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Research Article

Yield Response and Nutritional Value of White Oyster Mushroom (*Pleurotus pulmonarius*) in Different Mixing Ratios of Hardwood Sawdust

Roi Vincent R. Rivera, Gladys M. Manalo, John Paulo R. Villanueva, Johnmike A. Chaneco, and Evelyn Q. Alera
College of Agriculture, Bulacan Agricultural State College, Bulacan, Philippines

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Corresponding Author
Evelyn Q. Alera
aleraevelyn@gmail.com

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Abstract

This study investigated the effects of the different mixing ratios of acacia and mango hardwood sawdust on the growth, yield, and nutritional content of the white oyster mushroom (Pleurotus pulmonarius). Six treatments were utilized: Farmers' Practice (T1), 100% Mango Sawdust (T2), 100% Acacia Sawdust (T3), 50% Mango Sawdust: 50% Acacia Sawdust (T4), 75% Mango Sawdust: 25% Acacia Sawdust (T5) 75% Acacia Sawdust: 25% Mango Sawdust (T6). Each treatment was replicated four times and arranged in a complete randomized design (CRD). The collected data were reported from three flushes and presented in means plus the standard error mean. Mycelial running completion was found to be statistically similar among treatments and comparable with the rice straw substrate (control). The combination of acacia and mango sawdust (T4, T6) provided the shortest number of days for the first formation of fruiting bodies. The number of fruiting bodies in the mango and acacia sawdust treatments was statistically comparable to the control. The 100% mango sawdust provided significant mushroom yield in the different flushes. Mixed sawdust treatments (T4, T5, and T6) were observed to have significantly higher crude protein, crude fiber, and ash content, indicative of their potential as food and feed sources. Overall, the findings of this study revealed the potential of hardwood sawdust in different mixing ratios to be an alternative to rice straw when it comes to growing white oyster mushrooms. It should be noted, nevertheless, that further investigations are recommended to better establish and validate the present findings.

Keywords

acacia sawdust, mango sawdust, nutritional content, Pleurotus pulmonarius

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Introduction

Background of the Study

Mushroom cultivation in the Philippines is economically viable, as explained by its low cost of production and high profitability. The vast volume of agricultural waste and the warm climatic conditions of the country offer numerous opportunities for mushroom cultivation. *Pleurotus* spp., more popularly known as oyster mushrooms, are the easiest and cheapest mushrooms to grow commercially, as they are recognized for converting crop residues into food protein and are considered a prospective source of income, alternative food production, and a sustainable way of agricultural waste recycling (Banik & Nandi, 2004).

Aside from the profitability potential of mushroom production, it is also considered a food source with high nutritional and functional value and is also accepted as a dietary supplement (Chang & Miles, 2004). This is due to the mushrooms' carbohydrate, protein, fiber, vitamin, and mineral content (Correa et al., 2016; Deepalakshmi & Mirunalini, 2014).

In general, mushrooms are grown on pasteurized agricultural waste such as rice straw, rice husks, wheat, corn husks, banana leaves, fruit and vegetable surplus, and wood discards. Additionally, mushrooms can be grown on various substrates containing lignin, hemicellulose, and cellulose (Jeznabadi et al., 2016). Fungal mycelia have the ability to efficiently bioconvert substances containing lignocellulose and can be deposited on various residues as substrates. This ability of the fungus makes it easy to grow from agricultural and industrial waste (Alvarez & Bautista 2021).

Pleurotus species represent a well-defined group of Basidiomyceteous fungi normally characterized by producing fruit bodies with an eccentric stalk and a wide cap shaped like an oyster shell, with the widest portion of the cap being away from the stalk (Rajarathnam et al., 2009). Many Pleurotus species, such as *Pleurotus ostreatus*, *Pleurotus pulmonarius*, *Pleurotus eryngii, Pleurotus florida, Pleurotus citrinopileatus, and Pleurotus djamor* var. roseus, can be grown commercially, without the need for composting and artificial conditioning of the ambient temperature (Raman et al., 2021). Many of these edible oyster mushrooms are cultivated on plant materials that are high in lignocellulosic materials, given their seeming composition and good physical structure that allows gas exchange during fungal growth (Chen et al., 2020; Sanchez, 2009).

However, many local mushroom farmers use rice-based and banana agrowastes as their substrates for their local mushroom production (Chang et al., 2014). There have not been many local and scientific reports on the utilization of hardwood sawdust as substrate in cultivating oyster mushrooms. Moreover, there have also been a few studies on the nutritive value of oyster mushrooms, specifically *Pleurotus pulmonarius,* or white oyster mushrooms produced from local hardwood sawdust.

Hardwood sawdust has been known to contain high amounts of lignocellulosic materials like cellulose, hemicellulose, and lignin. These are polymers that can be easily degraded by many white-rot fungi, including oyster mushrooms, and be used as their carbon and energy source (Sanchez, 2009). Acacia and mango trees are widely distributed in tropical Asia and Oceania. And since their maturity is reached in only four to six years, Acacia and Mango trees are some common trees suited for commercial forest plantations.

As *Pleurotus* spp. are becoming increasingly important and in-demand edible mushrooms in many parts of the world, selecting the appropriate substrate to grow them in a particular location with consideration to substrate availability, abundance, and cost.

The present study was therefore undertaken to investigate the effects of the different mixing ratios of Acacia and mango hardwood sawdust on the growth, yield, and nutritional content of *Pleurotus pulmonarius,* or white oyster mushrooms.

