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Evaluation of Substrate Productivity and Market Quality of Oyster Mushroom (*Pleurotus ostreatus*) Grown on Different Substrates

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ABSTRACT

Substrate type is one of the major factors affecting the yield and quality of oyster mushroom (*Pleurotus ostreatus*). Six substrates; cotton lint waste, maize stover, jatropha cake, corncobs, wood shavings and wheat straw were evaluated for their productivity and impact on mushroom market quality of *P. ostreatus*. Wheat straw was used as a control because it is commonly used for mushroom production in Zimbabwe. The experiment was carried out in a low cost mushroom growing house and laid out in a randomized complete block design with each treatment replicated four times. Bags containing the pasteurized substrates were spawned at a rate of 8%. Three flushes were harvested from which substrate productivity was evaluated by determining mean number of basidiocarps (MNB), mean basidiocarp weight (MBW) and biological efficiency (BE) while mushroom market quality was evaluated on the basis of basidiocarp percentage number within pileus diameter groups; >7, 5-7, 3-5, <3 cm and a deformed group. Fruiting occurred in the other substrates with significant differences in MBW ($p<0.001$), MNB ($p<0.05$) and BE ($p<0.001$) among the substrates. There were no significant differences among cotton lint waste, wheat straw and maize stover in MBW and BE. However, cotton lint waste had the highest productivity followed by wheat straw. Corncobs and wood shavings performed poorly and there were no fruiting bodies on jatropha cake. Wood shavings had significantly lower basidiocarp percentage number within the >7 and 5-7 cm size groups and highest in the deformed group. There were, however, no significant differences in the 3-5 and <3 cm size groups ($p>0.05$). Cotton lint waste and maize stover are competent alternatives to wheat straw as they are equally productive and produce high market quality mushrooms.

Key words: *Pleurotus ostreatus*, substrate productivity, mushroom market quality

INTRODUCTION

Oyster mushroom is one of the leading mushrooms in terms of both customer preference and production worldwide due to its simplicity and low cost of its cultivation technology (Mswaka and Tagwira, 1997; Baysal *et al*., 2003). Many organic substrates have high potential for utilization as substrates in mushroom cultivation (Kimenju *et al*., 2009; Onyango *et al*., 2011).

Oyster mushroom is known for its ability to degrade lignocellulosic residues from agricultural fields and forests and convert them into protein-rich biomass (Rowel *et al.*, 2000). Species of oyster mushroom show good adaptability to a wide range of temperature, making it possible to grow this mushroom almost all year round without controlled climatic conditions (Chadha, 2001; Baysal *et al.*, 2003). In Zimbabwe oyster mushroom, particularly *Pleurotus ostreatus*, is the first preference for resource-disadvantaged farmers (Kashangura *et al.*, 2005).

Pleurotus ostreatus grows on a wider array of forest, industrial and agricultural wastes than species from any other group (Zadrazil and Brunnert, 1981; Jadhav and Bagal, 1998; Baysal *et al.*, 2003). In Zimbabwe, main substrates used for *P. ostreatus* cultivation are wheat straw and soybean straw with wheat straw giving the highest yield (Kashangura *et al.*, 2005). However, Zireva *et al.* (2007) highlighted the need to test performance of oyster mushroom under different substrates. Furthermore, the hectarage under wheat and soybean is low as compared to maize (FAO/WFP, 2010) hence, wheat and soybean straw are not readily available in some parts of the country. There is thus need for research on the productivity of alternative substrates that can be used and at the same time being easily accessible to oyster mushroom growers in the country.

Small scale farmer's cost effective production of *P. ostreatus* depends on the availability, utilisation and cost of substrates (Vetayasuporn *et al.*, 2006, 2007a). Maize stover and corncobs are readily available and found in almost every part of Zimbabwe and are cheap to access since maize is a staple food crop grown nationwide (Tavuyanago *et al.*, 2010). Therefore, knowledge of their effectiveness as compared to wheat straw is essential.

