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Bioremidiation Potential of *Pleurotus Ostreatus* (Jacquin; Fries) P. Kummer: A Case of Agro-Wastes in Umudike Abia State

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Abstract

Biodegradation of agricultural wastes that constitute major source of environmental hazards and pollution by *Pleurotus ostreatus* is of importance in bioremediation of plant organic residues. Different agro-wastes; saw dust (SD), sugarcane baggasse (SB) and maize stalk (MS) and in combination (SD+MS, SD+SB, SB+MS, SD+MS+SB), were used to investigate the polysaccharide degrading potentials of *P. ostreatus* at the Department of Plant Health Management, Michael Okpara University of Agriculture, Umudike, Umuahia, Abia State. The fungus significantly ($P<0.05$) degraded the hemicelluloses, cellulose and lignin contents of the substrates though to varying degrees. The loss of polysaccharide content of the test substrates due to the fungus ranged as follows; hemicelluloses, from 20.64% with MS substrate to 48.92% with SB substrate; cellulose from 24.06% with SD substrate to 41.92% with SB substrate and lignin content from 4.01 % with MS substrate to 27.45% with SD substrate. The average delignification of the substrate polysaccharides by *P. ostreatus* was highest with SB substrate (37.86%), followed by SD+SB substrate (31.76%) and SD substrate (27.56%). This not only showed the ability of *P. ostreatus* to degrade agricultural wastes efficiently and grow at a wide range of substrates but also a potent organism capable of biodegrading and detoxifying a wide range of wastes and pollutants.

Keywords: *Pleurotus ostreatus*; Agro-waste; Polysaccharide; Biodegradation; Bioremediation

Abbreviations: SD: Saw Dust; SB: Sugarcane Bagasse; MS: Maize Stalk.

Introduction

Species of *Pleurotus* are gilled oyster mushrooms that produce microscopic spores that help them spread across the ground or its substrates [1]. They are most widely cultivated for their nutritional, medicinal and other beneficial values [2]. They require carbon, nitrogen and inorganic compounds with less nitrogen and more carbon as nutritional sources suggesting that materials containing cellulose, hemicelluloses and lignin such as rice and wheat straw, cotton seed hulls, sawdust, waste paper, leaves, and sugarcane residues can be used as their substrates [3-5].

Agro-residues contain three major structural polymers, cellulose, hemicelluloses and lignin, which can be easily utilized or broken down by fungi producing lignocellulotic enzymes. *Pleurotus species* are the most efficient lignin-degrading organisms with the ability to produce enzymes such as lactases (EC 1.10.3.2), lignin peroxidase (EC 1.11. 10.14) and manganese peroxidase (EC1.11.1.13) [6]. They selectively attack lignin and related compounds by producing

one or more of phenol-targeting redox enzymes, namely the peroxidases and laccases/phenol-oxidases [7]. These enzymes are non-specific biocatalyst used for bioremediation process due to their ability to degrade heterocyclic, reactive and polymeric dyes [8,9]. Therefore, the huge amounts of lingo-cellulosic biomass of agro-wastes can be potentially bio converted into different high value raw materials and products such as bio-ethanol, enriched animal feed, cheap energy sources for microbial cultivation (mushrooms included) and enzyme production [7,10-12]. The problem of air pollution and hazards due to agro-wastes may be avoided by using *P. ostreatus* to bioprocess the lignocellulosic waste materials, which may later be used as highly proteinaceous feed for livestock [13].

Materials and Methods

Spawn Source

Culture of *P. ostreatus* was obtained from the Federal Institute of Industrial Research, Oshodi, (FIIRO) Lagos, Nigeria and multiplied according to [14] on sorghum grains. Sorghum grains were soaked for 24 hours and washed in a running tap water and then spread over a tilted platform to drain excess water. The washed grains (1kg) were placed in 10 medium sized bottles and autoclaved at 121°C and 15 psi for 30 minutes and left overnight to cool. The bottles were inoculated with cultures of *P. ostreatus,* covered and then shaken for even distribution of the culture on the grain. The inoculated bottles were placed in incubator set at a temperature of 25 ± 2°C and observed daily for mycelia growth (white net web) on the grains. The inoculated bottles were removed after 14 days of incubation and stored at 4°C until used.

