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Fruiting Characteristics of *Pleurotus ostreatus* Cultivated on Oil Palm Leaf, Empty Fruit Bunch and Frond-Based Substrates

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ABSTRACT

Oil palm residues offer potential co-substrates for oyster mushroom (*Pleurotus ostreatus*) cultivation. This study compared fruiting characteristics on three substrates containing 50% sawdust and 50% oil palm leaves (P1), empty fruit bunches (P2), or oil palm fronds (P3). A randomized block design comprising three treatments and eight blocks (24 baglogs) was used. The number of fruiting clumps, number of caps, and mean pileus diameter were evaluated by randomized-block ANOVA followed by Tukey's HSD test at the 5% level. The reported treatment means were highest for P3 (8.25 clumps, 10.50 caps, and 6.49 cm), intermediate for P1 (4.13 clumps, 7.50 caps, and 4.38 cm), and lowest for P2 (0.13 clumps, 0.38 caps, and 0.38 cm). The reported multiple-comparison groupings indicated differences among treatments for each variable ($P < 0.05$). These findings suggest that the frond–sawdust formulation supported better fruiting characteristics under the conditions evaluated. Differences in substrate structure and chemical composition may contribute to this pattern, but these properties were not measured. Further work should quantify fresh yield, biological efficiency, and substrate composition before drawing economic or mechanistic conclusions.

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INTRODUCTION

Oyster mushroom (valorization and reducing dependence on conventional wood-based substrates (Suwannarach et al., 2022). The global mushroom industry is dominated by several cultivated species, including Agaricus bisporus and Lentinula edodes, and *Pleurotus ostreatus* is one of the most widely cultivated edible mushrooms worldwide and is valued for its nutritional and functional properties, as well as its ability to grow on a wide range of lignocellulosic substrates

(Karmani et al., 2022). The species is particularly attractive for cultivation because agricultural and agro-industrial residues can be converted into edible fungal biomass, providing an alternative pathway for biomass *production. Pleurotus ostreatus* is particularly important, with Asia accounting for the largest share of global mushroom production (Doroški et al., 2022).

Conventionally, *P. ostreatus* is cultivated using lignocellulosic materials such as hardwood and rubberwood sawdust (Azman et al., 2023). However, the availability of conventional sawdust can become a constraint when wood-processing residues are limited or increasingly in demand by other industries (Fufa et al., 2021). Consequently, the use of locally available agricultural residues has received increasing attention as an alternative substrate strategy for oyster mushroom production (Orngu et al., 2021).

Among potential agricultural residues, oil palm biomass is particularly attractive in tropical oil palm-producing countries such as Indonesia and Malaysia. Oil palm cultivation and processing generate substantial quantities of biomass residues, including empty fruit bunches (EFB), oil palm fronds (OPF), oil palm trunks (OPT), mesocarp fiber, and palm kernel shells. In Indonesia, the quantity of oil palm biomass generated annually is substantial, and its accumulation presents both an environmental management challenge and an opportunity for biomass valorization (Azman et al., 2023). Earlier Research has also documented the potential of empty fruit bunches as a cultivation medium (De Mastro et al., 2023)

Oil palm fronds represent a particularly abundant biomass resource. Recent estimates indicate that approximately 156.5 million tonnes of oil palm fronds were generated in Indonesia in 2023, highlighting the considerable availability of this material for alternative biomass applications (Practical role of oil palm fronds, 2024). Oil palm residues contain structural carbohydrates, principally cellulose and hemicellulose, together with lignin, making them potential lignocellulosic feedstocks for biological conversion. Their utilization as mushroom substrates therefore offers a dual opportunity: reducing the accumulation of plantation and milling residues while replacing part of the conventional wood-based substrate used in mushroom production (Gebru et al., 2024).

Previous studies have evaluated oil palm residues as substrates for oyster mushroom cultivation, but the formulations and response variables have differed. (Aubrey et al., 2022) investigated empty fruit bunches (EFB), oil palm fronds, and oil palm trunks in substrate formulations and assessed agronomic performance and mushroom nutritional characteristics; their results showed that EFB could support cultivation under the conditions tested. (Dimawarnita et al., 2022) investigated EFB for oyster mushroom growth and biodelignification during cultivation. These studies demonstrate the potential of palm residues and indicate that performance depends on substrate preparation and formulation. Comparisons using alternative residues have likewise shown that substrate selection and preparation can influence cultivation outcomes (De Mastro et al., 2023).

