdust with rice husk could optimize substrate characteristics, improve aeration, and reduce costs without compromising yield.

In addition to enhancing productivity, substrate optimization contributes to broader sustainability goals. Utilizing agricultural residues such as rice husk minimizes waste, reduces dependence on deforestation-based inputs, and supports environmentally responsible farming systems (Rout et al., 2022). Studies have also indicated that the incorporation of rice husk into mushroom substrates may influence the nutritional composition of fruiting bodies, including protein and mineral content, thereby adding further value to the crop (Mensah et al., 2024). Moreover, substrate diversification enhances resilience for mushroom growers by ensuring production continuity even during shortages or rising costs of conventional raw materials.

Recent advances in mushroom biotechnology emphasize the role of substrate innovations in expanding production. Research on mixtures of rice husk with sawdust, wheat bran, cotton stalks, and other agro-residues has demonstrated variable effects on yield and biological efficiency, depending on formulation ratios and environmental conditions (Rahman et al., 2022; Haq et al., 2024). However, the substitution of sawdust with rice husk in different proportions remains underexplored in certain contexts, including tropical environments where rice production is abundant and mushroom farming offers livelihood opportunities. Understanding the effects of rice husk substitution on oyster mushroom productivity is therefore both scientifically relevant and practically important.

The present study investigates the effect of substituting rice husk into sawdust-based substrates on the growth and productivity of *Pleurotus ostreatus*. The objective is to evaluate how different combinations of sawdust and rice husk influence growth parameters, yield, and biological efficiency. By analyzing the

suitability of rice husk as a partial replacement for sawdust, this research aims to identify a sustainable substrate formulation that supports high productivity while reducing reliance on increasingly scarce and expensive sawdust. Ultimately, these findings contribute to developing cost-effective and environmentally friendly mushroom cultivation practices that can be readily adopted by smallholders and commercial producers alike.

2 MATERIALS AND METHODS

The study utilized cultivation facilities consisting of mushroom houses equipped with tiered bamboo racks, steamer units, manual press tools, and standard equipment such as scissors, ropes, plastic bags (17 x 30 cm), rubber bands, newspapers, PVC rings, spatulas, tarpaulins, hand sprayers, measuring tools, labels, and writing instruments. The materials included sawdust, rice husk, oyster mushroom (*Pleurotus ostreatus*) F1 spawn, water, lime, rice bran, M-Bio inoculant, and 70% ethanol for sterilization.

The experiment followed a randomized block design (RBD) with five treatments and five replications. The treatments consisted of different substrate compositions: T0: 100% sawdust, T1: 15% rice husk + 85% sawdust, T2: 30% rice husk + 70% sawdust, T3: 45% rice husk + 55% sawdust, and T4: 60% rice husk + 40% sawdust.

Each treatment included six cultivation bags (baglogs). The mushrooms were harvested at 40 days after inoculation when the caps had fully expanded, by gently removing the entire fruiting cluster. Data were analyzed using analysis of variance (ANOVA) with Fisher's test, followed by Duncan's Multiple Range Test (DMRT) for mean separation at a 5% significance level.

3 RESULTS

The overall environmental conditions during the experiment were within the optimal range for oyster mushroom cultivation. The daily average temperature was 23 °C, which falls within the recommended range of 23–28 °C for *Pleurotus ostreatus* growth. Relative humidity averaged 80%, matching the ideal range of 75–80%. The pH of the growth substrate was 7, also suitable for mycelial development, which generally requires a neutral pH between 6 and 7.

Mycelial colonization varied depending on substrate composition. The fastest colonization was observed in the treatment with 100% sawdust, achieving full bag colonization within 20 days after inoculation. Treatments with 15% and 30% rice husk substitutions required 22 days, while 45% rice husk substitution extended colonization to 25 days. The slowest colonization was found in the 60% rice husk + 40% sawdust medium, which required 26 days. Increased

rice husk content appeared to delay fruiting body emergence due to higher silica levels, which may hinder enzymatic degradation and mycelial penetration.

