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Enhancing food security: cultivation of oyster mushroom (*Pleurotus sajor-caju*) using agroforestry wastes

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Abstract
Maize cob, oil palm fibre and saw dust were screened for cultivation of oyster mushroom (*Pleurotus sajor-caju*) in a Completely Randomized Design consisting of nine treatments, replicated six times. The treatments are maize cob, boiled maize cob, oil palm fibre, boiled oil palm fibre, sawdust, mixture of oil palm fibre and sawdust, mixture of maize cob and oil palm fibre, mixture of maize cob and sawdust, mixture of maize cob, sawdust and oil palm fibre. The maize cob served as the control and the results showed that the maize cob naturally supported the mycelia growth and production of fruit bodies (312.89 g). Growth on mixture of maize cob and oil palm fibre was similar to that of maize cob but the yields are different (176.89 g). Oil palm fibre has a poor yield of 62.56 g. The result showed that unboiled oil palm fibre did not support the growth of mushrooms. The production of fruit bodies on the mixture of oil palm fibre and sawdust was scanty as well as the mixture of sawdust and maize cob. Statistically, mixture of sawdust and oil palm fibre and mixture of sawdust, maize cob and oil palm fibre are not significantly different (P>0.05) while all other substrates are significantly different (P<0.05) for the fresh weight at first flush. It also shows that boiled maize cob is the highest producing substrate at all flushes followed by unboiled maize cob and sawdust. The results showed that oyster mushroom (*Pleurotus sajor-caju*) can grow well on agroforestry wastes.
Key words: Saw dust; Maize cob; Sawdust; Oil palm fibre.

Introduction

Annual world production of mushroom exceeds three million tonnes worth a market value of US production. Major exporting countries of fresh mushrooms are Netherlands, Poland, Ireland and Belgium. China is the largest exporter of preserved mushrooms with a market share of 41.82%. Netherlands (25.11%) and Spain (7.37%) are the other major countries (Harsh and Joshi 2008).

Pleurotus species, commonly known as oyster mushrooms, are edible fungi cultivated worldwide especially in South East Asia, India, Europe and Africa. The genus is characterized by its high protein content (30–40% on dry weight basis) (Sharma and Madan 1993) and gourmet food quality, thus surpassing many other foods. Medically, *Pleurotus* species is reported to decrease cholesterol levels in experimental animals (Bobek et al. 1995; Hossain et al. 2003).

Chilton (1993) gives complete nutritional analyses of over 50 species of wild and cultivated mushrooms. They find that on average, dried mushroom contain 10% water, all of the essential amino acids, 2–8% fat, 3–28% carbohydrate, 3–32% fibre and approximately 10% minerals. They consider mushroom to be "good sources of several vitamins including thiamine, riboflavin, niacin and biotin". *Plerotus* species contain 1.16–4.8 mg thiamine, 108.7 mg niacin, 4.7 mg riboflavin and 0.0 mg ascorbic acid (Oei 2003). Because of their low caloric value (300–390 Kcal/100 g dry weight), low fat and high protein, they are considered as diabetic friendly. Also, folic acid and Vitamin B12 which are normally absent in vegetarian foods are present in mushrooms (3 g fresh mushroom can supply 1 µg vitamin B12, recommended for daily intake) (Harsh and Joshi 2008).

Mushrooms are highly nutritious and environmental friendly crops that carry numerous medicinal benefits (Bipasha 2011). Mushrooms are utilized for their cancer fighting qualities; they are low cost vegetables that are not only packed with nutrients like vitamin D, but also have properties to ward off cancer, HIV-1, AIDs and numerous other diseases (Beelman et al. 2003). Mushrooms can be generated from lignocellulosic waste materials; and are rich in crude fibre and protein; they contain low fat, low calories and vitamins. In addition, many mushrooms possess multi-functional medicinal properties (Sánchez et al. 2002).

Despite the numerous, nutritional, health benefits and medicinal values of mushrooms, the importance of mushrooms in food security, especially in developing nations is not appreciated. In addition, the economic importance of mushrooms is often overlooked. Mushroom is considered in this study because of its contribution to household nutrition, economy and food security, medicinal values, employment opportunities and environmental conservation. Nations such as Nigeria, that are battling with poverty would do well to begin to promote the cultivation of mushrooms which can help alleviate poverty, reduce disease incidences, and help promote skill acquisition by the local people.

The objective of this study is to cultivate mushroom using three commonly available substrates and to know the yield of mushroom on each substrate.

Material and methods

Study area

The experiment was carried out at the Waste-to-Wealth Forest Product Laboratory, besides the College of Environmental Resources Management (COLERM), Federal University of Agriculture, Abeokuta (FUNAAB), Ogun State, Nigeria.

