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UTILIZATION OF FISH WASTE FOR MUSHROOM CULTIVATION

by

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Abstract

Fresh fish waste (FFW) and cooked fish wastes (CFW) mixed with sawdust from *Tryplochyton scleroxylon* wood species (*Wawa*) were matured in compost heaps for 30 days. 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, generation of large numbers of micro-organisms 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 a more 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.

Keywords: Fish waste, slow release nitrogen, oyster mushroom, *Pleurotus* species.

Résumé

Des déchets de poisson frais [1] et de poisson cuit [2], mélangés de sciure de bois *Tryplochyton scleroxylon* (*Wawa*) ont été maturés en compost pour 30 jours. Du compost de contrôle avec du son de riz [3] a été aussi préparé. Les températures les plus élevées ont été enregistrées avec les tas de compost préparés avec FFW (38-52 °C) et CFW (37-52 °C) plutôt qu'avec CRB (33-45 °C); avec une réduction du temps de formation du compost, une génération de nombreux microorganismes dans le compost préparé avec du poisson. La colonisation de mycètes dans les sacs de compost et la croissance de pleurotes en huîtres qui en a résulté (*Pleurotus* sp.), ont été plus rapides dans les substrats à base de poisson (FFW and CFW) que dans les substrats CRB. *P. eous* et *P. oestreatus* ont montré une diffusion uniforme de mycètes dans les sacs de compost par rapport à l'hybride *P. eous*. Toutefois, l'hybride *P. eous* a eu un taux plus rapide de croissance de mycètes, en colonisant complètement le substrat en 26 jours. La croissance de chaque espèce de champignon expérimentée s'est avérée indépendante du substrat dans lequel il se reproduisait. Malgré la différence de substrats utilisés pour la croissance des champignons, le mode d'utilisation et de croissance restait le même. La croissance des pleurotes en huître sur des substrats contenant du poisson a produit des carpophores (organes portant des fruits) plus grands et fermes.

Mots clefs: Déchets de poisson, azote à libération lente, pleurote en huître, espèces de *Pleurotus*

1. INTRODUCTION

Artisanal fishing activities are carried out by residents along the coastal regions of Ghana with generated fish waste not adequately disposed of. This therefore results in gross environmental hazard causing foul odour because of the fast decomposition of the proteinaceous material under the prevailing high temperature and humidity. This is further compounded when the decomposed waste serves 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.

[1] Déchets de poisson frais – Fresh fish waste (FFW).
[2] Déchets de poisson cuit – Cooked fish wastes (CFW).
[3] Compost de son de riz – Compost from rice bran (CRB).

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 our health centres 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. Residues – such as 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 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.

It is estimated that the weight of by-products from 12 major crops grown in Ghana, including cocoa, oil palm, cassava and maize, amount to more than 9 million tonnes annually (Sawyerr, 1994). When only one-fourth of this amount is utilized in growing mushrooms, about 1.2 million tonnes 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. Depending on the variety, they contain high quality protein with levels ranging from 21 to 40 percent 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. Such diseases as Kwashiorkor, marasmus and anaemia 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 (FAO) 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 (Fauzia 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 (Mattila *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. It involves an initial composting of the substrate, bagging, sterilization, inoculation with mushroom spawn, incubation, cropping and harvesting of the fruiting bodies (Obodai *et al*., 2002). 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 odour by utilizing raw and cooked fish waste to produce edible and medicinal mushrooms from sawdust of *Tryplochyton scleroxylon* wood species; in addition, to disseminate technology and create jobs for the youth and reduce unemployment in fishing communities along the coastal regions of Ghana.

2. MATERIALS AND METHODS

Fish waste was obtained from Pioneer Food Cannery, a fish processing industry at Tema in Ghana, and conveyed to the 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), 300.0 kg fresh sawdust was mixed with 21.0 kg rice bran and 2.1 kg quicklime. Water was added to increase the moisture content to 65.0 percent from the initial value of 30 percent. 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 were 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 1.0 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. A rubber band was used to tie the overlapping polyethylene over the pipe to hold it upright and securely in place. These bags were respectively labelled FFW (fresh fish waste), CFW (cooked fish waste) and CRB (control rice bran).

