GROWTH AND YIELD OF BLACK OYSTER MUSHROOM (*Pleurotus ostreatus*) ON COMBINED COCONUT SAWDUST AND RICE STRAW AS LIGNOCELLULOSIC MATERIALS

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Abstract — The study was conducted to evaluate the growth and yield of *Pleurotus ostreatus* black strain on locally available substrates and to identify the most suitable substrates for black oyster mushrooms from November 2020 to February 2021. Completely Randomized Design (CRD) was followed in the study with five treatments replicated ten times. ANOVA and LSD were further used to test the difference between treatment means and data were analysed using STAR. Results showed that the shortest duration of the spawn run was on 100% rice straw at 18.40 days and the longest on 100% coconut sawdust and 75% coconut sawdust + 25% rice straw at 20.40 days. Primordia formed earlier on 100% rice straw at 7.90 days and the longest duration was observed in 50% coconut sawdust + 50% rice straw at 22.90 days. The full development of fruiting bodies was the same in all treatments, ranging from 3.10 to 3.28 days between flushes. The highest yield of mushrooms was observed in 75% coconut sawdust +25% rice straw at 6,119 grams and the lowest yield was obtained by 100% rice straw with 3,914 grams. Biological efficiency in black oyster mushroom *P. ostreatus* ranges from 39.14% to 61.19%. Higher ROI was recorded in 75% coconut sawdust +25% rice straw with 259.94%.

Keywords **— Biological efficiency, fruiting bodies, lignocellulosic, mycelia, spawn**

INTRODUCTION

Mushroom cultivation is a useful method of environmental waste management and waste disposal. Many agricultural and industrial by-products find uses in mushroom production (Wang and Suzuki, 2001). Mushroom has been recognized internationally as food, contributing to ameliorating the protein malnutrition of countries that are normally cereal dependent. Mushrooms used for food, medicinal and dietary supplement produce high quality and economic value to the world's mushroom market. Generally, edible mushrooms process three essential values for good food- nutrition, taste, and psychological functions (Chang, 2007).

The cultivation of oyster mushrooms with agricultural residues, such as rice straw, corn cobs, wood sawdust, etc. is a value-added process to convert these materials into human food (Pokhrel et al., 2013). It represents one of the most efficient biological ways by which these residues can be recycled (Madan et al., 1987). Mushroom cultivation not only helps to reduce protein deficiency, especially in developing countries but also increases the income of rural poor people (Sharma et al., 2013).

Mushroom cultivation can be a big source of income through rural development programs for farmers if they are made aware of its cultivation process and its importance. By taking into consideration the drought, food, and nutrition security problems in some countries, mushroom production could be an alternative source to overcome these problems. In addition, a livelihood can be improved because the demand for mushrooms has been increasing due to increasing population, market expansions, and changing consumer behavior (Celik & Pekker, 2009). The raw materials that can be applied for oyster mushroom cultivation are cheaply available in farmer's yards and easily cultivated in various climatic conditions as fast maturing crops.

The cultivation of black oysters is new in the Bicol Region; hence, the available agricultural wastes in the region must be explored for growing black oyster mushrooms. These mushroom species are known to thrive between temperatures ranging from 20 to 300 ^{o}C and humidity 55-70% for 5 months. Thus, the objectives of this study are to evaluate the growth and yield of *Pleurotus ostreatus* on combined coconut sawdust and rice straw substrates and to identify the most suitable substrates for black oyster mushrooms.

MATERIALS AND METHODS

Experimental Site

The study was conducted at Decena Compound at Zone 3 Railroad Side Concepcion Pequeña, Naga City. The mushroom growing room was made of semi-concrete materials with a cement foundation and, metal roofing, and the walls are made of galvanized flat sheets.

Mushroom Species

The study used oyster mushroom *P. ostreatus* black strain and the spawn was purchased from Rand John Mushroom Farm. A Filipino Citizen that visited Thailand brought the mushroom spawn and propagated in the Philippines for business purposes. The Mushroom Farm is located at Sta. Ana, San Mateo Rizal.

Experimental Design and Treatments

The study was laid out in a Completely Randomized Design (CRD). There were five treatments replicated ten times making a total of 50 bags or experimental units. The substrates used for the cultivation of black oyster mushrooms were coconut sawdust and rice straw with different combination treatments. These treatments were the following:

T1 = 100% coconut sawdust
T2 = 75% coconut sawdust & 25% rice straw

T3 = 50% coconut sawdust & 50% rice straw
T4 = 25% coconut sawdust & 75% rice straw
T5 = 100% rice straw

Substrate Collection

The different substrates were collected from different sources. The rice straw and coconut sawdust were collected from a local farm and coco lumber shop in Naga City, Camarines Sur.

Substrates Preparation

Rice straws were cut into small pieces that ranged in length from 2 to 4 cm, and they were soaked in fresh tap water overnight. The following day, the water was drained and straws were cleaned three to four more times in clean water until the water was clear. The excess water was drained until the required 65–75% moisture level was reached, then it was removed following the method used by Watanabe (2019). The rice straw was chopped into 1- to 2-inch long pieces using a machine and soaked in water for 5 to 15 minutes. After soaking, the rice straw was spread out on a plastic sheet that was laid on a surface on an inclined position and allowed to drain overnight. After draining, the moisture content was adjusted so that free water is generated when the straw is lightly grasped (65 to 75%). The weight of the rice straw at this moisture content was 2.6 to 2.8 times the dry weight. If the moisture content is 75% or higher, water will pool on the bottom of incubation bags, causing mycelial growth to slow.

