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The Effect of Different Lignocellulose Biomass-based Substrates on the Enhancement of Growth, Yield, and Nutritional Composition of Grey Oyster Mushrooms

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ABSTRACT

The local agricultural industry has produced a lot of biomass waste from agro-based materials, which contain much lignocellulose that can be used as substrates for oyster mushrooms (*Pleurotus ostreatus*) cultivation. This study aims to compare the effect of different lignocellulose biomass-based substrates on oyster mushrooms' growth, yield, and nutritional composition. Three different substrates (cassava peel, sugarcane bagasse, and sawdust) were prepared, and the growth response was observed and measured. The fastest mycelial colonization was achieved from sugarcane bagasse after 29 days of cultivation. Oyster mushrooms grown with sugarcane bagasse substrate showed the highest carbohydrate, fiber, and energy content with 10.70%, 7.70%, and 52.00 kcal, respectively, compared to mushrooms grown with other substrates. The biological efficiency of sugarcane bagasse is also comparable to sawdust. Thus, it can be concluded that sugarcane bagasse has a high potential to be used as an alternative biomass-based substrate for cultivating *P. ostreatus* with enhancement on the growth, yield, and nutritional composition.

Keywords: Cassava peel, *Pleurotus ostreatus*, sawdust, sugarcane bagasse

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INTRODUCTION

Grey oyster mushroom (*Pleurotus ostreatus*), which belongs to the family Pleurotaceae, is widely cultivated in the global market as they contain high protein and carbohydrates,

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multivitamins, minerals, and folic acid that are good for health (Sanchez, 2010). The mineral content of mushrooms, such as calcium, salt, potassium, phosphorus, and folic acid, exceeds that of fish meat, making them a good source for improving bloodstream circulation and preventing anemia (Kalac, 2013). Furthermore, due to the low carbohydrate, calorie, and salt content of mushrooms, they are safe to take by patients with kidney and cardiac problems. Apart from the traditional nutrients, they are also considered functional and valuable for nutraceutical, pharmaceutical, and cosmetic products (Morris et al., 2016). In Malaysia, about 1,000 tonnes of this mushroom is grown annually for the local and export markets (Amin et al., 2014). *Pleurotus ostreatus* possess medicinal values such as antioxidant (Mitra et al., 2013), antibacterial (Vamanu, 2012), antidiabetic (Ghaly et al., 2011), antitumor (Devi et al., 2013), and antihypercholesterolic (Deepalakshmi & Sankaran, 2014) potentials.

In the natural environment, *P. ostreatus* grows on decaying substances, requiring carbon, nitrogen, and micro minerals as their nutritional sources. *Pleurotus* mushroom species are the most efficient species at decomposing a complex lignocellulose substrate from agricultural waste using lignocellulosic enzymes into a simpler compound as their nutrition source (Kumla et al., 2020). *Pleurotus ostreatus* is easy to cultivate and can thrive at various temperatures. Furthermore, they require a short growth time and are less susceptible to diseases and pests (Tesfaw et al., 2015). A high percentage of fruiting bodies harvested from suitable growth substrates will increase profitability using low-cost cultivation technology (Baysal et al., 2003).

Sawdust has become the main substrate in oyster mushroom cultivation (Rizki & Tamai, 2011). The typical lignocellulose components in sawdust are cellulose (39%), hemicellulose (29%), lignin (28%) and ash (4%) (Petchpradab et al., 2009). Although proven as an effective substrate to date, the continual usage of sawdust could potentially contribute to the reduction of wooded areas and might lead to a shortage of the material in the future. Additionally, the high demand for sawdust from rubber palm has caused a spike in its price, which burdened mushroom growers (Marlina et al., 2015). Lignocellulose biomass-based materials from agricultural waste such as cassava peels, sugarcane bagasse, cottonseed hulls, rice, and wheat straws contain high amount of carbon and nitrogen, which makes them suitable candidates for mushroom substrates (Verma et al., 2013). In Malaysia, a vast amount of unused lignocellulose agricultural waste such as cassava peel and sugarcane bagasse are available, and they are frequently thrown in dump sites, burned, or left to decay in the field resulting in environmental pollution (Tesfaw et al., 2015). Cassava is regarded as one of the most commercially important crops in Malaysia, growing either for fresh consumption or for industrial processing as tapioca flour. In cassava processing, a considerable quantities of cassava peel are generated where the thickness of peel is about 1 ± 4 mm and it may consist of 10 to 13% of total dry matter in cassava root (Ezekiel et al., 2010). Cassava peel is high in energy and nutritional value, with a substantial amount of cellulose, hemicellulose and lignin content. It is more suitable for mushroom cultivation substrate than rice and wheat straw since it contains a lower ash concentration (Baah et al., 2011). With a projected boost in cassava production, waste production is expected to rise considerably. Although cassava peels can be used as livestock feed, the large numbers produced and the remoteness of many areas where processing occurs result in a lot of waste.

Sugarcane has been identified as one of the plants with the most excellent bioconversion efficiency of acquiring sunlight via photosynthesis, able to fix approximately 55 tons of dry matter on each hectare of land every year (Betancur & Pereira, 2010). The sugarcane stalk is divided into two parts, an interior pith containing most of the sucrose and an exterior containing lignocellulosic fibers. During the sugar production process, the stalk is pulverized for sucrose extraction and this process generates a substantial amount of residue (around 240 kg of bagasse with 50% moisture per tons of sugarcane) containing pulverized rind and pith fibers (Dias et al., 2009). The bagasse of sugarcane is made up of complex lignocellulose components such as cellulose (33-36%), hemicellulose (28-30%), and ash (4%), which is almost identical to the commercial base medium, sawdust (Betancur & Pereira, 2010). Any lignocellulose-containing agricultural by-product can be utilized as a viable substrate for *P. ostreatus* cultivation.