Statistical analysis showed that media composition significantly influenced the number of fruiting bodies per baglog across five harvests (Fig 1). The highest number of fruiting bodies was obtained from the 15% rice husk + 85% sawdust treatment (38.70 fruits/baglog), whereas the lowest was from the 60% rice husk + 40% sawdust treatment (24.27 fruits/baglog). These results highlight the beneficial role of moderate rice husk addition as a lignocellulosic supplement, while excessive incorporation may increase silica levels, reducing degradability and thus fruit body formation.

The substrate composition also influenced cap diameter across successive harvests (Fig 2). In the first three harvests, the 100% sawdust treatment consistently produced the largest caps, reaching 10.63 cm in the first flush. By contrast, the smallest caps were found in the 60% rice husk + 40% sawdust treatment, averaging 7.12 cm in the fifth harvest. The data suggest that nutrient availability and distribution

affect cap expansion, with higher fruit body numbers tending to reduce average cap size as resources are distributed across more structures.

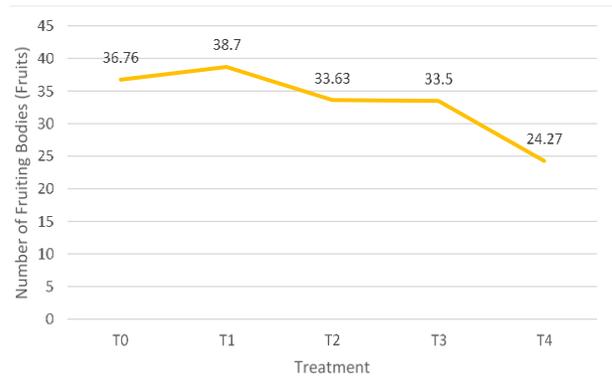


Fig. 1: Effect of substrate composition on the number of oyster mushroom fruiting bodies per baglog.

For stipe diameter, no significant differences were observed across treatments in the first four harvests; however, differences emerged in the fifth harvest (Fig 3). The 15% rice husk + 85% sawdust treatment

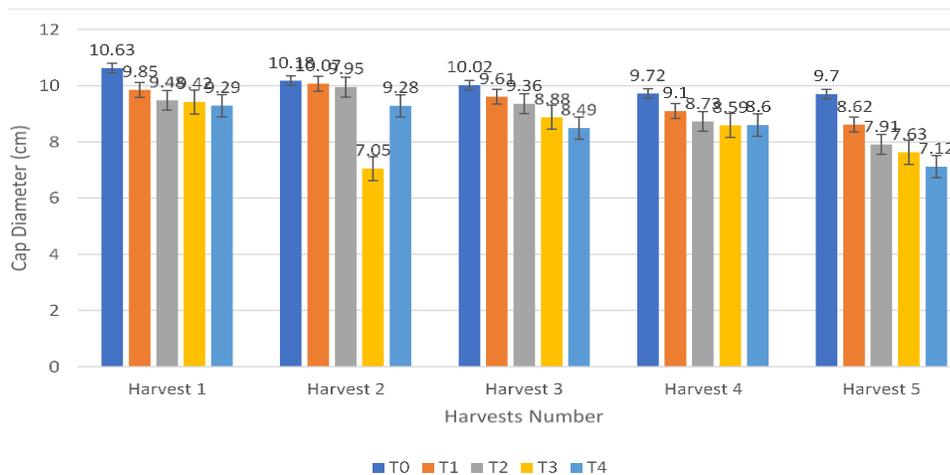


Fig. 2: Effect of substrate composition on cap diameter (cm) of oyster mushrooms across five harvests.

