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Biodegradation of lignocellulosic wastes through cultivation *of Pleurotus* sajor-caju

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ABSTRACT: The oyster mushroom *Pleurotus* sajor-caju (Fr.) Singer was cultivated on three chemically as well as steam sterilized lignocellulosic substrates i.e. paddy straw *(Oryza saliva),* wheat straw *(Triticum aestivum)* and grass *(Cyanodon dactylon).* During cultivation carbon, cellulose, hemicellulose and lignin content of substrates decreased, while nitrogen and ash content showed continuous increase. Steam sterilized substrates suited better for biodegradation than the chemically sterilized ones. The progressive breakdown of cellulose, hemicellulose and lignin was correlated with apparent increase in the yield and bioefficiency of *P.* sajor-caju. Among three substrates paddy straw showed maximum biodegradation and it supported optimum yield followed by wheat straw and lastly the grass.

1 INTRODUCTION

Lignocelluloses comprising three major groups of polymers-cellulose, hemicellulose and lignin are the most abundant renewable organic compounds available in the biosphere, being produced through photosynthesis and allied biological processes (Kuhad & Singh 1993). These polymers are very resistant. Hence, a major part of these lignocellulosic wastes are burnt resulting in multifacet hazards including oxygen deficient environment, respiratory diseases and poor visibility at night. The physico-chemical processes in degradation of lignocellulosic wastes are often non-eco-friendly and unviable. Hence, the present work was taken up with an aim to search an effective methodology for production of nutritional food and better lignocellulosic waste management.

2 MATERIALS AND METHODS

In the present work three lignocellulosic wastes (used as substrates) viz. paddy straw *(Oryza saliva),* wheat straw *(Triticum aestivum)* and grass *(Cyanodon dactylon)* along with the oyster mushroom *Pleurotus sajor-caju* (Fr.) Singer were selected.

The pure culture of *P.* sajor-caju was procured from National Center for Mushroom Research and Training, Chambaghat, Solan. Throughout the study cultures were maintained on malt extract agar (MEA) medium at 23-25°C and were subcultured at periodic intervals of three weeks. The oyster mushroom was cultivated on chemically and steam sterilized substrates (Singh 1997). Biological efficiency was calculated as the percentage conversion of dry substrate to fresh fruit bodies (Chang et al. 1981). Percentage of carbon and nitrogen was determined by CHN Elemental Analyser (PE 2400) using 20 mesh powdered sample. Ash content was determined following A.O.A.C. method (Horwitz 1980). The procedure of Updegraff (1969) was used for cellulose estimation. .Hemicellulose was estimated using Krober's formula (Horwitz 1975). Lignin estimation was done gravimetrically (Godbole 1986).

3 RESULTS AND DISCUSSION

The percentage of carbon, nitrogen and their ratio in the substrates at different stages of cultivation is given in Table 1. The results reveal that carbon content and C/N ratio decreased during cultivation. However, nitrogen content increased during this period. The decrease in carbon and increase in nitrogen content was more in paddy straw than in wheat straw and grass. In autoclaved substrates loss of carbon and increase of nitrogen was more pronounced than in chemically sterilized substrates.

The decrease in carbon content of the substrates in the present studies after completion of spawn run and ultimate cropping could be due to bioconversion of organic compounds and its removal by the growing mycelium as well as fruiting bodies of the mushroom. Zadrazil (1978) suggested that about 50% of the substratum is liberated as CO_2, during cultivation of *Pleurotus* species. The increase in nitrogen content during cultivation of oyster mushroom is perhaps because of its ability to fix atmospheric nitrogen. Cowling and Merril (1996), Ginterova (1973), Rangaswami et al. (1975), and Rangad and Jandaik (1977) also noted an increase in nitrogen content of the residues in *Pleurotus* beds and suggested that *Pleurotus* and some other species have the ability to fix nitrogen from air. However, Kurtzman (1979) visualized that increase in nitrogen content of the substrates is because of presence of nitrogen fixing bacteria in the bed. Zadrazil (1980) also reported increase in nitrogen content of composts during *Pleurotus* cultivation. However, Rajarathnam et al.(1979) observed that nitrogen content of rice straw compost decreased during cultivation of *P.flabellatus.*