The compost bags were placed on wooden racks (49.0 cm long x 10.0 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 hours. 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 of 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. eous* (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.

3. RESULTS AND DISCUSSIONS

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. This was the result of 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 and 60 °C might kill the mycelium in less than 24 hours. Although high temperatures were recorded in this study, the death of the mushroom mycelia was not observed. This might be because of the use of delayed release supplements (fish waste) providing nutrients that were released in stages and subsequently utilized for mushroom growth.

Figure 1 shows the temperature generated in the compost heaps prepared with fresh untreated (FFW) and cooked (CFW) fish waste as compared with 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 micro-organisms that accelerated the composting process in FFW and CFW as compared with CRB. For the 30 days during which composting was carried out, the temperature ranges for FFW and CFW were between 38 and 52 °C and between 37 and 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 30-day period of composting, the heaps were turned seven times (Table 1).

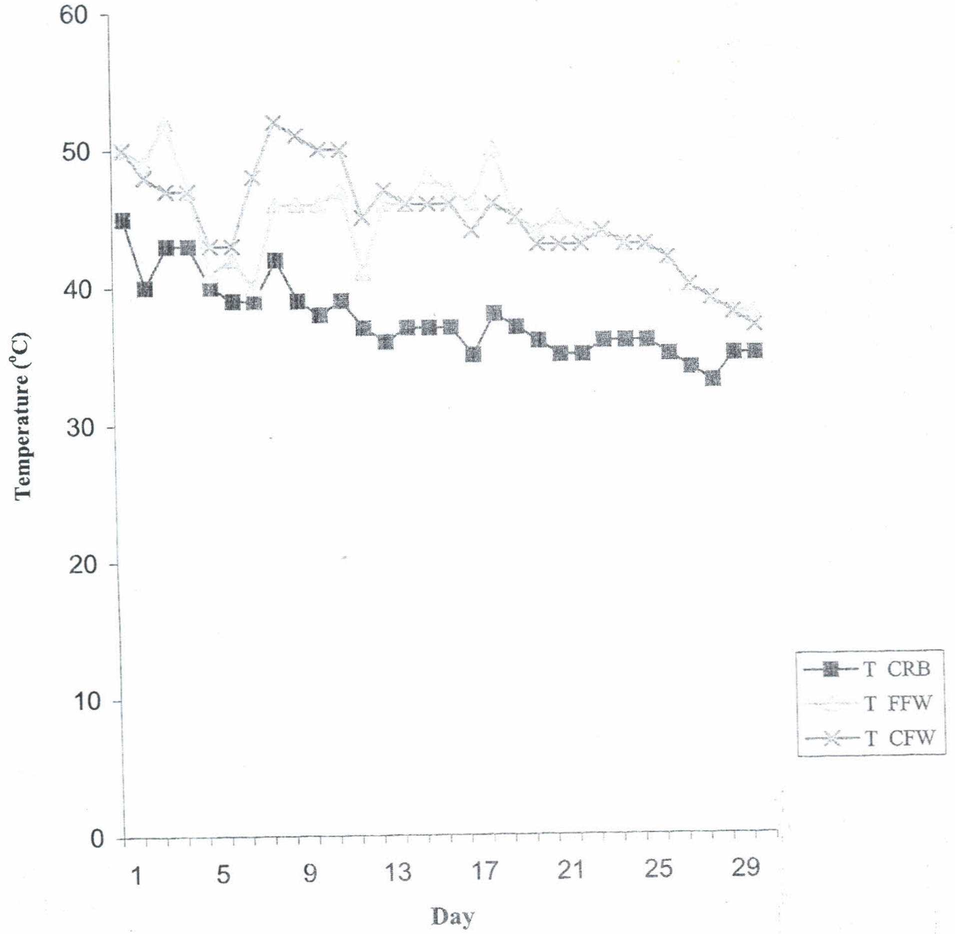

Figure 1: **Temperature of fermenting compost for mushroom growth**

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

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.