The suitability of oil palm residues is also supported by studies examining the broader conversion of palm biomass into value-added products. (Suwannarach et al., 2022) proposed the utilization of oil palm biomass within a cascade recycling system**,** in which biomass residues can first be used for mushroom production and subsequently directed toward other applications such as animal feed and fertilizer production. This approach positions mushroom cultivation not merely as a waste-treatment technology but as a biological pathway for converting low-value biomass into food and other value-added products.

A specific comparison remains useful because the performance of different oil palm fractions cannot be inferred reliably from studies using different formulations, pretreatments, and cultivation conditions. In particular, a direct

comparison of leaves, EFB, and fronds blended with the same proportion of sawdust, using the same fruiting-characteristic endpoints, would help identify promising materials for subsequent substrate optimization. The present study focuses on fruiting clump number, cap number, and pileus diameter; it does not measure fresh yield, biological efficiency, substrate chemistry, or enzyme activity. Accordingly, the present analysis focuses on fruiting morphology rather than direct yield measurement, which other studies have reported separately (Orngu et al., 2021).

Accordingly, this study compared oil palm leaves, EFB, and fronds, each combined with sawdust at a 50:50 dry-weight ratio, under a common experimental design. Its contribution is a standardized comparison of three fruiting characteristics rather than a demonstration of the physicochemical mechanisms underlying the observed responses.

MATERIALS AND METHODS

Experimental site and fungal material

This experiment was conducted in a mushroom cultivation house located in Masaran District, Sragen Regency, Central Java, Indonesia. The facility was designed for oyster mushroom production, utilizing shaded conditions and natural ventilation to support mycelial growth and fruiting body formation. Throughout the cultivation period, temperature and relative humidity were maintained within established ranges: 24–30°C and 80–90%, respectively.

Substrate preparation

Three types of oil palm residues, namely oil palm leaves, empty fruit bunches (EFB), and oil palm fronds, were used as the main substrate components. The materials were collected, cleaned to remove visible impurities, chopped into approximately 2–3 cm pieces, and sun-dried for 2–3 days to reduce their moisture content before substrate preparation. The dried materials were mixed with sawdust at a ratio of 1:1, resulting in three substrate treatments: P1 (50% oil palm leaves + 50% sawdust), P2 (50% empty fruit bunches + 50% sawdust), and P3 (50% oil palm fronds + 50% sawdust). Each substrate formulation was supplemented with rice bran at 10% and agricultural lime ($CaCO_3$) at 2–3%, calculated based on the dry weight of the main substrate mixture. The ingredients were mixed thoroughly to obtain a homogeneous substrate. Water was gradually added to achieve a target moisture content of approximately 60–65%. The prepared substrates were packed into heat-resistant polypropylene bags (*baglogs*), each containing approximately 1,000 g of moist substrate. Each baglog was compacted to a consistent density and closed using a plastic neck and cotton plug. The baglogs were sterilized using steam sterilization at 100 °C for 8 hours. After sterilization, the substrates were allowed to cool to room temperature before inoculation with *Pleurotus ostreatus* spawn under hygienic conditions. All three substrate treatments were subjected to the same preparation, moisture adjustment, bagging, sterilization, cooling, and inoculation procedures to minimize variation arising from substrate processing. No direct chemical characterization of the substrate mixtures, including carbon-to-nitrogen ratio, cellulose, hemicellulose, or lignin content, was conducted in this study. Consequently, potential differences in substrate chemical composition were discussed based on previously published literature rather than interpreted as direct experimental measurements.

