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Yield of Oyster Mushroom (*Pleurotus Pulmonarius* (Fr.) Quel.) Cultured in Different Agricultural Wastes as Substrates

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ABSTRACT

Oyster mushrooms are rich in protein and highly nutritious. The study was conducted to determine the yield performance of Oyster mushroom using different agricultural wastes and their combinations as substrates, and to identify the best substrate for mushroom culture. The different agricultural wastes used were rice straws (RS), corn stalks (CS), banana leaves (BL), and their combinations. The experiment was laid out in Completely Randomized Design (CRD), with six treatments and in three replications with a total of 18 experimental units. Polypropylene bags with different substrates were arranged in the 4m x 5m mushroom house located at Bliss, Buug, Zamboanga Sibugay. Random numbers for treatment assignment were ranked in ascending orders. The treatments were: T_1 – 98% RS, T_2 – 98% CS, T_3 – 98% BL, T_4 – 49% rice RS + 49% CS, T_5 – 49% RS + 49% BL, and T_6 – 49% CS + 49% BL. All treatments were added with 1% agricultural lime, and 1% rice bran to obtain the 100% dry weight of formulated substrate. The mushrooms were harvested in three flushing periods, which started eighteen days after seeding. Yield parameters were gathered, and the total yield obtained per treatment were collated and subjected to statistical analysis using the STAR software. ANOVA revealed highly significant differences among treatment means in terms of number, weight, and average weight of mushroom raised in different culture media. Tukey's HSD test revealed that mushroom cultured in 98% RS (T_1) had the highest yield compared to the other treatments. This may also suggest that substrate containing 98% RS produced higher yield compared to RS mixed with other agricultural wastes. The results further indicate that pure substrates produce heavier mushrooms than when in combined state. Further study be conducted to validate the results, particularly in areas where rice straws (RS) are unavailable.

Keywords : *oyster mushroom, substrates, rice straw, corn stalk, banana leaves, agricultural lime, rice bran*

1. INTRODUCTION

Oyster mushroom (*Pleurotus pulmonarius (Fr.) Quel*) or toadstool, is the fleshy, spore-bearing fruiting body of a fungus, typically produced above ground on soil or on its food source. Edible mushrooms are nutritious, cholesterol free and low in calories. Mushroom is a medicinal and good health food. Mushroom growing can be an ideal income generating activity for men and women and the out-of-school youth. The limited space requirement, abundance of raw materials, low labor and capital investment, and simple technology would make mushroom growing a worthwhile livelihood project that would supplement as source of food and income (DA-ZAMPIARC, 2016). Since centuries, mushrooms have been recognized and commercially cultivated worldwide as important food item and their usage is being increased day by day for their significant role in human health, nutritional and medicinal properties (Mshandete, 2011, Tesfaw et al., 2015). Edible mushrooms include fungi that thrive on damp decaying organic matter alone or in combination with soil as it depends on nutrients obtained from dead and decaying materials. There are over 200 genera of macro fungi which contain species of use to people. Twelve species are commonly grown for food and/or medicinal purpose, across tropical and temperate zones, including the common mushroom (*Agaricus*), Shiitake (*Lentinus*), Oyster (*Pleurotus*), Straw (*Volvariella*), Lion's Head or Pom Pom (*Hericum*), Ear (*Auricularis*), Ganoderma (*Reishi*),

