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Coconut Coir and Beans Straw as Substrates for Mushroom Growth

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Abstract
Coconut coir and beans straw could blend well for mushroom production. This would increase the biomass use and also serve as a way of recycling the agricultural wastes. The project was carried out to evaluate the mycelial growth rate, yield and cost benefit analysis of oyster mushroom (*Pleurotus ostreatus*) cultivation on sole coconut coir (CC), sole bean straw (BS), and a 2:3 ratio mixture of BS and CC (BS:CC Mix) as substrates. Each substrate type was subjected to 3 different composting periods of a day (no compost), 7days, and 14 days. Randomized complete block design with three replications was used for the experimental design. The best mushroom performance was obtained in the BS:CC Mix substrates, recording highest yields in the range of 43.2 - 47.4 g/kg substrate; the greatest biological efficiencies of 11.0 - 22.9% as well as the highest returns of 200.9 - 229.8%. The results indicated that beans straw could be an effective supplement to coconut coir and other highly lignified substrates for mushroom production.
Keywords: coconut coir; beans straw; mycelia; cost benefit analysis; mixed substrates

INTRODUCTION

Mushroom growers continue to explore effective substrates that would give higher yield with very wide profit margin. As mushroom cultivation involves providing the right medium and environment for the fungus (Anon, 2010), mixing different organic wastes could provide the right chemical, physical and environmental conditions necessary for the fungus (Elishashvili *et al*., 2008; Stajic *et al*., 2006). The main nutritional sources for oyster mushrooms are celluloses, hemicelluloses and lignin (Kang, 2004). Celluloses and hemicelluloses are often incrusted within lignin matrix which forms a physical seal around these giant carbohydrates and the proportion of these three structural components along with nitrogen content of residues affect mycelia growth, mushroom quality and crop yield (Philippoussis and Diamantopoulou, 2011). Oyster mushroom decomposes the lignin content to gain access to the celluloses and hemicelluloses which are embedded in the lignin matrix (Philippoussis and Diamantopoulou, 2011). In so doing, the fungi would need a starter to weaken the bonds that form up the lignin before the final breakage by laccase - the enzymes produced by the mushroom. This demands the right substrates combination and proper composting. Sawdust has been the main substrate for oyster mushroom in Ghana. As a lignocellulolytic fungi (Dzomeku, 2009; Oei 1991), oyster mushroom could thrive well on other substrates that contain lignin, hemicellulose and cellulose such as coconut coir. It is, however, assumed that the coir could be an effective substrate for mushroom production when supplemented with a nitrogen source such as beans straw to promote mushroom growth.

Coconut coir and beans straw are major agricultural wastes generated in Ghana. For now, most of these wastes are burnt to produce more carbon dioxide into the atmosphere as a greenhouse gas. A simple way of recycling these wastes is through mushroom production. After mushroom production, the spent substrate could be an excellent manure for crops production or even used as a feed for animals. Oyster mushrooms require more carbon and less nitrogen, however, very high lignin content cannot support mushroom growth (Thomas *et al.,* 2012) whilst very high nitrogen content may impair the activities of laccase which is the main enzyme used by the fungus to degrade the lignin content of the substrate (D'Agostini *et al.,* 2011; Upadhyay *et al*., 2002). Most of the substrates must therefore be supplemented with nitrogen source to reach optimal Carbon: Nitrogen (C:N) ratio for the mushroom (Philippoussis and Diamantopoulou, 2011). High cost of rice and wheat bran (also use as poultry feed) as a nitrogen source for mushroom production mostly increase the cost of production of the fungus. This reduces the interest of many youth in venturing into such a lucrative business. Many researchers (Shashirekha and Rajarathnam, 2007; Giménez, and Pardo-González, 2008; Kimenju *et al*., 2009; Musieba *et al*., 2012) have confirmed the use of coconut coir and beans straw as substrates for the growth of mushroom. There is, however,

virtually no documented evidence on how effective these two substrates could blend well for oyster mushroom production. Coconut coir with high lignin content (Thomas *et al.,* 2012) and beans straw with high protein content (about 5.1% crude protein, Naser *et al.,* 2011) could produce a good substrate combination. It is therefore hypothesized that coconut coir could be used as substrate for oyster mushroom production and could be effectively used when supplemented with beans straw. The objective of this study was to evaluate the mycelial growth rate, mushroom yield and profit margin for cultivation of edible oyster mushroom (*Pleurotus ostreatus*) on bean straw (BS), coconut coir (CC) and BS:CC Mix substrates.