Experimental design

The experiment was arranged using a randomized complete block design (RCBD) comprising three substrate treatments and eight spatial blocks within the mushroom cultivation house. A total of 120 baglogs were cultivated, with 40 per treatment. Each block contained 15 baglogs, with five baglogs representing each treatment. Within each block, the baglogs were randomly assigned to cultivation positions. Subsequently, one baglog from each treatment was randomly selected for observation, resulting

in 24 observational samples (eight baglogs per treatment). Each selected baglog served as one observational replicate. The number of fruiting clumps, number of pilei, and pileus diameter were recorded for the selected baglogs. Multiple measurements obtained from the same baglog were summarized at the baglog level to avoid pseudoreplication. Substrate preparation procedures were standardized across treatments to minimize technical variability. The number and allocation of independent substrate preparation batches were considered when interpreting potential batch effects.

Observed variables

Three fruiting characteristics were recorded per baglog: (1) number of fruiting clumps, defined as distinct clusters; (2) number of caps, defined as individual pilei; and (3) pileus diameter (cm), measured for mature caps at harvest. Fresh mushroom weight and biological efficiency were not reported and therefore are not treated as outcomes of this study. Three fruiting body characteristics were evaluated: the number of fruiting clumps, the number of pilei (caps), and pileus diameter (cm). All observations were conducted on the selected experimental baglogs. Mushroom development was monitored daily, and harvesting was performed when the fruiting bodies reached commercial maturity, as indicated by fully developed caps with margins beginning to flatten. Harvesting was carried out whenever mature fruiting bodies were available during the observation period. The number of harvests and the duration of the harvesting period were recorded for each baglog. The number of fruiting clumps was determined by counting the distinct clusters of fruiting bodies produced by each baglog.

In contrast, the number of pilei was determined by counting individual mushroom caps. Pileus diameter was measured using a digital caliper across the widest horizontal portion of each mature cap at harvest. For baglogs producing multiple caps, the arithmetic mean diameter was calculated from all measured caps across the recorded harvests, resulting in one mean pileus diameter value per sampled baglog. For baglogs that did not produce any fruiting bodies, the number of fruiting clumps and pilei was recorded as zero. However, the pileus diameter was recorded as missing (NA) because no measurable cap was present. These baglogs were excluded from the descriptive and statistical analysis of pileus diameter but remained included in the analyses of fruiting clump and pileus counts. This procedure ensured that pileus diameter represented the actual size of developed fruiting bodies, while the absence of fruiting was assessed separately through the count variables.

Statistical analysis

The original analysis used ANOVA for a randomized block design and Tukey's honestly significant difference procedure at $\alpha = 0.05$. The experimental unit was the baglog. The reported mean-separation letters are retained as supplied.

RESULTS AND DISCUSSION

The reported Tukey HSD groupings distinguish P3, P1, and P2 across the three fruiting characteristics (Table 2; Figures 1–3). The observed ordering was P3 > P1 > P2. Exact ANOVA test statistics were not included in the source manuscript and must be supplied from the original statistical output before submission.

Table 1. Effect of oil palm waste-based substrates on the number of fruiting clumps, number of pileus, and pileus diameter of *Pleurotus ostreatus*

Substrate treatment	Number of fruiting clumps	Number of pileus (caps)	Pileus diameter (cm)
P1 – Oil palm leaves 50% + sawdust 50%	4.13 b	7.50 b	4.38 b
P2 – Empty fruit bunches 50% + sawdust 50%	0.13 c	0.38 c	0.38 c
P3 – Oil palm fronds 50% + sawdust 50%	8.25 a	10.50 a	6.49 a

Note: Values are treatment means. Means followed by different letters (a, b, c) within a column differ significantly according to Tukey's test at the 5% level (P < 0.05).

Number of fruiting clumps

The mean number of fruiting clumps was 8.25 for P3, 4.13 for P1, and 0.13 for P2 (Figure 1). The reported Tukey groupings assigned a different letter to each treatment (P < 0.05). The low mean for P2 indicates that few clumps developed under this formulation.