The study used partially dried coconut sawdust and the preparation started with the physical removal of impurities like chips, plastics, leaves of plants, and other organic materials that might cause contamination. Afterward, rice straw was added to the coconut sawdust following the proportion of different treatments, mixed thoroughly, and stored in sacks for fourteen days of decomposition.

Preparation of Fruiting Bags

Polypropylene bags measuring 8'' x 14'' was used and filled with substrates. Each fruiting bag was filled with 1 kg of substrates and secured with a rubber band.

Pasteurization

Clean water was poured inside the drum to about 4-6 inches deep. After which, a perforated round tin plates was placed, supported by a stand. Then, the fruiting bags were placed layer by layer. The top opening of the drum was covered with thick clear plastic and secured with rubber. The fruiting bags were pasteurized for 6 to 8 hours at 70-80 ºC to kill insects and microorganisms. After pasteurization, the substrates were cooled down to about 25 ºC.

Inoculation/Spawning

Grain spawn was aseptically inoculated into the pasteurized bags. On top of the substrates, 14 grams of spawn was applied. The bag's mouth was firmly banded with a rubber band after being filled with spawn.

Incubation

The spawned bags were incubated in a dark, well-ventilated room until the mycelium had completely reached the substrate's base. The cotton plug on the fruiting bag's mouth was carefully removed once the entire bag was fully colonized with white mycelium. To keep the room's temperature below 30 °C and relative humidity range from 80 - 85 %, using a spray bottle regular watering was done at 7:30 am, 12:30 pm, and 4:00 pm. A little light was allowed to penetrate the room during this phase to aid in the growth of fruiting bodies.

To start mycelial growth, inoculation bags were placed in a dark locker following Chang and Miles (2004) methods. Parts of the bags were cut off to make perforations to aid in the formation of fruiting bodies after mycelial growth in the bags grew numerous and/or pinheads started to emerge. Substrates that were fully colonized were then moved to the growing chamber and arranged on racks with a spacing of 15-20 cm composed of wood and nylon rope. To keep the mycelia moist, inoculated bags were irrigated two to three times daily. Using a thermo-hygrometer to measure and maintain relative humidity (RH) and room temperature, RH was periodically kept between 80 and 85% by misting the air with a fine mist of water (Oei, 2003).

Harvesting

Mushroom was picked before the edges started to curl. It was harvested by delicately twisting the stalks and pulling them out, leaving no stalk behind or damaging the tiny fruiting bodies. By scraping with a knife, the base of the stipe that was adhered to the substrate was eliminated. The parameters were recorded when the collected mushroom was weighed. Biological efficiency was also determined by weighing the used substrates.

Data Gathered and Analysis

All data were recorded periodically during the growing season from colonization to harvesting.

- **Average Spawn Run.** Obtained by counting the number of days from spawning until 100% colonization of substrates by mushroom mycelia.
- **Average Duration of Primordia Formation.** Obtained by counting the number of days from colonization until the appearance of primordia.
- **Average Duration of Fruit Body Development.** Obtained by counting the number of days from the appearance of primordia until mushrooms were ready for harvesting.
- **The number of Flushes and Flushes Interval.** Obtained by counting the frequency of harvest and the interval (days) between harvests.
- **Mushroom Yield.** Obtained by getting the weight of freshly harvested mushrooms per treatment.
- **Biological Efficiency (BE).** Mushrooms can convert waste materials into highly valuable food (Wang et al., 2001). It is calculated using the formula:

Biological efficiency (%)

$$\%BE = \frac{FWm}{DWs} \times 100\%$$

where: **%BE** - Percentage of Biological efficiency
FWm - Fresh weight of mushroom
DWs - Dry weight of substrate

Cost and Return Analysis

This was computed to determine the profitability of mushroom cultivation.

Return on Investment

This was taken using the formula:

$$ROI = \frac{\text{Net Income}}{\text{Cost of Production}} \times 100$$

Analysis of Variance (ANOVA) was used in the analysis of the data. The Least Significant Difference (LSD) was further used to test the difference between treatment means and to determine which of the combination of the substrate exerted a positive effect on a black oyster mushroom. The data were computed using the Statistical Tool for Agricultural Research (STAR).

RESULTS AND DISCUSSION

Spawn Run

Spawn run determined the period from spawning until the appearance of white mycelia and complete colonization of substrates (Figure 1). As shown in Table 1, the fastest spawn running took place on 100% rice straw with an average of 18.40 days which is significantly (<0.005), different from other treatments, except 25% coconut sawdust +75% rice straw with no significant difference at 18.60 days. It was followed by 50% coconut sawdust +50% rice straw within 19.50 days. The longest spawn running was recorded on 100% coconut sawdust and 75% coconut sawdust +25% rice straw for 20.40 days

Figure 1. Bags fully colonized with white mycelia.

This duration of spawn running was similar to the findings of Stanley (2010) on *P. ostreatus*, that the spawn run on rice straw took place from 16-25 days and sawdust at 20-40 days. Substrates' structure is important because it aided mycelium penetration. Since the substrates for mushroom development contain carbohydrates, rice straw is frequently employed. The outcome was comparable to that reported by Iqbal et al. (2016), who noted that wheat, rice, maize, sugarcane bagasse, and sorghum straw encouraged the mushroom's good development and quick mycelial extension. Mycelium penetration depends in part on the substrate's structure. Due to the efficient use of the substrates' carbohydrates, straw substrates exhibit a higher rate of mycelium growth than other substrates. Rice straw has been used for the cultivation of oyster mushrooms since the beginning of the 19th century and it has been cultivated in many countries under natural conditions. Quimio (2002) found that oyster mushrooms are suited throughout the third world in areas that are rich in plant wastes such as sawdust, sugarcane bagasse, and others which can be used as substrates.