Figures 2 and 3 are respectively the fresh and cooked fish waste used in the compost preparation for the cultivation of mushrooms. The preparation of the compost heap (Figure 4) was carried out as earlier indicated and turned (Figure 5) several times within the maturation period to ensure aeration.

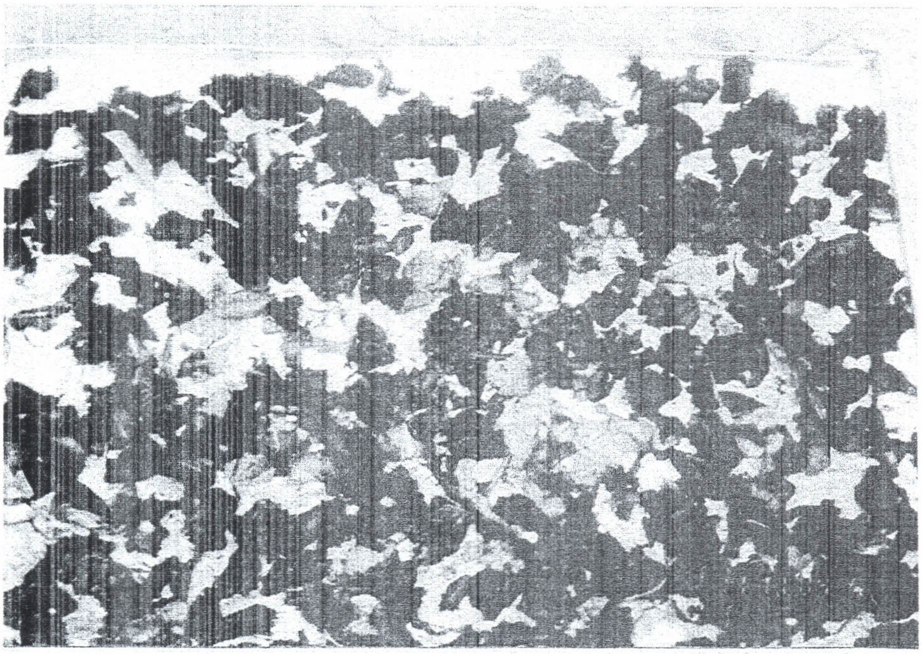

Figure 2: Fresh fish waste

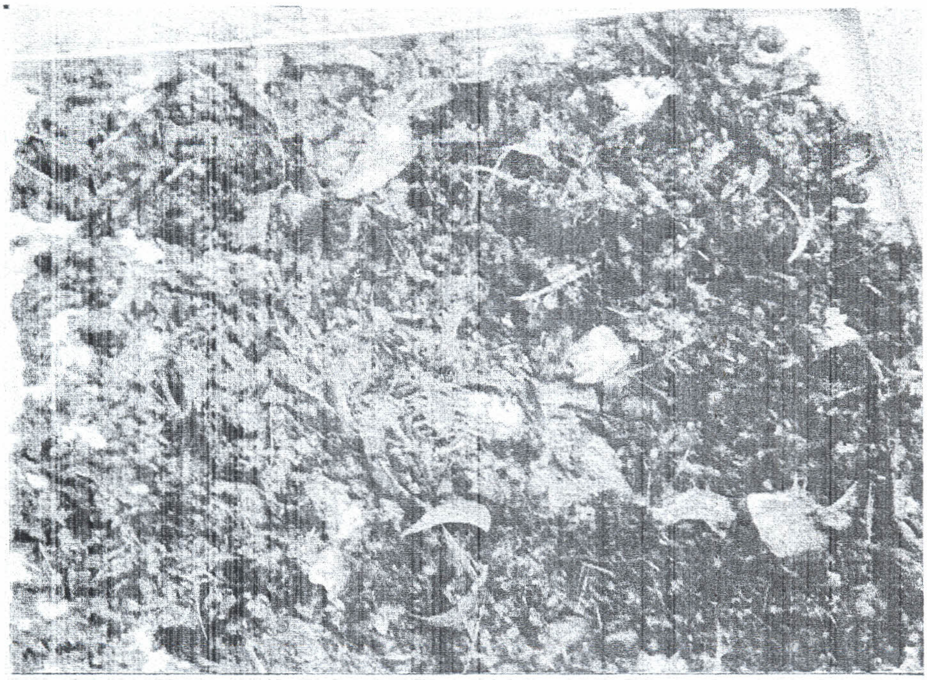

Figure 3: Cooked fish waste

Figure 4: Preparation of compost heap using fresh fish waste

Figure 5: Turning of the compost heap

The following figures show mycelial growth of *Pleurotus* species in compost bags of: rice bran/sawdust (Figure 6a), fresh fish waste/sawdust (Figure 6b), and cooked fish waste/sawdust mixture (Figure 6c).

