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Maximizing *Pleurotus ostreatus* yield with sustainable agricultural waste substrates in Arakan, Cotabato, Philippines

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Abstract. *Pedroso ML, Alagos ALC, Esgrina FJO, Habibun JF, Maun JN, Rodriguez RMM. 2025. Maximizing* Pleurotus ostreatus *yield with sustainable agricultural waste substrates in Arakan, Cotabato, Philippines. Nusantara Bioscience 17: 57-67.* Mushroom production supports a circular economy by transforming agricultural waste into valuable food resources while enhancing local agricultural economies. This study evaluates the potential of locally available agricultural waste substrates-chopped rice straw, aged rice hull, rough sawdust, and fine sawdust-for optimizing the production of oyster mushrooms (*Pleurotus ostreatus* (Jacq.) P.Kumm. in Arakan, Cotabato, Philippines. The effects of these substrates on key growth parameters, including mycelial growth, fruiting time, yield, and economic returns, were assessed. A Completely Randomized Design with five replicates per treatment was employed, using a substrate mixture of 89% agricultural waste, 10% molasses, and 1% lime. Statistical analysis revealed that fine sawdust facilitated faster mycelial growth and reduced fruiting time, whereas rough sawdust produced higher yields and larger mushrooms. Economic analysis indicated that rough sawdust yielded the highest return on investment at 190.21%, making it the most cost-effective substrate. These findings demonstrate the potential of agricultural waste as a sustainable substrate for oyster mushroom cultivation, promoting environmental sustainability and profitability for small-scale farmers. The study emphasizes the critical role of substrate selection in optimizing mushroom yield and provides practical insights for commercial mushroom production.

Keywords: Bioefficiency, mushroom substrate, oyster mushroom, sawdust, sustainable farming

INTRODUCTION

Mushrooms constitute a diverse group of fungi valued for their nutritional, medicinal, and ecological benefits. They are an important source of nutrition, particularly in regions facing food security challenges, due to their high protein content, low-fat levels, and bioactive compounds with health-promoting properties (Valverde et al. 2015; Hyde et al. 2019; Ślusarczyk et al. 2021). Among cultivated species, *Pleurotus ostreatus* (Jacq.) P.Kumm. (oyster mushroom) is particularly sought after for its rapid growth, adaptability to various organic waste substrates, and potential as a cost-effective protein alternative to meat (Khan et al. 2024; Pashaei et al. 2024). Additionally, oyster mushroom farming supports sustainable agriculture by utilizing agricultural waste, contributing to environmental conservation efforts (Akter et al. 2022; Aditya et al. 2024).

Despite these advantages, oyster mushrooms are highly perishable and require immediate consumption or preservation to maintain quality (Castellanos-Reyes et al. 2021; Dawadi et al. 2022). This perishability has driven efforts to enhance production efficiency, particularly for *P. ostreatus*, which thrives on low-cost agricultural waste such as rice straw, sawdust, and other organic by-products (Chauhan et al. 2024). The rapid colonization of substrates and minimal maintenance requirements make oyster mushrooms an attractive option for smallholder farmers seeking an additional income source while reducing waste (Dung et al. 2012; Jayaraman et al. 2024).

In the Philippines, oyster mushroom cultivation has gained prominence due to the country's favorable climate and abundant agricultural waste, which serve as suitable substrates (Chang et al. 2014; Alvarez and Bautista 2021). Converting agricultural waste into valuable food resources not only increases farmers' incomes but also reduces waste, contributing to environmental sustainability (Hoa et al. 2018; Riseh et al. 2024).

A critical factor influencing mushroom production is substrate selection. Substrate composition affects mycelial growth, fruiting, and overall yield. Various organic materials, including rice straw, sawdust, and sugarcane bagasse, have been evaluated for oyster mushroom cultivation, as they influence the carbon-to-nitrogen ratio, moisture retention, and aeration necessary for optimal growth (Hossain et al. 2005; Nithyatharani and Kavitha 2018; Bebarta et al. 2022). However, limited research has examined the comparative efficiency of locally available substrates under the specific environmental conditions of Arakan, Cotabato, Philippines. Arakan experiences warm temperatures year-round, ranging from 25 to 32°C (77 to 90°F), which exceeds the optimal fruiting range of 18 to 24°C for *P. ostreatus*. Consequently, this study implemented temperature regulation through shading and misting to optimize yields.

This study aims to evaluate the effects of four agricultural waste substrates- chopped rice straw, aged rice hull, rough sawdust, and fine sawdust on the growth and yield of *P. ostreatus* in Arakan, Cotabato, Philippines. Consistent with previous studies (Sanjel et al. 2021; Soriano and Mangune 2022; Latif et al. 2023), a controlled and uniform amount of molasses and lime was incorporated into the substrates. Molasses provides organic sugars essential for mycelial growth (Afify et al. 2012; Sughra et al. 2013) and enhances fungal colonization by supplying carbohydrates (Mangwanda et al. 2023), thereby improving substrate utilization efficiency. Lime was added primarily to increase the pH of the substrates, creating an alkaline environment that inhibits pathogenic growth while fostering optimal conditions for oyster mushrooms (Khan et al. 2013; Taylor et al. 2016).

