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Full Length Research Paper

Sustainable mushroom production in Africa: A case study in Ghana

Margaret Atikpo[1], Oghenekome Onokpise[2], Michael Abazinge[3], Clifford Louime[2]*, M. Dzomeku[1], L. Boateng[1] and Bawa Awumbilla[4]

[1]Food Research Institute, Council for Scientific and Industrial Research, P.O. Box M. 20, Accra, Ghana.
[2]College of Engineering Sciences, Technology and Agriculture, Florida A and M University, Tallahassee, Fl 32307, USA.
[3]Environmental Sciences Institute, Florida A and M University, Tallahassee, Florida, 32307, USA.
[4]Department of Animal Science, University of Ghana, Legon, Ghana.

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This study investigated a sustainable alternative to grow crops using organic wastes as biofertilizers. Fresh fish waste (FFW) and cooked fish waste (CFW) mixed with sawdust from *Tryplochyton scleroxylon* wood species *(Wawa)* were made into compost heaps. Control compost from rice bran (CRB) was also prepared. Higher temperatures were recorded from compost heaps prepared from both FFW (38 -52°C) and CFW (37 - 52°C) than from CRB (33 - 45°C); with reduction in composting time and generation of large numbers of microorganisms in the fish-based compost heaps. Mycelial colonization of compost bags and subsequent growth of oyster mushrooms *(Pleurotus* species) were faster in fish-based substrates (FFW and CFW) as compared to CRB. *P. eous* and *P. oestreatus* exhibited uniform spread of mycelia in the compost bags than *P. eous* hybrid. However, *P. eous* hybrid produced the fastest rate of mycelial growth, completely colonizing the substrate within 26 days. Growth of each species of mushroom investigated was independent of the substrate in which it was grown. Irrespective of the substrate used to grow the mushroom, the pattern of utilization and growth remained the same. Oyster mushrooms grown on fish-based substrates produced bigger and firmer fruiting bodies. This alternative could be very attractive to small farmers throughout the world, who are known to operate under adverse conditions and limited resources.

Key words: Fish waste, organic fertilizer, slow release nitrogen, oyster mushroom, *Pleurotus* species.

INTRODUCTION

Artisanal fishing activities are carried out by residents along the coastal regions of Ghana with generated fish waste not adequately disposed. This therefore results in gross environmental hazard causing foul odor due to fast decomposition of the proteinaceous material under the prevailing high temperature and humidity. This is further compounded when the decomposed waste serve as a potential source of health hazard to inhabitants in the vicinity. Additionally, domestic animals that roam the rubbish dumps may spread the contaminants to homes and humans.

Other disposal methods for fish waste include dumping into the sea or along the shores. Surface dumping of such waste especially during the rainy season has resulted in increased attendance at health centers because of rampant illnesses partly caused by contaminants or pathogens, especially in flood prone areas. More environmentally friendly methods include using the waste as feed in piggeries and/or in other animal feed industries.

Large volumes of lignocellulose agricultural residues (fish waste, vegetable materials) are generated annually through agricultural and food processing industries (Buswell, 1991). In Ghana, these are either disposed of by burning or dumping in landfills, thus posing hazard to the environment and human health; and which would otherwise be used in the cultivation of edible and medicinal mushrooms (Atipko et al., 2006). Residues like peelings from cassava, straw and stover from wild grasses, rice, maize, millet, sawdust, by-products of cotton, oil palm by-products have all been utilized as potential substrates for mushroom

*Corresponding author. E-mail: Clifford.Louime@Famu.edu. Tel: 850-599-3996. Fax: 850-561-2617.

cultivation. The application of appropriate bioconversion technology such as slow release of nutrients for mushroom cultivation would reduce the waste profitably. Moreover, environmental awareness has grown to such a proportion that enforcement of pollution control laws has become more effective. Waste recycling and supplementation techniques in the production of mushrooms, especially *Pleurotus* species that survive on a wide range of substrates, would be beneficial to ensuring pollution control (Onokpise et al., 2007).

It is estimated that the weight of by-products from twelve major crops grown in Ghana including cocoa, oil palm, cassava and maize amount to more than 9 million metric tons annually (Rasper, 2006). When only one-fourth of this amount is utilized in growing mushrooms, about 1.2 million metric tons of fresh mushrooms can be harvested within two months assuming a biological efficiency of 50 percent. This is enough to provide 18 million people each with over 1.1 kg of mushrooms daily.

