Growth and yield of three *Pleurotus* species on rice straw

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Abstract

Rice straw, composted *Triplochiton scleroexylon* sawdust and rice straw – *T. scleroxylon* sawdust (1:1 w/w ratio) combination were used as substrates to cultivate three species of oyster mushrooms, *Pleurotus ostreatus* strain EM1, *Pleurotus ostreatus floridarus* strain POF and *Pleurotus pulmonarus* strain PPO. Rice straw supported the best mycelial growth for the three strains and the rice straw-*T. scleroxylon* sawdust the least suitable. On the other hand, the rice straw-*T. scleroxylon* sawdust medium was the best substrate for mushroom production by the highest-yielding *Pleurotus ostreatus* strain EM1.

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Introduction

Pleurotus species are extensively cultivated in many countries including China, Indonesia, Japan, South Korea and Thailand both for their nutritive and medicinal properties (Chang, 1999). At present mushroom cultivation has become an important industry in Ghana and the oyster mushroom, *Pleurotus ostreatus*, is grown on composted sawdust of *Triplochiton scleroxylon* (Obodai *et al.*, 2000). Cultivation of edible mushrooms on other agricultural and industrial wastes, particularly, lingo-cellulosic by-products, has been recommended as the most efficient and valuable biological methods by which these wastes can be recycled (Hayes, 1978; Zadrazil, 1978; Madan *et al.*, 1987).

A possible by-product in Ghana beside sawdust for mushroom cultivation is rice straw (*Oryza sativa*) which occurs in abundance. Two decades ago, Sawyer (1994) estimated the amount of rice straw produced at 164,726 t per annum, and since then, annual production had increased substantially. Many countries, notably China, Indonesia, Korea and Philippines, widely and successfully cultivate edible mushrooms on rice straw (Tanaka, 1978).

The paper reports on tests carried out to cultivate three species of oyster mushrooms, *Pleurotus ostreatus* strain EM1, *Pleurotus ostreatus floridarus* strain POF, and *Pleurotus pulmonarus* strain PPO on rice straw in Ghana.

Materials and methods

Culture preparation and maintenance

Pleurotus ostreatus strain EM1 was obtained from the University of Mauritius, Mauritius. *Pleurotus ostreatus floridarus* strain POF and *Pleurotus pulmonarius* strain PPO were obtained from North Carolina A & E University, USA. *P. pulmonarius* strain PPO and *P. ostreatus floridarus* strain POF were selected for this experiment to compare their growth and yield characteristics to that of

Pleurotus ostreatus strain EM1, which is widely accepted and cultivated in Ghana, in order to determine an economically viable alternative of oyster mushroom for the mushroom industry in Ghana. The strains were maintained on potato dextrose agar (PDA) slants and spawn was prepared on sorghum grains as described by Oei (2003). Both the cultures and the spawn were incubated at 26–28 °C and relative humidity of between 60–65 per cent.

Substrate preparation

Rice straw preparation. Rice straw was cut into 4 cm lengths and water was sprinkled on the heap till a moisture content of between 65 and 70 per cent was attained. The moisture content was determined by the squeeze test (Buswell, 1984). The squeeze test involves taking a handful of the substrate and squeezing it. A moist palm without water dripping out between the fingers indicates a moisture content ranging between 65 and 70 per cent.

Composting of sawdust. Freshly milled *T. scleroxylon* sawdust (moisture content 30 ± 2% wet weight basis) was thoroughly mixed with 10 per cent rice bran and 1 per cent $CaCO_3$ on dry weight basis. Water was sprinkled on the mixture until the moisture content was about 70 ± 2 per cent. The mixture was piled up into a pyramidal heap (1.5 m high), and allowed to ferment for 28 days. The heap was turned every 4 days to ensure uniform composting (Obodai *et al.*, 2000).

Bagging, spawning, incubation and cropping

Three treatments were used for the experiment: rice straw, rice straw-sawdust mixture (in a ratio of 1:1 w/w) and sawdust. Rice bran (12%) and $CaCO_3$ (0.5%) were added to each treatment on dry weight basis of the substrate and thoroughly mixed. Water was added to the composted sawdust such that a moisture content of between 65–70 per cent (determined by the squeeze test; Buswell, 1984) was attained. There were four replicates for each of the *Pleurotus* species.

Heat resistant polypropylene bags, each 33 cm long and 18 cm wide were filled with the appropriate substrates to a weight of 1.0 kg (Auetrugal, 1984). The substrates were compacted in the bags and each bag was fixed with a 2 cm long neck, which was then plugged with cotton waste. The bags were steam sterilized for 3 h, cooled to room temperature (26-28 °C), and the *p*H of each medium was measured with an Alpha 500 model laboratory *p*H/mv meter. In addition, the dry weight of the sterilized substrates was determined by drying 5 g of each substrate at 107 °C overnight in a hot oven (Gallenkamp oven, 300 plus series, England).