Maitake (*Grifola frondosa*), Winter (*Flammulina*), White jelly (*Tremella*), Nameko (*Pholiota*), and Shaggy Mane mushrooms (*Coprinus*). Commercial markets are dominated by *Agaricus bisporus, Lentimula edodes* and *Pleurotus spp*, which represent three quarters of mushrooms cultivated globally (Marshall & Nair, 2009). The development of Oyster mushroom (Grey and pink) production methodologies on agricultural waste like paddy straw and wheat straw gives very high yield as well as the nutritional contain like carbohydrate, protein, ash, calcium, magnesium, crude fibers and lipid (SonalIi, 2011). Cultivated mushrooms have now become popular all over the world. Global mushroom production has increased tremendously, from about 0.3 million tons in 1961 to about 3.41 million tons in 2010. China is the leading producer of mushrooms worldwide, producing about 65% of global mushrooms and 85% of Oyster mushroom worldwide. Africa produces only 1% of the total world output of Oyster mushroom (Adjapong, et al., 2015). Mushrooms are usually sold in supermarkets and groceries. The rapid growth and market growth expansion of the mushroom business in China is a great example of good economic development. An alluring feature of Oyster mushrooms is that they can utilize most of the agricultural waste products and convert the lignocellulose biomass into high quality food with flavor and nutritive value (Mondal et al., 2010). The substrate serves as the organic host and mycelium as parasites that depend on substrates for food. Fungus connects mycelium to the substrate to get food. The substrate is the primary source of food for fungi so they can produce mushrooms. The ability of the fungi to breed mushrooms depends on the kind of substrate hosting the mycelium. Common substrate used in a mushroom cultivation includes rice straw, rice hull, grasses, banana leaves, wood shavings, sawdust, coffee grounds, coffee waste, sugar bagasse, corn stalk, and other agricultural waste (Nick, 2019). Cultivation of Oyster mushroom with agricultural residues, such as rice and wheat straw are a value-added process to convert these materials into human food (Pokhrel et al., 2013). The experiment used rice straw, banana leaves, corn stalk, and its combination at various compositions with a view to determine the best substrate that would give optimum yield performance of mushroom.

2. MATERIALS AND METHODS

2.1 EXPERIMENTAL EQUIPMENT AND INPUTS

The materials and equipment used in the study were the following: mushroom house, polypropylene bags, rubber band, steel drum, firewood, sprayer, weighing scale, alcohol lamp, inoculation loop, alcohol, and the different agricultural wastes such as rice straws (RS), corn stalks (CS), banana leaves (BL), rice bran (RB), and agricultural lime (AL), as raw materials in formulating the substrates.

2.2 EXPERIMENTAL DESIGN

The experiment used the Completely Randomize Design (CRD), to distribute the treatments to every experimental unit (EU). The study has six (6) treatments and was replicated three times with a total of 18 experimental units (EUs). The treatments were the following: T_1 – 98% RS, T_2 – 98% CS, T_3 – 98% BL, T_4 – 49% RS + 49% CS, T_5 – 49% RS + 49% BL, and T_6 – 49% CS + 49% BL. All treatments were added with 1% AL, and 1% RB in dry weight basis to have a total of 100% substrate formulations. Treatments were randomly distributed to the 18 EUs using random numbers. Each EU consisted of three fruiting bags, and these were placed in 4m x 5m shed with favorable climatic condition in Bliss, Buug, Zamboanga Sibugay.

2.3 MUSH ROOM HOUSE PREPARATION

The growing house for mushroom was constructed using lumber for building a structure with a concrete floor area of 20 square meters (4m x 5m). Proper ventilation and continues air flow circulation inside the mushroom house were maintained by providing open windows, but screen-covered to prevent the entry of insect pests throughout the growing period of the mushroom. The windows were also covered with black curtain to maintain partially dark environment in the room. The mushroom house was disinfected with chlorine solution done before placing the fruiting bags to avoid contamination.

2.4 SUBSTRATE AND FRUITING BAG PREPARATION

The different raw materials used for substrate formulations were the different agricultural wastes (RS, CS, and BL). These were gathered after dry season harvest and cleaned by removing all impurities like small stones and other foreign materials. All the raw materials were chopped into pieces, approximately 1.5 cm long for faster decomposition. After chopping, these were mixed with 1% AL (dry weight basis). The mixture was placed in a concrete floor covered with plastic sheets and allowed to decompose for 15 days. The set-ups were turned every 2 days to maintained proper air circulation and to facilitate release toxic gases and reactivate decomposing bacteria. While mixing, a little amount of water was added gradually to regulate moisture until approximately 60% moisture content was attained. After composting, each formulation was added with 1% RB and mixed thoroughly before bagging. One kilogram of substrate was placed into a 0.04mm thick, 12x20 inches polypropylene bag approximately filled up to 2/3 of its capacity. The opening of the bag was held secured by closing it using the rubber band. Fruiting bags were then arranged inside the steel drum filled with water up to 1/4 of its capacity. The fruiting bags were sterilized for four hours by steaming at 100^0C. After sterilization, the water was drained, and fruiting bags were allowed to completely cool down inside the steel drum. Fruiting bags were later transferred to the designated place in the mushroom house.

