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Nutritional status of *Pleurotus* spp. grown on various agro-wastes

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Abstract

Three species of*Pleurotus, P. sajor-caju, P. platypus* and *P. citrinopileatus* were cultivated on different agro-wastes: cotton stalk, coir fibre, sorghum stover and mixtures of these wastes. The primordial initiation day was observed between the 21st and 30th day after spawning. The yield was maximum on cotton stalks in *P. sajor-caju* and *P. citrinopileatus*. *P. platypus* yielded the maximum on sorghum stover. The biological efficiency, nutrient composition, energy value and energy recovery of the fruit bodies were estimated.
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Keywords: Agro-wastes; Biological efficiency; Energy value and energy recovery; *Pleurotus* spp; Yield

1. Introduction

The mushroom industry is a global, expanding industry, with world production greater than two million tonnes annually. The chief mushroom varieties cultivated are *Agaricus bisporus, Lentinus edodes* and the oyster mushroom, *Pleurotus ostreatus* (Suguimoto, Barbosa, Dekker, & Castro-Gomez, 2001). Cultivation of these mushrooms represents a major industry in the countries of south east Asia (Chang & Miles, 1991; Mehta, Gupta, & Kaushal, 1990). Kues and Liu (2000) reported that the *Pleurotus* species are well known edible mushrooms in different parts of the world. Shukla and Biswas (2000) stated that oyster mushroom (*Pleurotus florida*) cultivation is gaining popularity due to low cost technology and easy availability of various substrates for its cultivation. In India, prevalence of varied, agro-climatic conditions and availability of vast quantities of lignocellulosic raw materials have stimulated the cultivation of *Pleurotus* spp. especially *P. sajor-caju* (Sangwan & Saini, 1995).

Pleurotus spp., as primary wood rot fungi, are able to colonise different types of agricultural wastes as substrates. Thus they are cultivated on saw-dust, wood blocks, bagasse and coffee pulp. Exploitation of the substrate varies with the species, strain and cultivation technology (Zadrazil & Dube, 1992). Generally, oyster mushrooms are cultivated on single substrates, commonly wheat or paddy straw. With an aim to utilize other agro wastes also as substrates, cultivation of *Pleurotus* spp. on various agro-residues, such as paddy straw, maize stover, coir pith, sugarcane bagasse and mixtures of these wastes, has been tried by various workers (Bisaria, Madan, & Bisaria, 1987; Chang, Lau & Cho, 1981; Ragunathan, Gurusamy, Palaniswamy, & Swaminathan, 1996; Ramamoorthy, Meena, Muthusamy, Seetharaman, & Alice 1999; Sangwan & Saini, 1995). Das, Mahapatra, and Chattopadhyay (2000) used wild grasses as substrate for cultivation of *P. sajor-caju* and *P. florida*.

In the present study, three species of *Pleurotus, P. sajor-caju, P. platypus* and *P. citrinopileatus* were cultivated on cotton stalks, coir fibre, sorghum stover and mixtures of these wastes (w/w) in polythene bags. The yield of mushrooms, biological efficiency, nutrient composition of the fruit bodies, energy value of the substrates and energy recovery of the mushrooms were analyzed.

2. Materials and methods

2.1. Source of inoculum

The seed inoculum of *Pleurotus* spp. were obtained from the Department of Plant Pathology, Tamilnadu Agricultural University, Coimbatore, India and

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maintained on malt agar medium at 4 °C (Ragunathan et al., 1996).

2.2. Substrates and cultivation

Cotton stalks (*Gossypium indicum*), sorghum stover (*Sorghum vulgare*), coir fibre (*Cocos nucifera)* and mixture of these substrates (1:1:1 w/w) were used as substrates. For preparation of spawn, cultivation, maintenance of beds and harvest, the methods proposed by Marimuthu, Krishnamoorthy, Sivaprakasham, and Jeyarasan (1993) were followed.

2.3. Analytical methods

The nutrient value of the fruit bodies was determined in terms of their moisture content (AOAC, 1990); nitrogen (Umbriet, Burns, & Staffes, 1972), carbohydrate (Hodge & Hofreiter, 1962), amino nitrogen (Moore & Stein, 1948), crude protein (Crisan & Sand, 1978), fat (Bligh & Dyer, 1959), minerals (AOAC, 1990), phosphorus (Dyer, Tammers, & Routh, 1957), cellulose (Updegroff, 1969), hemicellulose, lignin (Thornber & Northcote, 1961) and crude fibre contents (Maynard, 1970).