Collections of substrates

Three substrates were used. Sawdust was collected from Camp (a settlement close to the University Campus); palm oil fibre was collected from Kotopo, Abeokuta, and maize cob from College of Animal Science and Livestock Production COLANIM) Farm, FUNAAB. All the three plant wastes were collected from Abeokuta, Ogun State. The spawn was collected at the Forestry Research Institute of Nigeria, Ibadan, Oyo State.

Preparation of substrates

The substrates used are:

- Maize cob (M).
- Boiled maize cob (MU).
- Oil palm fibre (P*).
- Boiled oil palm fibre (P).
- Sawdust (S).
- Mixture of oil palm fibre and sawdust (P*+S).
- Mixture of oil palm fibre and maize cob (P*+M).
- Mixture of maize cob and sawdust (M+S).
- Mixture of oil palm fibre, sawdust and maize cob (P*+S+M).

Since mushrooms are substrate-dependent, for them to be cultivated artificially, there is need for the preparation of the substrate on which they grow and it runs through the following processes:

1. Mixing: 3,000 g of each substrate were collected and were thoroughly mixed with water. Maize cob was chopped manually into small pieces while the oil palm fibre was rinsed thoroughly. 1,500 g of maize cob and oil palm fibre were boiled while the remaining 1,500 g were left unboiled. Part of maize cob was boiled to reduce its sugar content while that of oil palm fibre is to reduce the oil level. The substrates were measured with the use of a weighing scale.

2. Stuffing: 500 g of each substrate were puffed into polythene bag prior to sterilization.

3. Sterilization: The substrates were sterilized in an autoclave at 126°C for at least an hour and allow cooling. This will free the substrate from all living organisms or contamination.

Stages of production

There are many ways to grow mushrooms, but production always occur in three general steps-spawn run, pinning, and fruiting.

Data collection

The yield of *Pleurotus sajor-caju* on the different substrates was determined by recording the number and size of the fruit bodies after sprouting. The measurements from the various replicates were added and their mean value calculated.

The following parameters of growth/yield were measured:

Number of fruit bodies - This was done by directly counting the number of fruit bodies on each substrate.

Height of fruit bodies - The height was measured in centimetres using transparent ruler from the base of the stripe to the pileus.

Fresh weight of fruit bodies - This was done using an electrical weighing balance.

Yield (%) - This was calculated using the formula:

$$\text{Yield} = \text{WWM} \times 100$$

Where: WWM - Wet weight of mushroom (g)

Results obtained from these were subjected to statistical analysis (Statistical Analysis System - SAS) using Completely Randomized Design (CRD) at 5% level of significance.

Results and discussion

The percentage yield parameters of the mushroom from each of the substrates are shown in table 1. Results of the fresh and dry matter are presented in table 2. The mean number of fruit bodies produced was highest in the control (maize cob - M) with 7.2%, boiled maize cob (MU), sawdust (S) and mixture of oil palm fibre and maize cob (P*+M) equally produced good number of fruit bodies with 6.53%, 4.25% and 3.68%, respectively. Mixture of maize cob and sawdust (M+S) yielded 2.96% while the mixture of palm oil fibre and sawdust (P*+S) yielded 2.74%. The fruit bodies yielded on mixture of oil palm fibre, sawdust and maize cob (P*+S+M) with that of oil palm fibre (P*) are relatively low with 2.35% and 1.12%, respectively.

The mean fresh weight of the fruit bodies produced on maize cob (M), boiled maize cob (MU), sawdust (S) throughout the flush followed by mixture of oil palm fibre and maize cob (P*+M) were high with 104.63 g, 101.54 g, 68.21 g and 59.38 g, respectively. Also the mean fresh weight of the fruit bodies produced on oil palm fibre was relatively low. The mean dry weight of the fruit bodies produced on the different substrates also appeared in the order of the earlier parameter mentioned.

Table 1. Harvests at different flushes (fresh weight).

Substrates	1st Flush (g)	2nd Flush (g)	3rd Flush (g)	4th Flush (g)	Total (g)
M	122.15	108.99	66.96	46.18	344.28
MU	108.62	95.96	63.15	45.16	312.89
P*	0.00	0.00	30.09	27.43	57.52
S	85.96	70.00	36.02	20.94	212.96
P*+S	48.23	36.47	28.45	18.03	131.18
P*+M	70.85	57.77	30.63	17.64	176.89
M+S	56.73	34.98	25.77	14.44	131.92
P*+S+M	45.21	33.64	22.01	11.80	112.66

The term “Flush” - means a cropping cycle of mushroom, from the moment they pop their heads above the casing; M - Maize cob; MU - Boiled maize cob; P* - Oil palm fibre; S - Sawdust; P*+S - Mixture of oil palm fibre and sawdust; P*+M - Mixture of oil palm fibre and maize cob; M+S - Mixture of maize cob and sawdust; P*+S+M - Mixture of oil palm fibre, sawdust and maize cob. Source: Laboratory Work.