The study assessed key growth parameters, including mycelial growth, fruiting time, and overall yield, to determine the most effective substrate for optimizing mushroom production in the region. Given that these substrates are locally available and often discarded, their utilization offers a cost-effective and sustainable solution for mushroom cultivation. Additionally, a financial analysis was conducted to calculate the Return On Investment (ROI) for each substrate, providing farmers and agribusinesses with valuable insights on maximizing profitability while promoting sustainable farming practices.

The findings contribute to the growing body of research on sustainable agriculture and mushroom cultivation, particularly within the Philippine agricultural context. Unlike broader studies that examine generic substrates, this research specifically investigates locally available agricultural waste in Arakan, Cotabato, offering region-specific recommendations for enhancing oyster mushroom production. The comparative analysis of rough and fine sawdust, combined with a financial ROI evaluation, provides new insights into optimizing yield and profitability. By refining substrate selection, this study aims to improve yields, promote environmentally responsible practices, and enhance the economic sustainability of mushroom farming. Furthermore, this approach aligns with the principles of a circular economy by reducing waste and repurposing agricultural by-products. In support of the United Nations Sustainable Development Goals (SDGs), this study contributes to SDG 12 (Responsible Consumption and Production) by promoting agricultural waste utilization, SDG 13 (Climate Action) by advocating sustainable farming practices, and SDG 8 (Decent Work and Economic Growth) by improving the economic prospects of smallholder farmers. Additionally, this study contributes to Sustainable Development Goal 2 (Zero Hunger) by enhancing food security through sustainable and locally-sourced protein production.

MATERIALS AND METHODS

Study area

This study was conducted in a controlled mushroom production facility at the College of Agriculture, Agribusiness, Forestry, and Food Sciences, Cotabato Foundation College of Science and Technology (CFCST), located in Doroluman, Arakan, Cotabato, Philippines (7°20,48”N, 125°05’38”E, 482.3 masl) (Figure 1). The mushroom house measured 5×10 m, with a designated growing area of 4×8 m, accommodating 500 fruiting bags arranged following a Completely Randomized Design (CRD). The effects of four agricultural waste substrates-chopped rice straw (T1, control), aged rice hull (T2), rough sawdust (T3), and fine sawdust (T4)-were evaluated, with each treatment replicated five times.

Experimental design

A Completely Randomized Design (CRD) was implemented to minimize bias and ensure statistical reliability. Each of the four substrate treatments was tested with five replications to account for variability and enhance result reproducibility.

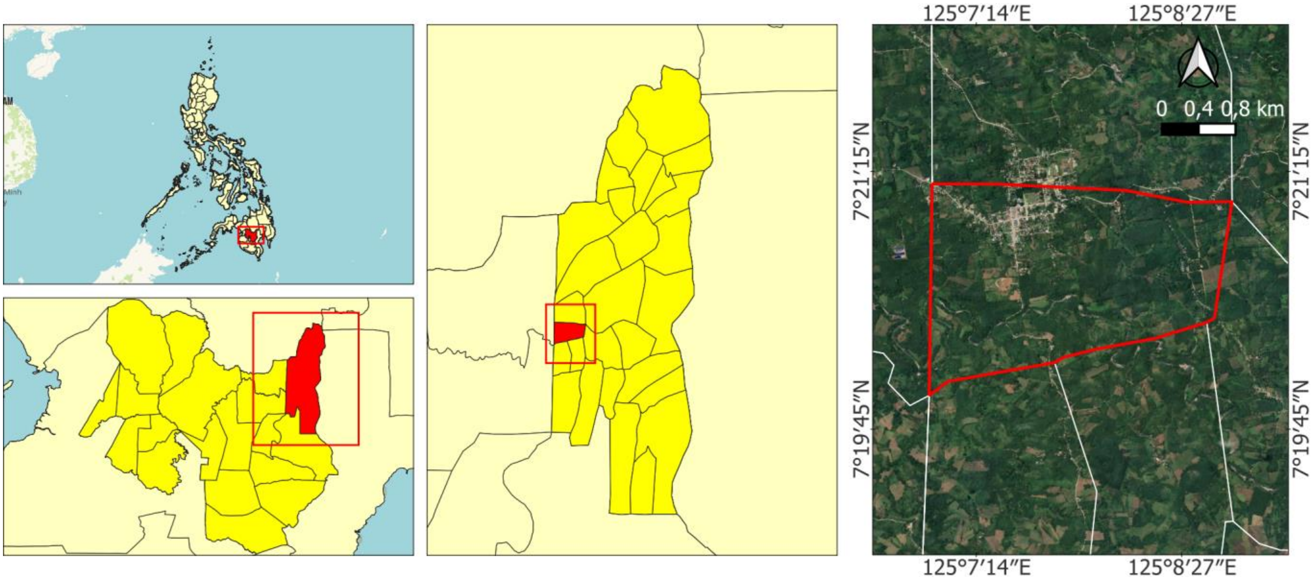

Figure 1. The location map of the experimental area at Doroluman, Arakan, North Cotabato, Philippines

Climatic conditions and cultivation

Oyster mushroom cultivation was conducted in a climate-controlled environment, where temperature, humidity, and irrigation were systematically regulated. The temperature ranged from 22 to 26°C, while relative humidity was maintained at 85-90% throughout the incubation and fruiting stages. Watering was performed twice daily to sustain optimal substrate moisture levels, ensuring successful mycelial growth and fruiting body development.