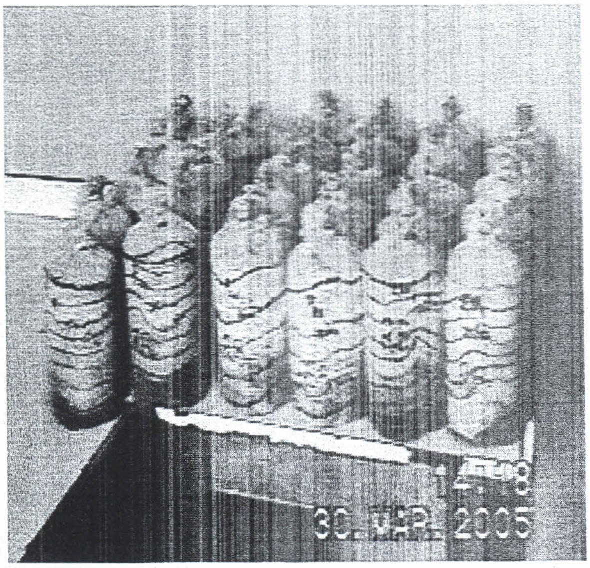

Figure 6a: ***Pleurotus*** **species growing in rice bran/sawdust mixture**

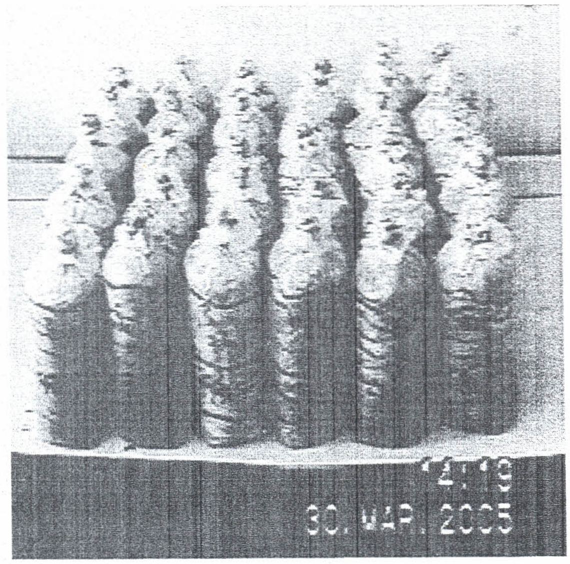

Figure 6b: ***Pleurotus*** **species growing in fresh fish waste/sawdust mixture**

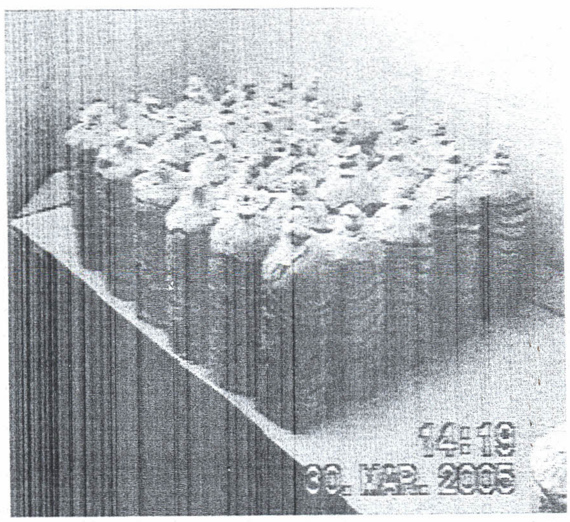

Figure 6c: ***Pleurotus*** **species growing in cooked fish waste/sawdust mixture**

Freshly prepared compost bags of cooked fish waste/sawdust, fresh fish waste/sawdust and rice bran/sawdust mixtures that have not been inoculated with mushroom spawn is shown in Figure 7a. Mycelia growth of *Pleurotus eous* colonizing fresh fish waste/sawdust, cooked fish waste/sawdust and rice bran/sawdust mixture is shown in Figure 7b.

