CULTIVATION OF INDIGENOUS MUSHROOMS USING AGRICULTURAL SUBSTRATES

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Citation*:* Njeru, P.W., Wagara, I.N., Kariuki, S.T. & Muchiri, S.N. (2016) Cultivation of indigenous mushrooms using agricultural substrates In: Isutsa, D.K. and Githae, E.W. *Proceedings of the Second Chuka University International Research Conference held in Chuka University, Chuka, Kenya from 28th to 30th October, 2015. 65-70 pp.*

ABSTRACT
Oyster mushrooms (*Pleurotus* species) have the ability to grow on a variety of agricultural and industrial wastes. The aim of this study was to domesticate indigenous oyster mushrooms that grow in the wild. Different agricultural substrates including straws of wheat, barley and beans, rice husks, maize cobs and sawdust were tested individually and in mixtures for indigenous oyster mushroom yield. Bean straw + maize cob gave the highest biological efficiency (BE) of 81.8% while bean straw alone gave BE of 81.6%. Sawdust had the lowest BE of 12.9% but a combination of bean straw and sawdust had a BE of 62.3%. Indigenous mushroom can be domesticated to increase food security and curb poverty.
Keywords: *Biological efficiency, straws, Pleurotus, substrate, indigenous oyster mushrooms.*

INTRODUCTION
Pleurotus species (Oyster mushroom) with a 24.2% of world production have the ability to grow directly on unfermented agricultural wastes (Stamets, 2000). Oyster mushroom cultivation can play an important role in managing organic wastes whose disposal has become a problem (Das and Mukherjee, 2007). Additionally, mushrooms are reported to be easily grown on different lignocelluloses wastes such as banana leaves, cereal straw, paper wastes, sawdust and poultry droppings (Shah et al., 2004; Onuoha, 2007). Most Pleurotus species can grow on ligno-cellulose materials such as rotten wood, wood chips and agricultural postharvest residues because they have high saprophyte characteristics (Stamets, 2000; Straatsma et al., 2000). For example, Pleurotus eryngii has been successfully cultivated on many agricultural and agro-industrial wastes including sawdust, wheat straw, cotton waste, peanut shells, sugar cane bagasse, wheat, rice bran, millet straw and soybean straw (Torng et al., 2000; Philippoussis et al., 2001; Zervakis et al., 2001; Ohga and Royse et al., 2004; Okano et al., 2007; Kirbag and Akyuz, 2008). This study evaluated different substrates for production and yield of indigenous oyster mushrooms.

MATERIALS AND METHODS
Testing single substrates and mixtures for indigenous mushroom production
Single substrates and mixtures of substrates in the ratio of 1:1 were tested for indigenous oyster mushroom production.

Single substrates
Perforated polyethylene bags of approximately 300 mm x 700 mm x 2 mm thickness were used as growing containers for this experiment. Different substrates including wheat straw, barley straw, bean

straw, maize cobs, sawdust and maize stover were tested. The substrates were sorted to remove foreign materials. Five hundred grams of each substrate were weighed and they were chopped into 1-2 cm (Royse, 1997) and soaked in water overnight. The substrates were mixed with 100g of wheat bran and 10g of gram flour. Each substrate was packed into three bags of equal wet weight and sterilized in an autoclave at 121^{o}C for 15 minutes. Each bag was spawned with 3% of wheat grain spawn per wet weight. The spawned substrates were incubated in the mushroom house and monitored for mushroom fruiting and yields. This was compared for the different substrates.

Substrate mixtures

Different substrates (wheat straw, maize cobs, bean straw, barley straw, maize stover, banana leaves and sawdust) were mixed in 1:1 proportion to make 500 grams. The substrates were chopped into 1-2 cm. Each mixture contained two different substrate weighing 250 grams each as follows; wheat straw + maize cobs, wheat straw + bean straw, wheat straw + sawdust, barley straw + maize cobs, barley straw + bean straw, barley straw + sawdust, bean straw + maize cobs, bean straw + maize stover, bean straw + sawdust, maize cobs + maize stover and maize cobs + sawdust. Five hundred grams of each substrates combination was packed into three bags of equal wet weight and sterilized in an autoclave at 121^{o}C for 15 minutes. The bags were spawned with 3% of wheat grain spawn per wet weight and monitored mushroom yield in different flushes.