Conceptual Framework

Figure 1
Conceptual Framework of the Study

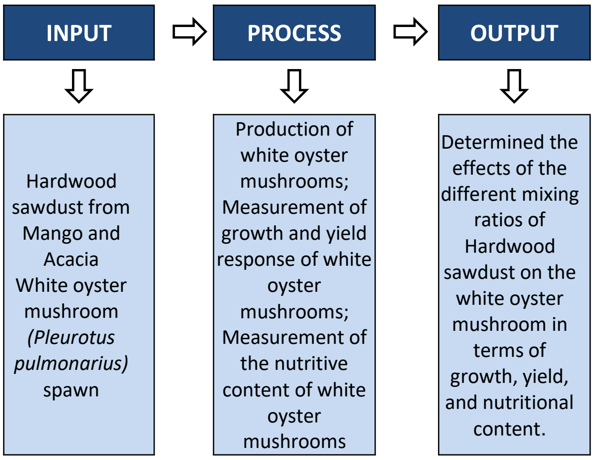

Figure 1 presents the IPO model utilized in the study. The input included the two main variables to be studied, namely: mango (*Mangifera indica*) and Philippine Acacia (*Acacia confusa*) sawdust, and the spawn inoculant of white oyster mushrooms (*Pleurotus pulmonarius*). As a method of data collection, the processes involved are the production of white oyster mushrooms, the measurement of the mushrooms' growth and yield response, and their nutritional content. Lastly, the expected output was the findings on the effects of the different mixing ratios of hardwood sawdust on the white oyster mushroom in terms of growth, yield, and nutritional content.

Statement of the Problem

The main objective of this study is to determine how different mixing ratios of sawdust affect the yield response and nutritional value of white oyster mushrooms. To assess the knowledge of white oyster mushroom growers and how they can improve the practice of cultivating white oyster mushrooms. Furthermore, the study seeks to evaluate the following specific objectives:

1. Evaluate the effects of different sawdust types in terms of vegetative stage growth parameters:
   a. Days of mycelial running completion
   b. Days to first primordia appearance
   c. Days to the first pinhead formation
2. Evaluate the effects of different sawdust types in terms of maturity stage growth parameters:
   a. Days to the first formation of fruiting bodies
   b. Average number of fruiting bodies in 3 flushes
   c. Average pileus (cap) diameter in 3 flushes
   d. Average yield in grams in 3 flushes of the representative samples
   e. % Biological efficiency
3. Determine the nutritional composition of the white oyster mushroom grown on different sawdust substrates:
   a. Moisture content
   b. Crude protein
   c. Crude fiber
   d. Ash content
   e. Crude fat

Methods

Collection of Substrate Materials

Five sacks of rice straw and coco peat, five sacks of mango sawdust, and five sacks of acacia sawdust were purchased from a local source in San Miguel, Bulacan. Twenty-five kg of rice bran, three kg of molasses, and three kg of lime were sourced from San Rafael, Bulacan, and Gapan, Nueva Ecija, respectively.

Preparation of Experimental Treatments

Using a complete randomized design in four replications, Table 1 presents the experimental treatment utilized in the study. Each treatment had 10 fruiting bags placed vertically by hanging them in the mushroom growing room. A distance of 8cm between each fruit was secured during the tying of the ropes. The purpose was to provide enough distance when the mushroom spawns, matures, and develops.

Table 1
Experimental Treatments of the Cultivation of White Oyster Mushrooms in Different Sawdust Mixing Ratios

Treatments	Substrate Composition
T1 Farmers' practice (control)	50% Rice straw + 50% Coco peat
T2	100% Mango sawdust
T3	100% Acacia sawdust
T4	50% Mango sawdust + 50% Acacia sawdust
T5	75% Mango sawdust + 25% Acacia sawdust
T6	75% Acacia sawdust + 25% Mango sawdust

Lime, molasses, and rice bran were thoroughly mixed with all of the hardwood sawdust to ferment it for 30 days. The sawdust mixture was kept in a clean container and covered at room temperature. It was carried out separately for the acacia sawdust, mango sawdust, and the farmers' practice substrate. After 14 days, the substrates were harvested. It was proportioned and put inside the fruiting bag according to the ratios of the treatments, with each polypropylene plastic bag carrying a total of 1000 g.

The plastic bags filled with the substrate mixtures were steamed or sterilized for 8 hours under low to medium heat. After the sterilization, the fruiting bags were put on tables and allowed to cool at room temperature before being filled with the white oyster mushroom spawn. All the fruiting bags were labeled properly based on the treatment and replication.

Spawn Inoculation

The white oyster mushroom spawn in powder form was measured at 60 grams using a plastic measuring spoon. The 60 grams of white oyster mushroom spawn were poured and spread inside the cooled fruiting bags. A total of 240 fruiting bags were spawned and set aside before hanging. Holes were made by piercing the fruiting bags. This served as the opening where the mushroom grew out during the maturity stage.

Sanitation and Maintenance of the Growing Room

The growing room was located in Camias, San Miguel, Bulacan, and had an area of 5m by 3m. Before transferring the fruiting bags, the room was kept clean using a disinfectant. Proper ventilation was maintained inside so that the temperature would be right for mushroom growth and development. There was a room thermometer placed inside to monitor the daily temperature. Also, a digital room hygrometer or humidity meter was put inside to monitor relative humidity. The jute sacks were rolled up from 6 p.m. to 8 a.m. to expose the fruiting bags to early morning natural lighting, which is the farmer's practice to induce the production of fruiting bodies. To maintain a humidity level above 70%, the room's walls were sprayed with water using a water hose twice a day. The floor was swept daily to avoid contamination of the fruiting bags.

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Measurement of Growth and Yield Parameters

Days of Mycelial Running Completion

The mycelial or spawn running was counted beginning the 1st day of the hanging of the fruiting bags in the growing room until the whole bag is filled with white powder, an indication that the mushroom spawn is spreading and colonizing the substrates. The days of mycelial completion were recorded for each treatment in all the 240 fruiting bags utilized in the study and then averaged.

