Asian Journal of Plant Sciences

ISSN 1682-3974

Asian Journal of Plant Sciences 8 (7): 510-514, 2009
ISSN 1682-3974

Suitability of Locally Available Substrates for Oyster Mushroom (*Pleurotus ostreatus*) Cultivation in Kenya

J.W. Kimenju, G.O.M. Odero, E.W. Mutitu, P.M. Wachira, R.D. Narla and W.M. Muiru
University of Nairobi, P.O. Box 30197 00100, Nairobi, Kenya

Abstract: This study aimed at evaluating the suitability of selected substrates for mushroom production. Ten different substrates namely water hyacinth (*Eichhornia crassipes*), maize cobs (*Zea mays*), coconut fibre (*Cocos nucifera*), finger millet straw (*Seteria microcheata*), banana fibre (*Musa* sp.), sawdust (*Eucalyptus* sp.), rice straw (*Oryza sativa*) bean straw (*Phaseolus vulgaris*) and wheat straw (*Tritichum aestivum*) were tested for their suitability in mushroom production. Plastic bags were filled with 250 g of substrate and arranged in a randomized complete block design. The substrates had a significant ($p \leq 0.05$) effect on days to pinning, number of caps and biological efficiency. Compared to the control, which pinned at 28 days, maize cobs, sawdust and coconut fiber had short pinning durations of 19, 22 and 23 days, respectively. With the exception of sawdust, water hyacinth and maize cobs, the rest of the organic substrates significantly increased the marketable caps of the oyster mushroom. The straws, namely, bean, rice, finger millet and wheat had the highest biological efficiency in decreasing order of 106, 92, 85 and 77%, respectively. Stipe length was longest in oyster mushroom grown on bean straw, followed by finger millet straw, maize cobs, banana fiber and shortest in sawdust. Mushroom yield was, 80, 78, 76, 73 and 68%, higher in bean straw, rice straw, millet straw, wheat straw and banana fibre treatment compared to the control. Mushroom yields on sawdust were 60% lower than the control. In descending order of suitability bean, rice, finger millet and wheat straws can be recommended for oyster mushroom production.

Key words: Average biological efficiency, pileus, pinning, stipe

INTRODUCTION

The Kenyan population is on a continuous increase against a declining acreage of arable land (Fermont *et al*., 2008). Consequently, the available arable land is being subdivided into smaller parcels which are intensively cultivated. The ultimate result has been a decline in agricultural productivity and sustainability of agroecosystems (Statistical Abstract, 1999). In order to alleviate food shortage, strategies of agricultural production that don't require large tracts of land are gaining popularity. One such strategy is cultivation of edible mushrooms which are a source of nutritional security and also help to diversify the farm based enterprises and generate income.

Cultivation and consummation of edible mushroom has found a niche among small scale farmers in Kenya for their nutritive value as well as for economic and medicinal purposes (Maundu *et al*., 1999; Zhang *et al*., 2001; Wachira, 2003). Two main types of mushrooms are being commercialized, the button (*Agaricus bisporus*) which account for 95% of the total mushroom production and oyster (*Pleurotus* species). Oyster mushrooms introduced in 2003, in particular, are valuable mushrooms with good marketability and are relatively easy to grow (Stamets, 1993). The mushrooms are advantageous to grow as compared to button mushrooms. They requires no arable land for production and the abundant agricultural waste found countrywide offers opportunity for production, which in turn provides a more economical and environmentally friendly disposal system (Stamets, 2000; Philoppousis and Diamantopoulou, 2001). However, the mushroom farmers are faced with a multiple problems which include high input costs, lack of quality spawn, diseases and pests, lack of proper skills in production and lack of information on substrates for mushroom cultivation (Stamets, 1993; Tisdale *et al*., 2006). Identification of suitable substrate material is critical for successful mushroom cultivation (Zandrazil and Kurtzman, 1982; Shah *et al*., 2004).

The objective of this study was therefore to determine the suitability of locally available substrates for oyster mushroom production.