With respect to table 3, the result shows that P*+S and P*+S+M are not significantly different while all other substrates are significantly different for the fresh weight at first flush. It also shows that M is the highest producing substrate at all flushes followed by MU and S. At the second flush, S and P*+M are not significantly different; M+S, P*+S, P*+S+M are not significantly different while M and MU are significantly different to all other substrates.

Also from the result, it shows that P* is the lowest producing substrate while M and MU are the highest producing substrates and others produces at average level at all flushes.

Based on this result, the result from oil palm fibre is contrary to the report according to Onuoha et al. (2009), which state that oil palm fibre can also serves as one of the best substrates in the cultivation of mushroom as it can be seen in figures 1G and 1H. So, it is recommended that more research should be carried out on oil palm fibre.

The nine substrates screened, all supported the growth of the mushroom though to a varying degrees as seen in the figures 1A-H. This confirms the report of Keshari (2004) and Tricita (2005), that *Pleurotus sajor-caju* could be grown on agroforestry wastes. Apart from the maize cob which is the traditional substrate for the cultivation of the mushroom, sawdust was equally good. In terms of the number of fruit bodies produced and weight of the fruit bodies and it was as good as the control. This agrees with the findings of Isikhemhen (2004) who reported that *Pleurotus sajor-caju* can be cultivated on other unsupplemented agroforestry wastes. The duration of growth is very short and many fruit bodies could be produced within the period.

Table 2. Effects of different plant waste on mushroom yield in grams (mean values) at different flushes.

Substrates	----- 1st Flush -----		----- 2nd Flush -----		----- 3rd Flush -----		----- 4th Flush -----	
	Fresh (g)	Dry (g)	Fresh (g)	Dry (g)	Fresh (g)	Dry (g)	Fresh (g)	Dry (g)
M	41.51	20.01	23.46	10.41	22.36	8.96	15.57	7.46
MU	36.21	16.71	31.59	15.07	21.71	8.72	15.12	7.23
P*	0.00	0.00	0.00	0.00	10.35	4.52	9.22	1.08
S	29.22	12.49	20.01	11.28	12.01	5.54	6.97	0.91
P*+S	16.10	9.07	13.23	6.21	9.46	3.62	6.01	0.62
P*+M	23.68	11.01	19.77	9.31	10.21	4.81	5.72	0.64
M+S	19.46	8.72	14.99	6.96	8.45	3.48	4.99	0.50
P*+S+M	15.07	7.04	12.47	5.39	7.24	0.95	3.94	0.37
LSD	6.15	2.77	6.15	2.77	6.15	2.77	6.15	2.77

M - Maize cob; MU - Boiled maize cob; P* - Oil palm fibre; S - Sawdust; P*+S - Mixture of oil palm fibre and sawdust; P*+M - Mixture of oil palm fibre and maize cob; M+S - Mixture of maize cob and sawdust; P*+S+M - Mixture of oil palm fibre, sawdust and maize cob. Source: Laboratory Work.

Figure 1. Substrates tested for cultivation of *Pleurotus sajor-caju*. (A) Mixture of oil palm fibre and sawdust - P*+S; (B) Mixture of oil palm fibre and maize cob - P*+M; (C) Sawdust - S; (D) Mixture of oil palm fibre, sawdust and maize cob - P*+S+M; (E) Boiled maize cob - MU; (F) Maize cob - M; (G) Boiled oil palm fibre - P; (H) Oil palm fibre - P*.

Table 3. Effect of different substrates on the fresh weight of mushroom.

Substrates	1st Flush (g)	2nd Flush (g)	3rd Flush (g)	4th Flush (g)
M	41.51^{a}	35.24^{a}	22.36^{a}	15.57^{a}
MU	36.21^{b}	31.60^{b}	21.71^{a}	15.12^{a}
P*	0.00^{g}	0.00^{f}	7.24^{e}	3.94^{e}
S	29.22^{c}	20.01^{c}	12.01^{b}	9.22^{b}
P*+S	16.10^{f}	12.47^{de}	9.46^{cd}	5.72^{d}
P*+M	23.68^{d}	19.78^{c}	10.35^{c}	6.97^{c}
M+S	19.46^{e}	14.99^{d}	10.21^{c}	6.01^{cd}
P*+S+M	15.07^{f}	11.67^{e}	8.45^{de}	4.99^{de}

M - Maize cob; MU - Boiled maize cob; P* - Oil palm fibre; S - Sawdust; P*+S - Mixture of oil palm fibre and sawdust; P*+M - Mixture of oil palm fibre and maize cob; M+S - Mixture of maize cob and sawdust; P*+S+M - Mixture of oil palm fibre, sawdust and maize cob. Mean in the same column followed by the same letter are not significantly different by Ducan test ($P<0.05$).