METHODOLOGY

The main substrate materials, beans straw (BS) and coconut coir (CC), were obtained from major beans and coconut farms in Western and Ashanti Regions of Ghana. These were sun-dried to a constant weight. Coconut coir (CC) was milled to a particle size of 0.5 mm thick and 1-2 cm long, while the BS was chopped and beaten into 1-4 cm long according to the suggestions made by Kimenju *et al.* (2009). The three substrates studied were the sole coconut coir (CC); the sole beans straw (BS); and the BS:CC Mix (prepared by mixing BS and CC in a 2:3 ratio). Two hundred (200) kilograms of each substrate-type was taken and mixed thoroughly with water; the water content of the substrates was checked with the squeezing test. The moist substrates were divided into 3 portions and after heaping to a height of 50 cm and covering with black polyethylene sheet, one portion was reserved for bagging without composting, the second portion was composted for 7 days and the remaining portion underwent a 14-day composting for BS and the BS: CC Mix substrates and 21 days for the sole CC substrate. The skipping of the 7 days composting time for the coconut coir substrate was due to the high C:N ratio of the coconut coir and therefore would need more composting time than the beans straw for an appreciable amount of substrate fermentation and lignin degradation.

Selections of composting durations were guided by previous works (Siqueira *et al.,* 2012; Musieba *et al.,* 2012). The heaped substrates, excluding the non-composted substrates, were turned at 3-days interval (CSIR, 2003) within the compost duration. Fifty grams (50g) of each substrate were taken after composting and were used for chemical analysis. The composted substrates were packed into 1kg capacity polypropylene bags (about 33 cm by 17.8 cm and 0.08 – 0.10 mm thick) and tightened with rubber band and 3-cm long polyvinyl chloride pipes. The bags were steam-pasteurized continuously for 6 hours at 80-100^{o}C and then cooled for 4 hours. The *Pleurotus ostreatus* grain spawn (5-ml spoonful) was introduced into each bag aseptically and cotton wool was placed quickly at the open end of the bags. The bags were shaken gently for proper distribution of the spawns and arranged on wooden shelves in an incubation room according to an experimental set up of 3 x 3 factorial Randomized Complete Block Design (RCBD). Formation of mycelia was monitored at each two days interval by observing the development of white threads through the substrates. Fully colonized bags were transferred to a cropping house for mushroom growth and were arranged according to the experimental design of RCBD.

Chemical Analysis of the substrates

Percentage moisture content, organic carbon, percentage total nitrogen and pH of the substrates were analyzed according to the procedures described in literature (AOAC, 2000). Fifty grams (50g) samples of each substrates were taken during the day of bagging and were used for the chemical analysis

Biological Efficiency

Total weight of the fruiting bodies harvested from the substrates within 30 days of fruiting was measured as total yield of the mushroom. The biological efficiency (yield of mushroom per kg substrate on dry weight basis) was calculated by the formula proposed by Chang *et al.* (1981).

$$\%\ \text{Biological Efficiency (B. E \%)} = \frac{Fresh\ Weight\ of\ Mushrooms}{Dry\ Weight\ of\ Substrates} x100$$

Yield

The yield per kilogram of substrate was calculated by dividing the total yield in grams taken from each treatment by the number of cropping bags fully colonized within each treatment.