The percentage of ash content in untreated substrates and in substrates of various stages of cultivation of *P.* sajor-caju is shown in Table 2. The ash content in untreated paddy straw, wheat straw and grass was observed to be 15.0, 8.0 and 5.8 percent, respectively. The results indicate that there was continuous increase in the ash content of substrates during the cultivation. The increase was more prominent in autoclaved substrates than chemically sterilized substrates.

Zadrazil (1976) and Rajarathnam et al. (1979) also observed an increase in the ash content during the growth of the mushroom. The probable reason for the relative increase in total ash content of substrates from inoculation until the end of fruit body harvesting could be due to constant utilization of organic matter (Rajarathnam et al. 1979).Bioconversion and loss of organic matter lead to increase in the concentration of inorganic elements. Thereby ash content of composts increases.

The biodegradation of cellulose and hemicellulose contents of substrates as a consequence of cultivation *of P.* sajor-caju is presented in Table 3. It is evident from the observations made during experiments that the rate of degradation of cellulose and hemicellulose was slow during spawn run but increased suddenly during fructification. Maximum degradation was observed in

Table 1. Percentage of carbon, nitrogen and their ratio in three substrates during cultivation *of Pleurotus* sajor-caju

Substrates	0 Day			At the completion of spawn run			Spent compost		
	C*	N	C:N*	C*	N	C:N*	C*	N	C:N*
RAP	36.60	0.89	41.12	32.40	1.24	26.12	25.12	1.54	16.31
RCP	36.63	0.88	41.62	33.00	1.07	30.84	25.90	1.28	20.23
WAP	34.67	0.62	55.90	31.45	0.79	39.81	25.30	1.00	25.30
WCP	34.66	0.62	55.90	32.00	0.75	42.60	25.57	0.91	28.41
GAP	30.51	0.98	31.13	28.44	1.10	25.85	22.88	1.14	20.07
GCP	30.54	0.98	31.16	28.26	1.05	26.91	14.28	1.10	22.61

R= paddy straw W= Wheat straw G= Grass
A= Autoclaved C= Chemically Sterilized *P= Pleurotus* sajor-caju

C= Carbon N= Nitrogen C : N= Carbon, nitrogen ratio

Table 2. Percentage of total ash content in three substrates during cultivation *of P.* sajor-caju.

Substrates	At the completion of spawn run	After 1st flush	Spent Compost
Paddy straw	15%		
RAP	17.0	22.0	30.5
RCP	16.8	18.7	22.8
Wheat straw	8%		
WAP	10.8	14.9	20.6
WCP	09.6	12.8	17.2
Grass	5.8%		
GAP	07.3	9.6	13.7
GCP	06.5	8.2	10.0

Table 3. Biodegradation of cellulose and hemicellulose of substrates during cultivation *of P.* sajor-caju

Substrates	Cellulose %				Hemicellulose %			
	a	b	c	d	a	b	c	d
RAP		34.74	32.03	26.63		23.24	21.36	19.57
	38.6	(10.00)	(17.02)	(31.01)	24.3	(4.36)	(12.09)	(19.46)
RCP		35.12	32.81	28.00		23.66	22.08	20.50
		(9.01)	(15.00)	(27.46)		(2.63)	(9.13)	(15.63)
WAP		31.10	29.49	25.76		25.20	(23.85	(22.20)
	33.9	(8.25)	(13.00)	(24.01)	26.5	(4.90)	(10.00)	(16.98)
WCP		32.20	29.49	26.78		25.54	(24.21)	(22.42)
		(5.01)	(13.00)	(21.00)		(3.62)	(8.64)	(15.39)
GAP		28.69	26.87	(24.46)		26.38	24.96	(23.12)
	30.2	(5.00)	(11.02)	(19.00)	27.2	(3.01)	(8.23)	(15.00)
GCP		29.58	28.12	26.57		26.80	25.56 •	24.20
		(2.05)	(6.88)	(12.01)		(1.47)	(6.02)	(11.02)

a = untreated substrates b= at the completion of spawn run
c= after 1 st flush d= spent compost
Figures in brackets indicate percentage loss.