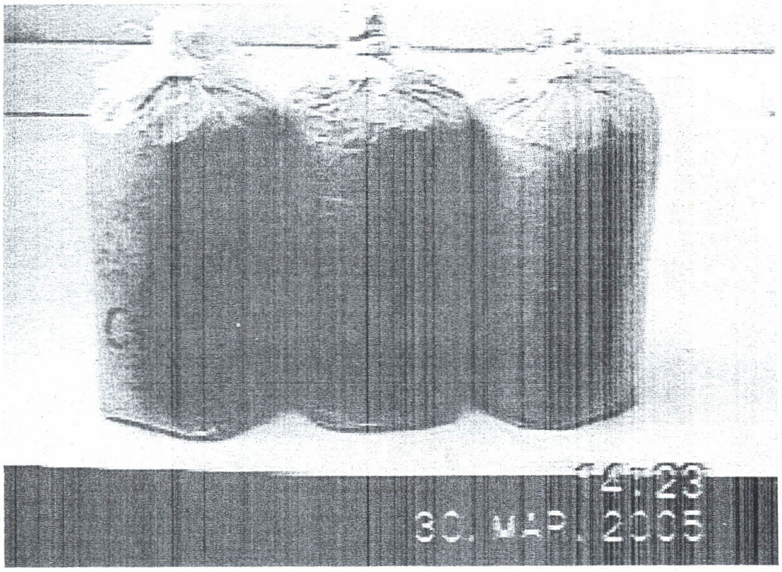

Figure 7a: Compost bags of cooked fish waste/sawdust (left), fresh fish waste/sawdust (middle) and rice bran/ sawdustmixture (right) without mushroom spawn

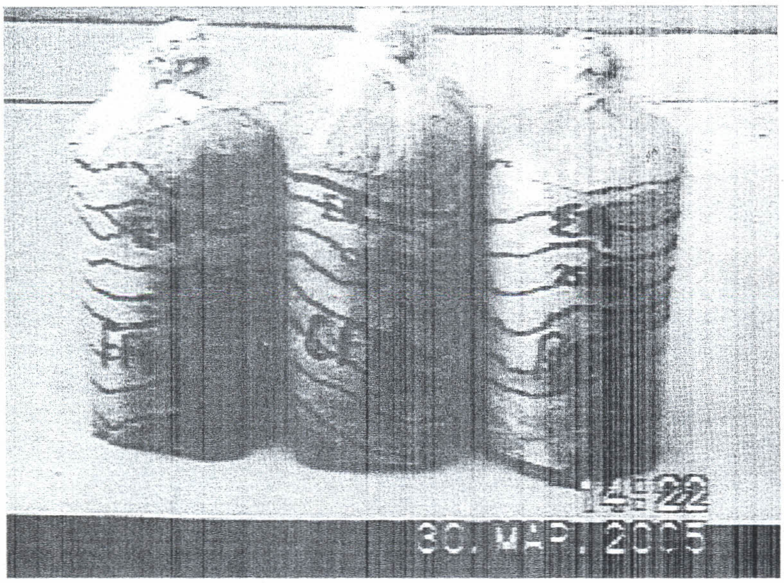

Figure 7b: Mycelia of *Pleurotus eous* colonizing fresh fish waste/sawdust (left), cooked fish waste/sawdust (middle) and rice bran/sawdust mixture (right)

Figure 8 shows mycelial growth of *Pleurotus* species in compost bags of a mixture of rice bran and sawdust. *P. eous* (Figure 8a) and *P. oestreatus* (Figure 8c) exhibited a more uniform spread of mycelia in the compost bags than *P. eous* hybrid (Figure 8b). Generally *Pleurotus eous* hybrid showed a typical plateau from day 26 to 38 (Figure 8b) during which the nutrients may have been depleted. This indicated that maximum growth of this species would be achieved in the compost bags at day 26, during which full maturity would have been achieved. Between days 26 and 38, mycelial growth was observed to be static, indicated by the uniform horizontal area of the curve shown by all the compost bags investigated.