2.4. Energy value of mushrooms

The energy values of fruit bodies were calculated on the basis of their content of crude protein, fat and carbohydrates by using the factors 2.62, 8.37, and 4.2 kcal/g, respectively (Crisan & Sand, 1978). The energy values of the substrates were calculated on the basis of their contents of cellulose, hemicellulose and lignin, using the factors 4.2,4.2 and 7.1 kcal/ g, respectively (Dent & Brown, 1978).

3. Results and discussion

3.1. Yield of mushroom

Pleurotus spp. were cultivated on various agro-wastes for about 35days, during which four fleshings were made. In *Pleurotus* spp. the primordial initiation was generally observed on the 24th–30th day (Khanna, Bhandari, Soni, & Garcha, 1992). Ragunathan et al. (1996) reported the day of primordia initiation as the 22nd–27th day. In the present study, it was observed on the 21st day on coir fibre in *P. sajor-caju*, 23rd day in *P. platypus* on coir fibre and 25th day in *P. citrinopileatus* on cotton stalks. Chang et al. (1981) reported a yield of 0.730 kg/kg on cotton wastes with used tea leaves. Bisaria et al. (1987) and Aslan Azizi, Shamalo, and Sreekantiah (1990) obtained a yield of 0.20–4.79 kg/kg on various substrates. Sangwan and Saini (1995) obtained 0.655 kg/kg fruit bodies on sorghum stover. Kathe, Balasubramanya, and Khandeparkar (1996) reported a yield of 0.355 kg/kg fruit bodies on cotton stalks. Madhusudhanan and Chandramohanan (1997) reported a yield of 0.117 kg/kg on arecal leaf sheath. Pradeep Kumar, Pal, and Sharma (2000) obtained a maximum yield of *P. sajor-caju* on *Ageratum* twigs. Ragunathan et al. (1996) reported a yield of 0.327 kg/kg on coir fibre. In the present trial, *P. sajor-caju* yielded 0.414 kg/kg on cotton stalks; the yield was 0.368 kg/kg on sorghum stover and 0.273 kg/kg on coir fibre. The mixed bed yielded 0.352 kg/kg fruit body. *P. platypus* yielded the maximum amount of fruit bodies on sorghum stover (0.334 kg/kg), followed by cotton stalk (0.330 kg/kg), mixed bed (0.314 kg/kg) and coir fibre (0.261 kg/kg). *P. citrinopileatus* yielded maximum on cotton stalks (0.326 kg/kg); sorghum stover yielded 0.321 kg/kg of fruit bodies, whereas mixed bed and coir fibre yielded 0.315 and 0.236 kg/kg fruit bodies, respectively (Table 1). When comparing to the previous reports, the yield on cotton stalks, sorghum stover and mixed bed were observed to be quite encouraging, but coir fibre was observed to be a non-preferable substrate for oyster mushroom cultivation.

3.2. Biological efficiency

The biological efficiency of the substrates indirectly denotes the suitability of the substrates for cultivation of particular strains of mushroom. The higher the biological efficiency, the greater will be the suitability of the substrate for cultivation of that particular strain of mushroom. Bisaria et al. (1987) reported that the biological

Table 1
Yield of *Pleurotus* spp. on various agro-residues

Substrate	Primordia initiation day			Total yield (g/kg substrate)			Biological efficiency (%)		
	Ps	Pp	Pc	Ps	Pp	Pc	Ps	Pp	Pc
Cotton stalk	26 ±1.2	25±0.82	25±0.82	414.18 ±1.4	330.4±1.6	326.48±1.1	4142±0.5	33.04±1.0	32.69±0.6
Coir fibre	21±1.3	23±1.3	27±1.0	23.32 ±2.0	261.18±1.1	236.42±1.5	27.33±0.9	26.11±0.9	23.64±1.0
Sorghum stover	24±1.2	26±0.82	29±0.82	368.37±1.0	334.5±1.0	321.7±1.3	36.84±0.8	33.45±0.7	32.17±0.9
Mixed bed	28±0.82	27±0.47	28±0.47	352.1±1.6	314.2±1.5	315.13±1.1	35.21±0.9	31.42±0.7	31.5±0.7

Values are means of triplicates ±SD. Ps, *Pleurotus sajo-caju*; Pp, *Pleurotus platypus*; Pc, *Pleurotus citrinopileatus*.