Spawn running duration was affected by the chemical characteristics of the substrates used. Table 1 showed that the fastest spawn running was recorded in 100% rice straw which contains micronutrients need by oyster mushrooms. Rice straw contains higher quantities of potassium (1.58% of DM), calcium (0.53%), and magnesium (0.24%). But it was low in phosphorus (0.12%), sodium (0.13%), iron (0.07%), and manganese (0.07%), (Shen et al., 1998 and Chivenge, P. et al., 2020). Similar to the study of the Japan Institute of Energy (2002), which reported that rice straw contains 38% cellulose, 25% hemicellulose, and 12% lignin, which is needed in the cultivation of oyster mushroom. The slowest spawn running was recorded in 100% coconut sawdust and 75% coconut sawdust +25% rice straw. The delay of spawn running in combined coconut sawdust and rice straw was affected by the physical properties of sawdust. The higher concentration of sawdust the slower the spawn running. The penetration of mycelia was much slower compared to the rice straw alone. This could also be due to the compactness of the substrate as also reported by Stamets (2005). The result was similar to the study of De Villa (2017), who reported that due to the physical structure of sawdust the penetration of mycelia was delayed by its compactness in a particular strain of *Pleurotus sp*.

Primordial Formation

The earliest appearance of young fruiting bodies after full colonization of substrates was observed in 100% rice straw at 7.90 days as shown in (Table 1), 25% coconut sawdust + 75% rice straw ranked 2nd at 18.60 days, 75% coconut sawdust + 25% rice straw ranked 3rd at 20.80 days and 100% coconut sawdust ranked 4th at 21.90 days. The longest duration was observed in 50% coconut sawdust + 50% rice straw which took almost 22.90 days before the primordia appeared on the substrates. According to statistical analysis, the primordial formation was extremely significant (<0.005).

Table 1. The average number of days of spawn run, primordia formation, and fruit body development of *P. ostreatus* on various substrates.

TREATMENTS	SPAWN RUN	PRIMORDIAL FORMATION	FRUIT BODY DEVELOPMENT
T1 - 100% CSD	20.40a	21.90ab	3.10a
T2 - 75% CSD 25% RS	20.40a	20.80ab	3.28a
T3 - 50% CSD 50% RS	19.50b	22.90a	3.16a
T4 - 25% CSD 75% RS	18.60c	18.60b	3.12a
T5 - 100% RS	18.40c	7.90c	3.18a
Pr (> F)	0.0001	0.002	0.5814

Note: Means with the same letter are not significantly different.

There were no significant (>0.005), differences observed in the appearance of primordia between 100% coconut sawdust, 75% coconut sawdust +25% rice straw, however, 100% rice straw, 50% coconut sawdust +50% rice straw, and 75% rice straw +25% coconut sawdust were not significantly different (<0.005). The relative humidity within the mushroom growing house ranged from 40% to 43%, while the average temperature during November was between 29.7°C and 30°C. *P. ostreatus* mycelia and primordia require an average temperature of 25°C and a relative humidity range of 70 to 80% for growth. This particular mushroom species needs low temperatures (Poope, 1995).

The walling structure of the mushroom growing house was made of galvanized flat sheet which absorbs and retains a higher amount of heat inside the growing house, which the temperature inside of the mushroom growing house was not favourable for the formation of primordia on 100% coconut sawdust, 75% coconut sawdust +25% rice straw and 50% coconut sawdust +50% rice straw (Figure 2).

The 100% rice straw was favored on its development, similar to the study of Beausejour (1999). The delayed development of primordia could be attributed to the high temperature and low humidity of the mushroom house. The relative humidity of the mushroom growing room was increased by spraying water on the walls and placing open containers filled with water in the corners of the room. The result was similar to the findings of Kab-Yeul et al. (2003), that high temperature and low relative humidity have a higher impact on the growth and development of primordia.

Figure 2. Mushroom growing house.

Fruit Body Development

This period was determined from the appearance of primordia until mushrooms were ready for harvest. Formation of the fruiting body was observed from the first to fifth flushes. As shown in Table 1, 100% coconut sawdust was the earliest to form a fruiting body at 3.10 days followed by 25% coconut sawdust +75% rice straw at 3.12 days, 50% coconut sawdust + 50% rice straw at 3.16 days, 100% rice straw at 3.18 days and 75% coconut sawdust +25% rice straw at 3.28 days. Statistical analysis showed that there was no significant (>0.5841), the difference observed in all treatments was not significant (>0.5841).

Fruiting bodies were observed in all treatments within 3.10 – 3.28 days from primordia formation.

The results were almost similar to the findings of Hassan et al. (2014), which recorded the duration from primordial to fruit body of 1 to 4 days in the case of Pleurotus sp. From inoculation to fruiting body development it would take about 29 – 44 days for all treatments to form fruiting bodies. The duration of fruit body development was almost the same from the first observation until the fifth observation and the formation of fruiting bodies range from 29 - 44 days after inoculation of spawn. Pokhrel et al. (2013), also reported that the formation of fruiting bodies was 32 - 44 days after inoculation of spawn, which is also observed in this experiment.

Characteristics of fruiting bodies in different substrates

This study observed that the formation and growth of fruiting bodies are sensitive to environmental conditions, such as temperature, humidity, and air exchange inside the mushroom growing house (Figure 3). The growth and development of the *P. ostreatus* fruiting bodies were reportedly compromised and suspended as a result of their sensitivity to humidity and temperature conditions (Aghajani et al., 2018). Improper balance of these factors can induce fruiting body deformations (Figure 4).