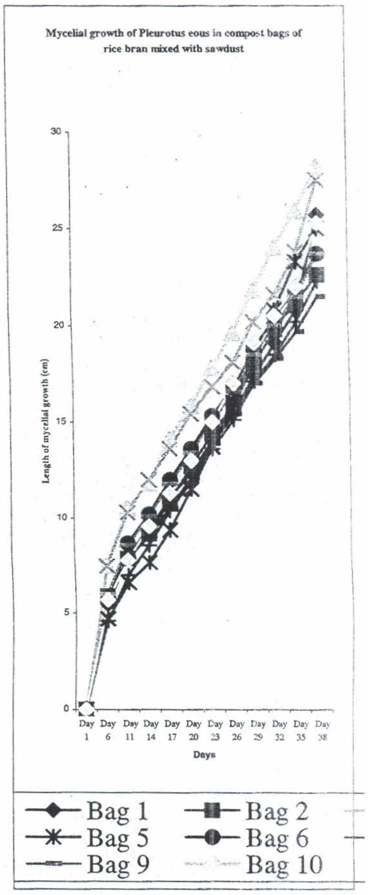

Figure 8a

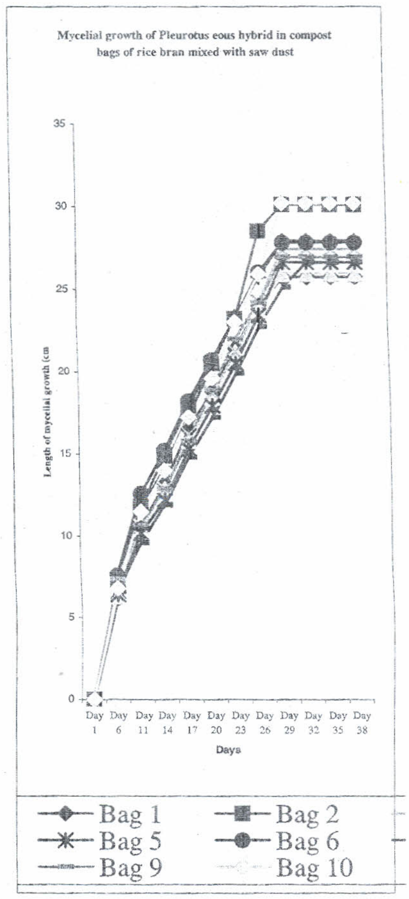

Figure 8b

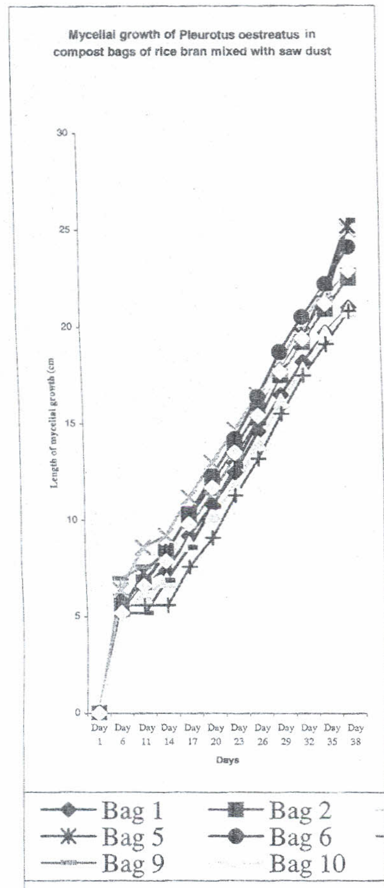

Figure 8c

Figure 8: Mycelial growth of *Pleurotus* species in compost bags of rice bran-sawdust mixture

Figure 9 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* (Figure 9a) and *P. oestreatus* (Figure 9c). As earlier observed in compost bags of rice bran/sawdust mixture, the growth of *P. eous* hybrid (Figure 9b) in fresh fish waste/sawdust mixture showed stagnation in spread of the mycelial in the compost bags generally beginning at day 29 till day 38 (Figure 9b).