Table 2
Nutrient content of fruit bodies of *Pleurotus* spp. grown on various agro-residues

Component	Substrates											
	Cotton stalk			Coir fibre			Sorghum stover			Mixed bed		
	Ps	Pp	Pc	Ps	Pp	Pc	Ps	Pp	Pc	Ps	Pp	Pc
Moisture[a]	93.08 ±0.6	91.03 ±0.3	92.87 ±0.5	91.12 ±0.8	90.84 ±0.6	90.14 ±0.8	90.14 ±0.1	91.18 ±0.5	90.8 ±0.6	91.03 ±1.0	92.08 ±0.8	91.4 ±0.4
Carbohydrate[b]	42.7±1.0	40.1±0.3	44.2 ±0.4	45.2 ±0.1	44.5 ±0.3	42.8 ±0.8	43.2 ±0.6	41.8 ±0.5	44.4 ±0.3	46.2 ±0.3	45.3 ±0.3	41.5 ±0.1
Crude protein[b]	31.4 ±1.3	36.8 ±0.1	31.1 ±0.2	44.3 ±0.4	32.5 ±0.1	30.1 ±0.3	36.2 ±0.1	33.2 ±0.1	36.8 ±0.2	38.3 ±0.5	25.6 ±0.7	40.6 ±0.2
Amino nitrogen[c]	6.18 ±0.3	6.34 ±0.1	3.26 ±0.3	4.75 ±0.1	6.14 ±0.0	3.18 ±0.1	6.34 ±0.3	5.98 ±0.6	2.98 ±0.1	8.36 ±0.1	5.7 ±0.1	3.4 ±0.1
Fat[c]	0.95 ±0.1	2.4 ±0.2	2.84 ±0.4	1.22 ±0.4	3.16 ±0.2	1.7 ±0.1	1.41 ±0.1	2.88 ±0.1	2.9 ±0.1	1.19 ±0.1	3.15 ±*0.5*	2.74 ±0.7
Calcium[c]	0.68 ±0.03	1.98 ±0.1	1.14 ±0.3	1.64 ±0.1	2.1 ±0.2	0.78 ±0.1	1.12 ±0.3	1.73 ±0.3	0.7 ±0.1	1.38 ±0.3	1.1 ±0.4	0.64 ±0.1
Iron[c]	8.66 ±0.17	7.18 ±0.4	5.84 ±0.4	12.7 ±0.3	10.48 ±0.0	6.24 ±0.6	9.24 ±0.1	11.41 ±0.6	5.28 ±0.6	11.21 ±0.2	11.24 ±*0.5*	6.1 ±0.2
Potassium[c]	16.3 ±0.22	11.2 ±0.3	10.3 ±0.2	14.3 ±0.3	14.2 ±0.1	11.3 ±0.3	12.2 ±0.3	12.8 ±0.1	14±0.3	14.7 ±0.2	12±0.3	33.8 ±0.3
Magnesium[c]	10.3±0.7	13.3 ±0.2	12.4 ±0.2	12.2 ±0.0	18.9 ±0.0	11.2 ±0.3	11.3 ±0.2	13.4 ±0.0	9.4 ±0.2	10.4 ±0.1	10.2 ±0.3	11.4 ±0.1
Sodium[c]	0.84 ±0.04	1.1 ±0.1	0.9 ±0.1	0.76 ±0.1	0.78 ±0.1	0.62 ±0.0	0.94 ±0.0	1.15 ±0.1	0.78 ±0,1	1.15 ±0.2	0.8 ±0.0	1.14 ±0.0
Phosphorus[c]	158 ±0.12	118 ±0.1	168 ±0.4	195 ±0.4	220±0.2	165 ±0.6	211 ±0.7	170 ±0.6	170.44 ±0.3	142 ±0.3	165 ±0.4	161 ±0.3

Values are mean of three replicates ±SD. Ps, *Pleurotus sajor-caju*; Pp, *Pleurotus platypus*; Pc, *Pleurotus citrinopileatus*.
[a] Fresh weight of the fruit body.
[b] Dry weight of the fruit body.
[c] mg/g Dry weight of the fruit body.