Utilizing lignocellulose waste for sustainable oyster mushroom cultivation is the best way for waste-to-wealth transformation that can solve an environmental pollution issue caused by agricultural waste and generate high profit from the production of high quality, large quantity, and nutritional oyster mushrooms. Additionally, using agricultural biomass can prevent mushroom growers from spending too much money on purchasing expensive sawdust raw materials. The present study aims to compare the effect of using different agricultural waste materials as substrates on the growth, yield, and nutritional composition of *P. ostreatus* oyster mushrooms.

MATERIALS AND METHODS

Spawn and Lignocellulose Substrates Preparation

Spawn of *P. ostreatus* were obtained from C & C Mushroom Cultivation Farm Sdn. Bhd, Johore, Malaysia. Fresh cassava peel, sugarcane bagasse, and sawdust were obtained from local food processing factories and sawmills in Kelantan, Malaysia. Cassava peels and sugarcane bagasse were cut into smaller pieces, dried, and ground into powder using a grinder. A total of 5 replicates were prepared for each different media using the following formula as described by Fasehah and Shah (2017):

$$\text{Substrate : Rice bran : Calcium carbonate} \quad (100 : 10 : 1) \tag{1}$$

A total of 3 kg of each media was weighed separately and put in a container, followed by the addition of 300 g of rice bran and 30 g of calcium carbonate. The mixture was then mixed thoroughly prior to the addition of water (80%) to the total weight of the mixture. The media was mixed properly until the water was absorbed. After that, the media was placed in a polyethylene bag (6 cm × 12 cm), compressed, and closed with polyvinyl chloride (PVC) necks, which were covered with a cap and sterilized at 100°C for 8 hr in a steamer.

After sterilization, the bags were left to cool down, followed by inoculation with 5 g of the spawn. The inoculated bags were then incubated at room temperature (25°C) for approximately 45 days. After incubation, the bags were shifted to a cropping room, where the bags were placed on a horizontal shelf. The room temperature was maintained at 25°C with 80–85% humidity by spraying water on the floor periodically.

Mycelium Growth and Yield Analysis

The mycelium growth of each substrate (n = 5) was measured every three days starting after the inoculation process until they filled the bags using a measuring tape (Marlina et al., 2015). Four flushes of mushrooms were harvested for each substrate bag. The growth from the inoculation stage to the first harvest and total harvesting time was observed and recorded. The stipe length, thickness, cap diameter, and the number of fruiting bodies from every flush were also measured and recorded. The mushroom's total yield (Y) and biological efficiency (BE) were calculated at the end of the harvesting period. BE refers to the weight (g) of fruiting bodies ratio for each dry weight (g) of substrates, and it was expressed in percentage (C. H. Liang et al., 2019). The equations used to calculate both BE and Y are shown below:

$$BE = \frac{MFW}{SDW} \times 100 \tag{2}$$

$$Y = \frac{MFW}{SDW} \tag{3}$$

where,
MFW = Mushroom fresh weight (g)
SDW = Substrate dry weight (g)

Meanwhile, the analysis for moisture, ash, protein, carbohydrate, dietary fiber, and energy content of mushrooms from each substrate was determined using the method as described by AOAC Method 991.43 (AOAC International, 2005).

Statistical Analysis

The data were subjected to analysis of variance (ANOVA), and the significant differences were determined using Duncan's multiple range test ($p < 0.05$) using SPSS (version 22.0).

RESULTS AND DISCUSSION

Mycelial Growth

Three different substrates, viz. cassava peel, sugarcane bagasse, and sawdust, were investigated to determine the daily growth responses of *P. ostreatus*, and the result is shown in Table 1. No growth was observed during the first two days of inoculation, whereas the first growth was recorded from day three of inoculation for all the tested substrates. There is a significant mycelial growth after 7 days of inoculation with sugarcane bagasse recorded the fastest growth (4.49 ± 0.11 cm), followed by cassava peel (4.28 ± 0.25 cm) and sawdust (4.22 ± 0.07 cm). There is a significant mycelial growth at day 3 of inoculation with sugarcane bagasse recorded the fastest growth (1.84 ± 0.28 cm), followed by cassava peel (1.23 ± 0.10 cm) and sawdust (0.83 ± 0.27 cm). Mycelial growth serves as an essential initial phase in mushroom cultivation as it aids in the colonization of substrate and permit mushroom growers to determine the optimum growth of mushroom (Pokhrel et al., 2013). Additionally, the rapid growth of mushroom mycelium can prevent contamination from other competing bacteria and fungi (Jonathan et al., 2008).

From day 12, sawdust showed the fastest mycelial growth with 5.66 ± 0.02 cm, followed by sugarcane bagasse and cassava peel (5.60 ± 0.11 and 5.49 ± 0.17 cm), respectively. Mycelial growth at day 30 was measured at 10.13 ± 0.03 and 10.12 ± 0.04 cm for sawdust and sugarcane bagasse, respectively. However, cassava peel's slowest mycelial growth was recorded as substrate at 7.79 ± 0.22 cm. Mycelial growth is a preliminary step that creates suitable internal conditions for fruiting. Thus, the outstanding growth of mycelium is a vital factor in mushroom cultivation (Zubairi et al., 2022). Mushroom primarily requires nitrogen for optimal growth. Sawdust contains a high amount