Days to First Primordia Appearance

The primordium was the balling or rounding of mycelial strands. It is the first point at which the development of the fruiting body into a pileus and stipe is visible. The days until the appearance of the primordia in all treatments were counted and recorded. The days to first appearance of the primordia were recorded for each treatment in all 240 fruiting bags (100%) and averaged.

Days to the First Pinhead Formation

Pinheads are small outgrowths of the mushroom where the stipe and small cap are visible. The days to first pinhead formation were recorded in the 240 fruiting bags (100%) and averaged.

Days to First Formation of Fruiting Bodies

Fruiting bodies are the reproductive structure of the mushroom, which grows from the mycelium. The fruiting body has a distinct and visible large pileus and stipe. The days to first formation of fruiting bodies were recorded for each treatment in the 240 fruiting bags (100%) and averaged.

Average Number of Fruiting Bodies in Three Flushes

The fruiting bodies of the 50% (20 fruiting bags) representative samples were counted in three flushes for each treatment and averaged.

Average Pileus (Cap) Diameter in Three Flushes

The pileus, or cap diameter, was measured using a Vernier caliper. 50%, or 20 randomly selected fruiting bags, were identified, and the largest pileus in those fruiting bags was measured and recorded.

Average Yield in Grams in Three Flushes in Representative Samples

The harvested mature fruiting bodies were weighed in the 20 randomly selected fruiting bags in the first and second flushing and computed for the average separately.

% Biological efficiency (BE)

The biological efficiency is the ratio of the weight of the fresh fruiting body (g) per dry weight of substrate (g), expressed as a percentage. To obtain the % BE, the fruiting bodies were harvested and weighed using a digital weighing scale without removing the stipe in all six treatments in the three flushings. The recorded fresh weights were totaled to get the total biological weight in grams. After the third flush, the 20 fruiting bags, or 50% representative samples of each treatment, were dried for seven days and then weighed individually. The weights of the dried fruiting bags in each replication per treatment were totaled and then divided by the total fresh weight in 3 flushes, which were then multiplied by 100 to acquire the BE value in percent. The formula is presented below:

$$\%\ \text{Biological efficiency} = \frac{\text{Total biological weight sample (g)}}{\text{Total weight substrate used (g)}} \times 100 \quad (1)$$

Nutrient Analysis of the Dried Oyster Mushroom

In each treatment, 250 g of dried white oyster mushrooms were prepared by drying the fresh mushrooms in the oven dryer (Memmert UM 300) at 75–80 °C for three days. After oven drying, the samples were powderized using a heavy-duty blender (JTC Omniblend). The powderized mushroom samples were subjected to moisture content analysis using the oven-drying method; for the determination of crude protein, the Kjeldahl method was used, while the furnace-ignition method was used to measure ash content. Crude fiber was determined using the ANKOM 200 Fiber Analyzer-Filter Bag Technology (Macedon, NY), and crude fat was tested using the ANKOM Hydrolysis System-Filter Bag Technology (Macedon, NY). The tests conducted followed the protocol of the Department of Agriculture's Region III Feed Chemical Analysis Laboratory.

Statistical Analysis

The data gathered were computed using one-way ANOVA and Tukey HSD at the 0.05 level of significance in STAR (IRRI) SPSS. For the data in the 2nd flush where unequal variance occurred, Welch ANOVA and the Games-Howell test were used using IBM SPSS 26 (Chicago, Il). All results were presented as means plus the standard error of the mean.

Results

Effects of the Different Mixing Ratios of Hardwood Sawdust on the Vegetative Growth of White Oyster Mushroom

Mycelial completion was observed when the fruiting bags (T1–T6) were filled with masses of white branching and threadlike networks of hyphae. The completion was determined once the whole fruiting bag was fully white and very little of the substrate could be seen. The counting of the days began when all the fruiting bags in each treatment were inoculated with the white oyster mushroom spawn and hung in the mushroom grow room.

The quickest mycelial running completion time was found in T1 (farmer's practice: 50% rice straw + 50% good lumber sawdust) and T6 (75% acacia sawdust + 25% mango sawdust). These two treatments took 25 days to complete the mycelium spreading on the fruiting bags. Followed by T4 (50% mango sawdust + 50% acacia sawdust) with 25.25 days; next is T3 (100% acacia sawdust) with 26 days, T5 (75% mango sawdust + 25% acacia sawdust) with 27.50 days; and lastly, T2 (100% mango sawdust) had the longest time of mycelial running completion with 29 days (Table 2).

The formation of tiny whitish balls or circles from the white mycelia strands is a sign of primordia. These small whitish circles could swell, become prominent, and sometimes be pressed against the fruiting bags. From the first day of putting the spawn inside the fruiting bags and getting suspended in the grow room, the first primordia appearance happened on Day 29 in T1, which was the farmer's practice consisting of 50% rice straw and 50% good lumber sawdust. T4 (50% mango sawdust and 50% acacia sawdust) was observed to have the second shortest time in primordia appearance, with 32.64 days. This was followed by T2 (100% mango sawdust) at 33.20 days and T6 (75% acacia sawdust plus 25% mango sawdust) at 33.50 days. Both T3 (100% acacia sawdust) and T5 (75% mango sawdust and 25% acacia sawdust) had the first appearance of their primordia on day 34. This was observed on all 40 bags for all the replications in each treatment (Table 2).