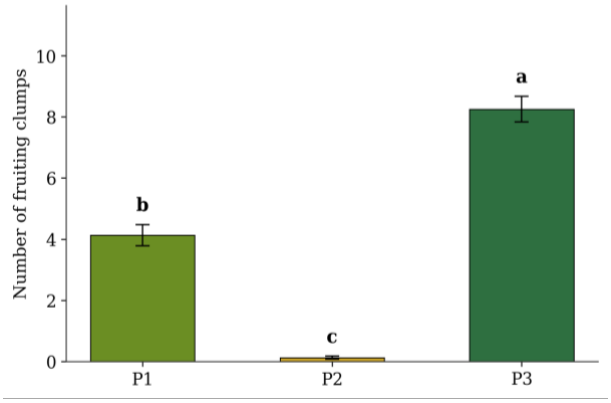


Figure 1. Number of fruiting clumps of *P. ostreatus* as affected by oil palm waste-based substrates. *Different letters above bars indicate significant differences among treatments (Tukey's test, P < 0.05).*

Number of pileus (caps)

The mean number of caps was 10.50 for P3, 7.50 for P1, and 0.38 for P2 (Figure 2). According to the Tukey groupings reported, all three treatments differed (P < 0.05). This pattern is consistent with the differences observed in the number of fruiting clumps.

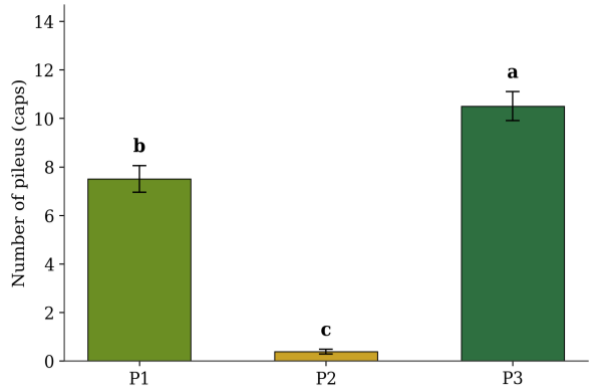


Figure 2. Number of pileus (fruit body caps) of *P. ostreatus* as affected by oil palm waste-based substrates. *Different letters above bars indicate significant differences among treatments (Tukey's test, P < 0.05).*

Pileus diameter

Mean pileus diameter was 6.49 cm for P3, 4.38 cm for P1, and 0.38 cm for P2 (Figure 3). The reported Tukey groupings distinguished all treatments (P < 0.05). Because very few caps developed in P2, the calculation and interpretation of its diameter mean require clarification, particularly for baglogs without fruiting bodies.

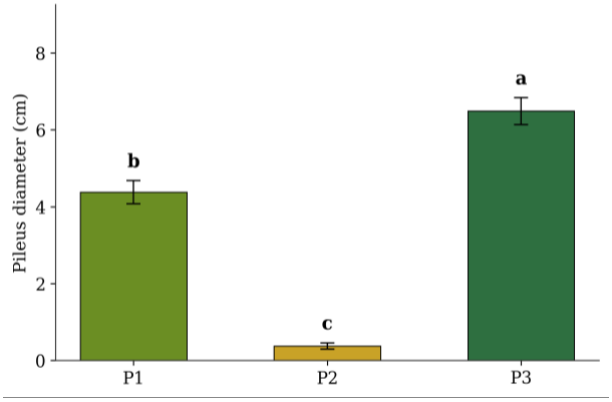


Figure 3. Pileus diameter of *P. ostreatus* as affected by oil palm waste-based substrates. *Different letters above bars indicate significant differences among treatments (Tukey's test, P < 0.05). Error bars represent standard deviation.*

The consistent ranking of treatments across the three measured variables indicates a similar response pattern among the evaluated fruiting characteristics. These data do not independently establish the underlying substrate mechanisms or quantify fresh mushroom yield.

The three substrate formulations produced different reported fruiting responses, with the frond–sawdust mixture (P3) performing best for clump number, cap number, and pileus diameter. Potential explanations involving substrate physical structure, nutrient balance, and fungal lignocellulose degradation are discussed below as hypotheses informed by published

ResearchResearch, rather than as properties directly measured in this experiment.