Substrate preparation

The agro-wastes; saw dust (SD), sugarcane bagasse (SB) and maize stalk (MS) were obtained from Michael Okpara University of Agriculture Umudike and the university community. The method of Adedokun, et al. [15] was adopted in the preparation of substrates. The sugarcane bagasse and maize stalk substrates were chopped into 5 cm pieces with a knife. The substrates individually and in combination were each sterilized separately by packing them into sack bags and tightly covered and then placed in a drum containing stacks of sticks (30cm). Water was poured into the drum up to the level of the sticks and covered with fresh plantain leaves in order to generate enough heat. The water in the drum containing the substrates was subjected to heating up to 100°C and allowed to steam for 2 hours using industrial gas cooker. The drum and contents were left overnight to cool. The sterilized substrates (1kg) were each poured separately into white sterile transparent buckets perforated with a sterile 5mm diameter cork borer.

Inoculation of substrate

The sterilized substrates in the perforated buckets were each separately inoculated with 5 g of *P. ostreatus* spawn and then covered. The inoculated buckets were watered every two days to maintain high relative humidity. Each treatment was replicated four times and observations made daily for fungal growth.

Treatment

Three major substrates (saw dust, maize stalk and sugar cane bagasse) were used individually and in combinations for the growth of *P. ostreatus* and they include;

i. Saw dust (100%) – SD.
ii. ii. Maize stalk (100%) – MS.
iii. Sugarcane bagasse (100%) – SB.
iv. Saw dust (50%) + Maize stalk (50%) - (SD+MS).
v. Saw dust (50%) + Sugarcane bagasse (50%) - (SD+SB).
vi. Sugarcane bagasse (50%) + Maize stalk (50%) - (SB+MS).
vii. Saw dust (33.33%) + Maize stalk (33.33%) + Sugarcane bagasse (33.33%) - (SD+MS+SB).

Data obtained were statically analyzed using ANOVA and the means separated with LSD at 5% level of probability.

Results

The delignification process of polysaccharide contents of the substrates by *P. ostreatus* showed that the fungus significantly ($P<0.05$) degraded the hemicelluloses, cellulose and lignin contents of the substrates though to varying degrees (Table 1). The loss of polysaccharide content of the test substrates due to the fungus ranged as follows; hemicelluloses, from 20.64% with MS substrate to 48.92% with SB substrate; cellulose from 24.06% with SD substrate to 41.92% with SB substrate and lignin content from 4.01 % with MS substrate to 27.45% with SD substrate. General average degradation of substrate polysaccharides and loss due to the fungus was highest with SB substrate (37.86%) followed by SD+SB substrate (31.76%) and SD substrate (27.56%) suggesting that the decomposition of substrate polysaccharides was highest in SB substrate and the delignified polysaccharides of the test substrates were made readily available for use by fruit bodies of *P. ostreatus* during growth and establishment.

Polysaccharide Content of substrate (mg/100g) and loss (%)												
	Hemicelluloses			Cellulose			Lignin			Mean		
Substrate	A	B	% Loss	A	B	% Loss	A	B	% Loss	A	B	% Loss
SD	17.37	26.3	33.95	35.54	46.8	24.06	25.71	35.44	27.45	26.21	36.18	27.56
SB	15.07	29.51	48.93	26.57	45.75	41.92	23.17	26.41	12.27	21.06	33.89	37.86
MS	20.49	25.82	20.64	36.75	49.46	25.7	30.38	31.65	4.01	29.21	35.64	18,01
SD+SB	16.22	27.91	41.88	31.06	46.28	32.89	24.44	30.93	20.98	23.91	35.04	31.76
SD+MS	18.93	26.06	27.36	36.15	48.13	24.89	28.05	33.55	16.39	27.71	35.91	22.83
SB+MS	17.78	27.67	35.74	31.66	47.61	33.5	26.78	29.03	7.75	25.41	34.77	26.92
SD+SB+MS	17.64	27.21	35.17	32.95	47.34	30.4	26.42	31.17	15.24	25.67	35.24	27.16
LSD (0.05)	2.6	1.81	5.32	2.35	1.04	4.71	3.1	2.65	4	2.16	1.87	4.23

Table 1: Effect of *Pleurotus ostreatus* on polysaccharide composition of substrates.
Values are means of four replicates in two separate experiments, A = substrate after cultivation, B = substrate before cultivation.