In the days leading to the first formation of fruiting bodies or pinheads, T2 had the shortest time to form fruiting bodies, with 38.25 days. T1 and T6 are not far from each other, with 39.20 days for T6 and 39.50 days for T1. This was followed by T5, which took 40.00 days to form fruiting bodies. In comparison, T4 had 42.25 days and T3 had 47.25 days. Like the days of mycelial running completion and the first primordia appearance, the pinhead formation parameter was taken on all the fruiting bags in all treatments and replications, equivalent to 240 bags. Table 2 presents the average days of mycelial running completion, first primordia appearance, and first pinhead formation.

Table 2
Mean Differences in the Vegetative Growth of White Oyster Mushrooms on Six Different Substrates

Treatment	Mean Mycelial Running Completion (Days)*	Mean First Primordia Appearance (Days)*	Mean First Pinhead Formation (Days)*
T1 Farmers' practice (control) 50% Rice straw + 50% Coco peat	25.00±.00[c]	29.00±.00[b]	35.00±.63[c]
T2 100% Mango sawdust	29.00±.00[a]	33.20±.55[a]	37.71±.90[bc]
T3 100% Acacia sawdust	26.00±.58[c]	34.00±.29[a]	45.00±1.11[a]
T4 50% Mango sawdust + 50% Acacia sawdust	25.25±.25[c]	32.64±.45[a]	37.91±.86[bc]
T5 75% Mango sawdust + 25% Acacia sawdust	27.50±.50[b]	34.00±.27[a]	39.50±.91[b]
T6 75% Acacia sawdust + 25% Mango sawdust	25.00±.00[c]	33.50±.44[a]	38.27±1.12[bc]

Note. *Data presented are means plus standard error; significant at 0.05 alpha. Means with different letters in the same column are significant.

As presented in Table 2, all three parameters in the vegetative growth of the white oyster mushroom showed significant differences in all treatments. The mean differences in the days were different between T1, T2, and T5, as well as between T5, T1, T2, T3, T4, and T6. On the other hand, T1, T3, T4, and T6 did not differ significantly, implying that the mycelial running completion in these treatments was the same and found statistically in the same range.

As for the first primordia appearance, T2 to T6 were found to have the same statistical significance. Even though T4 took 32.64 days before the appearance of primordia, it did not differ statistically from T3 and T5, which took 34 days before the appearance of their primordia. T1, which had the shortest time (29 days) observed in the appearance of the first primordia, significantly differed from the other 5 treatments. Based on these results, it is suggested that using different mixing ratios of sawdust from mango and acacia was found to be less effective in shortening the days of the appearance of primordia in white oyster mushroom spawn when compared with the farmer's practice.

Meanwhile, in the pinhead formation, significant differences were found in all treatments. T1, T2, T4, and T6 were all statistically the same, with days to pinhead formation ranging from 35–38.27 days. These results differ from the 45 days to first pinhead formation of T3 and the 39.50 days to first pinhead formation of T5.

It may be deduced that the use of 100% mango sawdust (T2), 50% mango sawdust + 50% acacia sawdust (T4), and 75% acacia sawdust + 25% mango sawdust (T6) may have provided the same effect as that of the farmer's practice (T1) consisting of 50% rice straw + 50% good lumber sawdust with regards to pinhead formation of the white oyster mushroom.

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Days to First Fruiting Bodies Formation

Regarding the average days to first fruiting body formation, T1 had the shortest time for forming the first fruiting bodies with a mean of 35.33 days. However, this was not significantly different from T4 (50% Mango sawdust + 50% Acacia sawdust) with an average of 38.75 days and T6 (75% Acacia sawdust + 25% Mango sawdust) at 41.93 days for the production of the first fruiting bodies. The significant difference occurred among T1, T2 (42.4 days), T3 (46.29 days), and T5 (41.93 days) (Table 3). The treatment that took the longest to first flush was T3, which used 100% acacia sawdust, but this was statistically the same with T2, which was 100% mango sawdust. Table 3 displays the average days to fruiting body formation.

Table 3
Mean Difference of the Days of First Fruiting Bodies Formation of White Oyster Mushrooms on Six Different Substrates

Treatments	Mean of Days to First Fruiting Bodies Formation*
T1 Farmers' practice (control) 50% Rice straw + 50% Coco peat	35.33±1.13[c]
T2 100% Mango sawdust	42.4±2.35[ab]
T3 100% Acacia sawdust	46.29±1.15[a]
T4 50% Mango sawdust + 50% Acacia sawdust	38.75±0.82[bc]
T5 75% Mango sawdust + 25% Acacia sawdust	41.93±1.61[ab]
T6 75% Acacia sawdust + 25% Mango sawdust	40.93±1.46[abc]

Note. *Data presented are means + standard error; significant at 0.05 alpha. Means with different letters in the same column are significant.

Number of Fruiting Bodies as Influenced by the Different Mixing Ratios of Hardwood Sawdust

As seen in Table 4, during the first flush, T1 had the highest number of fruiting bodies, averaging 22.10. T3 and T5 both had an average of 21.30 fruiting bodies and 21.45, respectively. T2 followed this with 19.85, T4 with 18.95, and T6 with 16.00 fruiting bodies on average. However, these varying numbers of fruiting bodies in the six treatments were not statistically significant from each other. For the second flush, not all the representative fruiting bags bore fruiting bodies. Only T3 and T6 representative samples were observed to have fruiting bodies in each of their 20 bags. For T4, only 19 bags formed fruiting bodies, T1 and T4 only had 18 bags that produced fruiting bodies, and T2 had the least number of bags that produced fruiting bodies, which were 16.

Meanwhile, T3 and T5 placed second and third with 17.75 and 17.58, respectively. Contrary to its performance during the first flush, T1, which had the highest number of fruiting bodies previously, only averaged 15.67 on the second flush.