Possible effects of substrate physical characteristics

Particle structure, water retention, and air exchange can influence the performance of lignocellulosic mushroom substrates (Suwannarach et al., 2022). Differences in the tissue structure of oil palm leaves, EFB, and fronds may therefore have contributed to the observed ranking. However, porosity, bulk density, particle-size distribution, and water-holding capacity were not measured here. The comparatively low fruiting response of P2 should not be attributed specifically to compaction or retained processing residues without direct measurements. Differences in EFB preparation between studies offer a further plausible explanation (Dimawarnita et al., 2022). Recent cultivation studies further emphasize that substrate composition and particle characteristics can affect mushroom development. (PEDROSO et al., 2025) compared coarse and fine sawdust and observed differences in growth and fruiting outcomes, while (Gebru et al., 2024) documented substrate-dependent performance on agricultural residues. These findings provide comparative context but do not establish the unmeasured physical properties of P1, P2, or P3.

Possible roles of nutrient balance and lignocellulose composition

The carbon-to-nitrogen ratio and the relative abundance and accessibility of lignocellulosic fractions are relevant to Pleurotus cultivation (Hoa et al., 2015). Leaves, EFB, and fronds may differ in these properties, potentially affecting nutrient availability during fruiting. Nevertheless, this study did not determine the concentrations of carbon, nitrogen, cellulose, hemicellulose, or lignin. Consequently, neither a more favorable C/N ratio in P3 nor an unfavorable ratio in P2 can be confirmed from these results. Chemical profiling of the prepared mixtures would be needed to test these explanations. (Silva et al., 2025) assessed both mushroom productivity and substrate biodegradation in mixtures of sugarcane bagasse and banana leaves. Their approach illustrates how direct measurements of degradation can help evaluate mechanistic explanations; such measurements were not undertaken in the present study.

Potential contribution of fungal lignocellulose degradation

More recently, Ramdhoani et al., 2025 investigated oil palm fruit-bunch substrate formulations for *P. ostreatus*. Alongside studies of other residues, this reinforces the need to compare preparation methods and substrate proportions before generalizing from the poor P2 response observed here. *Pleurotus ostreatus* can degrade lignocellulosic substrates through extracellular oxidative and hydrolytic enzymes, a process relevant to the conversion of agricultural residues into fungal biomass (Suwannarach et al., 2022). Variation in lignocellulose accessibility could therefore be associated with the differences observed among treatments. However, this experiment did not measure mycelial colonization rates, lignin loss, or the activities of laccase, manganese peroxidase, or lignin peroxidase (Melanouri et al., 2022). Consequently, the present results cannot establish faster colonization or more efficient enzymatic delignification in P3 (Andlar et al., 2018). (Pedroso et al., 2025) explicitly evaluated economic returns alongside production traits, whereas Miśkiewicz et al. (2025) examined biological efficiency and potential applications for spent substrate. These endpoints were not measured here; future work would need to measure them to evaluate commercial viability and circular-economy benefits.

Comparison with related lignocellulosic substrate studies

The present ranking favors fronds over leaves and EFB in a 50:50 mixture with sawdust. This result should be interpreted alongside Aubrey et al. (2022), who reported successful cultivation on

EFB-based formulations, and Dimawarnita et al. (2022), who investigated EFB utilization and biodelignification. The difference between those findings and the low-fruiting response of P2 here highlights the potential importance of processing, supplementation, cultivation conditions, and substrate formulation. Because the studies do not necessarily share the same pretreatment and response measurements, their outcomes should not be treated as direct contradictions. Desisa et al. (2024) and Megersa & Tolessa (2024) reported that combinations of agro-industrial residues and supplements affected mushroom cultivation outcomes. Because their substrates and measurements differed from those used here, these studies provide contextual comparisons rather than direct tests of oil palm frond superiority.

Practical and agribusiness implications

For further cultivation trials, oil palm fronds appear to be a promising co-substrate for sawdust when the objective is to improve the three measured fruiting characteristics. However, economic benefits, reduced production costs, and total marketable yield were not assessed. Before recommending commercial adoption, further studies should evaluate fresh mass, biological efficiency, contamination rates, substrate preparation costs, and reproducibility across cultivation cycles. Recent studies also measured harvested fresh mass and biological efficiency alongside fruiting traits (Sathiyaseelan et al., 2024), illustrating the additional measurements needed before the present observations can be translated into claims about commercial yield.