Corresponding Author: Peter M. Wachira, University of Nairobi, School of Biological Sciences, P.O. Box 30197 00100 Nairobi, Kenya Tel/Fax: 254-2-4442115

MATERIALS AND METHODS

The study was conducted at the University of Nairobi, Kabete Field Station in the period between September, 2007 and January, 2008. Ten substrates namely, bean straw (*Phaseolus vulgaris*), sawdust (*Eucalyptus* sp.), coconut fibre (*Cocos nucifera*), finger millet straw (*Seteria microchaeta*), water hyacinth (*Eichhornia crassipes*), rice straw (*Oryza sativa*), maize cobs (*Zea mays*), wheat straw (*Triticum aestivum*) and banana fiber (*Musa* spp.) were tested. All the substrates were compared to sugarcane baggase (*Saccharum officinarum*) which had been recommended as the best substrate for mushroom cultivation (Wachira, 2003). Plastic bag technology was used in this experiment with treatments replicated four times and arranged in a completely randomized block design. The substrates were collected, cleaned, air dried and chopped into pieces of about one centimeter in length. Oyster mushroom spawn GSP1POK2 from the University of Nairobi Microbiology Laboratory was used. Autoclavable polypropylene transparent bags (15×18 cm) were filled with 250 g of substrate. The substrate was soaked overnight and then steam sterilized in an autoclave. The substrates were left to cool at 25±3°C and spawned at a rate 4±1% w/w. Spawned bags were placed in a dark room at 23±3°C until spawn run was complete. Upon completion of spawn run, two holes of 10 mm diameter were made on each bag. Three to four days after the emergence of pinheads, mature mushrooms were harvested.

Observations on weight of fresh mushrooms, pileus diameter, stipe length and number of mature and aborted mushrooms were made. Days to pinning and flushing interval was recorded per bag. The biological efficiency against the dry weight of each substrate was calculated using the formula outlined by Shah *et al*. (2004). Total wet weight of mushroom was recorded during the four flushes. The diameter of the pileus was estimated by averaging the perpendicular measurements across the pileus, since the pileus was not perfectly round.

Data obtained were analyzed statistically by Statistical Analyses System package. Analysis of Variance (ANOVA) and Tukey's mean homogeneity test were used to indicate the significant differences between the mean values ($p<0.05$).

RESULTS

Organic substrates tested were significantly different ($p = 0.05$) in suitability for mushroom cultivation. The substrates had valuable effects on the duration to primordial induction ranging from 19 to 39 days for maize cobs and water hyacinth respectively. The control pinned in 28 days. Compared to the control (sugarcane baggase), maize cobs, sawdust and coconut fiber took a shorter time to pin with 19, 22 and 23 days, respectively. Wheat straw, bean straw, finger millet, banana fiber, rice straw and water hyacinth all had longer durations with 28, 29, 31, 32, 36 and 39 days recorded, respectively. The interval between on flush to the next was not significant ($p>0.05$) across the substrates tested (Table 1).

The number of marketable mature caps harvested from each bag varied significantly among the substrates. With the exception of sawdust, water hyacinth and maize cobs, the rest of the organic substrates had marketable pileus. Amongst the substrates, bean straw had the highest number of pileus (54) followed by rice straw (45) and the least on sawdust (4). The stipe length was longest in oyster mushroom grown on bean straw, followed by finger millet straw, maize cobs, banana fiber in that order and shortest in sawdust. Pinhead abortion was not affected by the substrates tested. Average biological efficiency was significantly ($p \leq 0.05$) different among the substrates tested. The straws, namely, bean, rice, finger millet and wheat had the highest BE in decreasing order of 106, 92, 85 and 77%, respectively. Sawdust had the least (4%) BE (Table 2).

Table 1: Effect of substrates on days to pinning and flushing intervals

		Flushing interval (days)	
Substrate	Days to pinning	1-2	2-3
Banana fibre	32.30^{bc}	16.9	18.5
Bean straw	29.80^{c}	12.6	14.8
Coconut fibre	22.60^{de}	18.6	19.2
Finger millet straw	31.10^{bc}	17.5	13.9
Maize cobs	19.60^{e}	20.2	19.5
Rice straw	36.30^{ab}	15.6	15.0
Sawdust	22.40^{de}	24.7	15.3
Sugarcane bagasse	28.20^{cd}	17.3	15.6
Water hyacinth	39.90^{a}	20.3	21.6
Wheat straw	28.80^{cd}	18.4	18.1
LSD at 5%	6.31	NS	NS
CV (%)	19.12	19.69	39.66

1-2: First to second flush; 2-3: Second to third flushes, Means flowed by different letters are significantly different at $p = 0.05$

Table 2: Influence of substrates on growth and yield parameters of oyster mushroom