Data were subjected to analysis of variance (ANOVA) using the GenStat software version 10.3DE, edition 4. Means were separated at $p \leq 0.05$

RESULTS AND DISCUSSION

Chemical Changes in Substrates as Influenced by Composting Time and Substrate Types

C:N ratio of the BS substrates after the composting periods ranged between 33 and 42, BS:CC Mix recorded C:N ratio between 33 and 53 while CC substrate gave the highest C:N ratio ranging from 93 to 107 (Table 1). The pH values decreased as time increased, ranging from a high of 7.95 to a low of 6.12 for all the substrates (Table 1). The BS: CC mix were slightly basic with average pH of 7.67 while the pH of the CC substrate was in the acidic

range. Aside the non-composted BS substrate which showed slightly basic pH of 7.95, the 7 and the 14 days composted BS substrates were also slightly acidic.

Table 1. Changes in C;N ratio and pH of the substrates as influenced by composting time

Substrate type (ST)	Composting time (CT)[days]	C:N	pH
Bean straw (BS)	0	42.03	7.95
	7	34.25	6.60
	14	33.70	6.12
	Average	*36.66*	*6.89*
Mixed substrates (BS:CC Mix)	0	33.90	7.73
	7	48.04	7.70
	14	53.48	7.58
	Average	*45.14*	*7.67*
Coconut coir(CC)	0	106.85	6.53
	7	104.47	6.46
	21	93.75	6.42
	Average	*101.69*	*6.47*
$Lsd_{(0.05)}$			
ST		1.86	0.09
CT		1.86	0.09

Where: 0 – No compost; ST – Substrates Types, CT – Composting Time, C:N - Carbon : Nitrogen., S.E – Standard Error, $LSD_{(0.05)}$ – Least Significant Difference at p =0.05; 0 day – No compost

Increasing composting time increased the amount of available nutrients and cation exchange capacities in the compost (TNAU, 2008). Trautmann and Krasny (1997) noted that as organic matter is decomposed; nutrients such as nitrogen, phosphorus and potassium are released and recycled into various chemical forms. Proteins decompose into amino acids such as glycine or cysteine and these nitrogen compounds then further decompose to yield simple inorganic ions such as ammonium (NH_4^+) and nitrate (NO_3^-) that become available for uptake (Trautmann, and Krasny, 1997). Carbon : Nitrogen (C:N) of the substrates reduces with time because two thirds of the carbon is lost into the atmosphere while most of the nitrogen is recycled into new microorganisms as composting process continues (Epstein, 1997). Generally the pH of the substrates attained acidic medium as the nutrients (carbon and nitrogen) increased with increasing composting time (Table 1). Ogunwande *et al.* (2008) reported that the decrease of the pH (the substrate becoming more acidic) may be due to the decomposition of the organic matter in the piles and therefore the production of short chain organic acids. As noted by Sundberg (2005), the final pH in the compost is reduced as a result of the pH being influenced by three acid-base systems: the carbonic system which is formed during the decomposition that dissolves in the liquid forming carbonic acid (H_2CO_3), bicarbonate (HCO_3) or carbonate (CO_3^{2-}); ammonium (NH_4^+) or ammonia (NH_3) which is formed when protein is decomposed; and the third system comprising several organic acids, of which acetic and lactic acids dominate.

Rate of Mycelia Formation

Composting time had no effect on mycelia formation but substrate types recorded different effects on mycelia growth. Rate of mycelia growth of BS:CC Mix and CC substrates attained their peak of 1.4 cm and 1.9 cm per day respectively on the 20th day after spawning (Figure 1). These were faster than the BS substrate which recorded a declining growth of mycelia of 0.1 cm per day on the 20th day after spawning.