It was also reported by Landlord (2004) that they are not only excellent edible mushroom but also can colonize substrates and grow quickly on some unsuplemented agroforestry wastes. There was statistically no significant difference between ($P>0.05$) the yield parameters of control (maize cob) and other substrates except P* and P*+S+M. This means that the other remaining substrates as an agroforestry waste could be used to produce the mushroom as much as the maize cob could produce. It might be a way of reducing agroforestry waste in the environment, as reported by Kuyper et al. (2002) that the cultivation of *Pleurotus sajor-caju* on local agroforestry waste creates a way of reducing environmental pollution.

From the results, mushroom can grow well on different agroforestry wastes such as maize cob, sawdust and oil palm fibre. It can be oncluded that maize cob being the control is the best substrate followed by sawdust and then, the mixture of maize cob and oil palm fibre.

The processes for cultivation can be easily followed, and therefore can be taught to interested people. This suggests that mushroom cultivation can be used as means poverty alleviation. The plant residues after mushroom cultivation can be used as compost manure, or in biogas production. Hence, in the mushroom cultivation, there is a value-chain production in the entire process.

References

Beelman RD, Royse D, Chikthimmah N (2003) Bioactive components in *Agaricus bisporus* Imbach of nutritional, medicinal or biological importance. *International Journal of Medicinal Mushrooms*, 5(4):321-337. doi: 10.1615/InterJMedicMush.v5.i4.10

Bipasha C (2011) Trends in mushroom cultivation and breeding. *Australian Journal of Agricultural Engineering*, 2(4):102-109.

Bobek P, Ozdin O, Mikus M (1995) Dietary oyster mushroom (*Pleurotus ostreatus*) accelerates plasma cholesterol turnover in hypercholesterolaemic rats. *Physiological Research*, 44(5):287-291.

Chilton MD (1993) *Agrobacterium* gene transfer: progress on a "poor man's vector" for maize. *Proceedings of the National Academy of Sciences of the United States of America*, 90(8):3119-3120. doi: 10.1073/pnas.90.8.3119

Harsh NSK, Joshi K (2008) Mushrooms: the vegetable of future. *India Science and Technology*. Available at SSRN: http://ssrn.com/abstract=1474175

Hossain S, Hashimoto M, Choudhury E, Alam N, Hussain S, Hasan M, Choudhury S, Mahmud I (2003) Dietary mushroom (*Pleurotus ostreatus)* ameliorates atherogenic lipid in hypercholesterolaemic rats. *Clinical and Experimental Pharmacology and Physiology*, 30(7):470-475. doi: 10.1046/j.1440-1681.2003.03857.x

Isikhemhen OS (2004) Volunteer trainer to Imo ADP extension staff on mushroom production using locally available substrates (palm fibre, and www.americanscience.org, editor@americanscience.org 137 - Cultivation of straw mushroom (*Volvariella volvacea*) using some agro-waste material Onuoha, et al. sawdust) A seminar 27th – 30th Dec. 2004. Owerri, Imo State, Nigeria.

Keshari LM (2004) Center for agricultural technology, Nepal Mushroom growing for a living. In: Gush R, Yoon KS, Bak WC (ed) *Mushroom grower's handbook 1*. Nepal: Mush World. p.13-18.

Kuyper TN, Vandigk JFN, Onguene NA (2002) Knowledge and utilization of edible mushroom by local population of mains forest of South Cameroun. *Abstract*, Oslo Norway, p.115.

Landlord KC (2004) *Poverty alleviation by mushroom growing in Zimbabwe*. Thesis, University of Zimbabwe. 408p.

Oei P (2003) *Mushroom cultivation; appropriate technology for Mushroom gromers*. 3rd ed. Leiden: Backhnys Publication Leiden Netherlands. 426p.

Onuoha CI, Ukalor U, Onuoha B (2009) Cultivation of *Pleurotus pulmonarius* mushroom using some agro waste materials. *Agricultural Journal*, 4(2):109-112.

Sánchez A, Ysunza F, Beltran-Gracia M, Esqueda M (2002) Biodegradation of viticulture wastes by *Pleurotus*: a source of microbial and human food and its potential use in animal feeding. *Journal of Agricultural and Food Chemistry*, 50(9):2537-2542. doi: 10.1021/jf011308s

Sharma S, Madan M (1993) Microbial protein from leguminous and non-leguminous substrates. *Acta Biotechnologica*, 13(2):131-139. doi: 10.1002/abio.370130210

Tricita HO (2005) Oyster mushroom cultivation. In: Gush R, Poppe J (ed) *Mushroom grower handbook 1*. Los Banos: Mush World. p.1-12.