Procedures

Substrate preparation

Each 500 g fruiting bag was filled with a substrate mixture comprising 89% agricultural waste material (based on treatment), 10% molasses, and 1% lime (Figure 2.A). Molasses served as an organic sugar source, enhancing oyster mushroom colonization and substrate utilization efficiency. Lime increased substrate alkalinity, creating favorable conditions for oyster growth while inhibiting harmful pathogens. The substrates were dried to approximately 65% moisture content at 60-70°C to optimize water retention for fungal colonization. After drying, substrates underwent pasteurization and sterilization in an autoclave (121°C, 1 hour, 1.5 kg/cm² pressure) to eliminate microorganisms. Pasteurization aims to reduce the microbial load, while sterilization through autoclaving ensures the total elimination of microorganisms in the material.

Table 1 presents nutrient analyses on various substrates used for oyster mushroom cultivation, highlighting their suitability based on nutrient composition. Rice straw contains moderate amounts of nitrogen, phosphorus, and potassium, along with high silicon, which supports mycelial growth and fruiting. However, its low nitrogen content may require supplementation with nitrogen-rich materials to enhance growth. Rice husks, rich in carbohydrates and fiber, provide a good energy source for the mycelium, but their low crude protein and nitrogen make them less ideal unless supplemented. Tree sawdust, although not fully detailed in terms of nutrient composition, typically requires nitrogen supplementation to optimize growth due to its high lignin and cellulose content.

Sawdust of mahogany wood (*Swietenia macrophylla* G.King) offers high dry matter and energy content, but its low nitrogen means it also needs supplementation for healthy fungal growth. The crude fiber and nitrogen-free extract provide energy, while its mineral content is modest. Tamarind (*Tamarindus indica* L.), with high fiber but lower protein and nitrogen-free extract, is more suited for energy provision than protein, requiring nitrogen supplementation for improved growth efficiency. Sawdust of mango wood (*Mangifera indica* L.), offering higher crude protein and nitrogen-free extract, is a better substrate than tamarind for faster mycelial growth with less nitrogen supplementation. It also contains substantial fiber.

Therefore, substrates like rice straw and sawdust are energy-rich but low in nitrogen, requiring supplementation for optimal oyster mushroom growth. On the other hand, substrates like mango and tamarind have better nitrogen content, reducing the need for additional additives. Table 2 emphasizes the importance of nutrient balance and supplementation to achieve high yields in oyster mushroom cultivation. Thus, adding a uniform amount of molasses to different substrates would provide initial energy, helping substrates like rice husks and sawdust that are low in nitrogen. In comparison, an equal amount of lime would improve the pH balance of these different substrates, supporting healthier mycelial growth. Together, these additives can enhance the quality of the substrates, leading to more efficient colonization, higher yields, and better fruiting in oyster mushroom cultivation.

Grain spawn acquisition

The grain spawn for oyster mushrooms was obtained from the Department of Agriculture Regional Office XII, Balindog Research and Experiment Station in Kidapawan City, Cotabato. This government agency is known for producing high-quality oyster mushroom grain spawn, which is distributed to growers and farmers across surrounding municipalities and provinces in South-Central Mindanao, Philippines.

Inoculation

Following sterilization, fruiting bags were cooled for 48 hours (Figure 2.B). During this period, all inoculation tools (e.g., forceps, scalpels, trays) were sterilized using alcohol or flame treatment. Oyster mushroom grain spawn (20-30 grains per bag) was inoculated (Figure 2.C) using sterile forceps. The inoculated bags were sealed and transferred to a controlled incubation chamber, where temperature, humidity, and airflow were monitored to optimize mycelial growth.

Incubation and fruiting

The incubation period lasted 30-45 days (Figure 2.D). Bags were inspected regularly for contamination, discoloration, or stunted growth, while environmental conditions were carefully regulated. Once full mycelial colonization was observed, fruiting was initiated by adjusting humidity levels and spraying bags two to three times daily to maintain optimal moisture (Figure 2.E). Mushrooms were harvested daily by gently twisting and pulling the fruiting bodies without damaging the remaining mycelium. Early blooms were removed to prevent obstruction to developing fruiting bodies (Figure 2.F).

Preparation for marketing

Post-harvest, mushrooms were packaged into 100 g portions and sold in the open market at 35.00 Philippine Pesos per pack or three packs for 100.00 Philippine Pesos as part of a promotional pricing strategy.

Data collection

Key growth parameters were recorded throughout the harvesting period, with data collected from ten randomly selected samples per treatment for systematic tabulation and analysis.