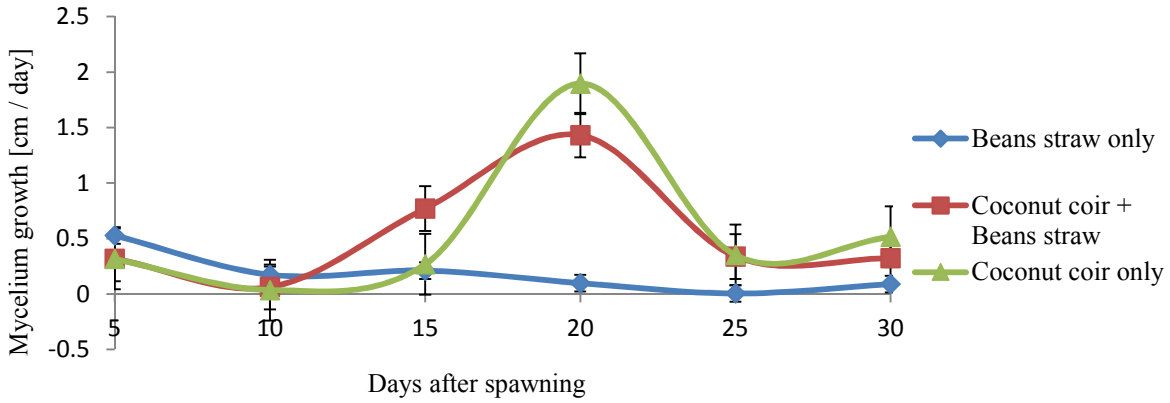

Figure 1. Rate of mycelia growth of *P. ostreatus* spawn cultivated on the three substrates

The fine particle sizes of CC and the well-blended particles sizes of the BS:CC Mix substrates influenced faster mycelia formation of *P. ostreatus* (Figure 1). On the other hand, the poor mycelia growth of the BS substrate could be due to the porous nature of the particles and the high nitrogen content of the substrate. Fine compost size fractions increase microbial biomass due to higher surface area to volume ratio and higher decomposability compared to coarser fraction (Verma and Marschner, 2013). Also, the activities of laccase, which is the main enzyme used by oyster mushroom to degrade the lignin content of the substrate is reduced when excess nitrogen is added to substrates (D'Agostini *et al.,* 2011). When working on effect of organic nitrogen supplementation in *Pleurotus* species, Upadhyay *et al.* (2002) concluded that substrates supplemented with 1% de-fatted soybean meal performed better than those supplemented with 2.5%, 5%, 7.5% and 10% of the same material or cotton seed cake and that substrates with higher supplementation gave lower yields of the mushroom. The poor mycelia growth observed on bean straw is therefore in contrast with the observations made by Musieba (2012), Poppe (2004) and Siqueira (2012) who noted that bean straw is one of the best substrates in mushroom production. The findings of this research indicate that the straw responds well when used with other substrates.

Mushroom performance on the substrates

- **Yield of Mushrooms**

The mixed substrates recorded the highest average yield of 45.1 g/kg of substrate followed by the sole coir substrate that recorded yield of 9.3g/kg (Table 2). The least yield was recorded from the straw substrates which gave 1.8g of mushrooms per 1 kg of substrate.

Table 2. Number of fruit bodies per flush, percentage dry matter, mushroom yield and biological efficiency of *P. ostreatus* as influenced by substrate types and composting time

	Composting time [days]	Av. no. of fruits per flush	Dry matter [%]	Yield [g/kg dry substrate]	Biological efficiency[%]
Beans straw (BS)	0	10.7	14.0	5.5	1.40
	7	0.0	0.0	0.0	0.00
	14	0.0	0.0	0.0	0.00
	Average	*3.6*	*4.7*	*1.8*	*0.46*
Mixed substrates (BS:CC Mix)	0	7.9	11.7	47.4	20.36
	7	5.7	11.6	43.2	17.95
	14	6.2	9.4	44.7	17.75
	Average	*6.6*	*10.9*	*45.1*	*18.69*
Coconut coir (CC)	0	4.3	8.6	6.5	2.19
	7	6.0	8.4	10.5	4.03
	21	5.7	8.1	11.0	3.30
	Average	*5.3*	*8.4*	*9.3*	*3.17*
$Lsd_{(0.05)}$					
ST		1.30	2.18	8.05	3.25
CT		1.30	2.18	8.05	3.25

Where ST – Substrate type; CT – Composting time; 0 – no compost;
Averages were calculated on the ten (10) bags used for each treatment.