Table 1
Effect of different substrates on mycelial growth of oyster mushrooms

Days of mycelial growth	Cassava peel (cm)	Sugarcane bagasse (cm)	Sawdust (cm)
1	-	-	-
2	-	-	-
3	1.23 ± 0.10[b]	1.84 ± 0.28[a]	0.83 ± 0.27[a]
5	3.11 ± 0.06[a]	3.45 ± 0.07[a]	1.76 ± 0.34[b]
7	4.28 ± 0.25[a]	4.49 ± 0.11[a]	4.22 ± 0.07[a]
12	5.49 ± 0.17[a]	5.60 ± 0.11[a]	5.66 ± 0.02[a]
16	7.08 ± 0.08[b]	6.87 ± 0.31[b]	7.96 ± 0.07[a]
21	7.28 ± 0.03[b]	8.32 ± 0.19[a]	8.43 ± 0.33[a]
25	7.43 ± 0.05[b]	9.53 ± 0.11[a]	9.47 ± 0.09[a]
30	7.79 ± 0.22[b]	10.12 ± 0.04[a]	10.13 ± 0.03[a]

Note. Superscripts with different letters across the rows are significantly different ($p < 0.05$)

of nitrogen (1.68%), which makes it easy for the mycelium to colonize the bag (Tabi et al., 2008). Oyster mushrooms grown on cassava peel showed the slowest colonization due to the low availability of nitrogen in the substrate compared to other substrates (Burns et al., 2012). Nitrogen is a vital element in mushroom growth used in cellular functions and numerous metabolic activities, especially in synthesizing proteins and enzymes. This element is utilized abundantly for mycelial growth during fructification. Generally, the nitrogen content in mycelia is in the range of 3–6%. Thus, nitrogen scarcity in the substrate during the fructification stage could lead to a reduction in the mushroom yield (Upadhyay et al., 2002).

Yield and Physical Characteristics

The colonization period, first harvest day, and morphological characteristics of mushrooms cultivated with different substrates are shown in Table 2. Total colonization of the substrates was completed between 29–51 days of incubation. The day for the first harvest of mushrooms was between 42–64 days, depending on the substrate used. The fastest colonization period (29 ± 0.58 days) and first harvest period (42 ± 0.58 days) were recorded from sugarcane bagasse and sawdust. There were no significant differences recorded for total colonization and the first harvest period for sawdust between sawdust and sugarcane bagasse. However, cassava peel took significantly longer for colonization and first harvest harvest as compared to sugarcane bagasse and sawdust with 51 ± 0.58 and 64 ± 0.58 days, respectively.

There was a significant difference in the cap diameter and stipe thickness of *P. ostreatus* grown on different substrates. The widest cap diameter was 10.10 ± 1.95 cm for sugarcane bagasse substrate, and the smallest was 6.70 ± 0.72 cm from

Table 2

Effect of different substrates on colonization period, first harvest, and morphological characteristics of the fruiting body of the oyster mushroom

Substrate	Total colonization period (day)	First harvest (day)	Cap diameter (cm)	Stipe length (cm)	Stipe thickness (cm)	No. of fruiting bodies	Weight (g)
Cassava peel	50.67 ± 0.58^{a}	64.33 ± 0.58^{a}	6.70 ± 0.72^{b}	11.57 ± 1.17^{ns}	0.80 ± 0.10^{c}	4.67 ± 2.52^{ns}	30.70 ± 6.46^{ns}
Sugarcane bagasse	29.33 ± 0.58^{b}	42.33 ± 0.58^{b}	10.10 ± 1.95^{a}	11.17 ± 2.08^{ns}	1.73 ± 0.25^{a}	5.33 ± 6.66^{ns}	34.20 ± 2.75^{ns}
Sawdust	29.67 ± 0.58^{b}	43.33 ± 0.58^{b}	7.83 ± 0.51^{ab}	11.83 ± 2.89^{ns}	1.23 ± 0.12^{b}	8.33 ± 2.08^{ns}	50.03 ± 5.32^{ns}

Note. Superscripts with different letters within the column are significantly different ($p < 0.05$);
ns = Not significant

P. ostreatus grown with cassava peels. The cap diameter for sawdust was 7.83 ± 0.51 cm and was not significantly different from sugarcane bagasse and cassava peel. The stipe thickness was the highest from sugarcane bagasse with 1.73 ± 0.25 cm, followed by sawdust (1.23 ± 0.12 cm) and cassava peel (0.80 ± 0.10 cm). The thickness measurements significantly differed among all the mushroom samples grown with different substrates. On the contrary, there was no significant difference in stipe length on all the substrates. Our result was different compared to previous study by Elsisura et al. (2022), whom reported 100% sawdust showed the longest stipe (19.45 cm). Mushroom size depends on the types of substrates used. Cellulosic, hemicellulosic, and lignin materials could be a physical barrier that led to the difficulty in breaking them down without lignin-degrading enzymes. Additionally, ecological factors such as compactness or compressibility also play an essential role in affecting the height of the stipe and diameter of the pileus (Sanjel et al., 2021), which explain different stipe lengths obtained from the current and previous study.