The treatment with the least number of fruiting bodies was T4. However, T4 and T1 had the same statistical significance in providing the lowest production of fruiting bodies for the second flush.

Table 4
Mean Differences in the Number of Fruiting Bodies in 3 Flushes of White Oyster Mushroom on 6 Different Substrates

Treatments	Number of Fruiting Bodies		
	1st Flush*	2nd Flush*	3rd Flush*
T1 Farmers' practice (control) 50% Rice straw + 50% Coco peat	22.10±1.32[a]	15.67±1.51[cd]	13.00±1.71[ab]
T2 100% Mango sawdust	19.85±1.75[a]	23.13±1.83[abc]	14.65±2.01[ab]
T3 100% Acacia sawdust	21.30±1.83[a]	17.75±1.35[bc]	11.05±1.15[b]
T4 50% Mango sawdust + 50% Acacia sawdust	18.95±1.40[a]	14.39±1.76b[cd]	16.00±2.01[ab]
T5 75% Mango sawdust + 25% Acacia sawdust	21.45±1.50[a]	17.58±2.64[bc]	17.30±1.98[ab]
T6 75% Acacia sawdust + 25% Mango sawdust	16.00±1.50[a]	16.05±1.35[bc]	19.85±1.61[a]

Note. *Data presented are means plus standard error; significant at 0.05 alpha. Means with different letters in the same column are significant.

In general, based on the computed composite means for all the flushes, the number of fruiting bodies was not significant, indicating that the use of mango and acacia sawdust performed the same as the farmer's practice. This may suggest that, in terms of giving fruiting bodies, mango and acacia sawdust, when used as substrates for the cultivation of white oyster mushrooms, may be as competent and productive as the usual use of rice straw and good lumber sawdust as substrates.

Average Pileus/Cap Diameter as Influenced by the Different Mixing Ratios of Hardwood Sawdust

In terms of the mean of the average pileus of 3 flushes, T2 got the highest pileus in diameter (cm) with an average of 8.23cm. T6 is almost consistent in the average pileus, with 7.68cm in the first flush, 8.38cm in the second flush, and 7.98cm in the third flush. The average mean of T6 in 3 flushes is 8.01cm. On the other hand, T4 had a pileus diameter averaging 7.87cm in 3 flushes, while T5 and T4 were almost the same at 7.84cm. T3 got an average of 7.43cm in pileus' diameter in all three flushes. Despite performing well in the vegetative stage of the white oyster mushroom by providing the shortest days before the appearance of primordia and pinhead, T1 gave the smallest pileus diameter at 7.39 cm. in 3 flushes.

Table 5
Mean Differences in the Pileus Diameter of White Oyster Mushroom on 6 Different Substrates

Treatments	Pileus Diameter (cm)		
	1st Flush*	2nd Flush*	3rd Flush*
T1 Farmers' practice (control) 50% Rice straw + 50% Coco peat	6.92±.3[a]	8.02±.45[a]	7.24±0.26[c]
T2 100% Mango sawdust	7.58±.35[a]	7.95±.27[a]	9.17±0.30[a]
T3 100% Acacia sawdust	7.14±.33[a]	8.01±.24[a]	7.15±0.34[c]
T4 50% Mango sawdust + 50% Acacia sawdust	7.70±.34[a]	8.08±.36[a]	7.84±0.29[bc]
T5 75% Mango sawdust + 25% Acacia sawdust	6.89±.27[a]	8.10±.29[a]	8.71±0.15[ab]
T6 75% Acacia sawdust + 25% Mango sawdust	7.68±.28[a]	8.38±.43[a]	7.98±0.26[bc]

Note. *Data presented are means plus standard error; significant at 0.05 alpha. Means with different letters in the same column are significant.

As revealed in Table 5, the overall means for the average diameter of the white oyster mushroom pileus were insignificant. This result showed that different mixing ratios of mango and acacia sawdust may have been as effective as the use of rice straw and good lumber sawdust as a substrate for growing white oyster mushrooms.

Effect of the Different Mixing Ratios of Hardwood Sawdust on the Average Yield of White Oyster Mushroom

The first flush happened 3–4 days after the first appearance of pinheads. From observation and analysis, T2 led all 6 treatments in terms of the average yield in 3 flushes (Table 6). T2 got the highest mean yield of 67.23g in 3 flushes. In the case of T1, it had a mean yield of 61.17g in 3 flushes. At the same time, the T5 averaged 55.74g and the T4 54.57 g. T3 and T6 got the least weight, averaging 52.97g for T6 and 52.30g for T3 in 3 flushes.

Even though mango and acacia sawdust contain high amounts of lignocellulose, mainly lignin, hemicellulose, and cellulose compounds that are hard to breakdown because of their high resistance to hydrolytic activities and complex structures (Bugg et al., 2011), the white oyster mushroom spawn in these substrates were able to decompose the lignocellulose on these substrates and perform at the same rate with rice straw substrate, which had a lower lignocellulose content (35% cellulose, 18% hemicellulose, and 15% lignin) based on the study of Jiang et al. (2011) and produced the same weight of mushroom harvests in 3 flushes.

Table 6
The Average Yield in g of White Oyster Mushroom in 3 Flushes

Treatments	Mean Yield (g)		
	1st Flush*	2nd Flush*	3rd Flush*
T1 Farmers' practice (control) 50% Rice straw + 50% Coco peat	74.90±4.49[a]	56.00±3.83[a]	52.60±5.15[ab]
T2 100% Mango sawdust	69.60±3.58[ab]	71.50±6.30[a]	60.60±5.11[a]
T3 100% Acacia sawdust	53.20±2.42[c]	60.40±3.98[a]	43.30±4.58[ab]
T4 50% Mango sawdust + 50% Acacia sawdust	61.70±2.95[abc]	61.67±4.18[a]	40.35±3.54[b]
T5 75% Mango sawdust + 25% Acacia sawdust	60.40±2.59[bc]	61.58±6.17[a]	45.25±3.82[ab]
T6 75% Acacia sawdust + 25% Mango sawdust	50.60±3.42[c]	54.65±5.00[a]	53.65±4.37[ab]

Note. *Data presented are means plus standard error; significant at 0.05 alpha. Means with different letters in the same column are significant.