According to Chang and Miles (2004), improper environmental conditions and the nutrient content of substrates affect the growth and formation of fruit bodies of *Pleurotus* species.

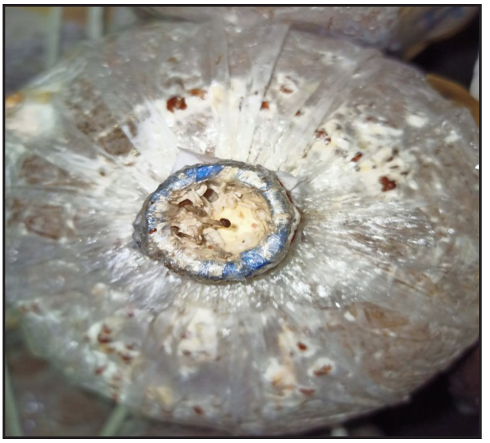

Figure 3. Suspended growth of fruiting bodies due to high temperature and low relative humidity.

Figure 4. Twisted fruiting bodies due to high temperature and low relative humidity.

The amount of light present in the growing house had an impact on the pileus' color; prolonged exposure to light will alter its appearance (Figure 5). Due to low light exposure, treatment with 25% coconut sawdust +75% rice straw results in a deeper black color for the pileus, while 100% coconut sawdust, 50% coconut sawdust +50% rice straw, and 75% coconut sawdust +25% rice straw produced pale black results and 100% rice straw produced the same results in terms of color.

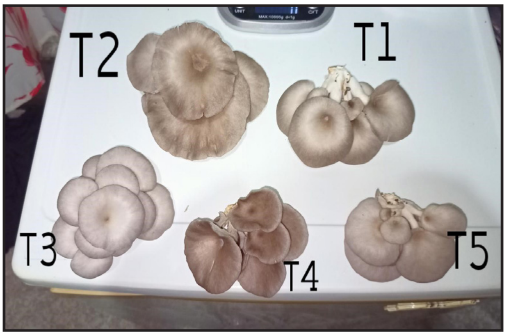

Figure 5. Harvested black oyster mushrooms showed a variation of caps.

Similar to the study of Eira and Bueno, (2005), who reported that the bright white color of the cap (pileus) of *Pleurotus spp*. can be changed to dark and opaque in the presence of light, due to phenol oxidase release that oxidizes phenols, forming melanoidins.

Stipe length and pileus diameter of oyster mushrooms grown in different substrates depend on the structure, compactness, and physical properties of the substrate which in turn depends on the type of substrate. The substrates with higher moisture-retaining capacity perform better than those with lower moisture-retaining capacity (Chukwurah et al., 2013). Fruit bodies with larger pileus (caps) and shorter stipes (stalk) are better than those with smaller pileus and longer stipes (Synytsya et al., 2008).

According to Urben (2004) and Marino et al. (2003). environments that have a lot of light can cause paleness, deformations, elongated stipe, and reduction of pileus coloration. According to Kues and Liu (2000), whenever tested, the active wavelengths that control fruiting body initiation and maturation were found to be in the blue light/UV range. In the complete absence of light, oyster mushrooms will form no cap but stipes (mushroom stalks) forming a coral-like structure (Oei and Nieuwenhuijzen, 2005).

Flush and Flush Interval

Mushroom flush is the period from the first harvest until the succeeding appearance of fruiting bodies. The result was presented in Table 2. An average of five flushes was recorded on all substrates. The fastest days of the interval were found on 100% coconut sawdust at 11.72 days, 50% coconut sawdust + 50% rice straw at 11.78 days, and 75% coconut sawdust + 25% rice straw at 11.83 days.

The longest flush interval was in 25% coconut sawdust +75% rice straw at 12.40 days and 100% rice straw at 12.22 days. Statistical analysis showed that the flush interval was not significantly different among treatment means (>0.5613). The result showed a maximum of five flush and flush interval ranges from 11-13 days that depends on temperature and relative humidity inside the mushroom growing house. The high temperature and low relative humidity inside the mushroom growing house delayed the flush interval of fruiting bodies. The result was similar to Shahid et al. (2006) who reported that maximum flushes formation depends on the type of substrates, temperature flexibility, humidity level, and quality of spawn. Mendez et al. (2005), also reported that decrease in nitrogen contents of the substrate, temperature, relative humidity, and weather conditions result in later flushes of harvest.

All of the fifth flushes had considerably variable quantity harvests depending on the various substrates (Table 2). In the first flush, the combination of 25% coconut sawdust and 75% rice straw produced the maximum yield (121.50 g), while 100% rice straw produced the lowest yield (94.50 g). The lowest yield was obtained with 100% rice straw in the second flush (75% coconut sawdust +25% rice straw, 138.80 g) (97.40 g). In the third flush, the combination of 75% coconut sawdust and 25% rice straw produced the maximum yield (126.50 g), whereas 25% coconut sawdust and 75% rice straw produced the lowest yield (73.70 g).

Table 2. The average number of days of Flush Interval and Mushroom Yield (gm) of *P. ostreatus* on various substrates.