Table 1. Nutrient analyses of the different substrates used for the production of oyster mushroom

Substrate type	Nutritional components	References
Rice straw	N (0.65%); P_2O_5 (0.225%); K_2O (1.68%); Ca (0.3%); Mg (0.2%); S (0.075%); Si (5.5%); Zn (0.003%); Fe (0.035%); Mn (0.045%); Cu (0.003%); Bo (0.001%)	Dobermann and Fairhurst (2000)
Rice hull/rice husk	carbohydrate (37.04%); crude protein (1.85%); moisture (7.93%); crude fat (3.76%); fiber (25.74%); ash content (23.39%); Ca (0.002949%); Mg (0.001932%); K (0.004828%); Na (0.000281%); Zn (0.000613%); Fe (0.001401%); Se (0.000125%); Co (0.000185%); Mn (0.001154%); Cu (0.000985%); P (0.000402%)	Nnadiukwu et al. (2023)
Tree sawdust		Hossain et al. (2012)
Swietenia macrophylla G.King	DM (95%); ME (1611.7 kcal/kg); CP (2.5%); CF (46%); NFE (44.6%); EE (1.2%); TA (0.7%)	*DM-Dry Matter *ME-Metabolized Energy
Tamarindus indica L.	DM (92.4%); ME (615 kcal/kg); CP (2.4%); CF (66%); NFE (15.8%); EE (0.6%); TA (7.6%)	*CP-Crude Protein *CF-Crude Fiber *NFE-Nitrogen Free Extract
Mangifera indica L.	DM (93%); ME (967.5 kcal/kg); CP (3.5%); CF (63%); NFE (24.5%); EE (1.0%); TA (1.0%)	*EE-Ether Extract *TA-Total Ask

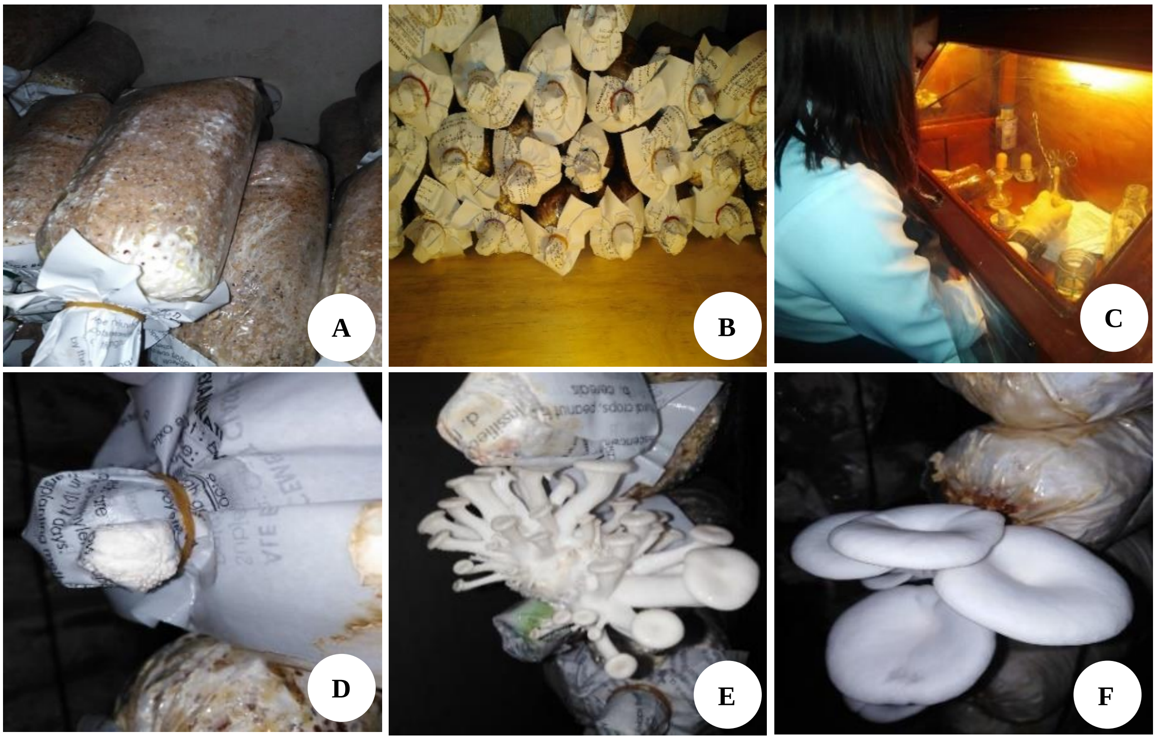

Figure 2. Overview of the substrate preparation, inoculation, and incubation process. A. Mixing of substrates; B. Inoculation of bags; C. Incubation phase; D. E. F. Fruiting initiation

Data analysis

Statistical analysis

Data were analyzed using the Statistical Tool for Agricultural Research (STAR-2.0.1) within a Completely Randomized Design (CRD) framework. The effects of different agricultural waste substrates on oyster mushroom yield and growth characteristics were assessed for statistical significance. A post hoc Least Significant Difference (LSD) test was performed to identify significant treatment differences.