Biological Efficiency of the 6 Different Substrates

The sawdust mixing ratios had an impact on the biological efficiency of the white oyster mushroom, with T1 achieving the highest level of biological efficiency (125.21%). This BE is statistically similar to the BE of T2 at 123.42%. Subsequently, T5 provided the third highest BE, 100.72% followed by T6 with 99.11% and T4 with 98.40%. Table 7 shows the mean biological efficiency of the treatments using representative samples from the study in the three flushes.

Table 7
Average Biological Efficiency (%) of the Six Substrates

Treatment	Average Biological Efficiency (%)*
T1 Farmers' practice (control) 50% Rice straw + 50% Coco peat	125.21±6.29[a]
T2 100% Mango sawdust	123.42±4.53[a]
T3 100% Acacia sawdust	93.09±2.86[b]
T4 50% Mango sawdust + 50% Acacia sawdust	98.40±6.20[b]
T5 75% Mango sawdust + 25% Acacia sawdust	100.72±3.43[b]
T6 75% Acacia sawdust + 25% Mango sawdust	99.11±1.95[b]

Note. *Data presented are means plus standard error; significant at 0.05 alpha. Means with different letters in the same column are significant.

As displayed in Table 7, T3 got the lowest percentage of the BE with 93.09%. However, the statistical analysis calculated that the T3, T4, T5, and T6 percentages of BE were all the same and not significant. The biological efficiency of the six treatments was computed for all three flushes combined.

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Nutritional Value of the White Oyster Mushroom Grown on Six Different Substrates

Moisture content was statistically similar for T3, T4, and T6, while T1 had the highest moisture content. The crude protein composition, on the other hand, was statistically comparable for T2 (27.63), T5 (27.20), and T6 (27.47). T4, which was 50% acacia and 50% mango sawdust, had the highest crude protein content. Treatments with mixed acacia and sawdust (T2, T4, and T5) also showed the highest ash content (6.97, 7.10, and 7.23). On the other hand, five treatments (T1, T2, T3, T4, and T6) had a comparable composition of crude fats, and for crude fiber, T5 and T6 obtained significantly different amounts compared to T1, T2, T3, and T4 (Table 8).

Table 8

Nutritional Value of the White Oyster Mushroom Grown on Six Different Substrates

Treatment	Moisture Content (%)	Crude Protein (%)	Ash (%)	Crude Fat (%)	Crude Fiber (%)
T1	6.30±0.20^{a}	24.90±0.30^{d}	6.53±0.05^{bc}	1.10±0.10^{a}	6.16±0.11^{b}
T2	2.97±0.21^{d}	27.63±0.25^{b}	6.97±0.15^{ab}	1.13±0.15^{a}	6.06±0.30^{b}
T3	4.27±0.31^{bc}	26.67±0.12^{c}	6.03±0.05^{d}	0.87±0.06^{ab}	6.27±0.12^{b}
T4	3.43±0.40^{cd}	28.27±0.31^{a}	7.10±0.35^{a}	1.03±0.21^{ab}	5.97±0.15^{b}
T5	4.60±0.26^{b}	27.20±0.17^{bc}	7.23±0.06^{a}	0.73±0.11^{b}	7.37±0.06^{a}
T6	4.30±0.70^{bc}	27.47±0.15^{b}	6.50±0.10^{c}	1.17±0.05^{a}	7.27±0.21^{a}

Note. *Data presented are means + standard error; significant at 0.05 alpha. Means with different letters in the same column are significant.

Discussion

The Vegetative Growth of the White Oyster Mushroom as Influenced by Mango and Acacia Sawdust

When compared with the study of Rambey et al. (2019) that used a mixture of sawdust and corncobs in different amounts in the cultivation of white oyster mushrooms, the result of this study (Table 2) obtained shorter days of mycelial completion than all the treatments consisting of varying mixing ratios of sawdust and crushed corncobs. In Rambey's results, the shortest mycelial growth of 32 days was obtained from treatment with 100g of corncobs and 750g of sawdust, while the shortest mycelial run in the present study was at 25 days (T1, T4, and T6). Sharma et al. (2013) also evaluated the response of *Pleurotus ostreatus* on different substrates, in which the pure rice straw treatment had mycelial colonization for 22.4 days, while the treatment of sawdust and rice bran had 26 days of complete mycelial growth. This result is similar to that obtained in the present study, in which mango and acacia sawdust obtained a complete mycelial run for 25–29 days.

Another study that supported the longer complete mycelial colonization of mango and acacia sawdust substrates was the study of Khan et al. (2012), wherein the use of mango sawdust took 31.50 days to complete the spread of mycelia in the fruiting bag, while the use of acacia sawdust took 26.50 days for complete mycelial colonization. The longer days of colonization of mycelia in the sawdust treatments were due to the higher content of hemicellulose, alpha-cellulose, and lignin. The higher the hemicellulose and lignin content, the longer the mycelial colonization will take (Chen et al., 2020). Because both mango and acacia are hardwoods, they contain between 15-25% of total lignin (Rowell et al., 2012). According to the study by Sharma and Mohanty (2021), mango wood has 23.75% lignin and 46.25% cellulose.