The number of fruiting bodies harvested from the different substrates is shown in Figure 1. The highest number of fruiting bodies and mushroom weight were recorded from sawdust with 8.33 ± 2.08 and 50.03 ± 5.32 g, followed by sugarcane bagasse (5.33 ± 6.66 and 34.20 ± 2.75 g) and cassava peel (4.67 ± 2.52 and 30.70 ± 6.46 g), respectively. The differences in both parameters, however, were not statistically significant. Different substrates provide different nutrients composition for mushroom growth. Averagely, sawdust and sugarcane bagasse substrates produced mushrooms with better physical characteristics than cassava peel substrates. It is probably due to the cassava peel's low nitrogen content (Burns et al., 2012), a crucial element in mushroom growth (Naraian et al., 2009). The current finding is supported by S. Ahmed (1998), who emphasized that oyster mushroom growth was best achieved

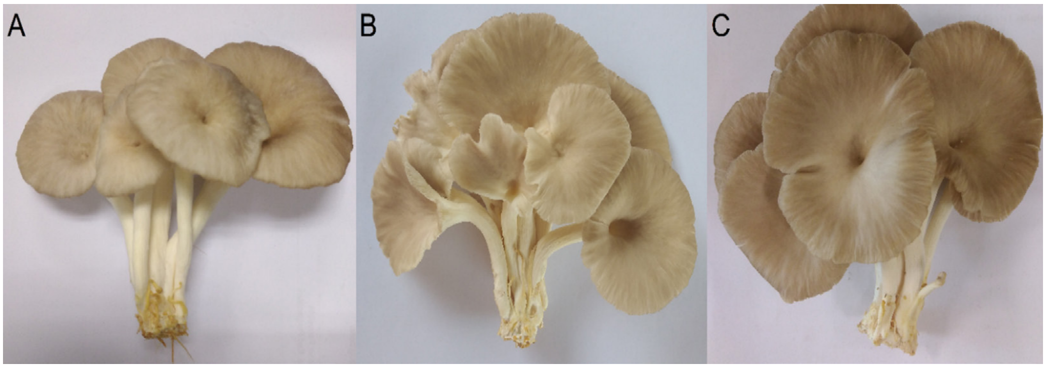

Figure 1. Fruiting bodies of *Pleurotus ostreatus* mushroom grown on different substrates: (A) cassava peels; (B) sugarcane bagasse; and (C) sawdust, respectively

using sawdust and sugarcane bagasse as substrates compared to other agricultural wastes. Sawdust and sugarcane bagasse are lignocellulosic agricultural wastes comprising three major components, lignin, cellulose, and hemicellulose, which could serve as a promising substrate for mushroom cultivation. *Pleurotus* species possess extensive enzyme systems that can degrade complex organic compounds efficiently. The degraded materials would then be utilized to produce mushroom fruiting bodies (Grimm & Wösten, 2018; Sanchez, 2009).

The characteristics of fruiting bodies that were recorded for 5 days prior harvest is shown in Figure 1 whereas the mean growth for mushroom pinhead on different substrates is presented in Table 3. On the first day, there was no significant difference in cap diameter and stipe length between the three substrates cultivated. Stipe thickness for mushrooms grown on sugarcane bagasse was significantly higher compared to cassava peels. There was no significant difference in stipe thickness between cassava peels and sawdust. Cap diameter and stipe thickness for sugarcane bagasse were the highest (8.64 ± 1.49 and 1.60 ± 0.24 cm) on day 3 of pinhead growth. The same parameters were significantly lower in cassava peels, with 5.43 ± 0.60 and 0.63 ± 0.11 cm, respectively. Cap diameter and stipe thickness for mushroom grown on sawdust were not significantly different as compared to sugarcane bagasse. According to Gunde-Cimerman and Cinerman (1995), the diameter range for the oyster mushroom caps is 5 to 25 cm during maturity, and the results obtained in the current study are still within that range. On the other hand, the stipe length of mushrooms grown on all substrates ranged from 9.10 to 9.98 cm, but the difference was insignificant. On day 5 prior to harvesting process,

Table 3
Effect of different substrates on the pinhead growth of oyster mushroom

Time	Substrate	Cap diameter (cm)	Stipe length (cm)	Stipe thickness (cm)
1 day	Cassava peel	1.09 ± 0.06^{d}	4.59 ± 0.43^{c}	0.51 ± 0.17^{c}
	Sugarcane bagasse	1.08 ± 0.52^{d}	4.28 ± 0.52^{c}	1.28 ± 0.27^{ab}
	Sawdust	1.05 ± 0.07^{d}	3.95 ± 0.26^{c}	0.89 ± 0.04^{c}
3 days	Cassava peel	5.43 ± 0.60^{c}	9.44 ± 1.16^{b}	0.63 ± 0.11^{c}
	Sugarcane bagasse	8.64 ± 1.49^{ab}	9.10 ± 2.49^{b}	1.60 ± 0.24^{ab}
	Sawdust	6.38 ± 0.58^{b}	9.98 ± 3.31^{b}	1.16 ± 0.12^{b}
5 days	Cassava peel	6.70 ± 0.72^{b}	11.57 ± 1.17^{a}	0.80 ± 0.10^{b}
	Sugarcane bagasse	10.10 ± 1.95^{a}	11.17 ± 2.08^{a}	1.73 ± 0.25^{a}
	Sawdust	7.83 ± 0.51^{ab}	11.83 ± 2.89^{a}	1.23 ± 0.12^{ab}

Note. Superscripts with different letters within the column are significantly different ($p < 0.05$)

it was observed that sugarcane bagasse and sawdust have significantly larger cap diameter (10.10 ± 1.95 and 7.83 ± 0.51 cm) and stipe thickness (1.73 ± 0.25 and 1.23 ± 0.12 cm), respectively compared to cassava peels. Cassava peels recorded smaller cap diameter and less thickness, with 6.70 ± 0.72 and 0.80 ± 0.10 cm, respectively. The stipe length for mushrooms grown on cassava peel, sugarcane bagasse, and sawdust were 11.57 ± 1.17, 11.17 ± 2.08, and 11.83 ± 2.89 cm, respectively, but the differences were not significant. The fruiting body of the oyster mushroom involving the stipe length, pileus width, and stipe girth varies depending on the types and mixtures of agricultural wastes used as substrates in mushroom cultivation. Different agricultural waste combinations produced different sizes of mushrooms whereas single agricultural waste composition produced uniform sizes (Chukwurah et al., 2013).