Table 4. Biodegradation of lignin of substrates during cultivation.

Substrates	Lignin %			
	a	b	c	d
RAP	20.7	12.00	10.00	8.40
		(42.02) •	(51.69)	(59.42)
RCP		11.80	10.60	9.20
		(42.99)	(48.79)	(55.55)
WAP	17.4	10.54	9.52	8.33
		(39.42)	(45.28)	(52.12)
WCP		11.90	10.20	8.84
		(31.60)	(41.37)	(49.19)
CAP	14.7	10.36	9.38	9.40
		(29.52)	(36.19)	(42.85)
GCP		11.76	10.92	10.36
		(26.00)	(25.71)	(29.52)

Table 5. Yield performance of P. sajor-caju of three substrates.

Substrates	1st Flush (g)	2nd Flush (g)	3rd Flush (g)	4th Flush (g)	Total (g)Yield	Bioefficiency (%)
RAP	312.55	135.60	74.66	24.00	546.81	109.3
RCP	247.10	117.55	54.54	22.00	441.19	88.1
WAP	169.20	69.04	41.74	26.82	306.80	61.3
WCP	144.49	60.97	30.48	21.28	257.22	51.4
GAP	142.41	75.21	21.68	10.04	249.34	49.8
GCP	85.28	36.54	18.51	8.93	149.26	29.8

case of paddy straw followed by that in wheat straw and the grass. Autoclaved substrates were degraded better than the chemically sterilized substrates.

Biodegradation of lignin content of substrates during cultivation is shown in Table 4. The results on degradation of lignin indicate that quite differently from degradation of cellulose and hemicellulose, considerable amounts of lignin were degraded during spawn run. However, the rate of degradation slowed down during fructification. Similar to cellulose and hemicellulose, lignin suffered maximum degradation in autoclaved substrates and in paddy straw followed by wheat straw and lastly the grass.

Gerrits (1968) also recorded the rapid degradation of lignin and slow degradation of cellulose and hemicellulose during spawn run and slow degradation of lignin and fast depletion of cellulose and hemicellulose during fructification. Zadrazil(1980) and Bisaria et al.(1987) reported the ability *of P.* sajor-caju to degrade major components of lignocellulosic materials. Rajarathnam et al.(1979) recorded degradation of cellulose, hemicellulose and lignin of rice straw by *P. flabellatus.*

The mean yield of *P.* sajor-caju (fresh form) per 500 gm dry substrate and their biological efficiency is given in Table 5. The cumulative yield and bioefficiency of the mushroom in the present studies were invariably higher on autoclaved substrates than on chemically sterilized substrates. Paddy straw supported maximum production of mushrooms followed by wheat straw and lastly the grass. Many other workers also reported paddy straw to give a very high yield. Chang et al. (1981) reported a yield of P. sajor-caju of 1.77 kg/kg of paddy straw. Bano et al. (1979) reported yield of the mushroom of 0.84 kg/kg dry paddy straw.

4 SUMMARY AND CONCLUSIONS

A perusal of the present investigations enunciate that the paddy straw, available in plenty as an agricultural by product in the countryside, is the best suited material for the cultivation of the oyster mushroom. Chemical sterilization and the autoclaving, is found the better technique in preparation of substrate for the growth and development of oyster mushroom compared to chemical sterilization. The added advantage of autoclaving is that the contact of hazardous chemicals is completely obliterated which is imminent in the chemical sterilization. Thus, the autoclaving is not only safer but economically more profitable since the yield performance of oyster mushroom has been adjudged very high on the autoclaved substrates as compared to chemically sterilized substrates. This is a low cost, viable multipurpose technology that can meet the growing demand of food, feed, fodder, fertilizer and energy.

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