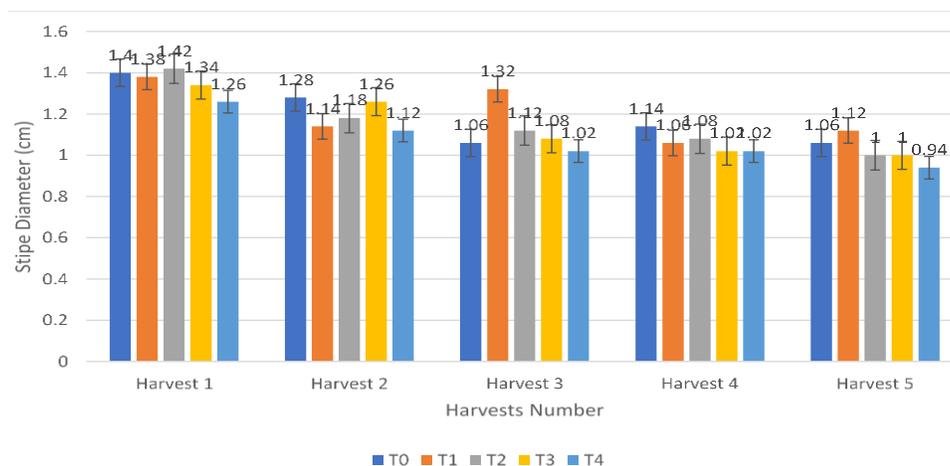


Fig. 3: Effect of substrate composition on stipe diameter (cm) of oyster mushrooms across five harvests.

produced the thickest stipes (1.12 cm), while the 60% rice husk + 40% sawdust medium yielded the thinnest (0.94 cm). This trend indicates that moderate rice husk supplementation supports stipe development, but higher proportions hinder it.

The height of the stipe was also significantly affected by substrate composition (Fig 4). The highest stipes were consistently obtained from the 100% sawdust treatment across all harvests, with the first flush reaching 9.88 cm. In contrast, the 60% rice husk + 40% sawdust treatment produced the shortest stipes in most cases. This pattern suggests that sawdust-based substrates provide superior support for vertical growth compared to rice husk-dominant media.

Finally, total fresh weight was significantly influenced by substrate composition (Fig 5). The highest fresh weight yield was obtained from the 15% rice husk + 85% sawdust treatment (493.98 g/baglog), followed closely by the 100% sawdust treatment (471.82 g/baglog). The lowest yield was observed in the 60% rice husk + 40% sawdust treatment (408.38 g/baglog). These findings indicate that modest rice husk supplementation enhances yield, while excessive substitution reduces productivity.

4 | DISCUSSION

The present study demonstrated that the composition of cultivation substrates significantly influenced the growth and productivity of oyster mushrooms (*Pleurotus ostreatus*). Variations in substrate formulation, particularly the proportion of rice husk and sawdust, altered biological parameters such as the number of fruiting bodies, cap diameter, stipe diameter, stipe height, and fresh weight yield. These findings reaffirm the crucial role of substrate optimization in mushroom cultivation, where the physical and chemical properties of the medium dictate

nutrient availability, aeration, and water-holding capacity, which in turn regulate mycelial colonization and fruiting efficiency.

One of the most important observations was that excessive incorporation of rice husk (up to 60%) delayed the emergence of fruiting bodies and reduced yield parameters. This phenomenon can be attributed to the high silica content of rice husk, which is known to increase substrate rigidity and reduce its degradability by ligninolytic enzymes. Silica forms physical barriers that hinder fungal penetration into lignocellulosic complexes, thus slowing down mycelial extension and subsequent fruiting (Kim et al., 2023). In contrast, moderate levels of rice husk addition (15–30%) improved the number of fruiting bodies and biological efficiency. This suggests that while rice husk can provide additional porosity and enhance aeration, its optimal balance with sawdust is critical to avoid inhibitory effects.

The results regarding the number of fruiting bodies align with studies conducted in other mushroom species. For instance, Al-Shammari et al. (2022) reported that partial substitution of sawdust with agricultural residues improved fruit body initiation in *Pleurotus eryngii*, but yields declined when residue content exceeded 50%. Similarly, Xu et al. (2023) emphasized that substrate porosity and water retention, influenced by the choice of lignocellulosic materials, are decisive factors for primordia differentiation. This indicates that the observed outcomes are not species-specific but rather a broader characteristic of substrate–fungus interactions in oyster mushrooms.