For each of the substrates tested in the current study, four flushes mushroom flushes were harvested for each of the substrates tested in the current study, and the result of its yield and BE is shown in Table 4. All substrates produced the highest yield during first flush. The yield was the highest in the first flush of all substrates. The study revealed that the yield for sawdust (131.69 ± 13.25 g) was significantly higher compared with the other two substrates. The mushroom yield was not significantly different between sugarcane bagasse and cassava peels. BE of mushroom cultivated on sawdust (43.87 ± 4.41%) was significantly higher compared to sugarcane bagasse and cassava peels (30.90 ± 1.40% and 26.86 ± 4.05%), respectively. The results of this study were similar to the study conducted by Kortei et al. (2014) and Z. C. Liang et al. (2011). Z. C. Liang et al. (2011) reported BE of oyster mushrooms grown on grass plant stalks ranging from 39.55 to 58.33%, whereas Kortei et al. (2014) reported that BE for oyster mushroom grown on various mixtures of cassava peel substrates were in the range of 26.0–42.4%. BE measures substrate conversion efficiency in mushroom cultivation, representing the ratio of harvested yield to the substrate's dry weight. Depending on the types of agricultural waste

Table 4

Effect of different substrates on yield and biological efficiency (BE) of oyster mushroom

Substrate	1st flush (g/bag)	2nd flush (g/bag)	3rd flush (g/bag)	4th flush (g/bag)	Total yield (g/bag)	BE (%)
Cassava peel	30.70 ± 6.46^{b}	20.56 ± 4.02^{b}	16.49 ± 0.92^{b}	12.87 ± 0.87^{b}	80.62 ± 12.15^{b}	26.86 ± 4.05^{b}
Sugarcane bagasse	34.20 ± 2.75^{b}	22.48 ± 4.33^{b}	18.97 ± 1.89^{b}	17.07 ± 1.74^{a}	92.72 ± 4.19^{b}	30.90 ± 1.40^{b}
Sawdust	50.03 ± 5.32^{a}	36.77 ± 5.67^{a}	25.85 ± 1.15^{a}	19.04 ± 1.27^{a}	131.69 ± 13.25^{a}	43.87 ± 4.41^{a}

Note. Superscripts with different letters within the column are significantly different ($p < 0.05$)

substrate used in mushroom cultivation, the BE percentage varied among the substrate (Girmay et al., 2016).

Nutritional Analysis

The nutritional composition of mushrooms cultivated on different substrates is shown in Table 5. Moisture content is a crucial analysis to determine the mushroom quality. Low moisture can cause textural changes in mushrooms (shrinkage) and loss of weight, which will affect the economic value of the produce. High moisture content will favor microbial growth and discoloration (Singh et al., 2010). The findings revealed that moisture content was significantly higher in sawdust substrates (89.00 ± 0.36%) than in cassava peels and sugarcane bagasse. There was no significant difference between cassava peels and sugarcane bagasse. This result is in line with the study conducted by Hoa et al. (2018), which reported that the moisture content was 86.95–92.45% for substrates containing sugarcane bagasse and sawdust. Similar moisture content (80.00–92.50%) was also reported for *Pleurotus* species grown on different lignocellulose waste (S. A. Ahmed et al., 2009).

Ash content analysis measures the mineral content in the mushrooms (Alam et al., 2007). Ash content plays a significant role in mushrooms' nutritional and physiochemical properties. Thus, determining the ash content is very important to ensure that no hazardous minerals are present in the mushroom and that it is safe to consume. Based on the current study, ash content was significantly lower in sugarcane bagasse with 7.16 ± 0.05% compared to sawdust. Both cassava peels and sawdust showed higher ash content but no significant different. The present result was slightly lower compared to previous study, which reported that ash content for *P. ostreatus* cultivated on different substrates were ranging from 7.32-7.83% (Kortei et al., 2014). On the other hand, our results were higher than previous study by Hoa et al. (2018), which reported ash content ranging from 5.90 to 7.10%.

Table 5

Effect of different substrates on the nutritional composition of oyster mushroom

Substrate	Moisture (%)	Ash (%)	Carbohydrate (%)	Protein (%)	Fat (%)	Fiber (%)	Energy (kcal/100 g)
Cassava peel	87.56 ± 0.27^{b}	7.20 ± 0.02^{ab}	6.40 ± 0.03^{c}	2.90 ± 0.03^{a}	NA	3.30 ± 0.04^{c}	37.00 ± 0.177^{c}
Sugarcane bagasse	88.01 ± 0.48^{b}	7.16 ± 0.05^{b}	10.70 ± 0.06^{a}	2.20 ± 0.02^{c}	NA	7.70 ± 0.02^{a}	52.00 ± 0.17^{a}
Sawdust	89.00 ± 0.36^{a}	7.25 ± 0.02^{a}	9.50 ± 0.08^{b}	2.40 ± 0.04^{b}	NA	5.80 ± 0.02^{b}	48.00 ± 0.26^{b}

Note. Superscripts with different letters within the column are significantly different ($p < 0.05$); NA = Not available