Mushroom is an important food in the diet of Ghanaians (Atipko et al., 2006). Depending on the variety, they contain high quality protein with levels ranging from 21 - 40% dry weight. They also contain vitamins B1, B2, B6, B12, C, D and rich in minerals essential for human health. Dry mushrooms can be powdered and used in infant food preparations for increased nutritional value. Protein energy malnutrition has been identified as one of the biggest nutritional problems of the vulnerable group. Diseases such as Kwashiorkor, marasmus and anemia are becoming widespread because protein is lacking in the daily dietary intake of the average Ghanaian. To combat the crisis, the Food and Agricultural Organization has recommended the use of mushrooms as a potential food source especially since mushrooms have the capacity to convert agricultural wastes into high protein food (Chang and Hayes, 1978). Nutritional analysis (Hafiz et al., 2003) showed that mushrooms are a more valuable source of protein than either cattle or fish on dry weight basis, and are good sources of almost all the essential amino acids when compared with most vegetables and fruits (Matila et al., 2002).

The cultivation of mushrooms in Ghana is basically the Plastic Bag Method, with the use of decomposed sawdust from cereals (rice or millet) to produce *Pleurotus* species of mushrooms (Obodai and Apetorgbor, 2001). It involves an initial composting of the substrate, bagging, sterilization, inoculation with mushroom spawn, incubation, cropping. It is estimated that the weight of by-products from twelve major crops grown in Ghana including cocoa, oil palm, cassava and maize amount to more than 9 million metric tons annually (Rasper, 2006). When only one-fourth of this amount is utilized in growing mushrooms, about 1.2 million metric tons of fresh mushrooms can be harvested within two months assuming a biological efficiency of 50 percent. This is enough to provide 18 million people each with over 1.1 kg of mushrooms daily. Nevertheless, fish waste has not been used as slow release nitrogen organic fertilizer for mushrooms or field plants. The use of fish waste as slow release nitrogen organic fertilizer for mushroom production is novel in Ghana. The study therefore aims at reducing environmental pollution and odor by utilizing raw and cooked fish waste to produce edible and medicinal mushrooms from sawdust of *Tryplochyton scleroxylon* wood species. In addition, it will disseminate the technology and create jobs for the youth and reduce unemployment in fishing communities along the coastal regions of Ghana.

MATERIALS AND METHODS

Fish waste was obtained from Pioneer Food Cannery, a fish processing industry at Tema in Ghana; and conveyed to Food Research Institute for analyses. The samples consisted of Fresh fish waste (FFW) and Cooked fish waste (CFW). A control treatment with rice bran (CRB) normally employed for mushroom cultivation was used. Sawdust from *Tryplochyton scleroxylon* wood species *(Wawa)* was used to compost three heaps respectively for FFW, CFW and CRB.

For composting the control heap (CRB), 300 kg fresh sawdust was mixed with 21 kg rice bran and 2.1 kg quicklime. Water was added to increase the moisture content to 65% from the initial value of 30%. The contents were thoroughly mixed several times before heaping. The heap was left to ferment for 30 days during which it was turned every 4 days. Temperature readings monitored daily. The fish waste was ground in a mill and respective heaps prepared (FFW and CFW) and similarly treated as for the control. The matured compost was bagged in heat-resistant transparent polyethylene sachets, with each containing 1 kg of compressed substrate. The open end of each bag was passed through PVC pipe of dimension 2.0 cm thick and 2.5 cm long, which served as a bottleneck into which cotton wool was inserted. Rubber band was used to tie the overlapping polyethylene over the pipe to hold it upright and securely in place. These bags were respectively labeled FFW (Fresh fish waste), CFW (Cooked fish waste) and CRB (Control rice bran).

The compost bags were placed on wooden racks (49 cm long x 10 cm high) in a metal drum filled up to one-fifth its volume with water. The container was tightly sealed and the bags sterilized for 3 h. The bags were then transferred to a sterile room to cool to room temperature.