Economic analysis

Next, to evaluate the financial viability of each substrate, the study calculated the Return on Investment (ROI) using the following formula:

$$\text{Return on Investment (ROI)} = \frac{\text{Net Income} \times 100}{\text{Production Cost}}$$

Where: Net Income = Total Sales - Total Production Costs; Production costs include all expenses related to substrate preparation, inoculation, environmental control, and labor.

The Return on Investment (ROI) was calculated by dividing the net income by the total production cost, using the formula: ROI (%) = (Net Income / Total Production Cost) × 100. Net income was determined by subtracting the total production cost from the total revenue. The total production cost included both direct and indirect expenses incurred during mushroom cultivation. Direct costs accounted for energy consumption, which was calculated based on electricity usage for pasteurization and control of the environment, along with water usage quantified by the total liters used for irrigation. Labor costs were estimated based on the number of working hours dedicated to substrate preparation, inoculation, incubation, and harvesting. Additionally, substrate preparation costs included the expenses for raw materials such as agricultural waste, molasses, and lime, as well as sterilization costs. This ROI calculation provided insights into the profitability and cost-effectiveness of each substrate, helping to identify the most sustainable and economically viable method for oyster mushroom cultivation.

The economic analysis such as; Break-Even Point (BEP), Payback Period, Net Present Value (NPV), and Internal Rate of Return (IRR), were used to determine the profitability of the oyster mushroom production. The data were analyzed using manual formulas for NPV and IRR. Additionally, spreadsheet software like Microsoft Excel was used to compute the IRR using the built-in IRR function and NPV with different discount rates. Here's a detailed breakdown:

Break-Even Point (BEP): This calculates the number of units (or monetary value) needed to cover the total expenses. It was determined using the formula:

$$\text{BEP (Units)} = \frac{\text{Total Expenses}}{\text{Price per Unit}}$$

Payback Period: It is the time taken for the initial investment to be recouped through the net profits. It is computed by dividing the initial investment by the monthly profit:

$$\text{Payback Period (Months)} = \frac{\text{Initial Investment}}{\text{Monthly Profit}}$$

Net Present Value (NPV): Net Present Value (NPV) is a financial metric used to determine the value of a series of future cash flows (profits or revenues) in today's terms, taking into account the time value of money. It is essential for evaluating the profitability of investments. This was calculated by discounting future cash flows at a rate of 10% per month. The formula used was:

$$NPV = \sum \left(\frac{CFt}{(1 + \mathrm{r})t} \right) - I$$

Where: $\boldsymbol{CF_t}$ is the cash flow at time **t**, **r** is the discount rate, and ***I*** is the initial investment.

A positive NPV indicates a profitable investment, where the returns exceed the cost of capital. While, a negative NPV would indicate that the investment will not recover the cost and will result in a loss.

Internal Rate of Return (IRR): This was calculated using an iterative process, where the NPV is set to zero and the discount rate that satisfies this condition is found. The IRR formula is:

$$0 = \sum \left(\frac{CFt}{(1 + IRR)t} \right) - I$$

If the IRR is greater than the discount rate (e.g., 10%), the investment is profitable because it exceeds the required rate of return. However, if the IRR is lower than the discount rate, the investment is not profitable as it does not generate enough return to justify the costs.

RESULTS AND DISCUSSION

Oyster mushroom growth characteristics and yield performance

The growth characteristics and yield performance of oyster mushrooms cultivated on different agricultural waste substrates are summarized in Tables 2 and 3. Key parameters measured included mycelial growth length after planting, the number of flushes per batch and per bag, the number of flushes post-planting, fruit weight (g), mushroom cap circumference (cm), stalk length (cm), and overall yield performance. Each substrate formulation consisted of 89% agricultural waste, 10% molasses, and 1% lime, ensuring a balanced nutrient composition for optimal mycelial development and fruiting body formation. The variation in these growth parameters across different substrates highlights the influence of substrate composition on mushroom productivity and quality.

Mycelial growth in 1st and 2nd week after planting

Significant differences in mycelial growth were observed across the different substrates (Tables 2 and 3). At one and two weeks after planting, the fine sawdust substrate (T4) produced the longest mycelial growth, with mean lengths of 3.47 and 7.46 cm, respectively. In contrast, the rice hull substrate (T2) exhibited the shortest mycelial growth, with mean lengths of 2.35 and 5.47 cm, respectively. The control substrate, rice straw (T1), showed moderate performance. Using fine sawdust increased colonization time by 15.66% at two weeks and 18.84% at one week. This suggests that fine sawdust promotes faster and more extensive mycelial expansion (Miah et al. 2017), which is important for subsequent mushroom development. A well-established mycelial network enhances nutrient absorption and accelerates the transition to fruiting stages (Stanley and Awi-Waadu 2010; Ufitinema et al. 2023), with fine sawdust likely contributing to optimal fungal colonization due to its texture and aeration properties (Abiodun et al. 2022; Hultberg and Golovko 2024).