		MUSHROOM YIELD (g)					
TREATMENTS	**FLUSH INTERVAL**	**1st Flush**	**2nd Flush**	**3rd Flush**	**4th Flush**	**5th Flush**	**Total**
T1 - 100% CSD	11.72	116.60	128.30a	121.10a	95b	96.10b	557.10b
T2 - 75% CSD 25% RS	11.83	119.90	138.80a	126.50a	116.17a	110.30a	611.90a
T3 - 50% CSD 50% RS	11.78	114.50	117.60ab	95.10b	89.80b	85.90c	502.90c
T4 - 25% CSD 75% RS	12.40	121.50	103.10b	73.70c	89.80b	73.30d	461.40c
T5 - 100% RS	12.22	94.50	97.40b	89.80bc	64.30c	45.50e	391.40d

Note: Means with the same letter are not significantly different.

In the fourth flushes, the best yield (116.17 g) was recorded on 75% coconut sawdust +25% rice straw, and the lowest yield (100% rice straw) was noted (64.30 g). In the fifth flush, the mixture of 75% coconut sawdust and 25% rice straw produced the maximum yield (110.30 g), whereas 100% rice straw produced the lowest yield (45.50 g). Overall, rice straw and coconut sawdust together might be regarded as the ideal substrates for growing black oyster mushrooms, but coconut sawdust will also be taken into consideration due to its high productivity in terms of mushroom harvest. The study was similar to the findings of Udugama and Ranjani (1997), Arulnandhy, and Gayathri (2007), who reported that sawdust incorporated with substrates like straw, grasses, and shredded paper enhanced the yield rather than sawdust alone.

Mushroom Yield

Mushrooms were harvested before they showed curling of the edges. Table 3 showed that the average yield of harvested mushroom was 557.10g in 100% coconut sawdust, 611.90g in 75% coconut sawdust +25% rice straw, 502.90g in 50% coconut sawdust +50% rice straw, 461.40g in 25% coconut sawdust +75% rice straw and 391.40g in 100% rice straw from the first flush to the fifth flush. The highest yield was recorded on 75% coconut sawdust +25% rice straw with an average yield of 611.90g and the lowest yield was on 100% rice straw at 391.40g. The size of the mushroom caps was significantly influenced by the substrates. The treatment with 75% coconut sawdust +25% rice straw produced large mushroom caps, in contrast to 50% coconut sawdust +50% rice straw, which produced smaller mushroom caps compared to the other treatments. It was found that there was a substantial correlation between the pileus diameter and the number of caps per cluster, with the treatment consisting of 75% coconut sawdust +25% rice straw resulting in larger caps and fewer clusters than the other treatments, which had larger clusters but lower caps diameter. The fewer there were, the greater the diameter (Figure 6).

Figure 6. Bigger clusters (left) and fewer clusters (right).

Table 3. Average mushroom yield (grams) per treatment and biological efficiency of *P. ostreatus.*

TREATMENTS	AVERAGE WEIGHT OF HARVESTED MUSHROOM (g)	BIOLOGICAL EFFICIENCY (%)
T1 - 100% CSD	557.10b	55.71b
T2 - 75% CSD 25% RS	611.90a	61.19a
T3 - 50% CSD 50% RS	502.90c	50.29c
T4- 25% CSD 75% RS	461.40c	46.14c
T5- 100% RS	391.40d	39.14d

Note: Means with the same letter are not significantly different.

The result was similar to Ajonina and Tatah (2012), who reported that pileus diameter was very much dependent on the number of caps per cluster. The fewer they were, the wider the diameter due to lower competition for space and available nutrients. Mondal et al. (2011), stated that the higher the stalk length, the poorer the quality of the mushroom.

In addition, the size of the mushroom is dependent on substrates that were poor in cellulose, hemicellulose, and size site depending on the amount of aeration and light; lignin which constitutes a physical barrier and difficult to be broken down without the presence of lignin-degrading enzymes (Jonathan et al., 2011). Good growths on agricultural substrates have also been linked with suitable nutrients and adequate environmental conditions (Gbolagade et al., 2006).

Biological Efficiency

The effect of different treatments on the biological efficiency (BE) of black oyster mushrooms showed significant (<0.005) differences in coconut sawdust with the addition of rice straw. The BE recorded in this substrate's treatment of coconut sawdust with the addition of rice straw ranged from 39.14% to 61.19%. In this study, the highest biological efficiency was obtained in 75% coconut sawdust +25% rice straw with 61.19% while the lowest was in 100% rice straw with 39.14%.

The result showed that treatment with 75% coconut sawdust +25% rice straw and 100% coconut sawdust gives more yield and biological efficiency than the other treatments. The combined coconut sawdust + rice straw enhances the growth, and yield and gives higher biological efficiency to the black oyster mushroom. This study observed that the higher ratio of coconut sawdust with the addition of rice straw gives more yield than sawdust and rice straw alone. These results were similar to Hami, (1990) who reported that *P. ostreatus* gave maximum bio efficiency on sawdust with the addition of wheat straw than wheat straw and sawdust alone.

Nunez and Mendoza (2002) reported the biological efficiency values varied from 50.8 to 106.2 % in *Pleurotus ostreatus* on different substrates. Results confirmed related to the findings of Patra and Pani, (1995) that the biological efficiency of 50-75% *Pleurotus* species grew on most of the agro-industrial residues, namely, corncobs, various types of grass, and reed stems, vine shoots, cottonseed hulls, and sugarcane bagasse. In this study, the most effective substrate in the bioconversion of fresh fruiting bodies was 75% coconut sawdust +25% rice straw.

Pleurotus cultivated on sawdust reportedly had the best biological efficiency (BE%), according to Mona et al. (2009). Cotton waste and sawdust were found to be good substrates for the cultivation of oyster mushrooms that produced the highest yield (Khan et al., 2001 and Obaidi et al., 2003).