The pH of the bags was measured with a pH meter (PHM 92). The moisture content was obtained by difference between the calculated percentage fresh and dry weights of the sampled compost bags. Equal numbers of sterile bags from the different treatments were then aseptically inoculated with three different varieties of oyster mushroom spawns *(Pleurotus* species); namely *P. eons* (EM1); hybrid of *P. eous* (P21) and *P. oestreatus* (P34). The bags were subsequently incubated for 5 weeks under ambient temperature during which mycelial growth in each bag was measured at 3 day intervals. This was done by marking and measuring the length of the progression of mycelial growth at three different foci on each bag; and the average calculated. After the incubation period, the matured compost bags were transferred to the cropping house where they were opened for the fruiting bodies to emerge.

RESULTS AND DISCUSSION

Supplementation of substrate with fish waste for mushroom production was observed to cause a rise in the temperature during incubation of the bags at spawning (Figure 1d). This was due to the increase in the nutrient content (carbohydrates and nitrogen), such that resident bacteria and competitive moulds in the substrate increased in numbers to cause the high temperature. Lelley and Janben (1993) observed that a rise in temperature of between 40 - 60°C might kill the mycelium in less than 24 h. Although high

Figure 1. (A) Fresh fish waste used in this study for mushroom production. (B) Cooked fish waste used in this study for mushroom production. (C) Preparation of the seafood waste and sawdust mixture. (D) Mushroom (*Pleurotus species*) growing in compost bags.

high temperatures were recorded in this study, the death of the mushroom mycelia was not observed. This might be due to the use of delayed release supplements (fish waste, Figures 1a, 1b and 1c) providing nutrients that were released in stages and subsequently utilized for mushroom growth (Figure 1d).

Table 1 shows the temperature generated in the compost heaps prepared with fresh untreated (FFW) and cooked (CFW) fish waste as compared to the control heap of rice bran (CRB). High temperatures were generated in the compost heaps prepared with fish waste. This indicated that there might have been greater activity of fermenting microorganisms that accelerated the composting process in FFW and CFW as compared to CRB. For the thirty days during which composting was carried out, the temperature ranges for FFW and CFW were between 38 - 52°C and 37 - 52°C respectively (Table 1). For FFW, the maximum temperature occurred on the third day while for CFW it was on the eighth day of fermentation. This indicated that there was early rise in temperature in the compost prepared with fresh fish than in any of the other heaps. Thus decomposition of the substrates when fresh fish was incorporated was achieved faster for the release of nutrients than when cooked fish was used. For CRB, lower temperature range of 33 - 45°C was obtained. During the thirty-day period of composting, the heaps were turned seven times.

In Figure 2a we determined the growth of mycelia of *Pleurotus* species on Ricebran. A uniform pattern of the mycelia was recorded for both *P. eous* and *P. oesrreatus*. Figure 2b shows mycelial growth of *Pleurotus* species in compost bags of fresh fish waste and sawdust mixture. Similar uniform growth pattern of the mycelia was observed in this substrate for both *P. eous* and *P. oesrreatus*. As earlier observed in compost bags of rice bran/sawdust mixture, the growth *of P. eous* hybrid in fresh fish waste/sawdust mixture showed stagnation in the spread of mycelial growth in the compost bags generally beginning at day 29 till day 38. Figure 2c shows the mycelial growth *of Pleurotus* species in compost bags of cooked fish waste and sawdust mixture. Similar growth patterns were observed for *P. eous* and *P. oesrreatus* using cooked fish waste/sawdust mixture. The growth *of P. eous* hybrid followed a similar pattern as observed for the other substrates used. Stagnation of the mycelia started at day 26.

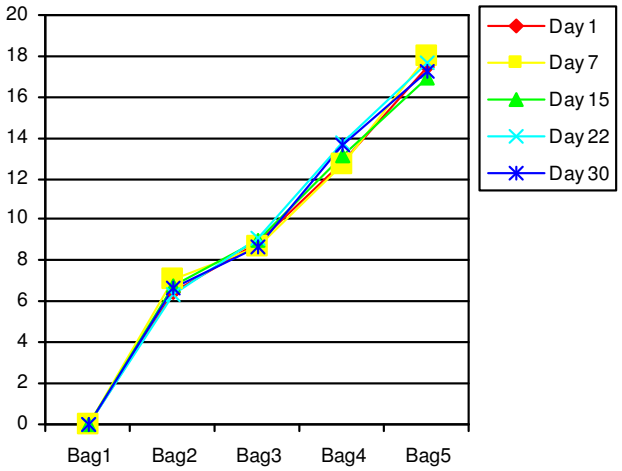
Generally, comparative analysis of the growth of the three types of oyster mushroom showed that *P. eous* hybrid exhibited the fastest mycelial growth, completely colonizing the substrate during the period of growth. However, during the first week of colonization, substrates with rice bran /sawdust mixture showed earliest signs of mycelial growth. Each species of mushroom investigated showed a peculiar pattern that was independent of the substrate in which it was

Table 1. Temperature readings in compost heaps for mushroom cultivation.