The cap diameter findings provide further insight into the nutrient distribution dynamics within the substrate. Larger caps were consistently obtained in pure sawdust substrates, while mixed substrates with higher rice husk proportions yielded smaller caps. This

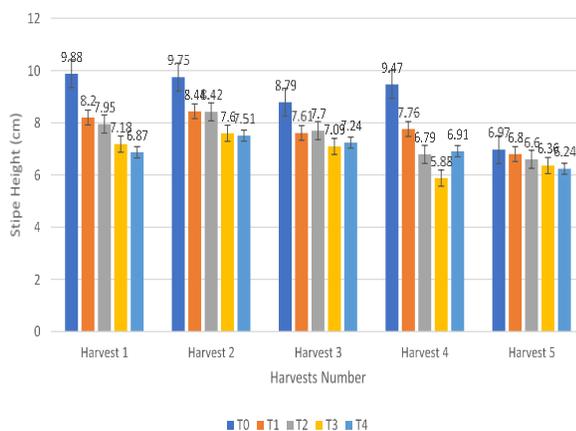


Fig. 4: Effect of substrate composition on stipe height (cm) of oyster mushrooms across five harvests.

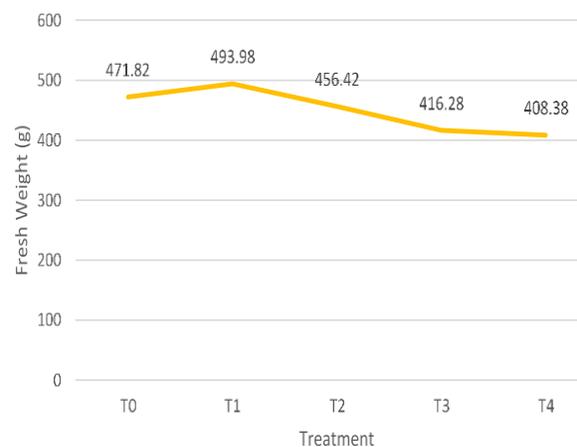


Fig. 5: Effect of substrate composition on total fresh weight of oyster mushrooms per baglog.

can be explained by nutrient competition among developing primordia. When substrates favor high numbers of fruit bodies, nutrient partitioning results in smaller cap diameters. Conversely, in substrates where fewer fruit bodies emerge, such as in pure sawdust, nutrient allocation per fruit body is greater, leading to larger caps. This trade-off is consistent with the resource allocation theory proposed in fungal physiology (Chang et al., 2022). Moreover, nutritional imbalance in high-rice-husk substrates may limit the availability of essential elements such as nitrogen and phosphorus, thereby reducing tissue expansion during pileus development (Rahi et al., 2024).

The stipe diameter and height measurements also highlighted the influence of substrate composition on morphological traits. Although early harvests showed little variation across treatments, significant differences emerged in later flushes. Substrates with balanced proportions of sawdust and rice husk promoted thicker and sturdier stipes, while those with excessive rice husk content resulted in thinner and elongated stipes. This morphological plasticity is often linked to environmental stress during fruit body development. When substrates are nutrient-deficient or structurally compact, mushrooms tend to elongate stipes in an adaptive attempt to maximize spore dispersal efficiency (Sun et al., 2024). Such morphological responses may negatively affect market value, as consumers often prefer mushrooms with broad caps and short stipes.

The data on fresh weight yield reinforce the conclusion that substrate formulation is a determining factor for commercial productivity. Substrates with 15% rice husk consistently outperformed both the control (100% sawdust) and higher-rice-husk mixtures, suggesting that a small addition of rice husk improves biological efficiency. This improvement is likely related to increased aeration and moderate lignin content, which stimulate ligninolytic enzyme production, including laccase and manganese peroxidase, both essential for lignocellulose degradation (Gupta et al., 2022). However, at higher inclusion rates, inhibitory compounds from rice husk, such as phenolics and silica, may accumulate and reduce enzymatic efficiency, thus lowering yield (Oyetayo et al., 2023).