Number of days to flush after planting

The time required for the first flush varied significantly among substrates (Tables 2 and 3). The fine sawdust substrate (T4) resulted in the shortest flush time, averaging 37.92 days, while the rice straw substrate (T1) had the longest flush time at 50.86 days. The 25.44% reduction in flush time with fine sawdust highlights its efficiency in initiating fruiting, allowing shorter production cycles and more frequent harvests. This may be attributed to superior moisture retention and microbial composition in fine sawdust, which creates an optimal environment for primordia formation (Horisawa et al. 1999). Shorter flush times also reduce labor and operational costs, making fine sawdust a practical choice for commercial production (Ejigu et al. 2022; Argaw et al. 2023).

Number of flushes of fruitbodies per bag

The number of flushes per bag, a key indicator of productivity, varied significantly (Tables 2 and 3). The rough sawdust substrate (T3) had the highest flushes per bag, with a mean of 10.60, whereas aged rice hull (T2) produced the fewest at 4.46. Compared to the control (T1: rice straw), rough sawdust, supplemented with 10% molasses and 1% lime, increased fruit production by 107.03%. This demonstrates that wood-based substrates enhance fruiting potential (Sofi et al. 2014; Tarko and Sirna 2018; Nwaogu et al. 2024). Higher flush numbers sustain market supply and increase profitability, likely due to improved aeration and substrate stability in rough sawdust (Jackson 2018; Oyebanji et al. 2021).

Length of stalk (cm)

Mushroom stalk length influences consumer preference and marketability. Tables 2 and 3 indicate that the rough sawdust substrate (T3) produced the longest stalks, averaging 6.13 cm, while rice straw (T1) yielded the shortest. Using rough sawdust increased stalk length by 29.32%, enhancing visual appeal and handling ease. Longer stalks often correlate with improved nutrient uptake and substrate utilization (Kinge et al. 2016; Onyeka et al. 2018), supporting higher biomass accumulation and yield potential (Megersa and Tolessa 2024).

Circumference of fruit (cm)

The study measured cap circumference to assess the effect of different substrates on fruit size. Tables 2 and 3 show that the widest caps were produced on the fine sawdust substrate (T4), with a mean circumference of 26.08 cm, whereas the smallest were observed in mushrooms grown on rice straw (T1) at 18.30 cm. This 42.51% increase in cap size with fine sawdust highlights its effectiveness in promoting larger fruit bodies, which enhance marketability (De Cianni et al. 2023). Larger caps are preferred due to their visual appeal, cooking versatility, and potential nutritional benefits (Das et al. 2021). The improved cap development in fine sawdust may be linked to superior aeration, moisture retention, and nutrient availability (Marinou et al. 2013; Kinge et al. 2016).

Table 2. Oyster mushroom agronomic characteristics and yield performance using different agricultural waste materials (89% substrate, 10% molasses, and 1% lime) from a CRD experiment with 4 (T) Treatments and 5 (R) Replications

Treatments	Length of mycelia (cm)		No. of days to flush	No. of flushes/bag	Length of stalk (cm)	Circumference of cap (cm)	Fruit weight (cm)	Total yield (g)
	1 week	2 weeks						
T1-Rice straw	2.92^{b}	6.45^{b}	50.86^{a}	5.12^{bc}	4.74^{c}	18.30^{c}	13.64^{b}	136.38^{b}
T2-Aged rice hull	2.35^{c}	5.47^{c}	48.26^{b}	4.46^{c}	5.31^{bc}	19.54^{c}	16.28^{b}	158.54^{b}
T3-Rough sawdust	2.95^{b}	5.58^{c}	40.86^{c}	10.60^{a}	6.13^{a}	23.03^{b}	36.49^{a}	364.94^{a}
T4-Fine sawdust	3.47^{a}	7.46^{a}	37.92^{d}	7.02^{b}	5.59^{ab}	26.08^{a}	35.79^{a}	357.92^{a}
F-Test value	**500.65**	**253.38**	**456.05**	**16.58**	**6.96**	**15.01**	**35.61**	**36.60**
F-Tab value	**5.95**	**5.95**	**5.95**	**5.95**	**5.95**	**5.95**	**5.95**	**5.95**
CV (%)	**1.57**	**2.27**	**1.43**	**22.26**	**9.02**	**9.35**	**18.01**	**18.00**
F-Test > F-Tab	**	**	**	**	**	**	**	**

Note: The means in a column with the same letter superscripts are not significantly different based on the Least Significant Difference (LSD) test at the 1% level. The coefficient of variation (C.V.) expresses the degree of variation relative to the mean for each growth parameter, providing insights into the consistency of the data. A highly significant (**) difference was observed between treatments, as indicated by the F-test, where the computed F-value exceeded the F-tabulated value at a 1% significance level. The high F-coefficients further confirm that the differences among substrate treatments significantly influenced oyster mushroom growth characteristics and yield performance.