There was a significant difference in the nutritional composition of carbohydrates, protein, fiber, and energy for all mushrooms cultivated with the three substrates. Mushrooms cultivated on sugarcane bagasse showed the highest carbohydrate, fiber, and energy content with 10.70 ± 0.06%, 7.70 ± 0.02%, and 52.00 ± 0.17 kcal/100 g, respectively. On the other hand, protein content in mushrooms grown with cassava peels was significantly highest, at 2.90 ± 0.03%, compared to other substrates. The study indicated that oyster mushrooms grown on different substrates were rich in carbohydrates, fiber, protein, and energy but had very low-fat content, making them excellent for healthy and low-calorie diets. Sugarcane bagasse contains cellulose and sucrose, which are easily absorbed for the growth of oyster mushrooms (Rajapakse et al., 2007). It, in turn, resulted in the high nutrient content of mushrooms grown on the substrate. The result showed lower carbohydrate content in all the tested substrates compared to the study conducted by Sharma et al. (2013) and Sopanrao et al. (2010), with the carbohydrates amount ranging from 30.24–42.26% and 50.50–55.33%, respectively. In another study, carbohydrate, protein, and fiber content in oyster mushrooms grown on rubber sawdust were reported to be 3.54, 4.00, and 17.27%, respectively (Rashidi &Yang, 2016). Mushrooms are a potential source of dietary fiber due to the presence of non-starch polysaccharides. A high-fiber diet can reduce the risk of heart disease and diabetes (Khan et al., 2008). In the present study, it can be suggested that the mushrooms grown with sugarcane bagasse produce high-quality and nutritious fruiting bodies comparable to mushrooms grown with the commercial substrate, sawdust.

CONCLUSION

Determination of chemical and nutrient composition, especially for the substrate used in commercial cultivation of oyster mushrooms, is essential as it affects mycelium colonization and fruiting body development. The results of the present study showed that sugarcane bagasse and cassava peels have the potential to be substitute materials for sawdust in the cultivation of oyster mushrooms. Mycelial colonization was faster on sugarcane bagasse during the first harvest period and the mushroom showed the highest carbohydrate, fiber, and energy content (10.70%, 7.70%, and 52.00 kcal/100 g, respectively). The physical characteristics of mushrooms grown on sugarcane bagasse are also similar to those grown with commercial sawdust substrates. It can be concluded that sugarcane bagasse is a promising alternative substrate for cultivating high-quality oyster mushrooms and can save on the cost of purchasing sawdust. In return, the profit margin of mushroom growers can be increased, and at the same time, it can attract indigenous farmers to venture into the business of mushroom farming by utilizing local agricultural wastes that are available throughout the year.

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REFERENCES

Ahmed, S. (1998). *Performance of different substrates on the growth and yield of oyster mushroom* Pleurotus sajorcaju *(Fr.) Sing*. [Unpublished Master's Thesis]. Bangabandhu Sheikh Mujibur Rahman Agricultural University.

Ahmed, S. A., Kadam, J. A., Mane, V. P., Patil, S. S., & Baig, M. M. V. (2009). Biological efficiency and nutritional contents of *Pleurotus florida* (Mont.) Singer cultivated on different agro-wastes. *Nature and Science*, *7*(1), 44-48.

Alam, N., Khan, A., Hossain, M., Amin, S. R., & Khan, L. A. (2007). Nutritional analysis of dietary mushroom *Pleurotus florida* Eger and *Pleurotus sajor-caju* (Fr.) Singer. *Bangladesh Journal of Mushroom*, *1*(2), 1-7.

Amin, M. Z. M., Harun, A., & Wahab, M. A. M. A. (2014). Status and potential of mushroom industry in Malaysia. *Economic and Technology Management Review*, *9*(2014), 103-111.

AOAC International. (2005). *AOAC Official Method 991.43: Total, soluble, and insoluble dietary fiber in foods*. AOAC International.

Baah, J., Tait, R. M., & Tuah, A. K. (2011). Selecting browse plants to supplement cassava peel-based diet for peri-urban small ruminants. *Small Ruminant Research*, *96*(1), 36-40. https://doi.org/10.1016/j.smallrumres.2010.11.006

Baysal, E., Peker, H., Yalinkiliç, M. K., & Temiz, A. (2003). Cultivation of oyster mushroom on waste paper with some added supplementary materials. *Bioresource Technology*, *89*(1), 95-97. https://doi.org/10.1016/s0960-8524(03)00028-2

Betancur, G. J. V., & Pereira, Jr. N. (2010). Sugarcane bagasse as feedstock for second generation ethanol production. Part I: diluted acid pretreatment optimization. *Electronic Journal of Biotechnology*, *13*(3), 1–9. https://doi.org/10.2225/vol13-issue3-fulltext-3

Burns, A. E., Gleadow, R. M., Zacarias, A. M., Cuambe, C. E., Miller, R. E., & Cavagnaro, T. R. (2012). Variations in the chemical composition of cassava (*Manihot esculenta* Crantz) leaves and roots as affected by genotypic and environmental variation. *Journal of Agricultural and Food Chemistry*, *60*(19), 4946-4956. https://doi.org/10.1021/jf2047288

Chukwurah, N. F., Eze, S. C., Chiejina, N. V., Onyeonagu, C. C., Okezie, C. E. A., Ugwuoke, K., Ugwu, F. S. O., Aruah, C. B., Akobueze, E. U., & Nkwonta, C. G. (2013). Correlation of stipe length, pileus width and stipe girthof oyster mushroom (*Pleurotus ostreatus*) grown indifferent farm substrates. *Journal of Agricultural Biotechnology and Sustainable Development*, *5*(3), 54-60. https://doi.org/10.5897/jabsd12.20

Deepalakshmi, K., & Sankaran, M. (2014). *Pleurotus ostreatus*: An oyster mushroom with nutritional and medicinal properties. *Journal of Biochemical Technology*, *5*(2), 718-726.