Cost and Return Analysis

Table 4 shows the Return on Investment (ROI) of mushroom production for each treatment. It shows a summary of the study's overall costs and Returns on Investment (ROI). Treatment using 75% coconut sawdust +25% rice straw had the highest ROI (259,94%), whereas 100% rice straw had the lowest ROI (87.88%).

Result of this study shown in Table 4, each treatment had a total production cost of 340 pesos, or 34 pesos per bag. In terms of production net revenue, 75% coconut sawdust plus 25% rice straw brought in the most income (883.80 pesos), while 100% rice straw brought in the least income (298.80 pesos). The combination of 75% coconut sawdust and 25% rice straw produced the most earnings per bag, totaling 88.30 pesos, whereas 100% rice straw produced the lowest earnings per bag, totaling 29.88 pesos.

Table 4. Cost and return analysis per treatment of black oyster mushroom from the month of November to February.

Materials	PHP				
	T1	T2	T3	T4	T5
Compost Mixture (Coconut Sawdust and Rice Straw)	40.00	40.00	40.00	40.00	40.00
Polypropylene Bag (8" x 14”)	20.00	20.00	20.00	20.00	20.00
Cotton	20.00	20.00	20.00	20.00	20.00
Pvc Pipe	30.00	30.00	30.00	30.00	30.00
Rubber Band	10.00	10.00	10.00	10.00	10.00
Denatured Alcohol	20.00	20.00	20.00	20.00	20.00
Luna / Trapal	41.67	41.67	41.67	41.67	41.67
Drum	58.33	58.33	58.33	58.33	58.33
Unpaid Labor	100.00	100.00	100.00	100.00	100.00
Total Cost of Production	340.00	340.00	340.00	340.00	340.00
Production Cost / Bag	34.00	34.00	34.00	34.00	34.00
Yield / Treatment	5,577.00	6,119.00	5,090.00	4,614.00	3,194.00
Gross Income / Bag	1,115.4	1,223.8	1,018	922.8	638.8
Net Income	775.40	883.80	678.00	582.80	298.80
Return On Investment (%)	228.06	259.94	199.41	171.41	87.88

CONCLUSION

This study confirmed that black oyster mushrooms may be grown with differential growth performance in various ratios of coconut sawdust and rice straw. It also proved that the usage of various substrates has a big impact on yield. The biological effectiveness varies greatly among the many substrates employed in a similar manner. Black oyster growth and yield on substrates made of rice straw were modest, but yield in substrates made of coconut sawdust and rice straw combined was higher. However pure coconut sawdust would also produce a greater biological output and higher return on investment.

RECOMMENDATIONS

In comparison to the other substrates, a mixture of coconut sawdust and rice straw (75% coconut sawdust +25% rice straw and 100% coconut sawdust) provided a much greater yield, biological efficiency, and return on investment. Additionally, it demonstrated improved mycelia density, pinhead formation time, and fruiting body development. Therefore, the produced substrates 75% coconut sawdust +25% rice straw and 100% coconut sawdust were suggested for the growth of black oyster mushrooms. Additionally, the remaining portion of the treatment can be an alternative substrate; this could be a way to make use of the enormous rice straw wastes that are accessible on a nearby farm.

Treatment using 75% coconut sawdust and 25% rice straw is a recommended method for commercial use since it increases yield, biological efficiency, and ROI percentage. Therefore, additional research on the growth of black oyster mushrooms utilizing this substrate should be encouraged. It is necessary to investigate additional substrates, such as banana leaves, coco coir, sugarcane bagasse, and pili leaves. Consideration should also be given to how the environment affects the development of the fruit body and the primordial formation of black oyster mushrooms.

REFERENCES

Aghajani, H., Bari, E., Bahmani, M., Humar, M., Ghanbary, M. A.T., Nicholas, D. D., and Zahedian, E. 2018. Influence of relative humidity and temperature on cultivation of *Pleurotus* species. Maderas. Ciencia y tecnología, vol. 20, no. 4, pp. 571-578, 2018. Universidad del Bío-Bío. Retrieved from: https://www.scielo.cl/scielo.php?script=sci_arttext&pid=S0718-221X2018005004501&lng=en&nrm=iso&tlng=en.

Ajonina, A. S., & Tatah, L. E. 2012. Growth performance and yield of oyster mushroom (*Pleurotus ostreatus*) on different substrates composition in Buea southwest Cameroon. Science Journal of Biochemistry, 139: 1-6. Retrieved from: https://www.sjpub.org/sjbch/sjbch-139.pdf.

Arulnandhy, V. & Gayathri, T. 2007. Identification of suitable and efficient substrate for the production of oyster *(Pleurotus ostreatus)* mushrooms. The undergraduate research report, Department of Agricultural Biology, Faculty of Agriculture, Eastern University, Sri Lanka.

Beausejour, T. M. 1999. Mushroom in the garden, The Journal of Wild Mushroom 1511 E. 54th St. Chicago, Il 60615.

Celik, Y. & Pekker, K. 2009. Benefit/cost analysis of mushroom production for diversification of income in developing countries. Bulgarian Journal of Agricultural Science 15(3): 228-237. Retrieved from: https://agrojournal.org/15/03-07-09.pdf.

Chivenge, P., Rubianes., F., Duong, V.C., Khang, V. U., Romasanta, R., Nguyen, V.H., Trinh, M.V., Thach, T.V. 2020. Rice Straw Incorporation Influences Nutrient Cycling and Soil Organic Matter. In Books:

Sustainable Rice Straw Management (pp. 131-144) Gummert, M., Hung, N., Chivenge, P., Douthwaite, B. (eds) Springer, Cham. Retrieved from: https://doi.org/10.1007/978-3-030-32373-8_8.