Substrate	No. of pileus/250 g	BE (%)	Pileus diameter	Stipe length	Pinhead abortion (%)
			-------(mm)--------		
Banana fibre	30.90^{c}	65.10^{c}	45.50^{a}	36.70^{ab}	63.3
Bean straw	54.30^{a}	106.20^{a}	45.80^{a}	40.60^{a}	63.9
Coconut fibre	15.80^{d}	22.80^{d}	45.20^{a}	26.70^{d}	59.4
Finger millet straw	41.70^{b}	85.40^{b}	48.30^{a}	38.9^{a}	59.0
Maize cobs	12.90^{de}	25.20^{d}	47.20^{a}	30.40^{bd}	61.3
Rice straw	45.40^{ab}	92.10^{ab}	41.90^{ab}	38.00^{a}	61.9
Sawdust	4.00^{e}	4.00^{e}	34.60^{b}	18.60^{d}	49.9
Sugarcane bagasse	12.20^{de}	22.50^{d}	48.40^{a}	28.20^{c}	62.0
Water hyacinth	12.30^{de}	21.90^{d}	43.20^{ab}	34.40^{abc}	61.8
Wheat straw	36.50^{bc}	77.10^{bc}	46.40^{a}	39.40^{a}	60.3
$LSD_{5\%}$	9.43	16.37	6.31	7.16	NS
CV (%)	31.25	27.60	17.83	19.00	19.69

Means flowed by different letters are significantly different at $p = 0.05$, along the columns. NS: Not significant

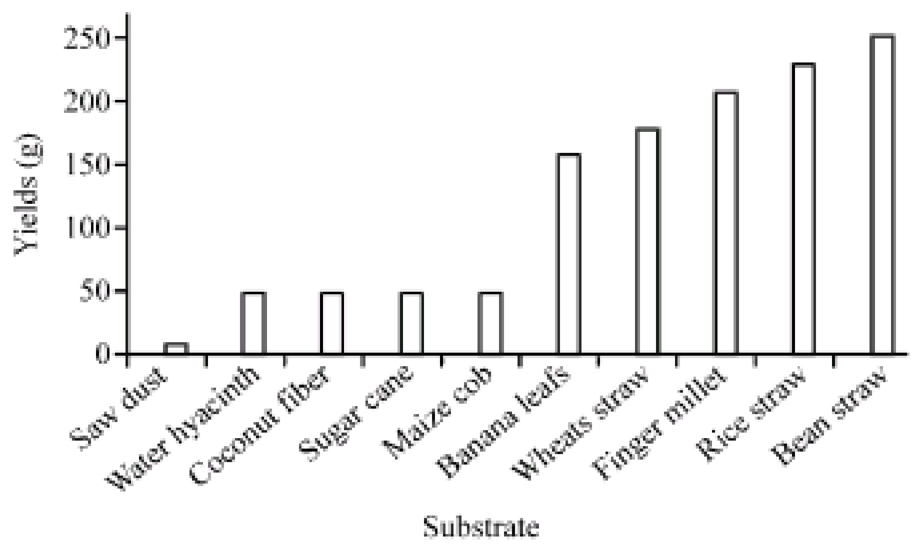

Fig. 1: Yields of fresh mushroom per 250 g dry substrate

Table 3: Effect of substrate on yield per flush and percentage of yield per flush

	Yield per flush (g)			Percent yield per flush		
Substrate	1st	2nd	3rd	1st	2nd	3rd
Banana fiber	83.8^{c}	49.9^{b}	26.2^{bc}	54.0^{cd}	31.1^{a}	14.9^{abc}
Bean straw	143.5^{a}	66.4^{ab}	44.7^{ab}	57.2^{cd}	25.6^{a}	17.3^{abc}
Coconut fiber	25.7d^{e}	13.8^{c}	14.3^{cde}	49.3^{d}	27.2^{a}	23.5^{a}
Finger millet straw	96.5^{bc}	48.4^{b}	50.3^{a}	49.6^{d}	24.6^{a}	25.8^{a}
Maize cobs	40.4^{d}	14.0^{c}	6.4^{de}	67.0^{bc}	23.1^{a}	9.9^{bcd}
Rice straw	101.7^{bc}	69.4^{a}	49.2^{a}	48.2^{d}	31.2^{a}	20.6^{ab}
Sawdust	5.5^{e}	0.8^{c}	0.1^{e}	92.0^{a}	5.8^{b}	2.2^{d}
Sugarcane bagasse	41.5^{d}	11.2^{c}	3.1^{de}	74.6^{b}	20.0^{a}	5.4^{cd}
Water hyacinth	32.2^{d}	17.1^{c}	5.5^{de}	69.6^{bc}	23.6^{a}	6.8^{cd}
Wheat straw	115.4^{b}	55.1^{ab}	21.5^{dc}	60.0^{bcd}	29.0^{a}	11.0^{bcd}
LSD 5%	20.2	19.5	19.8	16.2	13.1	12.1
CV (%)	25.9	49.6	78.6	22.9	47.9	77.6

Similar letters show no significant different between substrates

On total mushroom yield, the organic substrates tested had variable effects on the yields (Fig. 1). The highest yields were recorded on bean straw and the least on sawdust. Bean straw, rice straw, millet straw, wheat straw and banana fibre performed better than the control by 80, 78, 76, 73 and 68%, respectively. Mushroom yield on sawdust was 60% lower than in the control. Water hyacinth, coconut fibre and maize cob substrates were not significantly different compared to the control.