RESULTS AND DISCUSSION

Bean straw had high yield as a single substrate and in combination. The same case applied to wheat straw as a single substrate as well as in combination with inferior substrates like sawdust. According to Zadrazil and Brunnert (1980) the number of fruit bodies per flush recorded decreased progressively from flush to flush indicating that the nature and amount of nitrogen available in a substrate after each flush influence the degree of cellulose degradation which in turn affects the yield. This could be the reason for varying yields in flush 1, flush 2 and flush 3. Substrate mixture has got complementary advantages over single type substrate. The mixtures have delayed release of nutrients therefore reported to increase oyster mushroom yield significantly (Royse, 2002). This could be the reason why supplementing other substrates like sawdust and maize cobs with bean straw increased the yields in this study. Sawdust contains very high amount of lignin and therefore low degradation of the lignin substances by oyster mushrooms (Royse, 2002). This could be the factor affecting the overall yield of sawdust that led to its poor performance (Table 1). High yield of fresh mushrooms was obtained in the first flush in all the substrates with a reduction in the second and third flushes as shown in Table 1.

Table 1: Mean weight for the three mushroom flushes produced by different substrates

Substrate	Flush 1 (g)	Flush 2 (g)	Flush 3 (g)
BNS	227.3a*	106.8abcd	73.8a
BNSBS	233.1a	95.0bcde	42.7b
BNSMC	207.9ab	124.5ab	76.4a
BNSMS	90.4abc	37.6fghi	15.5e
BNSSD	155.9cde	96.3abcde	59.2b
BNSWS	165.4bcde	127.2ab	57.3b
BS	184.3abcd	79.1cdef	44.6bc
BSMC	210.6ab	101.2abcde	75.0a
BSSD	85.4fgh	33.3ghi	6.4e
MC	123.7ef	60.2efgh	20.5c
MCMS	32.4h	4.8i	0.0e
RH	32.7h	11.8i	0.0e
SD	45.8gh	18.8hi	0.0e
SDMC	151.8de	64.1defg	38.5bc
WS	181.3abcd	139.1a	74.3a
WSMC	206.8abc	112.4abc	72.6a
WSRH	119.2ef	71.4cdefg	35.9bc
WSSD	171.3bcde	126.1ab	91.0a

*Means followed by same letter are not significantly different at $P<0.05$

These observations agree with those of Obodai and Vowotor (2003) and Tisdale et al. (2006) who demonstrated that regardless of the mushroom species and of the substrate (composted or non-composted) used to grow mushrooms, the pattern of gradually lessening mean yield per flush remains the same for any cultivated edible mushroom. This has also been attributed to the finding that the quantity of mushrooms harvested in each flush is directly proportional to the nutrients disappearing from the substrate. The assimilable nutrient sources (carbon and nitrogen) in the organic waste substrate are absorbed by mycelia, translocated and mobilized to supply the fruit bodies (Stamets, 2000). This supports the reason for yield variation in various flushes. Substrates that are used in cultivating mushrooms have effect on the chemical, functional and organoleptic characteristics of mushrooms (Oyetayo and Ariyo, 2013). Michael et al. (2011) reported that protein, ash, iron and phosphorus contents were high for mushrooms grown on bean straw compared to wheat straw. According to Mane et al. (2007) P. sajor-caju showed high protein content when grown on soybean straw. Therefore, indigenous oyster mushrooms cultivated in this study might vary in nutrient contents depending on the type of substrates and substrate combination used. It is, therefore of importance to know the chemical composition of the substrates before being used in mushroom cultivation (Patil et al., 2010). This could be similar to indigenous mushrooms grown on bean straw and its combinations (Table 4) which might have more protein content and therefore more suitable for human consumption.

Effect of single substrates and substrate mixtures on mushroom yields and biological efficiency

The indigenous oyster mushroom yield was significantly higher ($P< 0.05$) when grown on a combination of bean straw and maize cob (408.8 g) followed by bean straw (407.8 g) and wheat straw (394.6 g) (Table 2). High total mushroom yields led to high biological efficiencies as in case of a combination of bean straw and maize cobs that had the highest biological efficiency of 81.8%. Rice husks as a single substrate had the least yield of 44.5g while a combination of maize cobs and maize stovers had the least yield of (37.1 g) with the lowest biological efficiency of.7.4%.

Table 2: Mean total yields and biological efficiency of mushrooms produced on different substrates

Substrate	Total yield (g)	Biological efficiency (%)
BNS	407.8a	81.6a
BNSBS	370.8abc	74.2abc
BNSMC	408.8ab	81.8ab
BNSMS	143.5fg	28.7fg
BNSSD	311.3bcd	62.3bcd
BNSWS	349.9abc	70.0abc
BS	308.0cd	61.6cd
BSMC	386.8ab	77.4ab
BSSD	125.1bcd	25.0bcd
MC	204.3ef	40.9ef
MCMS	37.1i	7.4i
RH	44.5i	8.9i
SD	64.7hi	12.9hi
SDMC	254.5de	50.9de
WS	394.6a	78.9a
WSMC	391.8a	78.4a
WSRH	226.5e	45.3e
WSSD	388.5a	77.7a