Chang, S. & Miles P. G. 2004. Mushrooms: cultivation, nutritional value, medicinal effect, and environmental impact, 2nd Ed, CRC Press, Boca Raton, Florida. 451pp. Retrieved from: https://doi.org/10.1201/9780203492086.

Chang, S. 2007. Products of medicinal mushrooms as a good source of dietary supplements for HIV/AIDS patients. International Journal of Medicinal Mushroom, Vol. 9, No. 3-4, Pp. 189-190.

Chukwurah, N. F., Eze S. C., Chiejina, N. V., Onyeonagu, C. C., Okezie, C. E., Ugwuoke, K. I., Ugwu, F. S., Aruah, C. B., Akobueze E. U., Nkwonta, C. G. 2013. Correlation of stipe length, pileus width and stipe girth of oyster mushroom (*Pleurotus ostreatus)* grown in different farm substrates. Journal of Agricultural Biotechnology Sustainable Development. Vol. 5(3): pp. 54–60. Retrieved from: https://academic.journals.org/journal/JABSD/article-full-text-pdf/8D449D11967.

De Villa, J. 2017. Production of pink oyster mushroom (*Pleurotus djamor* var. roseus) on sugarcane bagasse and sawdust combination. The Central Bicol State University of Agriculture. Department of Landscape and Environmental Management. Retrieved from: https://www.academia.edu/31825930/JESSA_THESIS.

Eira, A. A., Bueno, F. S., First ed. CPT; Viçosa: 2005. Cultivation of Shimeji and Hiratake mushrooms. Interactive Content: 221 pages.

Gbolagade, J. S., Sobowale, A., & Adejoye, D. 2006. Optimization of submerged culture conditions for biomass production in *Pleurotus florida* (Mont) Singer, A Nigerian edible fungus. African Journal of Biotechnology. Vol. 5 (16): 1464-1469. Retrieved from: https://academicjournals.org/journal/AJB/article-full-text-pdf/7A8E84D9670.

Hassan, F. R. H. & Medany, G. M. 2014. Effect of pretreatments and drying temperatures on the quality of dried Pleurotus mushroom SPP. Egypt. Journal of Agriculture Research, 92: 1009–1023. Retrieved from: https://journals.ekb.eg/article_156436_bc8b5c4671fd3d91d546ba3ca4052125.pdf.

Hami, H., 1990. Cultivation of oyster mushroom. (*Pleurotus spp.*) on sawdust of different woods. M.S.c. Thesis, Department of Plant Pathology, University of Agriculture, Faisalabad, Pakistan.

Iqbal, B., Khan, H., Saifullah., Khan, I., Shah, B., Naeem, A., Ullah, W., Khan, N., Adnan, M., Shah, SRA., Junaid, K., Ahmed, N., & Mazhar, I. 2016, Substrate's evaluation for the quality, production, and growth of oyster mushroom (*Pleurotus florida* Cetto). Journal of Entomology and Zoology Studies. Retrieved from: https://www.entomoljournal.com/archives/2016/vol4issue3/PartB/4-3-57-159.pdf.

Japan Institute of Energy. 2002. Asian biomass handbook: A guide for biomass production and utilization. Ed., Ohm-sha, pp.311-323.

Jonathan, S. G., Fadahunsi, I. F. & Esho E. O. 2011. Nutritional evaluation of two stored edible fungi (*Pleurotus ostreatus* and *Pleurotus pulmonarius*) cultivated in Nigeria. Journal of Science Research (In press).

Kab-Yeul, J., Chang-Sung, J., Jeong-Sik, P., Soo-Muk, C., Hang- Yeon, W., Jong-Chun, C., Sung-Gyu, C., & Jae-Mo, S. 2013 Characterization of fruitbody morphology on various environmental conditions in *Pleurotus ostreatus*. Microbiology 31(3): 145-150 (2003). DOI:10.4489/MYCO.2003.31.3.145.

Khan, A. M., Khan, S. M. & Shakir, A. S. 2001. Studies on the cultivation of the oyster mushroom on different substrates. Pak. J. Phytopathol., 13: 140-143.

Kues, U., & Liu, Y. 2000. Fruiting body production in basidiomycetes. Appl. Microbiol. Biotechnol. 54:141–152. Retrieved from: https://doi.org/10.1007/s002530000396.

Madan, M., Vasudevan, P., & Sharma, S. 1987. Cultivation of *Pleurotus sajar-caju* on different wastes. Biological Wastes 22: 241-250. Retrieved from: https://doi.org/10.1016/0269-7483(87)90110-8.

Marino, R. H., Eira, A. F., Kuramae, E. E. & Queiroz E. C. 2003. Morphomolecular characterization of *Pleurotus ostreatus* (Jacq. fr.) Kummer strains concerning luminosity and temperature of fruitification. Scientia Agricola. V. 60: 531–535. Retrieved from: https://www.scielo.br/j/sa/a/Q3xwKWDmJdMBL48vwTRHhxJ/?lang=en&format=pdf.

Mendez, L. A., Castro, CAS., Casoo, R. B. & Leal, CMC. 2005. Effect of substrate and harvest on the amino acid profile of Oyster mushroom (*Pleurotus ostreatus*). J. Food Compos. Anal. 18: 447-450. Retrieved from: https://doi.org/10.1016/j.jfca.2004.02.002.