Discussion

Polysaccharide composition of the substrates was degraded by extracellular enzymes of *P. ostreatus* [16] which caused a decrease or loss in the values of hemicelluloses, cellulose and lignin contents. The degraded substrate polysaccharides provided energy for the oyster mushroom that possesses bioactive compounds with hypocholesterolaemic activities [17]. According to Isikhuemhen and Nerude [18] fungi produce extracellular lignin modifying enzymes, in which the best characterized enzymes were laccase, lignin peroxidase and manganese peroxidases. Akinfemi, et al. [19] reported that hemicelluloses and cellulose present in the substrates [20] are reduced when *Pleurotus ostreatus* was used during biodegradation of agricultural waste and the emergence of mushrooms from substrates. The delignification process of degrading the agro-wastes/substrates by *P. ostreatus* appears to increase the digestibility of the spent/used substrates for feeding animals as some species of *Pleurotus* have been reported to possess the ability to upgrade cattle feed by colonizing different types of crop/vegetable wastes thereby increasing their digestibility [21,22]. Also, *Pleurotus spp.* have been used in the degradation of organic pollutants and bioconversion of agro-wastes due to the presence of non-specific oxygenases, as well as being explored in bioremediation efforts including biodegradation of xenobiotic compounds [21], purification of air, water and soil, clean-up of contaminated soils and in the treatment of industrial effluents [23]. Studies have shown that *P. ostreatus* is able to degrade a variety of polycyclic aromatic hydrocarbons [24] and several scientists have proved its importance in biodegradation [25,26] on various types of agro-wastes such as spent beer grain [27], elephant grass, sugarcane baggase wastes and coffee husk [28,29] which have been evaluated as alternative substrates for mushroom cultivation [30]. The fact that the mushroom grew on materials that would otherwise be considered as waste makes it a valuable venture in self-sustaining and empowerment of communities in future [31]. Degradation and solubilisation of plant organic wastes using an edible fungus like *P. ostreatus* is therefore a recycling technology that could be explored and adopted by farmers in developing countries [32]. In Nigeria, large volumes of unused lignocellulosic by-products are readily available and growing of *P. ostreatus* using these agricultural wastes could provide more food and reduce the hazards and pollution problems associated with crop residues.

References

1. Miles PG, Chang ST (2004) *Pleurotus- A mushroom of broad adaptivity*. In: Mushrooms: Cultivation, nutritional value, medicinal effect and environmental impact. 2nd (Edn), CRC Press, Boca Raton, USA pp: 315-325.

2. Pandiarajan G, Govindaraj R, Mareeswaran J, Makesh Kumar B (2011) *Antibacterial activity* and *heavy metal accumulation of edible Oyster Mushroom (Pleurotus Sajor-Caju) Grown on two Substrates*. Department of Plant Biology and Plant Biotechnology, G.V.N. College, Kovilpatti, 2UPASI Tea Research Foundation, Valparai, Coimbatore, pp: 12-22.

3. Chang ST, Miles PG (1989) Edible mushrooms and their Cultivations. CRC Press Inc., Boca Raton, Florida, U.S.A, pp: 27, 83, 88.

4. Chang ST, Miles PG (1991) Recent trends in world production of cultivated edible mushrooms. The Mushroom Journal 504: 15-18.

5. Chang ST, Miles PG (1992) Mushroom biology – A new discipline. Mycologist 6: 64-65.

6. Adebayo EA, Oloke JK, Achana Y, Bora TC (2012) Improvement of Laccase production in *Pleurotus pulmonarius*-LAU 09 by mutation. Journal of Microbiology Research 2(1): 11-17.

7. Ntougias S, Baldrian P, Ehaliotis C, Nerud F, Antoniou T, et al. (2012) Biodegradation and detoxification of olive mill waste water by selected strains of the mushroom genera Ganoderma and Pleurotus. Chemosphere 88(5): 620-626.

8. Baldrian P, Snajdr J (2006) Production of ligninolytic enzymes by litter-decomposing fungi and their ability to decolorize synthetic dyes. Enzyme Microbiol. Technol 39: 1023-1029.

9. Forgacs E, Cserháti T, Oros G (2004) Removal of synthetic dyes from waste waters: A review. Environ Int 30(7): 953-971.

10. Anwar Z, Muhammad G, Muhammad I (2014) Agro-industrial lignocellulosic biomass a key to unlock the future bio-energy: A brief review. Journal Rad Res Appl Sci 7(2): 163-173.

11. Asgher M, Ahmad Z, Iqbal HMN (2013) Alkali and enzymatic delignification of sugarcane bagasse to expose cellulose polymers for saccharification and bio-ethanol production. Industrial Crops Production 44: 488-495.