CONCLUSIONS

This study demonstrated that oil palm waste-based substrate formulations were associated with significant differences in the fruiting characteristics of Pleurotus ostreatus under the experimental conditions. Among the three evaluated formulations, the substrate containing 50% oil palm fronds and 50% sawdust (P3) exhibited the highest mean number of fruiting clumps (8.25), number of pilei (10.50), and pileus diameter (6.49 cm). The substrate containing 50% oil palm leaves and 50% sawdust (P1) showed intermediate values, whereas the formulation containing 50% empty fruit bunches and 50% sawdust (P2) exhibited the lowest values across the evaluated characteristics. These findings indicate that the oil palm frond–sawdust formulation was the most promising among the three tested substrates for supporting fruiting body formation under the conditions of this study. However, the underlying mechanisms responsible for the observed differences remain to be established, as the physicochemical properties of the substrate, mycelial colonization rates, and ligninolytic enzyme activities were not directly measured. Further ResearchResearch should incorporate substrate characterization, mycelial growth assessment, fresh mushroom weight, and biological efficiency to clarify the mechanisms involved and evaluate the practical productivity of these substrate formulations.

REFERENCE

Andlar, M., Rezić, T., Marđetko, N., Kracher, D., Ludwig, R., & Šantek, B. (2018). Lignocellulose degradation: An overview of fungi and fungal enzymes involved in lignocellulose degradation. In *Engineering in Life Sciences* (Vol. 18, Number 11, pp. 768–778). Wiley-VCH Verlag. https://doi.org/10.1002/elsc.201800039

Aubrey, M. L. L., Chin, C. F. S., Seelan, J. S. S., Chye, F. Y., Lee, H. H., & Rakib, M. R. M. (2022). Conversion of Oil Palm By-Products into Value-Added Products through Oyster Mushroom (Pleurotus ostreatus) Cultivation. *Horticulturae*, 8(11). https://doi.org/10.3390/horticulturae8111040

Azman, N. F., Katahira, T., Nakanishi, Y., Chisyaki, N., Uemura, S., Yamada, M., Takayama, K., Oshima, I., Yamaguchi, T., Hara, H., & Yamauchi, M. (2023). Sustainable oil palm biomass waste utilization in Southeast Asia: Cascade recycling for mushroom growing, animal feedstock production, and composting animal excrement as fertilizer.

Cleaner and Circular Bioeconomy, 6. https://doi.org/10.1016/j.clcb.2023.100058

De Mastro, F., Traversa, A., Matarrese, F., Cocozza, C., & Brunetti, G. (2023). Influence of Growing Substrate Preparation on the Biological Efficiency of Pleurotus ostreatus. *Horticulturae*, 9(4). https://doi.org/10.3390/horticulturae9040439

Desisa, B., Muleta, D., Dejene, T., Jida, M., Goshu, A., Negi, T., & Martin-Pinto, P. (2024). Utilization of local agro-industrial by-products-based substrates to enhance production and dietary value of mushroom (*P. ostreatus*) in Ethiopia. *World Journal of Microbiology and Biotechnology*, 40(9). https://doi.org/10.1007/s11274-024-04062-3

Dimawarnita, F., Perwitasari, U., Marsudi, S., Faramitha, Y., & Suharyanto. (2022). The Utilization of Oil Palm Empty Fruit Bunches for Growth of Oyster Mushroom (Pleurotus ostreatus) and Biodelignification Process During Planting Cycle. *Agrivita*, 44(1), 165–177. https://doi.org/10.17503/agrivita.v44i1.2311

Doroški, A., Klaus, A., Režek Jambrak, A., & Djekic, I. (2022). Food Waste Originated Material as an Alternative Substrate Used for the Cultivation of Oyster Mushroom (Pleurotus ostreatus): A Review. In *Sustainability (Switzerland)* (Vol. 14, Number 19). MDPI. https://doi.org/10.3390/su141912509

Fufa, B. K., Tadesse, B. A., & Tulu, M. M. (2021). Cultivation of Pleurotus ostreatus on Agricultural Wastes and Their Combination. *International Journal of Agronomy*, 2021. https://doi.org/10.1155/2021/1465597

Gebru, H., Belete, T., & Faye, G. (2024). Growth and Yield Performance of Pleurotus ostreatus Cultivated on Agricultural Residues. *Mycobiology*, 52(6), 388–397. https://doi.org/10.1080/12298093.2024.2399353