It is worth noting that the overall productivity observed in this study is within the global benchmark for oyster mushroom cultivation. Recent advances in substrate optimization across Asia and Africa have reported biological efficiencies ranging from 70% to 120% depending on the substrate type (Chukwuma et al., 2022; Yildiz et al., 2024). The values obtained here for yields in mixed sawdust–rice husk substrates fall within this range, underscoring the practical applicability of these results in real-world mushroom farming systems.

From a sustainability perspective, the use of rice husk as a partial substrate component is highly

desirable. Rice husk is an abundant byproduct of rice milling industries, particularly in Southeast Asia, where disposal often poses environmental challenges. Incorporating rice husk into mushroom cultivation not only reduces waste but also adds value to an otherwise underutilized residue (Nguyen et al., 2023). However, as shown in this study, careful proportioning is essential to harness the benefits without compromising mushroom yield and quality.

Another important aspect concerns the implications of substrate choice for the nutritional composition of oyster mushrooms. Although this study did not directly measure proximate or bioactive composition, literature suggests that substrate type influences protein, carbohydrate, and antioxidant content in oyster mushrooms (Bains et al., 2022; Rashidi et al., 2024). For example, mushrooms grown on rice-husk-enriched substrates tend to have slightly higher carbohydrate content due to the slower degradation of hemicellulose and cellulose, while protein levels are often higher in sawdust-dominant substrates. These nutritional shifts highlight the need for integrated evaluation of both yield and quality when selecting substrate formulations for commercial cultivation.

The broader ecological significance of substrate amendments should also be emphasized. The use of rice husk, in particular, may alter microbial dynamics within the substrate. Several studies have shown that microbial consortia interact synergistically with mushroom mycelia, influencing enzyme activity, substrate colonization, and resistance against pathogens (Chen et al., 2023). Excessive silica-rich husk may reduce microbial diversity and thereby limit synergistic benefits. Therefore, further research is warranted to explore the microbiome–substrate–fungus nexus, which could open new frontiers in sustainable mushroom farming.

In practical terms, the findings suggest that smallholder farmers should adopt substrate formulations that balance sawdust and rice husk, particularly around 15–30% husk inclusion, to optimize yield without compromising fruit body quality. Scaling up such practices can provide economic benefits while promoting circular agriculture. Furthermore, integrating rice husk into mushroom farming systems contributes to climate-smart agriculture by recycling carbon-rich residues into high-value food commodities.

Finally, this study underscores the importance of tailoring substrate formulations to local resource availability and environmental conditions. While rice husk proved effective at moderate proportions, other agro-residues such as corn cobs, sugarcane bagasse, or banana leaves may provide complementary or superior benefits depending on regional contexts (Ali et al., 2023). Future research should therefore expand to multi-residue substrate trials, combined with advanced analyses of enzyme kinetics, nutrient cycling, and

postharvest quality. Such holistic approaches will not only enhance mushroom productivity but also strengthen its role in sustainable food systems.

Conclusion

The study confirmed that the composition of cultivation substrates substantially influences the growth performance and yield of oyster mushrooms (*Pleurotus ostreatus*). While pure sawdust supported the fastest colonization and largest cap size, supplementation with moderate proportions of rice husk (15–30%) enhanced biological efficiency, fruiting body number, and fresh weight yield. However, excessive husk inclusion ($\geq 45\%$) suppressed growth and reduced productivity due to elevated silica content and structural constraints. These findings highlight the importance of optimizing substrate formulation to balance aeration, nutrient availability, and degradability. Beyond agronomic benefits, incorporating agricultural byproducts like rice husk provides a sustainable pathway to recycle waste, reduce environmental burdens, and support circular food production systems. Thus, adopting tailored substrate compositions offers both productivity gains for farmers and broader contributions to sustainable agriculture.

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