Mona, M.R., Abdou, H. M., Mahmound, A. E., and Nooman, M. U. 2009. Nutritional analysis and enzyme activities of *Pleurotus ostreatus* cultivated on *Citrus limonium* and *Carica papaya* Wastes. Australian Journal of Basic and Applied Sciences, 3(4): 3352-3360. Retrieved from: https://www.researchgate.net/publication/229004791_Nutritional_analysis_and_enzyme_activities_of_*Pleurotus*_*Ostreatus*_cultivated_on_*Citrus*_*Limonium*_and_*Carica*_*Papaya*_wastes.

Mondal, S. R, Rehana, M. J., Noman, M. S., & Adhikary, S. K. 2011. Comparative study on growth and yield performance of oyster mushroom (*Pleurotus florida*) on different substrates. Agrotechnology Discipline, Khulna University, Khulna-9208, Bangladesh. J. Bangladesh Agril. Univ. 8(2): 213–220, 2010. Retrieved from: https://www.researchgate.net/publication/265802917_Comparative_study_on_growth_and_yield_performance_of_oyster_mushroom_*Pleurotus*_*florida*_on_different_substrates.

Nuñez, J. P., & Mendoza, C. G. 2002. Submerged fermentation of Ligno-cellulosic wastes under moderate temperature conditions for oyster mushroom growing substrates. Mushroom Biology and Mushroom Products, 5:545−549.

Obaidi, M., Okine, J. C. & Vowotor K. A, 2003. Comparative study on the growth and yield of *Pleurotus ostreatus* mushroom on different lignocellulosic by-products. J. Indian Microbiol. Biotechnology, 30: 146-149. Retrieved from: https://doi.org/10.1007/s10295-002-0021-1.

Oei, P. 2003. Mushroom cultivation, appropriate technology for mushroom growers. Leiden: Backhuys Publishers.

Oei, P., & Nieuwenhuijzen, B. V. 2005. First ed. Agromisa foundation and CTA; wageningen. Small-scale mushroom cultivation: Oyster, Shiitake and Wood Ear Mushrooms. Retrieved from: http://journeytoforever.org/farm_library/AD40.pdf.

Patra, A., & Pani, B. 1995. Evaluation of banana leaf as a new alternative substrate to paddy straw for oyster mushroom cultivation. Journal of Phytological Research, 8, 145-148.

Pokhrel, C. P., Yadav, R. K. P., & Ohga S. 2009. Effects of physical factors and synthetic media on mycelial growth of *Lyophyllum decastes*. Journal of ecobiotech 1: 046-050. Retrieved from: https://updatepublishing.com/journal/index.php/jebt/article/view/10/10.

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. Retrieved from: https://journalissues.org/wp-content/uploads/2014/07/Pokhrel-et-al.pdf.

Poppe, J. 1995. Cultivation of edible mushroom on tropical agricultural wastes. Biennial Course, Abos & Vlir, University Gent.

Quimio, T.H. 2002, Tropical Mushroom Cultivation. Mandaluyong City: National Book Store. Retrieved October 25, 2014.

Shen, H.S., Ni, D.B, and Sundstol, F. 1998. Studies on untreated and urea-treated rice straw from three cultivation seasons: 1. Physical and chemical measurements in straw and straw fractions. Animal Feed Science Technology 73:243–261. Retrieved from: https://doi.org/10.1016/S0377-8401(98)00157-6.

Shahid, M. N., Abbasi N. A. & Saleem N. 2006. Studied the effect of different methods of compost preparation and lime concentration on the yield of *Pleurotus sajor-caju*. Int. J. Agric. Biol., 8: 129-131. Retrieved from: http://www.fspublishers.org/published_papers/62199_..pdf.

Sharma, S., Yadav, R. K. P., and Pokhrel, C. P. 2013. Growth and yield of oyster mushroom (*Pleurotus osteratus*) on a different substrate. Journal of New Biological Reports 2 (1): 3-8. Retrieved from: https://www.academia.edu/28145552/Growth_and_Yield_of_Oyster_mushroom_Pleurotus_ostreatus_on_different_substrates.

Stanley, H.O. 2010. Effect of substrates of spawn production on mycelial growth of oyster mushroom species. Agriculture and Biology Journal of North America. 2(8)1239-1243. Retrieved from: https://scihub.org/ABJNA/PDF/2010/5/ABJNA-1-5-817-820.pdf.

Stamets, P. 2005. Mycelium running, how mushroom can save the world? Ten Speed Press, Berkeley, CA. ISBN: 1580085792, pp: 339. Retrieved from: https://library.uniteddiversity.coop/Permaculture/Mycelium_Running.pdf.

Synytsya, A., Mickova, K., Jablonsky, I., Slukova., M. & Copikova, J. 2008. Mushrooms of genus Pleurotus as a source of dietary fibers and glucans for food supplements. Czech J. Food Sci 26:441–446. Retrieved from: https://www.agriculturejournals.cz/publicFiles/03098.pdf.

Udugama, S. and Ranjini, S. 1997. Mushroom as an agent of recycling wild grass to edible food for man. Annual Sessions of the Department of Agriculture (ASDA). 53:8.

Urben, A. F. Embrapa genetic resources and Biotechnology; Brasília: 2004. Mushroom production using modified Chinese technology. DF. CEP 70770-900.

Wang, D., Sakuda, A., & Suzuki, M. 2001. Biological efficiency and nutritional value of *Pleurotus ostreatus* cultivated on spent beer grain. Bioresource Technology 78 (2001) 293-300. Retrieved from: https://www.academia.edu/14181956/Biological_efficiency_and_nutritional_value_of_Pleurotus_ostreatus_cultivated_on_spent_beer_grain.

Watanabe, K, 2019, Guidelines for Oyster mushroom cultivation with straw.