12. Irshad M, Anwar Z, But HI, Afroz A, Ikram N, et al. (2013) The industrial applicability of purified cellulose complex indigenously produced by *Trichoderma viride* through solid-state bio-processing of agro-industrial and municipal paper wastes. Bio Resources 8(1): 145-157.

13. Belewu MA (2003) Nutritional qualities of corncob and waste paper incubated with edible mushroom. Nig J Anim Prod 30(1): 20-26.

14. Ali MA, Mehmood MI, Nawaz R, Hanif MA, Wasim R (2007) Influence of substrate pasteurization methods on the yield of oyster mushroom (*Pleurotus species*). Pakistan Journal Agriculture, Science 44(2): 300-303.

15. Adedokun OM, Fasidi IO, Ayodele VI (2003) Spawn production and growth of *Pleurotus tuber-regium* (Fries) Singers on agricultural wastes. Biosciences Research and Communication 15(6): 437-444.

16. Akinfemi A, Adu OA, Adebiyi OA (2009) Use of white-rot-fungi in upgrading maize straw and the resulting impact on chemical composition and *in vitro* digestibility. Livestock Research for Rural Development 21(10): 162.

17. Gunde-Cimerman N (1999) Medicinal value of the genus, *Pleurotus* (Fr.), P. Karst (Agaricles S.R., Basidiomycetes. Intjmedmushrooms 1(1): 69-80.

18. Isikhuemhen OS, Nerud F (1999) Preliminary studies on lignolytic enzymes produced by the tropical fungus Pleurotus tuber-regium. Antonie Van Leeuwenhoek 75(3): 257-260.

19. Akinfemi A, Jonathan SG, Adu OA (2010) Improving the nutritive value of millet stovers using biological treatment. Libyan Agriculture Research Centre Journal International 1(3): 195-201.

20. Sivaprakasam K, Kandasawmy TK (1981) Waste material for the cultivation of *Pleurotus sajor-caju.* Mushroom Journal 101: 178–179.

21. Rajarathnam S, Wankhede DB, Patwardhan MV (1979) Some chemical and biochemical changes in straw constituents during growth of *Pleurotus flabellatus.* European journal of applied microbiology and biotechnology 8: 125–134.

22. Salmones D, Mata G, Waliszewski KN (2005) Comparative culturing of *Pleurotus spp*. on coffee pulp and wheat straw: biomass production and substrate biodegradation. Bioresources Technology 96(5): 537-544.

23. Reid BJ, Fervor TR, Semple KT (2002) Induction of Pah-Catabolism in mushroom compost and its use in the biodegradation of soil-associated Phenanthrene. Environmental Pollution 118(1): 65–73.

24. Sack U, Günther T (1993) Metabolism of PAH by fungi and correction with extracellular enzymatic activities. J Basic Microbiol 33(4): 269-277.

25. Adenipekun CO, Fasidi IO (2005) Bioremediation of oil polluted soil by *Lentinus subnudus,* a Nigerian white rot fungus. African Journal of Biotechnology 4(8): 796-798.

26. Estévez E, Veiga MC, Kennes C (2005) Biodegradation of toluene by the new fungal isolates Paecilomyces varioti and Exophialaol digosperma. J Ind Microbiol Botechnol 32(1): 33-37.

27. Wang D, Sakoda AK, Suzuki M (2001) Biological efficiency and nutritional values of *Pleurotous ostreatus* cultivated on spent beer grain. Bioresource Technology 78(3): 293-300.

28. Obodai M, Cleland-Okine J, Vowotor KA (2003) Comparative study on the growth and yield of *Pleurotus ostreatus* mushroom on different lignocellulosic by-products J Ind Microbiol Biotechnol 30(3): 146-149.

29. Obodai M, Ferreira IC, Fernandes A, Barros L, Mensah DL,

et al. (2014) Evaluation of the chemical and antioxidant properties of wild and cultivated mushrooms of Ghana. Molecules 19(12): 532-548.

30. Nwokoye AI, Kuforiji OO, Oni PI (2010) Studies on mycelial growth requirements of *Pleurotus ostreatus* (fr.) Singer. International Journal of Basic and Applied Sciences 10(2): 47-53

31. Udayasimha L, Vijayalakshmi YC (2012) Sustainable waste management by growing mushroom (*Pleurotus florida*) on anaerobically digested waste and agro residues. International Journal of Engeneering Research Technology 1(5): 1-8.

32. Taurachand D (2004) Sugarcane bagasse. In: Choi KW (Ed.), Mushroom growers' handbook 1. Oyster mushroom cultivation. Seoul: Mush World, pp: 118-122.