Devi, K. S. P., Roy, B., Patra, P., Sahoo, B., Islam, S. S., & Maiti, T. K. (2013). Characterization and lectin microarray of an immunomodulatory heteroglucan from *Pleurotus ostreatus* mycelia. *Carbohydrate Polymers*, *94*(2), 857-865. https://doi.10.1016/j.carbpol.2013.02.017

Dias, M. O. S., Ensinas, A. V., Nebra, S. A., Maciel Filho, R., Rossell, C. E. V., & Maciel, M. R. W. (2009). Production of bioethanol and other bio-based materials from sugarcane bagasse: Integration to conventional bioethanol production process. *Chemical Engineering Research and Design*, 87(9), 1206–1216. https://doi.org/10.1016/j.cherd.2009.06.020

Elsisura, I. B., Amor, M., & Figueroa, G. (2022). Growth and yield performance of oyster mushroom cultivated in combined cassava peels, coconut residue and coffee waste substrates. *American Journal of Environment and Climate*, *1*(1), 1-11. https://doi.org/10.54536/ajec.v1i1.206

Ezekiel, O.O., Aworh, O.C., Blaschek, H.P., & Ezeji, T.C. (2010). Protein enrichment of cassava peel by submerged fermentation with *Trichoderma viride* (ATCC 36316). *African Journal of Biotechnology*, *9*(12), 187-194.

Fasehah, S. N., & Shah, A. (2017). Effect of using various substrates on cultivation of *Pleurotus sajor-caju*. *Journal of Engineering Science and Technology*, *12*(4), 1104-1110.

Ghaly, I. S., Ahmed, E. S., Booles, H. F., Farag, I. M., & Nada, S. A. (2011). Evaluation of antihyperglycemic action of oyster mushroom (*Pleurotus ostreatus*) and its effect on DNA damage, chromosome aberrations and sperm abnormalities in streptozotocin-induced diabetic rats. *Global Veterinaria*, *7*(6), 532-544.

Girmay, Z., Gorems, W., Birhanu, G., & Solomon, Z. (2016). Growth and yield performance of *Pleurotus ostreatus* (Jacq. Fr.) Kumm (oyster mushroom) on different substrates. *AMB Express*, *6*, 87. https://doi.org/10.1186/s13568-016-0265-1

Grimm, D., & Wösten, H. A. B. (2018). Mushroom cultivation in the circular economy. *Applied Microbiology and Biotechnology*, *102*, 7795-7803. https://doi.org/10.1007/s00253-018-9226-8

Gunde-Cimerman, N., & Cinerman, A. (1995). *Pleurotus* fruiting bodies contain the inhibitor of 3-hydroxy-3-methylglutaryl-coenzyme A reductase-lovastatin. *Experimental Mycology*, *19*(1), 1-6. https://doi.org/10.1006/emyc.1995.1001

Hoa, H. T., Wang, C. L., & Wang, C. H. (2018). 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

Jonathan, S. G., Fasidi, I. O., Ajayi, A. O., & Adegeye, O. (2008). Biodegradation of Nigerian wood wastes by *Pleurotus tuber-regium* (Fries) Singer. *Bioresource Technology*, *99*(4), 807-811. https://doi.org/10.1016/j.biortech.2007.01.005

Kalac, P. (2013). A review of chemical composition and nutritional value of wild-growing and cultivated mushrooms. *Journal of the Science of Food and Agriculture*, *93*(2), 209-218. https://doi:10.1002/jsfa.5960

Khan, M. A., Amin, S. R., Uddin, M. N., Tania, M., & Alam, N. (2008). Comparative study of the nutritional composition of oyster mushrooms cultivated in Bangladesh. *Bangladesh Journal of Mushroom*, *2*(1), 9-14.

Kortei, N. K., Dzogbefia, V. P., & Obodai, M. (2014). Assessing the effect of composting cassava peel based substrates on the yield, nutritional quality, and physical characteristics of *Pleurotus ostreatus* (Jacq. ex Fr.) Kummer. *Biotechnology Research International*, *2014*, 571520. https://doi.org.10.1155/2014/571520

Kumla, J., Suwannarach, N., Sujarit, K., Penkhrue, W., Kakumyan, P., Jatuwong, K., Vadthanarat, S., and Lumyong, S. (2020). Cultivation of mushrooms and their lignocellulolytic enzyme production through the utilization of agro-industrial waste. *Molecules*, *25*(12), 2811-2852. https://doi: 10.3390/molecules25122811

Liang, C. H., Wu, C. Y., Lu, P. L., Kuo, Y. C., & Liang, Z. C. (2019). *Auricularia* cultivated on a sawdust basal substrate supplement with different proportions of grass plants. *Saudi Journal of Biological Sciences*, *26*(2), 263-269. https://doi.org/10.1016/j.sjbs.2016.10.017

Liang, Z. C., Wu, K. J., Wang, J. C., Lin, C. H., & Wu, C. Y. (2011). Cultivation of the culinary-medicinal lung oyster mushroom, *Pleurotus* *pulmonarius* (Fr.) Quél. (Agaricomycetideae) on grass plants in Taiwan. *International Journal of Medicinal Mushrooms*, *13*(2), 193-199. https://doi.org/10.1615/intjmedmushr.v13.i2.120

Marlina, L., Sukotjo, S., & Marsudi, S. (2015). Potential of oil palm empty fruit bunch (EFB) as media for oyster mushroom, *Pleurotus ostreatus* cultivation. *Procedia Chemistry*, *16*, 427-431. https://doi.org/10.1016/j.proche.2015.12.074

Mitra, P., Khatua, S. O., & Acharya, K. (2013). Free radical scavenging and NOS activation properties of water soluble crude polysaccharide from *Pleurotus ostreatus*. *Asian Journal of Pharmaceutical and Clinical Research*, *6*(3), 67-70.