Environmental pollution is a threat from many industries including agro-based ones due to the dumping of wastes like wood shavings and cotton waste from ginneries. A non-timber forest product (NTFP) such as mushroom is a major option or alternative to the incineration of these wastes, in order to ensure economy of the industries, a safe and healthy environment (Murthy and Manonmani, 2008; Ukoima *et al.*, 2009). Bioconversion of wastes by extracellular enzymes produced by mushroom is viewed as a biotechnological tool for the transformation of wastes into biological products (Akinyele *et al.*, 2011). There is thus need to utilize and evaluate the productivity potential of these waste materials for mushroom production since they are rich in ligno-cellulose, hence helping reduce environmental pollution. Jatropha cake is another waste residue from the bio-diesel industry after the processing of *Jatropha curcas* seed. There is thus need to evaluate the productivity of jatropha cake on yield and quality of *P. ostreatus*. The research also sought to provide a cyclic relationship between farmers and agro-based industries, with farmers providing the raw materials (farm produce, like jatropha seed and cotton) to the industries whilst the industries provide wastes (cotton waste and jatropha cake) that are used for *P. ostreatus* production by the farmers.

The main objective of the study was to evaluate the effect of maize stover, cotton lint waste, corncobs, wood shavings, jatropha cake and wheat straw on productivity and market quality of *P. ostreatus*.

MATERIALS AND METHODS

The experiment was carried out in a mushroom growing house (MGH) at Midlands State University, Gweru in Zimbabwe in June 2007. The area falls under Natural Region III of Zimbabwe's Agro-ecological zones. Six treatments replicated four times were laid out in a

Randomized Complete Block Design (RCBD). The substrates making up the treatments were maize stover, corncobs, cotton lint waste, wood shavings, jatropha cake and wheat straw which was used as a control. Wheat straw, corncobs and maize stover were chopped into small pieces of about 6-10 cm to improve surface area for water absorption and ease mycelia colonization and growth. Cotton waste and jatropha cake were used uncut since they are fine textured.

Dry substrates each measuring 4 kg were put differently in metal containers filled with water so as to immerse the substrates. The substrates were soaked overnight so that they would achieve a moisture content of about 70-80%. They were then pasteurized by boiling in water for 1 h using firewood. The pasteurized substrates were collected using a heat sterilized fork. The substrates were placed on a sodium hypochlorite disinfected plastic sheet and were allowed to cool to a temperature of about 25-37°C. The wet pasteurized substrates were each divided into four equal parts making the four replications and were packed in clear sodium hypochlorite disinfected plastic bags. Spawning was done in three layers at a rate of 8%. The bags were hung in the MGH and holes were punched on the bottom of the bags to drain off excess water. The bags were then left for spawn running (incubation).

During the spawn running period, humidity was maintained by daily watering the MGH walls and floors. Sand was put on the floor to aid moisture conservation and the room was always kept closed. A footbath was put at the door so as to avoid introducing contaminants. No entry of sunlight was permitted and this was achieved by closing all the gaps of the MGH with a black polyethylene plastic sheet. When the substrate appeared completely white as a result of successful spawn run, holes were punched on the surface of the bags to allow the pin-heads to come out. High humidity was maintained by daily watering and spraying of the bags to avoid withering of the growing mushrooms especially at pin-head stage.

Harvesting of the basidiocarps was done by hand pulling. Each bag was harvested separately and the mass of the basidiocarps was recorded in grams using a digital scale. Biological efficiency (BE), calculated as:

$$\text{BE (\%)} = \frac{\text{Mushroom fresh weight}}{\text{Substrate dry weight}} \times 100$$

The mean number of basidiocarps (MNB), corresponding to number of basidiocarps per bag and mean basidiocarp weight (MBW) were determined for evaluation of substrate productivity. The quality of the basidiocarps was evaluated on the basis of 4 pileus diameter size groups (larger than 7, 5 to 7, 3 to 5, smaller than 3 cm) and a deformed group. Marketable mushrooms were those measuring more than 3 cm in diameter and mushrooms of highest commercial value were those measuring more than 5 cm in diameter (Rossi *et al.*, 2003). Number of days to first fruiting (DFF) was also recorded among the treatments. The collected data was subjected to analysis of variance (ANOVA) using GENSTAT 7.1 package and their mans were separated by Least Significance Difference (LSD 0.05).