2.6 INOCULATION, AND CARE AND MAINTENANCE

After placing the fruiting bags in the designated location, these were opened and inoculated with planting spawn approximately 4g (spoon size) per 1 kg fruiting bag. After seeding, fruiting bags were covered again immediately and shaken to disperse the spawns (seeds) inside the bag for uniform distribution of the grains. Inoculated bags were incubated inside the mushroom house until the mycelia grew through the grains in the bag. Spraying clean

water thrice daily was done to maintain the ideal level of temperature and humidity inside the mushroom house. Contamination of growing mushrooms was avoided by maintaining cleanliness and good hygiene throughout the experiment as preventive measures against insect pests and diseases.

2.7 HARVESTING AND COLLECTION OF DATA

The mushrooms were harvested in three flushing periods that started eighteen days after seeding. Harvested mushrooms per treatment were placed in separate containers, properly labelled per treatment and replication to avoid misrepresentation of data during statistical analysis. Data on yield parameters, such as the number, weight, and average weight of mushroom per flush per treatment were carefully gathered and recorded using appropriate tools and equipment. All harvested mushrooms starting from the first to third flushes per treatment were counted, weighed and summed-up, and collated before subjected to statistical analysis.

2.8 STATISTICAL ANALYSIS

Data gathered were analyzed using the Analysis of Variance (ANOVA). Differences between treatment means were compared using the Tukey's HSD test. The tool used for the statistical analysis of data was the Statistical Tool for Agricultural Research (STAR) of the International Rice Research Institute (IRRI).

3. RESULTS AND DISCUSSION

This section presents and discusses the results and findings of the study.

Table 1. Number (pcs) of Oyster mushroom per treatment

Culture Media at Different Ratio	Replication			Total	Mean
	I	II	III		
T_1 (98% RS)	320	316	281	917	306
T_2 (98% CS)	170	136	130	436	145
T_3 (98% BL)	265	217	174	656	219
T_4 (49% RS + 49% CS)	36	32	29	97	32
T_5 (49% RS + 49% BL)	58	46	40	144	48
T_6 (49% CS + 49% BL)	87	72	64	223	74

RS – Rice Straws CS – Corn Stalks BL – Banana Leaves

The table above presents the number of harvested Oyster mushrooms per treatment. It shows that T_1 (98% RS) got the highest number of mushrooms with a mean of 306 pcs, followed by T_3 with 219 pcs, T_2 got a mean of 145 pcs followed by T_6 and T_5 with a mean of 74 and 48 pcs, respectively. The lowest number was obtained from T_4 with a mean of 32 pcs only. The results indicate that more mushrooms were produced in pure substrates. However, for this parameter, rice straws at 98% is considered the best substrate. This also implies that the more mushrooms produced, the higher would be the yield and income.

Table 2. Weight (g) of Oyster mushroom per treatment

Treatment	Replication			Total	Mean
	I	II	III		
T_1 (98% RS)	795.75	743.32	692	2231.07	743.69
T_2 (98% CS)	615.29	570.8	531.37	1717.46	572.48
T_3 (98% BL)	651.53	639.21	613.7	1904.44	634.81
T_4 (49% RS+49% CS)	228.19	183.8	161.72	573.26	191.08
T_5 (49% RS+49% BL)	293.54	279.63	245.11	818.29	272.76
T_6 (49% RS+49% BL)	483.26	461.71	437.9	1382.87	460.95

RS – Rice Straws CS – Corn Stalks BL – Banana Leaves

The weight of Oyster mushroom per treatment was presented in Table 2 above. The table shows that T_1 obtained the heaviest mushroom with a mean of 743.69 grams, followed by T_3 with 634.81 grams, T_2 got 572.48 grams, T_6 with 460.95 grams, T_5 with 272.76 grams, and the lightest mushrooms weight of 191.08 grams was obtained from T_4.

Table 3. Average weight (g) of Oyster mushroom per treatment

Treatment	Replication			Total	Mean
	I	II	III		
T_1 (98% RS)	53.05	49.55	46.13	148.74	49.57
T_2 (98% CS)	47.33	43.90	40.87	90.40	44.03
T_3 (98% BL)	50.11	49.17	47.20	146.48	48.82
T_4 (49% RS+49% CS)	22.81	18.38	16.12	57.30	19.10
T_5 (49% RS+49% BL)	29.35	27.96	24.51	81.82	27.27
T_6 (49% CS+49%BL)	40.27	38.97	36.49	115.23	38.41

RS – Rice Straws CS – Corn Stalks BL – Banana Leaves

The average weight of mushroom per treatment is presented in Table 3. It shows that T_1 (98% RS) had the heaviest weight with a mean of 49.57g, followed by those in T_3 and T_2 with means of 48.82 and 44.03g, respectively, T_6 with 38.41g followed by T_5 with a mean of 21.27g. The lightest was obtained from T_4 with only 19.10 g. The results imply that those treatments with pure substrate produced heavier weight of mushrooms.