Morris, H. J., Llauradó, G., Beltrán, Y., Lebeque, Y., Bermúdez, R. C., García, N., & Moukha, S. (2016). *The use of mushrooms in the development of functional foods, drugs, and nutraceuticals*. In I. C. F. R. Ferreira, P. Morales, & L. Barros (Eds.), *Wild plants, mushrooms and nuts: Functional food properties and applications* (pp. 123-157). John Wiley & Sons, Ltd. https://doi.org/10.1002/9781118944653.ch5

Naraian, R., Sahu, R. K., Kumar, S., & Garg, S. K. (2009). Influence of different nitrogen rich supplements during cultivation of *Pleurotus florida* on corn cob substrate. *Environmentalist*, *29*, 1–7. https://doi.org/10.1007/s10669-008-9174-4

Petchpradab, P., Yoshida, T., Charinpanitkul, T., & Matsumura, Y. (2009). Hydrothermal pretreatment of rubber wood for the saccharification process. *Industrial and Engineering Chemistry Research, 48*(9), 4587-4591. https://doi.org/10.1021/ie801314h

Pokhrel, C. P., Kalyan, N., Budathoki, U., & Yadav, R. K. P. (2013). Cultivation of *Pleurotus sajor-caju* using different agricultural residues. *International Journal of Agricultural Policy and Research*, *1*(2), 19-23.

Rajapakse, J. C., Rubasingha, P., & Dissanayake, N. N. (2007). The effect of six substrates on the growth and yield of American oyster mushrooms based on juncao technology. *Journal of Agricultural Sciences - Sri Lanka*, *3*(2), 82–85. http://doi.org/10.4038/jas.v3i2.8105

Rashidi, A. M., & Yang, T. A. (2016). Nutritional and antioxidant values of oyster mushroom (*P. sajor-caju*) cultivated on rubber sawdust. *International Journal on Advanced Science, Engineering and Information Technology*, *6*(2), 161-164. https://doi.org.10.18517/ijaseit.6.2.610

Rizki, M., & Tamai, Y. (2011). Effects of different nitrogen rich substrates and their combination to the yield performance of oyster mushroom (*Pleurotus ostreatus*). *World Journal of Microbiology and Biotechnology*, *27*(7), 1695-1702. https://doi.org/10.1007/s11274-010-0624-z

Sanchez, C. (2009). Lignocellulosic residues: Biodegradation and bioconversion by fungi. *Biotechnology Advances*, *27*(2), 85–194. https://doi.org/10.1016/j.biotechadv.2008.11.001

Sanchez, C. (2010). Cultivation of *Pleurotus ostreatus* and other edible mushrooms. *Applied Microbiology and Biotechnology*, *85*(5), 1321-1337. https://doi.org/10.1007/s00253-009-2343-7.

Sanjel, P., Shrestha, R. K., & Shrestha, J. (2021). Performance of oyster mushroom (*Pleurotus ostreatus*) grown on different finger millet husk substrates. *Journal of Agriculture and Natural Resources*, *4*(1), 291–300. https://doi.org/10.3126/janr.v4i1.33370

Sharma, S., Yadav, R. K. P., & Pokhrel, C. P. (2013). Growth and yield of oyster mushroom (*Pleurotus ostreatus*) on different substrates. *Journal on New Biological Reports*, *8*(2), 1-8. https://doi.org.10.38112/agw.2020.v08i01.001

Singh, P., Langowski, H. C., Wani, A. A., & Saengerlaub, S. (2010). Recent advances in extending the shelf life of fresh *Agaricus* mushrooms: A review. *Journal of the Science of Food and Agriculture*, *90*(9), 1393-1402. https://doi.org/10.1002/jsfa.3971

Sopanrao, P. S., Abrar, A. S., Manoharrao, T. S., & Vaseem, B. M. M. (2010). The nutritional value of *Pleurotus ostreatus* (Jacq: Fr) Kumm cultivated on different lignocellulosic agrowastes. *Innovative Romanian Food Biotechnology*, *7*, 66-76.

Tabi, A. N. M., Zakil, F. A., Fauzai, W. N. F. M., Ali, N., & Hassan, O. (2008). The usage of empty fruit bunch (EFB) and palm pressed fibre (PPF) as substrates for the cultivation of *Pleurotus ostreatus*. *Jurnal Teknologi*, *49*, 189-196.

Tesfaw, A., Tadesse, A., & Kiros, G. (2015). Optimization of oyster (*Pleurotus ostreatus*) mushroom cultivation using locally available substrates and materials in Debre Berhan, Ethiopia. *Journal of Applied Biology and Biotechnology*, *3*(1), 15-20. https://doi.org/10.7324/jabb.2015.3103

Upadhyay, R. C., Verma, R.N., Singh, S. K., & Yadav, M. C. (2002). Effect of organic nitrogen supplementation in *Pleurotus* species. *Mushroom Biology and Mushroom Products*, *105*(3), 225-232.

Vamanu, E. (2012). *In vitro* antimicrobial and antioxidant activities of ethanolic extract of lyophilized mycelium of *Pleurotus ostreatus* PQMZ91109. *Molecules*, *17*(4), 3653-3671. https://doi.org.10.3390/molecules17043653

Verma, A., Singh, A., & Mathur, N. (2013). Bioremediation of environmental and agricultural lignocellulosic waste through mushroom cultivation. *International Journal of Chemical Science*, *11*(1), 399-409.

Zubairi, S. I., Zabidi, N. A. S. M., Azman, Z. Z., Kamaruddin, S. N. D. M., Kasim, Z. M. K., Lazim, A. M., Nurzahim, Z., & Jamil, M. S. M. (2022). *Pleurotus ostreatus* cultivation: Physico-chemical characteristics of a robust preblocks oyster mushroom substrate with absorptive starch binders. *Sains Malaysiana*, *51*(2), 329-343. http://doi.org/10.17576/jsm-2022-5102-01