Hoa, H. T., Wang, C. L., & Wang, C. H. (2015). The effects of different substrates on the growth, yield, and nutritional composition of two oyster mushrooms (Pleurotus ostreatus and Pleurotus cystidiosus). *Mycobiology*, 43(4), 423–434. https://doi.org/10.5941/MYCO.2015.43.4.423

Karmani, M., Subramaniam, G., Sivasamugham, L. A., Cheng, W. H., & Wong, L. S. (2022). Effects of Different Substrates on the Growth and Nutritional Composition of Pleurotus ostreatus: A Review. *Journal of Experimental Biology and Agricultural Sciences*, 10(3), 481–486. https://doi.org/10.18006/2022.10(3).481.486

Megersa, S., & Tolessa, A. (2024). Enhancing yields of Pleurotus ostreatus and Lentinula edodes mushrooms using water hyacinth (Eichhornia crassipes [Mart.] Solms) supplemented with locally available feedstock as substrate. *Heliyon*, 10(20). https://doi.org/10.1016/j.heliyon.2024.e39113

Melanouri, E. M., Dedousi, M., & Diamantopoulou, P. (2022). Cultivating Pleurotus ostreatus and Pleurotus eryngii mushroom strains on agro-industrial residues in solid-state fermentation. Part I: Screening for growth, endoglucanase, laccase, and biomass production in the colonization phase. *Carbon Resources Conversion*, 5(1), 61–70. https://doi.org/10.1016/j.crcon.2021.12.004

Okoko. (2025). Creative Commons Attribution 4.0 License. Journal of Research in Forestry. In *JOURNAL OF RESEARCH IN FORESTRY, WILDLIFE AND ENVIRONMENT* (Vol. 17, Number 2). http://www.ajol.info/index.php/jrfwe

Orngu, O. A., Mbaeyi-Nwaoha, I. E., Unagwu, B. O., & Etim, V. E. (2021). Oyster Mushroom (Pleurotus ostreatus) Cultivation Using Sawdust and Different Organic Manures. *Asian Food Science Journal*, 67–74. https://doi.org/10.9734/afsj/2021/v20i530299

Pedroso, M. L., Alagos, A. L. C., Esgrina, F. Jr. O., Habibun, J. F., Maun, J. N., & Rodriguez, R. M. M. (2025). Maximizing Pleurotus ostreatus yield with sustainable agricultural waste substrates in Arakan, Cotabato, Philippines. *Nusantara Bioscience*, 17(1). https://doi.org/10.13057/nusbiosci/n170107

Ramdhoani, Luh Putu Yuni Widyastuti, & Ni Putu Eka Pratiwi. (2025). Pertumbuhan dan Hasil Produksi Jamur Tiram Putih (Pleorotus ostreatus) pada Variasi Media Tumbuh yang Diperkaya Limbah Organik. *Jurnal Hortikultura Indonesia*, 16(1), 24–31. https://doi.org/10.29244/jhi.16.1.24-31

Sathiyaseelan, M., Kannadhasan, V., Tamilpriyan, S., Balaji, K., & Saranya, V. (2024). Cultivation potential of oyster mushroom (Pleurotus ostreatus) using agricultural wastes as substrates. *Indian Journal of Horticulture*, 81(2), 196–199. https://doi.org/10.58993/ijh/2024.81.2.12

Silva, S. A. da, Zárate-Salazar, J. R., Monteiro, R. E. P., Medeiros, R. L. de, Souza, H. A. N. de, de Oliveira Dias, B., & Pereira, F. de O. (2025). Assessment of the productive and biodegradative non-enzymatic performance of Pleurotus mushrooms grown on agricultural wastes of sugarcane bagasse and banana leaves. *World Journal of Microbiology and Biotechnology*, 41(5). https://doi.org/10.1007/s11274-025-04373-z

Suwannarach, N., Kumla, J., Zhao, Y., & Kakumyan, P. (2022). Impact of Cultivation Substrate and Microbial Community on Improving Mushroom Productivity: A Review. In *Biology* (Vol. 11, Number 4). MDPI. https://doi.org/10.3390/biology11040569