Table 3. Significance testing of growth and yield parameters in oyster mushrooms under different substrate treatments

Parameters	F-test Value	F-tab Value	Comparison	Conclusion
Mycelial growth (1 week)	500.65	5.95	F-test > F-tab	Significant difference
Mycelial growth (2 weeks)	253.38	5.95	F-test > F-tab	Significant difference
Days to flush	456.05	5.95	F-test > F-tab	Significant difference
Number of flushes per bag	16.58	5.95	F-test > F-tab	Significant difference
Stalk length	6.96	5.95	F-test > F-tab	Significant difference
Cap circumference	15.01	5.95	F-test > F-tab	Significant difference
Fruit weight	35.61	5.95	F-test > F-tab	Significant difference
Total yield	36.6	5.95	F-test > F-tab	Significant difference

Fruit weight (g) per bag

Fruit weight per bag is a vital metric for assessing yield efficiency. Tables 2 and 3 reveal that rough sawdust (T3) resulted in the heaviest fruits, with a mean weight of 36.49 g, followed closely by fine sawdust (T4) at 35.79 g. Both significantly outperformed rice straw (T1), which yielded the lightest mushrooms. Mushrooms grown on rough sawdust were 167.57% heavier than those on rice straw, demonstrating the benefits of sawdust-based substrates for enhancing fruit weight. This aligns with studies showing that lignocellulosic substrates provide a stable, nutrient-rich environment for mushroom growth (Kumla et al. 2020; Boadu et al. 2023; Sour et al. 2024).

Total yield (g)

Total yield is a key measure of productivity. According to Tables 2 and 3, the rough sawdust substrate (T3) produced the highest total yield at 364.94 g per bag, significantly higher than the 136.38 g per bag recorded for rice straw (T1). This 167.60% increase highlights the superior efficiency of rough sawdust in oyster mushroom production. The high yield potential of rough sawdust may be attributed to its high cellulose and hemicellulose content, which serve as primary energy sources for fungal growth (Ahmed and Mohesien 2020; Kaoke et al. 2024). Its coarser texture also facilitates better air circulation, reducing compaction and supporting sustained fruiting. These findings suggest that selecting the appropriate substrate is critical for optimizing yield and improving the overall efficiency of oyster mushroom farming.

Return on Investment (ROI)

Table 4 summarizes the return on investment (ROI) analysis for oyster mushroom production across different substrates. This table presents a detailed income statement for 1,000 fruiting bags over a three-month production cycle, offering insights into the financial viability of each substrate. ROI serves as a crucial performance indicator, assessing the profitability and cost-effectiveness of various cultivation methods. Understanding these financial dynamics helps growers optimize production strategies for maximum economic returns.

Among the tested substrates, rough sawdust (T3) demonstrated the highest financial viability, yielding a net income of 17,939.25 pesos and an impressive ROI of 190.21%. This result highlights the efficiency and profitability of rough sawdust as a substrate for oyster mushroom cultivation. Closely following, fine sawdust (T4) generated a net income of 17,412.75 pesos, achieving an ROI of 184.63%. These high returns highlight the economic advantage of using sawdust, whether rough or fine-textured, as an optimal substrate for commercial production (Chen et al. 2020; Adams et al. 2022).

In contrast, the aged rice hull substrate (T2) produced a significantly lower net income of 2,709.25 pesos, resulting in an ROI of 29.51% (Table 4). While less efficient than sawdust, aged rice hulls still provided a positive return, suggesting they can serve as an alternative substrate, albeit with limitations. The lower profitability of rice hulls may be attributed to their reduced structural stability, lower organic matter content, and limited capacity for sustained fruiting across multiple flushes (Okigbo et al. 2021; Costa et al. 2023; Kordi et al. 2024).

The control substrate, chopped rice straw (T1), yielded the lowest net income at 1,547.25 pesos, with an ROI of 17.82% (Table 4). This modest return highlights the limited economic feasibility of using rice straw compared to other tested substrates. The lower performance of rice straw may be linked to its lower nutrient availability, rapid decomposition rate, and reduced moisture retention capacity, all of which can negatively impact mushroom yield, growth, and overall profitability (Sitaula et al. 2018; Muswati et al. 2021; Subedi et al. 2023).

Discussion

Effect of substrate composition on mushroom growth and yield

The findings of this study demonstrate that substrate composition significantly influences the growth performance and yield of oyster mushrooms (*P. ostreatus*). Statistical analyses confirmed that all treatments exhibited highly significant effects, with P-values of 0.00-well below the 0.01 significance threshold. The high F-test values further support this conclusion, particularly for mycelial length after one week (F = 500.65) and two weeks (F = 253.38), number of days to flush (F = 456.05), number of flushes per bag (F = 16.58), stalk length (F = 6.96), cap circumference (F = 15.01), fruit weight (F = 35.61), and overall yield (F = 36.60). These results highlight the pivotal role of substrate composition in optimizing oyster mushroom cultivation.