Table 4. Statistical analysis of the yield parameters of mushrooms

Treatments	Yield Parameters/Response Variable		
	Number of Oyster mushroom	Weight of Oyster mushroom, (g)	Average weight of Oyster mushroom (g)
T_1 (98% RS)	305.67^{a}	744.02^{a}	49.58^{a}
T_2 (98% BL)	145.33^{c}	572.49^{b}	44.03^{ab}
T_3 (98% CS)	218.67^{b}	634.81^{b}	45.83^{ab}
T_4 (49% CS+49% BL)	32.33^{d}	191.24^{d}	19.10^{c}
T_5 (49% RS+49% BL)	48.00^{d}	272.76^{d}	27.27^{c}
T_6 (49% RS+49% CS)	74.33^{d}	460.96^{c}	38.41^{b}
f-value	64.62^{**}	115.08^{**}	36.13^{**}
p-value	0.0000	0.0000	0.0000
CV (%)	16.89	7.21	9.13

Means with the same letters are not significantly different, HSD.
RS - rice straw, BL - banana leaves, CS - corn stalks

3.1 Number of Oyster mushroom

Table 4 presents the summary of the statistical analysis on the yield parameters of mushrooms. On the number of Oyster mushrooms, the result shows that the p-value (0.0000) is lesser than the 0.01 level of significance. This implies that there was a highly significant difference on the number of Oyster mushrooms produced as influenced by the different agricultural wastes as substrates. Tukey's HSD test revealed that T_1 (98% RS) is significantly different from all other treatments. However, T_4, T_5, and T_6 were not significantly different from each other but significantly different from T_1, T_2, and T_3. This suggests that the pure substrate containing 98% RS produced more mushrooms compared to RS mixed with other agricultural wastes.

3.2 Weight of Oyster mushroom

The result shows that the p-value (0.0000) is less than the 0.01 level of significance with the f-value of 115.08. This means that there is a highly significant difference on the weight of Oyster mushroom per treatment using the different agricultural wastes as substrates. Tukey's HSD test revealed that T_1 is significantly different from all treatments. However, T_2, and T_3 were not significantly different, yet significantly different from T_4, T_5, and T_6, respectively. This implies that those spawns grown in substrate with 98% RS had heavier weight, followed by those in 98% CS and 98% BL. The results further indicate that pure substrates produce heavier mushrooms than when in combined state.

3.3 Average weight of Oyster mushroom

On the average weight of mushroom, Table 4 shows that the p-value (0.0000) is lesser than the 0.01 level of significance with the f-value of 36.13. This means that there is a highly significant difference on the average weight of Oyster mushroom per treatment as grown in different culture media. Tukey's HSD test revealed that T_1 is significantly different from all other treatments. However, T_2 and T_3 were not significantly different from each other but significantly different from T_4, T_5, and T_6, respectively. This may also suggest that substrate containing 98% RS produced higher yield compared to RS mixed with other substrates.

The results and findings of this study conform to that of Chandraprakash et al., (2022) who studied the performance of various substrates on Oyster mushroom (*Pleurotus florida*) cultivation. The authors found out that banana leaves (438.95g) produced a significantly higher yield next to paddy straws (455.54g). Mondal et al., (2010) also noted that the number of total primordia and effective primordia were higher in control treatment, but the maximum pileus thickness was measured from rice straw. The same authors also recorded that the highest biological yield and economic yield (164.4g and 151.1g) were obtained from rice straw, higher than control. On the other hand, Pawan et al., (2020) opined that, in Oyster production, rice straw mixed with cobs is more efficient as compared to rice straw only.

4. CONCLUSIONS

Although Oyster mushroom grown in T_2 (98% Corn Stalks a) and T_3 (98% Banana Leaves) showed promising yield, statistically, those grown in T_1 (98% Rice Straws) is the best substrate. Combined substrates from various sources seemed not an ideal form of media for Oyster mushroom. However, in places where rice straws are not available, corn Stovers and banana leaves may be used as alternative substrate for mushroom culture.

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