This higher yield observed in the mixed substrates may be due to good physical and chemical qualities that

ensured a smooth transition from vegetative phase to reproductive phase. This agrees with reports from Shashirekha and Rajarathnam (2007) who observed that supplementing the coir with rice straw increased the activities of cellulases, hemicellulases and protease enzymes from inoculation till the end of fruitification, while laccase activity decreased during fruitification in consonance with decreased lignin degradation during fruitification. The observation also confirms the findings of Kapoor *et al.* (2009) who noted that the supplementation of different brans (wheat or rice brans) into a substrate for mushroom growth resulted not only in improved linear growth, but also in higher activity of cellulases in supplemented straw as compared to the unsupplemented straw. The CC, having fine texture and the BS being porous in nature blended well with good environmental conditions for the mushroom. These created balanced physical conditions such as aeration and good water holding capacity to support the mycelia growth as well as yield.

- **Fruit Bodies and Biological Efficiencies**

An average of 11 fruits per flush were harvested on the non-composted BS substrate being the highest among the three substrates studied as well as the highest dry matter content of 14%. The growth of mushrooms from the non-composted BS substrate was more of a cluster type than the mixed and the sole coir substrates. However, the biological efficiencies of the BS substrates were low. This is indicated in the low yield of the non-composted and no yield from the composted BS substrates. Generally, the efficiency of all the substrates to produce mushrooms was low within the days data on yield was collected. However, the mixed substrates were more efficient than the sole coir and the sole straw substrates. Differences in biological efficiencies of the various substrates are suggested to be due to different substrate compositions (Ajonina and Tatah, 2012).

Cost Benefit Analysis of the Substrates

Table 3. Partial budget analysis of the substrates

	Sole bean straw			Mixed substrates			Sole coconut coir		
Composting Time (days)	0	7	14	0	7	14	0	7	21
Gross benefit yield [kg/ton]	5.5	0.0	0.0	47.4	43.2	44.7	6.5	10.5	11.0
Adjusted yield (10%) downward [kg/ton]	4.9	0.0	0.0	42.7	38.9	40.2	5.9	9.5	9.9
Price per 100g of mushroom [GH₵]	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Gross benefit (GB) [GH/ton of subs.]	99.00	0.00	0.00	853.20	777.6	804.6	117.0	189.0	198.0
Total variable cost (TVC) [GH₵/ton]	163.3	163.3	163.3	258.7	258.7	258.7	223.3	223.3	223.3
Net benefit(NB) (GB-TVC) [GH₵]	-64.3	-163.3	-163.3	594.5	518.9	545.9	-106.3	-34.3	-25.3
RR=NB/TVC ×100%	-39.4	-100.0	-100.0	229.8	200.6	211.0	-47.6	-15.4	-11.3

Where RR – Rate of Return. Labour and time cost were not factored into this analysis. The total variable cost (TVC) was the cost incurred when using such specific substrates and it includes transportation, buying the spawns, the composting and the bagging materials

The mixed substrates gave the highest rate of return among the three substrates. Higher profit obtained from the BS:CC Mix substrates are attributed to the favorable chemical and physical conditions such as low C:N ratio, appropriate pH and good substrate particle sizes (Griensven 2000; Oseni *et al*., 2012; Mondal *et al.,* 2010). Higher profit recorded in the mixed substrates may be linked to the effective activities of hydrolyzing and oxidizing enzymes which are capable of utilizing organic compounds in the substrate to convert biomass into mushrooms (Bhattachrjya *et al*., 2014) as compared to the other substrates. Generally the profit level of using the sole substrates (sole coir and sole straw) was very low. Selecting the mixed substrates would mean higher profit in the mushroom business.

CONCLUSION

Cost management is very crucial in the quest for gaining profit in a mushroom business. Cost minimization and profit maximization are the main goals of every mushroom farmer. Substrates selected must be biologically

efficient, time effective, high yielding and profitable. Based on our findings, coconut coir could be used as a substrate for mushroom production and could be effectively used when supplemented with beans straw. The BS:CC Mix is time effective with high profit margin. It is therefore recommended to be a potential substrate for oyster mushroom production.

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