RESULTS

Substrate productivity: There was no mycelia growth and hence no fruiting bodies on jatropha cake. Fruiting occurred in the other substrates with significant differences ($p<0.001$) in MBW. As shown in Table 1, cotton lint waste had the highest MBW but it was however not significantly different from wheat and maize stover. There were significant differences in MNB among the substrates ($p<0.05$), with wheat straw having the highest MNB followed by cotton lint waste, maize stover, corn cobs and wood shavings (Table 1). There were significant differences in BE among the substrates ($p<0.001$) with cotton lint waste having the highest BE (Table 1). Wood shavings and corn cobs had also lower BEs while wheat straw had the second highest BE. The substrates significantly differed ($p<0.001$) in the DFF with wheat straw fruiting relatively earlier followed by maize stover, cotton lint waste, corn cobs and lastly wood shavings.

Mushroom market quality: Mushroom market quality in terms of basidiocarp pileus diameter was affected by substrate type. There were significant differences ($p<0.05$) in the percentage number of basidiocarps in the market quality size groups >7, 5-7 cm and the deformed group as shown in Fig. 1. There were no significant differences in mushroom quality ($p>0.05$) among the substrates in the 3-5 and <3 cm size groups (Fig. 1). Cotton lint waste yielded the highest quality mushrooms, with 31% in the >7 cm group while wood shavings had none in the same quality group. Maize stover stimulated highest production of basidiocarps in the 5-7 cm size group. Wood shavings had many of the basidiocarps in the <3 cm size group and the deformed group with 35.9

Table 1: Substrate effect on mean basidiocarp weight (MBW), mean number of basidiocarps (MNB), biological efficiency (BE) and days to first fruiting (DFF)

Substrate	MBW (g)	MNB	BE (%)	DFF (days)
Cotton waste	594^{a}	140^{a}	59.4^{a}	36^{ab}
Wheat straw	574^{a}	115^{a}	57.4^{a}	32.75^{b}
Maize stover	418^{ab}	98^{ab}	41.8^{ab}	33.75^{b}
Corncobs	283^{bc}	84^{ab}	28.3^{bc}	40^{a}
Wood shavings	51^{cd}	27^{bc}	5.1^{cd}	36.5^{ab}
Jatropha cake	0^{d}	0^{c}	0^{d}	*NF
Grand	320	77	32.0	29.83
F prob.	<0.001	0.022	<0.001	<0.001
LSD	269	83.4	26.9	4.23

Means followed by the same letter are not significantly different at $p = 0.05$, *NF: No fruiting occurred on the substrate hence undefined DFF

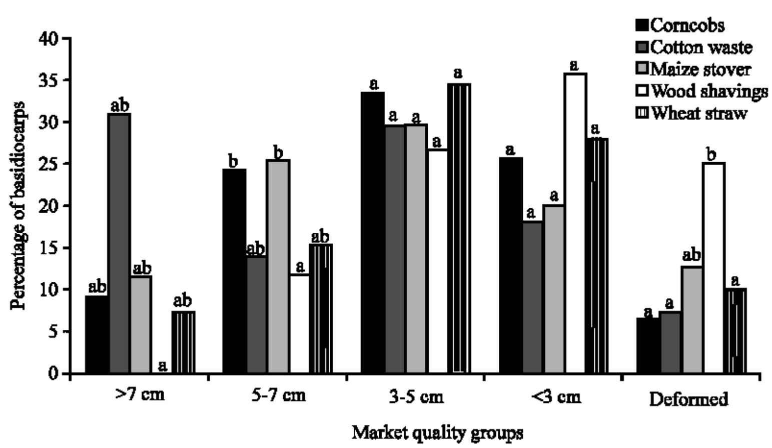

Fig. 1: Substrate effect on *P. ostreatus* quality evaluated by cap size groups

and 25.2%, respectively. Irrespective of lack of significant differences in the quality size group 3-5 cm, generally this quality group had the highest percentage number of basidiocarps in all the substrates.