The yield per flush and the percentage yield per flush for the first three flushes varied with the substrates. In all the treatments, the yields were highest in the first flush then declined gently in the second and third flushes (Table 3). Among the flushes, mushroom yields from bean straw were highest compared to the rest. No harvestable produce was recorded from saw dust after the second flush. Despite the continuous low performance observed with sawdust, it recorded the highest percentage yield (92.0%) in the first flush while rice straw gave the lowest 48.2%. Finger millet straw had more evenly spread production over the three flushes compared to the other substrates which were tested.

DISCUSSION

This study has demonstrated that locally available organic substrates are potentially suitable for use in the production of mushrooms. It means that the substrates contain lignin and cellulose which is utilized by the mushroom mycelium as a source of nutrition. The diverse range of substrates indicates that the mushrooms can be grown on almost all available organic wastes. The ability of mushroom mycelia to degrade organic substrates can also be utilized in management of organic waste in the environment, which is otherwise left to decompose hence causing health hazards. It is one of the methods that can help in recycling the organic wastes into profitable products as reported by Olfati and Peyvast (2008) and Silveira *et al*. (2001). This is made possible by the ability of mushrooms (basidiomycetes) to secrete a wide range of hydrolyzing and oxidizing enzymes which breaks down natural lignocellulosic waste into simple soluble compounds (Yolisa, 1997). *Pleurotus* mushrooms also occur as saprophytes in dead and decomposing wood in addition to being a weak parasite on some trees (Brouk, 1975; Alexopoulos *et al*., 1979; Poppe and Hofte, 1995).

The time taken by the mycelia to start pinning after ramification depends on the substrate used. Materials with high quality lignin and cellulose contents take a longer time to start pinning compared to the substrates with low contents of the lignin and cellulose. Compared to the substrates with low nutrition values, the substrates with high nutrition value take a short time to be fully colonized and ramification. This is because the mycelia remains vegetative for a longer period hence the vigorous growth and late pinning. In return, the highly colonized substrates had high mycelia densities. Poor nutritional substrates exhibited low mycelia densities making them prone to contamination especially by the green mold. This is in agreement with Oei (2003). Except for the water hycinth which delayed in pinning due to the high moisture, all other poor substrates pinned earlier than the sugarcane baggase was used as a control. This observation differed with that Nageswaran *et al*. (2003), who reported a shorter period for the water hyacinth. The possible reason for this could have been the high moisture it contained (83%) compared to the optimum (75%) as reported in MushWorld (2004).

The suitability of different substrates for mushroom cultivation was also confirmed by the average biological efficiency which was variable among the substrates. This agreed with the study done by Dass and Mukherjee

(2007) who reported significant differences while studying use of different weed plants as substrates for *Pleurotus ostreatus* production. The size of the mushroom cap and diameter was significantly affected by the substrates. Big mushroom caps were produced on the more suitable substrates compared to the poor substrates. It was observed that pileus diameter was very much dependent on the number of caps per cluster. The fewer they were the wider the diameter. In addition, the size of the caps and the site depended on amount of aeration and light (Kivaisi *et al*., 2003). It was observed during the study, that the two parameters also depend on the length of time taken from pinhead appearance to harvesting. There was no significant difference on substrates on pinhead abortion when was more than 50% in most substrates. This means that more than half of the pinheads that emerge do not grow to marketable produce. It was observed that the high producing substrates exhibited shorter flushing interval which implies shorter cropping cycles and therefore more crops in a given length of time.

CONCLUSION

It is evident that many organic substrates have high potential for utilization as substrates in mushroom cultivation. Mushrooms farmers are advised to make the right choice of substrates based on the locally available materials. It is clear that bean straw, rice straw, finger millet straw and wheat straw are superior as substrates for oyster mushroom cultivation

ACKNOWLEDGMENTS

This research was financially supported through The Mushroom Project, which was a subproject under the Kenya Agricultural Productivity Project (KAPP No. 04/07). The University of Nairobi is acknowledged for providing laboratory space and equipment. Technical assistance from Mr. Mathenge is greatly acknowledged.

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