Yao et al. (2010) also reported that the lignin content of Acacia spp. was found to be highly variable depending on the species, ranging from 18–23% total lignin, while the cellulose content may range from 40–46% depending on the species (Pinto et al., 2005). These experiments show the slight difference in the lignin and cellulose content of mango and acacia, reflected in the difference on the days of mycelial completion of the white oyster mushroom. It supported the observation that mango sawdust has a longer time of mycelial running because it contains slightly more cellulose and lignin. Hence, the white oyster mushroom spawn had a longer time decomposing the mango sawdust due to higher lignin and cellulose content.

The result of the development of primordia during the vegetative stage of the white oyster mushroom in the present study was the same as in Sharma et al. (2013), when 100% use of rice straw obtained 26.40 days of primordial formation, while rice straw combined with wheat straw obtained 28.40 days of primordial formation. It was also similar to the investigation of Jeewanthi et al. (2017), when primordia appeared on the pure mango sawdust treatment on day 33.6, while the combination of rubber and mango sawdust got its primordia on day 34.1, and the combination of mango and jackfruit sawdust had the first primordia on day 40.7.

The pinheads of the white oyster mushroom grown in the different mixing ratios of Mango and Acacia sawdust were compared with the results in the study of Onyeka et al. (2018) using *Pleurotus ostreatus*. Findings from the latter study showed that the pinhead formation of their pure sawdust treatment took only 22 days, while the sawdust mixed with cassava peel took 32 days before the pinhead formation. Lastly, sawdust mixed with banana leaves had the shortest time to pinhead formation at 18 days. All these results are shorter than the findings of the present study.

It was mentioned by Baysal (2003) and Naraian et al. (2008) that the speed of spawn running and colonization, and pinhead formation indicate the overall health of the substrate used in mushroom cultivation. From this knowledge, it can probably be said that during the vegetative phase of the mushroom, the substrate of 50% rice straw and 50% coco peat can be considered the healthiest substrate because it was the substrate that gave the shortest time of vegetative phase completion for the white oyster mushroom.

But this was contradicted by Ko et al. (2001), as they believed that primordia formation and mushroom productivity are related to environmental (temperature, humidity, light, and aeration), nutritional (carbohydrate, nitrogen, and vitamins), and chemical factors. And in this study, especially with the yield parameters, it has been observed that several factors could be possibly considered in contributing to the early completion of vegetative growth of the mushroom and its total productivity. The study we conducted generated varying responses from the different parameters we measured.

The Yield of the White Oyster Mushroom

Mango and acacia sawdust have higher lignin, cellulose, and hemicellulose levels when compared to rice straw, according to Sharma and Mohanty (2021) and Yao et al. (2010). Thus, these polysaccharides could take time to break down. Meanwhile, rice straw is composed of approximately 35% cellulose, 18% hemicellulose, and 15% lignin, which are lower than those found in mango and acacia sawdust (Jiang et al., 2011). Based on these data, it can be suggested that the different composition of the lignocellulose biomass of the rice straw and hardwood sawdust contributed to the significantly different time points for fruiting body formation given that the fruiting bags in all treatments were in the same room condition.

These observations can be further investigated because, in the findings of Pathmashini et al. (2009), the time required for the first flush was the longest in the paddy spawn (43 days) when it was compared with finger millet (31 days), maize (38 days), and sorghum (32 days). However, Mondal et al. (2010) found out that sawdust, like banana stalks, had the shortest days to form fruiting bodies at only around 10–20 days, which was shorter than the results of this study. Because the results vary, more experiments are needed, disregarding environmental conditions and focusing on the lignocellulose biomass of the substrates.

Comparing the results of the present study with the investigation of Bhattacharjya et al. (2014), when they used pure mahogany sawdust on a common oyster mushroom, the average number of fruiting bodies was 17.33, while the ipil-ipil (*Leucaena leucocephala*) sawdust was found to have a 16.33 average number of fruiting bodies. It can be said that the average number of fruiting bodies attained using mango sawdust in this study was relatively higher. Still, the acacia sawdust arguably performed similarly to mahogany and ipil-ipil sawdust. The present study's findings were similar to those of Otunla and Idowu (2012), when they used mango and acacia sawdust to grow white oyster mushrooms and recorded a statistically significant result in producing the highest number of fruiting bodies against the use of coconut and mixed sawdust.

The explanation for why the number of fruiting bodies continuously went down in some treatments (T1, T3, and T5) during the second and third flush may be due to the cellulolytic and lignocellulolytic activity of the mushroom declining as the substrates' sugar, carbon, nutrient, and energy contents decreased over time, based on Sanchez et al. (2009). Due to the fact that T2 (100% mango sawdust) has a relatively higher composition of lignocellulose biomass, Sharma and Mohanty (2021) note that it has the highest overall number of fruiting bodies.

Findings from the study of Otunla and Idowu (2012) differ from the observations in the present study, in which mango sawdust provided a pileus diameter ranging from 6-7 cm, while in this experiment, 100% mango sawdust was able to provide a pileus diameter as high as 9.17cm. At the same time, Islam et al. (2009), who also used pure mango sawdust to produce white oyster mushrooms, only obtained a pileus diameter averaging 7cm, making the pileus diameter in this study still slightly larger.

The study's use of rice straw produced a cap size of 6-7.50 cm in diameter, which was in line with the findings made by Sharma et al. (2013). On the other hand, Preethy and Anbuselvi (2021) demonstrated that when they used acacia sawdust mixed with green tea dust, they could obtain an average pileus diameter of 4.5–16.5 cm, which was lower than the substrate that used rice straw combined with green tea dust. Principally, the 100% mango sawdust consistently gave the largest pileus. According to Sharma and Mohanty (2021) and Philippoussis et al. (2001), the higher levels of lignin and cellulose found in mango sawdust could be the reason for this.