Each bag was inoculated at the neck with about 5 g sorghum spawn of the test species. The bags were placed vertically on shelves in a well-ventilated semi-dark room and incubated at 28 ± 2 °C and 65 per cent RH for 48 days (Auetrugal, 1984). The mycelia grew from the bottle-neck end of the compost bags downwards. The mean mycelia extension per week, the spawn run period (the number of days from inoculation to complete colonisation of the compost bag by the mycelium), the mycelial density (measured by physical observation) and the number of days taken for appearance of pinheads were recorded.

After complete colonisation, the bags were transferred and packed horizontally in stacks, onto horizontal racks inside a cropping house for cropping. The mushrooms were harvested by holding the end of the stipe attached to the substrates, gently wriggling it out of the bags and cutting off the substrate attached to the stipe (Obodai & Johnson, 2002). The biological efficiency was determined as a percentage of the weight of fresh mushrooms to the dry weight of substrate at spawning (Mueller *et al.*, 1985).

A 3×3 factorial experimental design was employed in the experiment. All the analyses were carried out in quadruplicate. Data were subjected to a one-way ANOVA. The total yield of mushroom per substrate was separated by the Duncan's multiple range test (DMRT) at $P = 0.05$. All statistical analyses were done using SPSS10 for Windows (1999).

Results and discussion

pH and moisture content of substrates

The *p*H is of the substrates at 25 °C at inoculation shown in Table 1 were not significantly different from each other and were all within the optimum range of 6.0 – 8.0 suggested by Stamets (2000). The values of moisture contents of the three substrates at inoculation were also not significantly different, but were lower than the recommended moisture content of between 85–95 per cent (Stamets, 2000).

TABLE 1

Mean pH at 25 °C and Moisture Content of Substrates at Inoculation

Substrate	pH	*Moisture content (%)*
Rice straw-sawdust mixture	7.99 ± 0.02	66.61 ± 0.32
Rice straw	7.85 ± 0.03	64.97 ± 0.40
Sawdust (control)	7.41 ± 0.02	63.53 ± 0.65

Mean extensional mycelial growth rate of Pleurotus *species*

Growth of the three types of fungi species was related to substrate (Table 2). Shorter period of spawn run, indicating faster growth rate, was recorded for mycelia on rice straw-sawdust mixture and sawdust than rice straw. The rice straw-sawdust mixture and the sawdust were completely colonised between 21and 29 days and 23 and 27 days, respectively, while the rice straw was completely colonised by the fungi between 32 and 43 days (Table 3). The fast mycelial growth on the sawdust medium was accompanied by development of highly dense mycelia. Generally, the mycelia of the *Pleurotus ostreatus floridarus* strain POF grew faster than either *P. ostreatus* strain EM1 or *P. pulmonarus* strain PPO (Table 3).

For all the substrates the mycelial growth rate decreased with increasing period of growth. This can be attributed to the release of CO_2 (Donoghue & Denison, 1995) by the growing mycelia in the media, as well as depletion of nutrients in the substrates.

Mean yield and biological efficiency of fresh fruiting bodies

It took 4 – 5 days following the opening of the bags for the first flush of *P. ostreatus* strain EM1 to appear on all the substrates (Table 3). The interval could, however, be as long as 19 days for *P. pulmunarius* strain PPO on rice straw, whereas *P. ostreatus floridarus* strain POF did not produce fruiting bodies on the sawdust medium within the 6 weeks of cropping. Since *P. ostreatus floridarus* strain POF flushed only once on the rice straw-sawdust substrate, sawdust of *T. scleroxylon* may contain certain substances such as lignin in higher concentrations than rice straw (Obodai *et al.*, 2003b), which inhibited reproduction of this fungus on the substrate. There was a progressive reduction in yield of all the strains indicating nutrient depletion with increasing time of growth. There could be a reduction in cellulose content as the level of cellulose content in the substrate has been found to be directly related to the amount of yield (Xiujin *et al.*, 2000; Obodai *et al.*, 2003a).

The biological efficiency of 64.08 per cent of *P. ostreatus* strain EM1 mushrooms, formed on the rice straw-sawdust medium in the study, is closely similar to 64.69 per cent obtained in a study by Shah *et al.*, (2004) on the cultivation and yield performance of *P. ostreatus* on different substrates. The biological efficiencies of *P. ostreatus* strain EM1 mushrooms formed on rice straw and sawdust individually (27.00% and 54.29%, respectively) were significantly inferior (Table 3).