Figure 10 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* (Figure 10a) and *P. oestreatus* (Figure 10c) using cooked fish waste/sawdust mixture. The growth of *P. eous* hybrid (Figure 10b) followed a similar pattern as observed for the other substrates used. Stagnation of the mycelia started at day 26 (Figure 10b).

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 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 8a, 9a, and 10a showed that the growth of *Pleurotus 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 (Figures 8b, 9b, 10b) and *P. oestreatus* (Figures 8c, 9c and 10c) in the aforementioned substrates

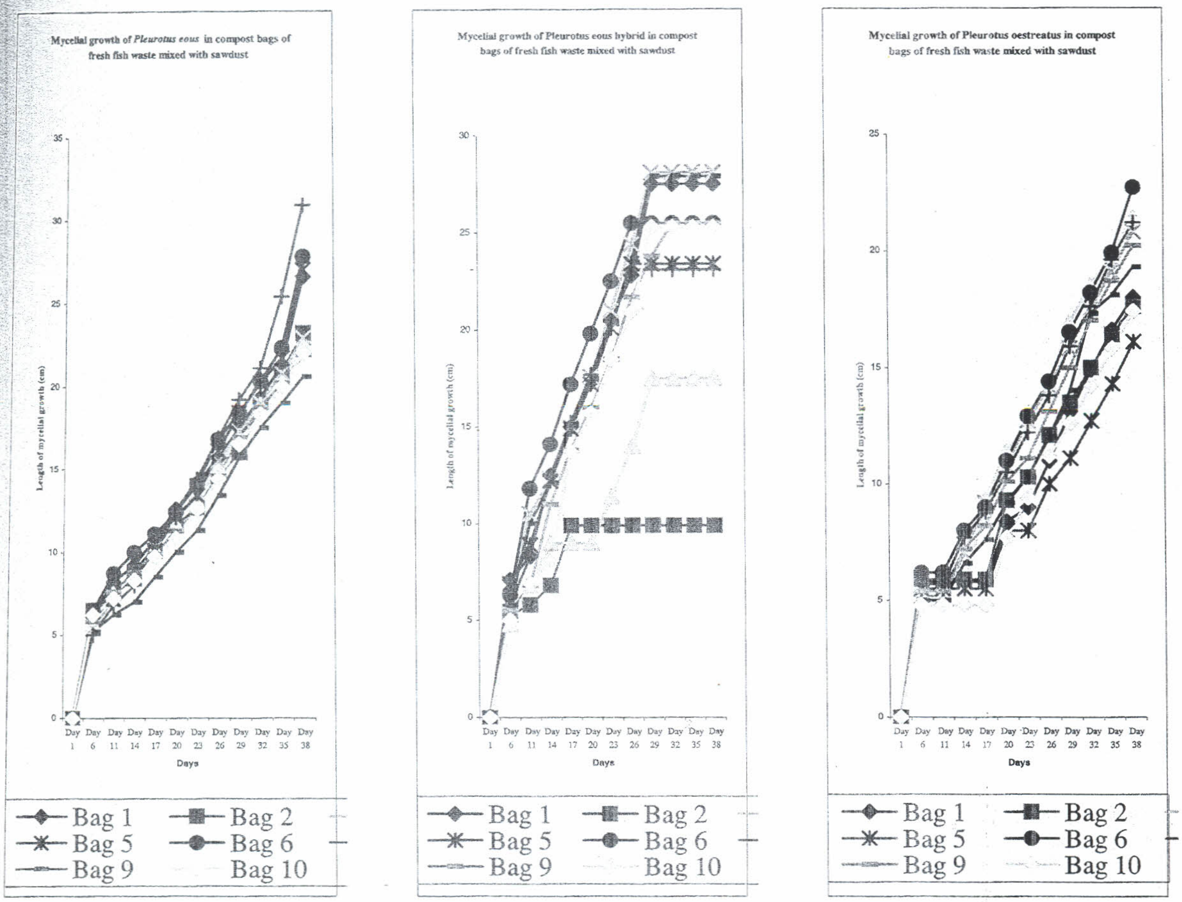

Figure 9a Figure 9b Figure 9c

Figure 9: Mycelial growth of *Pleurotus* species in compost bags of fresh fish waste-sawdust mixture