The present results on yield (Table 6) were consistent with the study of Timbreza and Arcelona (2004), who reported that acacia sawdust could perform better in the yield of oyster mushrooms than mahogany and gmelina wood sawdust. The experiment of Islam et al. (2009) gave the same observations with the use of mango sawdust because it gave the highest yield response and highest return on investment when compared with mahogany, jackfruit, and coconut sawdust, stating the high potential of mango sawdust substrate for farming *Pleurotus flabellatus*. Since the performance of the 6 substrates was all the same in terms of yield response, the results of this study may suggest that mango and acacia sawdust can be an alternative substrate for cultivating white oyster mushrooms.

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As for biological efficiency, the findings of Islam et al. (2009) that used different types of substrates in *Pleurotus flavelatus* viz, Mango, Jackfruit, Coconut, Jam, Kadom, Mahogony, Shiris sawdust with wheat bran and $CaCO_3$ paralleled the results obtained by using Mango and Acacia sawdust (Table 7). The maximum biological yield per packet was obtained with Mango sawdust (150 gm), followed by Mahogany (148 gm), Shiris (146 gm), Kadom (136 gm), Jam (114 gm), Jackfruit (97 gm), and Coconut sawdust (83 gm). The lowest yield was observed in Coconut sawdust (83 gm).

Chang et al. (2016), which included acacia sawdust in growing oyster mushrooms, demonstrated that sugarcane bagasse and rubber tree sawdust showed similarly high BEs of 60% and 60.8%, respectively, while acacia sawdust showed a relatively low BE of 22.4%. However, it is expected that acacia sawdust has the potential to grow mushrooms when supplemented with the currently used sawdust substrate. The study revealed the same observation because the BE increased when the acacia sawdust was mixed with mango sawdust. Comparing all the hardwood sawdust's biological efficiency, this study determined that only the use of 100% mango sawdust (T2) can produce similar BE results to farmers' practices of rice straw and coco peat.

Nutritional Content of the White Oyster Mushroom Grown in Mango and Acacia Sawdust

The results of Oyetayo et al. (2021) using *Pleurotus pulmonarius* on rice bran and maize stalk substrate fortified with Zn and Fe-produced mushrooms had a lower ash content of 3–4% as compared with the present study's reported ash content of 6.5–7.23%. Similarly, the crude protein recorded in the present study, ranging from 25.90 to 28.27%, was relatively higher than the fortified and Zn and Fe-fortified white oyster mushroom of Oyetayo et al. (2021). In contrast, the results in the crude fiber of this study, from 5.97% to 7.37%, were lower when compared with the same study's 8.0% to 9.4% crude fiber composition. As Akinfemi and Ogunwole (2012) investigated, *Pleurotus pulmonarius* grown in rice straw substrate showed lower crude protein than all the crude proteins of the 5 treatments in the present study. Ash and fiber were also higher in the present study's findings, inferring the hardwood sawdust's potential to have contributed to the mushroom's nutritional content.

Conclusion and Recommendations

Conclusion

From the study's findings, the effectivity of the different mixing ratios of mango and acacia sawdust produced varied responses on the growth, yield, and nutritional composition of the white oyster mushroom. Considering all the parameters and observations, the use of 100% mango sawdust can be the preferred alternative substrate for growing white oyster mushrooms since its performance is better than the mixture of rice straw and coco peat. This was primarily exhibited in the vegetative growth, mushroom cap diameter size, and yield weight. As for the mixing ratios of the different hardwood sawdusts, this study was able to determine that acacia sawdust can improve the growth and yield performance of white oyster mushrooms when it is combined with mango sawdust. But this must be taken cautiously, as further studies are needed to validate these findings.

Recommendations

The present experiment had the following recommendations for future researchers: For those who would like to conduct this kind of study, it is recommended that they try other mixing ratios of mango and acacia sawdust to find out which mixing ratio can provide the optimum yield in the shortest time and the highest number of flushes.

The second recommendation is to put supplement substances like rice bran and fruit peelings, among others, into the wood sawdust to increase the nutrient content that the mushroom will absorb during the growth phase and, therefore, increase the weight of the mature mushroom and increase the pileus diameter.

The third recommendation is to mix the mango and acacia sawdust with other local hardwood sawdust so that a comparison of the local wood substrate may provide important information on its use in the cultivation of the mushroom.

Lastly, in terms of the adaption of the mushroom growers, they should consider the availability of the substrates for their mushroom business and their capacity to produce a yield in the shortest time. Wood sawdust is always available and low-cost. Rice straw's availability varies greatly during the rice cropping season, though it is more expensive than wood sawdust. These factors should be considered before choosing the substrate for mushroom growing.

Implications

The results of the present study may contribute to the growing knowledge of sustainable agricultural waste management, particularly mushroom cultivation from farm waste such as rice straw and agro-forestry wastes like hardwood sawdust. Likewise, the potential of hardwood sawdust in the local production of mushrooms as a cheaper and readily available substrate may help improve the profitability of growing mushrooms among Filipino farmers.

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Author Biographies

Roi Vincent R. Rivera, College of Agriculture, Bulacan Agricultural State College, Bulacan, Philippines.

Gladys M. Manalo, College of Agriculture, Bulacan Agricultural State College, Bulacan, Philippines.

John Paulo R. Villanueva, College of Agriculture, Bulacan Agricultural State College, Bulacan, Philippines.

Johnmike A. Chaneco, College of Agriculture, Bulacan Agricultural State College, Bulacan, Philippines.

Evelyn Q. Alera, College of Agriculture, Bulacan Agricultural State College, Bulacan, Philippines. Email: aleraevelyn@gmail.com