P. ostreatus strain EM1, the choice oyster mushroom in Ghana, produced the highest yield on the rice straw-composted *T. scleroxylon* sawdust mixture, rather than on sawdust medium widely used in the country. Rice straw-composted *T. scleroxylon* sawdust mixture could, therefore, be considered an alternative substrate for *P. ostreatus* strain EM1 cultivation, but only after the best rice straw-sawdust ratio that would

TABLE 2

Weekly Mean Extensional Mycelial Growth of Pleurotus *species on Different Media*

Substrate	Pleurotus *species*	*Spawn run period (days)*	**Surface mycelial density*	*Mean radial mycelial growth rate (cm/wk)*					*Mean extensional mycelial growth per week (cm/wk)*
				Week 1	*Week 2*	*Week 3*	*Week 4*	*Week 5*	
Rice straw-sawdust	*P. ostreatus*	28.50 ± 1.55	++	7.35 ± 0.62e	5.93 ± 0.22de	5.68 ± 0.42de	5.60 ± 0.52d	C a	6.14 ± 0.40
	P.ostreatus floridarus	20.75 ± 0.25	+++	9.33 ± 0.13f	7.75 ± 0.27ef	8.25 ± 0.36ef	C a	C a	8.44 ± 0.50
	P. pulmonarius	23.50 ± 0.65	++	7.38 ± 0.22e	7.65 ± 0.12ef	7.30 ± 0.09e	C a	C a	7.44 ± 0.10
Rice straw	*P. ostreatus*	43.50 ± 0.87	++	6.10 ± 0.21de	4.98 ± 0.21cd	4.85 ± 0.27c	4.68 ± 0.39c	3.65 ± 0.43c	4.85 ± 0.40
	P.ostreatus floridarus	31.50 ± 1.55	++	6.43 ± 0.14de	5.80 ± 0.33de	5.45 ± 0.35de	6.03 ± 0.64d	5.00 ± 0.00cd	5.93 ± 0.20
	P. pulmonarius	33.50 ± 1.55	++	6.53 ± 0.14de	5.33 ± 0.10d	4.75 ± 0.20cd	5.43 ± 0.35d	1.90 ± 0.00b	5.51 ± 0.80
Sawdust	*P. ostreatus*	26.50 ± 1.50	+++	8.00 ± 0.13ef	5.48 ± 0.25d	5.88 ± 0.27de	6.65 ± 0.11de	C a	6.55 ± 0.60
	P.ostreatus floridarus	23.75 ± 0.63	+++	9.23 ± 0.46f	7.30 ± 0.41de	7.18 ± 0.44e	C a	C a	7.90 ± 0.70
	P. pulmonarius	25.00 ± 0.41	+++	8.25 ± 0.43ef	6.68 ± 0.14de	6.45 ± 0.50de	C a	C a	7.13 ± 0.60

Values followed by different letters are significantly different at 5 per cent level of probability according to Duncan's multiple range test. N = 4

* : Degree of mycelial density when the mycelia fully colonize the substrate

C : Complete colonisation of substrate

++ : Moderately dense mycelia

+++ : Highly dense mycelia

support optimal yield has been determined.

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TABLE 3

Yield of Fruiting Bodies of Pleurotus species on Different Media

Substrate	Pleurotus strains	Mean no. of days from bag opening to 1st flush (days)	Mean yield of fruiting bodies/ flush (g)			Biological efficiency(%)
			1st flush	2nd flush	3rd flush	
Rice straw-sawdust	*P. ostreatus*	5.00 ± 0.20	120.25 ± 11.56e	50.63 ± 6.44cd	47.00 ±8.86c	64.08c
	P. ostreatus floridarus	19.20 ± 0.16	33.50 ± 8.13b	NF a	NF a	9.86ab
	P. pulmonarius	5.00 ± 0.30	77.13 ± 7.94cd	69.00 ± 4.16d	33.83 ± 8.04bc	50.44c
Rice straw	*P. ostreatus*	5.10 ± 0.10	36.63 ± 15.94b	27.63 ± 6.01b	30.25 ± 6.38bc	27.00b
	P. ostreatus floridarus	7.25 ± 0.20	90.75 ± 4.48d	29.00 ± 2.48b	NF a3	0.07b
	P. pulmonarius	19.25 ± 0.35	17.88 ± 4.60ab	22.33 ± 7.57b	19.50 ± 0.71b	12.68ab
Sawdust	*P. ostreatus*	4.00 ± 0.00	86.63 ± 22.19cd	54.25 ±19.49cd	41.00 ±13.23c	54.29c
	P. ostreatus floridarus	*NF	NF a	NF a	NF a	0.00a
	P. pulmonarius	15.30 ± 0.30	71.13 ± 14.31c	49.25 ±10.68c	NF a	35.93bc

Values in the same column followed by a different letter are significantly different at 5 per cent level of probability according to Duncan's multiple range test. N = 4

*NF : No flushes recorded

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