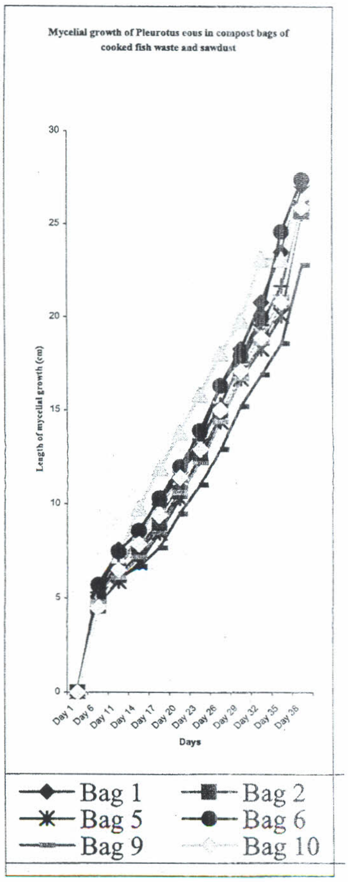

Figure 10a

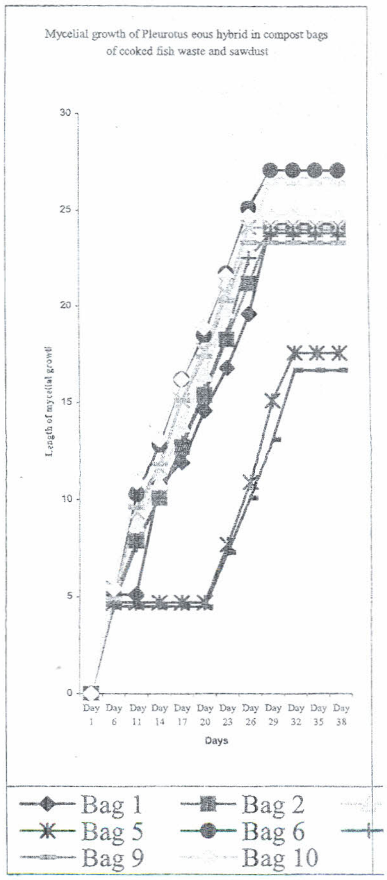

Figure 10b

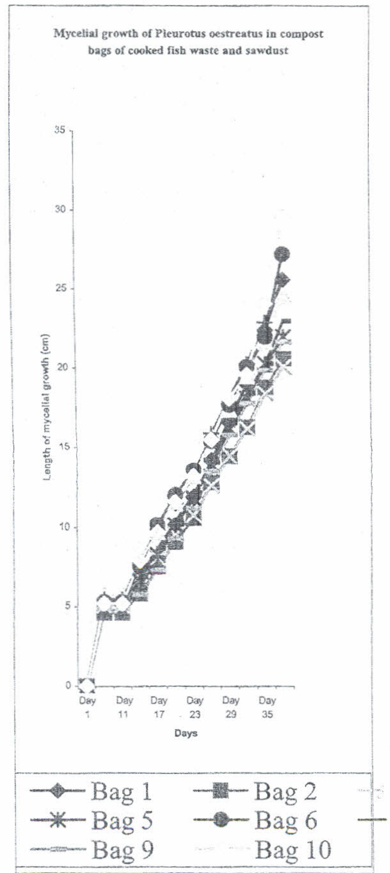

Figure 10c

Figure 10: Mycelial growth of *Pleurotus* species in compost bags of cooked fish waste-sawdust mixture

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