Means followed by same letters are not significantly different at $P<0.05$

Mushroom substrate may be defined as a kind of lignocellulose material which supports the growth, development and fruiting of mushroom (Chang and Miles, 1988). Pleurotus as a class of edible mushroom has the capacity to convert nutritionally valueless substances into high protein food and are reputed to have a high saprophytic ability and to grow on a variety of cellulosic wastes (Yildiz et al., 2002). Fanadzol (2010) found that cotton seed husks mixing to wheat straw significantly improved yield of P. ostreatus in comparison with maize stover and thatched grass. Mixing different substrates improves yield of mushrooms and might have supplemented poor substrates to improve yields. This could be the reason of high biological efficiency in the combinations of maize cob and bean straw as well as wheat straw.

These results indicate versatility in the mushroom cultivation systems, since they indicate the possibility of simplifying the substrates formulation, depending on the availability and cost of production or transportation of necessary raw materials. Veena and Savalgi (1991) reported a low yield of mushrooms on groundnut haulms. They attributed the low yield to high moisture holding capacity and a high susceptibility to fungi and improper aeration. High moisture content in a combination of maize cob and maize stovers may have led to low yields hence low biological efficiency of 7.4%. Anastazia et al. (1982) observed that cereal straws rich in nitrogen gave a higher yield in combination with paddy or wheat straw or corncobs. The high yield in bean straw could be attributed to high level of nitrogen in the substrate. This could be the reason why combination of wheat straw and bean straw improved yields of inferior substrates like sawdust.

Sawdust gave poor yield of 64.7 g that resulted to 12.9% biological efficiency (BE). The low yields could be due to either phenol content of wood (Ranjini and Padmavathi, 2012) or this wood may have been pretreated with fungicides in wood processing to protect it from decomposition which led to decrease in mycelial growth (Kalpana et al., 2011). This agrees with Davis and Aegerter (2000) and Owaid et al. (2014) who used sawdust in mixture but not alone. Therefore from this study, best biological efficiency (77.7%) for sawdust combination was obtained on a combination of sawdust and wheat straw. Further Obodai et al. (2002) reported that sawdust substrate for mushroom production should undergo a period of composting to breakdown the cellulose and lignin components of the wood, in order to release the essential materials for the establishment of mushroom mycelium. The ligno-cellulosic materials in sawdust are generally low in protein content and thus insufficient for the cultivation of mushrooms and therefore require additional nitrogen, phosphate and potassium. This would improve mushroom cultivation on sawdust in future.

There was a significant difference ($P < 0.05$) of the mushroom biological efficiency for the different substrates and substrate combination as highlighted in Table 2. High biological efficiency is attributed to higher yield from various types of substrates used (Beyer and Muthersbaugh, 1996) and there is a positive correlation between total mushroom yields and biological efficiency which affects the dry weight of the substrate. In this study, the productivity and biological efficiency were increased in some mixtures as compared to single substrates alone because of variation of capability of these substrates to save and aid the nutritional and environmental requirements and difference of their cellulose, hemicelluloses and lignin (Kuhad et al., 1997). This also agrees with Upadhyay et al. (2002) who found that mushroom yield and BE are directly related to strain, growth conditions and substrate nutrition. However, substrate supplementation with various additives including nitrogen sources has been reported to improve growth, yield and quality of mushrooms (Khare et al., 2010; Onyango et al., 2011). Therefore supplementation (mixing) of inferior substrates like sawdust and maize cobs with nitrogen rich substrates like bean straw improved yields greatly as shown in Table 2.

The mushrooms obtained in this study were large sized and of high quality and this resulted to high yields and high biological efficiencies. These results agree with those of Onyango et al. (2011) who reported that large sized fruit bodies were considered to be of good quality and rated highly in mushroom production. On the other hand, Shen and Royse (2001) reported that this was an inferior quality since such fruit bodies tend to break during packaging thereby reducing their quality.

CONCLUSIONS

Bean straw is a superior substrate over all the other agricultural waste substrates tested (wheat straw, barley straw, maize cobs, sawdust and rice husks) in cultivation of indigenous oyster mushrooms. However, a combination of bean straw and maize cobs is a more suitable substrate as it gave the highest yields of 408g. Thus bean straw can be used alone or as a supplement in combination with other agricultural wastes to improve mushroom production.

RECOMMENDATIONS

Indigenous Pleurotus species should be recommended for cultivation in Kenya because there are enough agricultural wastes such as wheat straw, barley straw, bean straw, maize cobs, rice straw and sawdust for its cultivation. More agricultural and industrial wastes should be tested as possible substrates for indigenous oyster mushroom cultivation so as to have a wide range of substrates for the different regions.

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