DISCUSSION

Substrate productivity: Highest productivity of cotton lint waste in terms of BE, MBW and MNB may be attributed to high cellulose content of 95% (Collop, 2008) and hence has a high capacity to accumulate dry matter. High productivity of cotton waste was also obtained by Ahmad *et al.* (2011). Poor performance of wood shavings may be attributed to low cellulose content (40-50%). In this study variability in BE was observed making the results consistent with findings by Liang *et al.* (2009). The results on BE of wheat straw (57.4%) were closer to that by Shah *et al.* (2004) which was 57.85%. The results on MBW conform to those of Chang (1984) where he reported that cotton lint waste gave a higher and more stable yield of mushrooms than any other agro-industrial wastes.

Corncobs ranked fourth after wheat straw in terms of yield with BE of 28.3%, this can be attributed to the fact that the spawn tended to settle down at the bottom of bags with corncobs hence partial and uneven mycelia colonization. Furthermore, Mamiro and Mamiro (2011) found out low BE value of 44.2% even though it was relatively higher than our findings. The low productivity of wood shavings can be attributed to the fact that the rate of delignification of wood shavings is lower than that of cotton lint waste, wheat straw, maize stover and corncobs. These results agree with Ponmurugan *et al.* (2007), Vetayasuporn (2007b) and Buah *et al.* (2010) who found out that wood shavings generally perform poorly and corn cobs perform better than wood shavings. Jatropha cake did not fruit at all as it decayed during the spawn-run period. This might be due to the fact that Jatropha cake, when soaked in water for a long time, gets too saturated, becomes greasy and fine textured that it was difficult for excess water to drain off hence creating a favourable environment for competitor organisms like Phycomycetes leading to the decay. Therefore, this may mean that the boiling method of pasteurization may not be appropriate for the substrate.

Mushroom market quality: Cotton lint waste had highest quality mushrooms of >5 cm hence it produced highly marketable mushroom sizes followed by wheat straw and maize stover. Cotton waste was also found to be a superior substrate in Kenya (Nout and Keya, 1983) and Australia (Choi *et al.*, 1981). Wheat straw and corn cobs also produced much of the mushrooms in the 3-5 cm size quality group which are also marketable. No mushrooms of >7 cm were found from wood shavings hence it did not produce highly marketable mushrooms. Moreover, wheat straw, maize stover and corn cobs produced many deformed and smaller (<3 cm) mushrooms which are unmarketable hence poor quality mushrooms. These differences in mushroom quality among the different substrates may be due to higher nitrogen content in cotton lint waste and higher proportion of cellulose content and compactness on wetting (Adebayo *et al.*, 2009). Nitrogen is important in fungal growth through protein, chitin and nucleic acid syntheses.

Significant differences in the number of days to first fruiting ($p<0.001$) were found. Wheat straw fruited first followed by maize stover, cotton lint waste, wood shavings and lastly corn cobs. However, maize stover and cotton waste had the same effect on the number of days to fruiting as wheat unlike corn cobs. This might be due to differences in rates of delignification among the substrates with corn cobs being most resistant and wheat and maize stover being least resistant.

CONCLUSIONS

Use of jatropha cake for *P. ostreatus* production is not possible because no fruiting bodies were obtained from this industrial waste. Corn cobs and wood shavings have little potential for use in *P. ostreatus* production since they had low productivity and produced poor market quality mushrooms. Cotton lint waste and maize stover are competent alternatives to wheat straw as they are equally productive and produced high market quality mushrooms. The abundance of maize stover and cotton lint waste should be taken as an advantage for *P. ostreatus* production by farmers in maize and cotton production areas of Zimbabwe.

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