Table 4. Income statement of one thousand (1,000) fruiting bags of oyster mushroom production for three months

Particulars	T1-chopped rice straw (control)	T2-aged rice hull	T3-rough sawdust	T4-fine sawdust
Gross income	10, 228.50	11, 890.50	27, 370.50	26, 844.00
Total expenses	8,681.25	9, 181.25	9, 431.25	9, 431.75
Net income	1, 547.25	2, 709.25	17, 939.25	17, 412.75
ROI (%)	17.82%	29.51%	190.21%	184.63%

Note: Assumption = Suggested retail price is 35.00 Philippine pesos/100 g fruiting bag/3 months production

These findings align with previous research emphasizing the importance of substrate selection. Naeem et al. (2014) reported that sawdust-based substrates enhance growth rates and increase stalk heights in *P. ostreatus*, supporting this study's observations. Similarly, Islam et al. (2009), Orngu et al. (2021), and Hultberg et al. (2023), identified sawdust as the most effective medium for mycelial colonization and fruit body development. The direct influence of substrate composition on both mycelial expansion and fruiting body development is well established, reinforcing the current study's results. Additionally, Buah et al. (2010), Getachew et al. (2019), and Grimm et al. (2024) reported that oyster mushrooms typically begin fruiting within three to eight weeks, depending on the substrate used-consistent with the flush cycles observed in this study. These findings collectively suggest that substrate selection is crucial not only for maximizing yield but also for ensuring predictable and efficient production cycles.

Comparison of substrates: Sawdust vs. rice straw and rice hull

The study results indicate that oyster mushrooms cultivated on sawdust-based substrates, particularly rough sawdust, exhibited superior growth and yield compared to other tested substrates. Argaw et al. (2023) and Naeem et al. (2014) previously observed that *P. ostreatus* grown on sawdust yielded the highest number of fruiting bodies, a trend corroborated by the present study. Sawdust appears to provide an optimal environment for mycelial colonization and fruiting, as also noted by Shah et al. (2004), Bhattacharjya et al. (2014), Adams et al. (2022), and who reported biological efficiency values as high as 65.22% when using sawdust substrates.

Furthermore, Bhattacharjya et al. (2014), Besufekad et al. (2019), and Pedroso et al. (2024) found that sawdust substrates produced larger cap circumferences compared to straw-based substrates, which typically yielded smaller fruiting bodies (Rambey et al. 2020). These observations reinforce the idea that sawdust not only enhances growth rates but also promotes the development of larger, more commercially viable mushrooms. Studies by Pardeep et al. (2002) and Varghese and Amritkumar (2020) further established sawdust as the most effective substrate for maximizing mushroom production. Shah et al. (2004) and Pathmashini et al. (2008) also emphasized the superior bioefficiency of sawdust compared to other agricultural waste materials. These consistent findings highlight the advantages of sawdust-based substrates in terms of both productivity and economic return.

Economic implications: Return on Investment (ROI)

Beyond its biological advantages, sawdust-based substrates also demonstrated significant economic benefits. This study found that rough sawdust yielded the highest net income and ROI, representing a 172.39% increase compared to the control substrate. These findings emphasize the importance of selecting high-yielding substrates to enhance both production efficiency and financial viability in mushroom farming (Dulay et al. 2021; Suwannarach et al. 2022). The economic advantages of rough sawdust make it a highly attractive option for both small-scale and commercial mushroom growers seeking to maximize profitability.

The economic potential of oyster mushroom farming is particularly relevant within the Philippine agricultural sector. Historical production challenges, including high input costs and inconsistent cultivation practices, have led to declines in national mushroom production (Chang et al. 2014). However, adopting high-yielding substrates such as rough sawdust may help reverse these trends by increasing yield potential while reducing production costs. The widespread use of cost-effective substrates could support industry revitalization, benefiting both smallholder farmers and larger agribusinesses by ensuring sustainable production and improved financial returns.

Sustainability and waste reduction

Utilizing agricultural waste materials as mushroom substrates presents an opportunity for both economic and environmental sustainability. This study demonstrates that repurposing sawdust and rice hulls for mushroom cultivation can significantly improve yield and profitability while reducing organic waste accumulation. By adopting sawdust-based substrates, mushroom farmers can lower production costs and increase financial returns while simultaneously contributing to sustainable farming practices.

The use of agricultural by-products in mushroom cultivation aligns with the principles of circular economy and resource efficiency. Repurposing these materials helps mitigate environmental impact by diverting organic waste from landfills, promoting a more sustainable agricultural model. Additionally, sawdust and rice hull substrates are readily available and cost-effective, making them viable options for mushroom growers in regions with limited access to traditional cultivation materials. These findings highlight the potential for integrating sustainability into commercial mushroom farming, supporting both economic development and environmental conservation.

In conclusion, this study highlights the critical role of substrate selection in optimizing oyster mushroom yield and profitability. Rough sawdust emerged as the most effective substrate, offering the highest yield and ROI, making it particularly suitable for commercial production. Fine sawdust also demonstrated potential for enhancing mycelial growth, providing an alternative for growers seeking a faster production cycle. Although aged rice hulls and rice straw yielded lower returns, they remain viable alternatives, particularly in areas where sawdust is less accessible. By utilizing agricultural waste materials, this study supports the United Nations Sustainable Development Goals (SDGs), particularly SDG 12 (Responsible Consumption and Production) and SDG 13 (Climate Action), by promoting sustainable agricultural practices and waste reduction. Sawdust-based substrates not only enhance economic returns but also contribute to environmental sustenance. Future research should explore additional alternative substrates, such as corn cobs and coffee grounds, to further improve sustainability and profitability in mushroom farming. Expanding the scope of substrate testing could provide valuable insights into optimizing mushroom production while advancing resource-efficient agricultural practices.

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