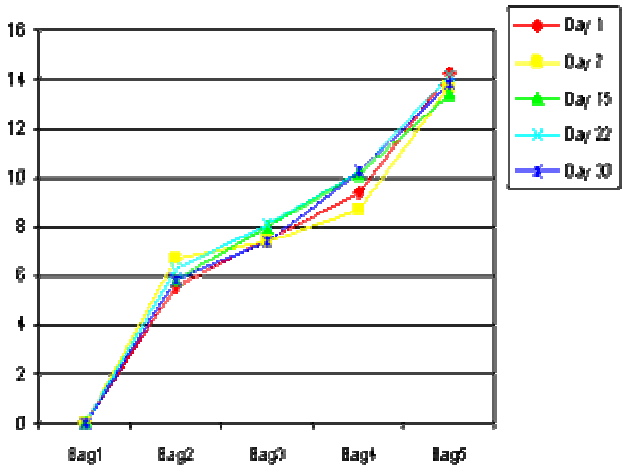
Day	Temperature (°C)			Action
	CRB	FFW	CFW	
1	45	50	50	
2	40	49	48	
3	43	52	47	
4	43	47	47	1st turn
5	40	41	43	
6	39	42	43	
7	39	40	48	
8	42	46	52	2nd turn
9	39	46	51	
10	38	46	50	
11	39	47	50	
12	37	41	45	3rd turn
13	36	46	47	
14	37	46	46	
15	37	48	46	
16	37	47	46	4th turn
17	35	46	44	
18	38	50	46	
19	37	45	45	
20	36	44	43	5th turn
21	35	45	43	
22	35	44	43	
23	36	44	44	6th turn
24	36	43	43	
25	36	43	43	
26	35	42	42	
27	34	40	40	7th turn
28	33	39	39	
29	35	38	38	
30	35	38	37	

CRB: Temperature of compost with fish waste mixed with rice bran (control). FFW: Temperature of compost with fresh (untreated) fish waste. CFW: Temperature of compost with cooked fish waste.

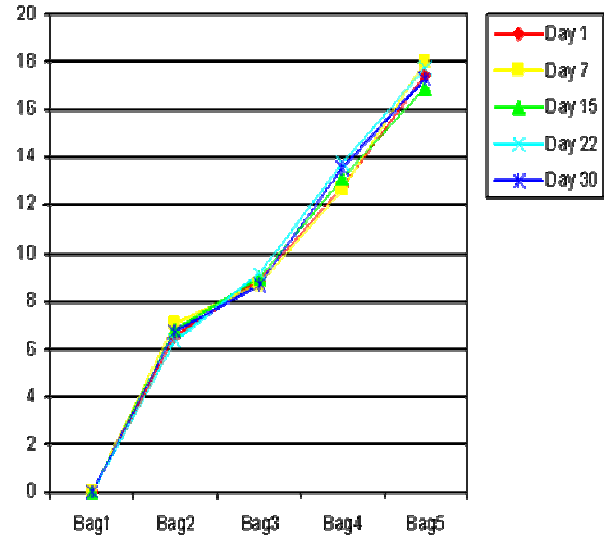
grown. Thus it would be concluded that irrespective of the substrate used to grow the mushroom, the pattern of utilization and growth remained the same. Figures 2a, 2b, and 2c showed that the growth of *P. eous* in three different substrates of ricebran/sawdust, fresh fish waste/sawdust and cooked fish waste/sawdust mixture exhibited a similar pattern; likewise that *of P. eous* hybrid and *P. oestreatus* in the aforementioned substrates.



a. Ricebran



b. Fresh fish waste.



c. Cooked fish waste.

Figure 2. Mycelia Growth (cm) of *P. eous* in Compost Bags of Mixed Sawdust Containing: a) Ricebran b) Fresh Fish Waste and c) Cooked Fish Waste.

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