Table 3
Lignocellulosic content of fruit bodies of *Pleurotus* spp. grown on various agro-residues

Component	Substrates											
	Cotton stalk			Coir fibre			Sorghum stover			Mixed bed		
	Ps	Pp	Pc	Ps	Pp	Pc	Ps	Pp	Pc	Ps	Pp	Pc
Cellulose	46.20±0.16	36.40±0.25	34.60±0.48	27.40±0.29	43.40±0.31	38.80±0.27	42.30±0.19	40.10 ±0.35	36.40 ±0.33	40.30±0.48	39.80±0.44	41.30′±0.14
Hemicellulose	26.10±0.09	32.20±0.42	23.40±0.27	31.40±0.31	28.60±0.39	31.40±0.28	27.40±0.74	30.60±1.00	26.50±0.24	28.40±0.25	40.30±0.62	29.30±0.65
Lignin	14.00 ±0.25	18.00±0.49	14.80±0.36	16.00±0.42	16.00±0.28	16.80±0.20	14.40±0.18	17.80±0.38	17.00±0.42	17.20±0.18	17.60±0.14	20.40±0.12
Crude fibre	20.48±0.22	20.14 ±0.35	21.6±0.2]	16.40±0.24	11.40±0.17	18.3±0.05	15.00±0.04	17.40±0.10	16.80 ±0.35	16.20±0.11	18.40±0.06	19.40±0.19
Ash	8.40 ±0.25	7.40 ±0.19	8.00 ±0.10	6.40±0.13	6.20 ±0.34	6.10 ±0.12	5.40 ±0.22	5.80 ±0.14	6.30 ±0.11	7.00 ±0.07	5,50±0.21	6.10 ±0.16

Values are mean of three replicates and expressed as % dry weight of the fruit body ±SD. Ps, *Pleurotus sajor-caju*; Pp, *Pleurotus platypus*; Pc, *Pleurotus citrinopileatus*.

efficiency on paddy straw was 11.66%; Chang et al. (1981) reported that the *P. sajor-caju*, grown on paddy straw and cotton waste, gave biological efficiencies of 177.41 and 79.81%, respectively. Mathew, Mathai, and Suharban (1996) observed 0.30–0.80% biological efficiency of five *Pleurotus* spp. grown on various agro-residues. Ragunathan et al. (1996) observed biological efficiency of 35.94% on coir fibre. Pradeep Kumar et al. (2000) obtained a maximum biological efficiency of 98.0% in *Ageratum* twigs, followed by 90% on paddy straw. In the present study, the biological efficiency of *Pleurotus* spp. on cotton stalk was observed to be in the range of 32.69–41.42%; on coir fibre it was in the range of 23.64 – 27.33%; on sorghum stover it was 32.17–36.84% and on mixed bed the biological efficiency was 31.51–35.21%.

3.3. Nutrient composition of fruit bodies

The fruit bodies of mushrooms are rich in carbohydrates, proteins, amino nitrogen and minerals; they have very low fat contents. Generally the fruit bodies contained 84.70–91.90% moisture, 40.6–53.3% carbohydrate, 27.3–42.5% crude protein, 1.09% amino nitrogen, 1.1–8.0% fat, 0.189–2.45 mg/g calcium, 0.25–12.2 mg/g iron, 8.10–24.0 mg/g potassium, 1.52–14.3 mg/g magnesium, 0.02–2.5 mg/g sodium and 5.87–218 mg/g phosphoros. The fruit bodies also contained the polymeric substances, cellulose, hemicellulose, lignin and crude fibre in the range of 28.5–41.0, 13.0–39.3%, 14.0–20.20% and 14.1–20.2% respectively (Bisaria et al., 1897; Chang et al., 1981; Khanna et al., 1992; Ragunathan et al., 1996). In the present study, it was observed that the type of substrate used for cultivation of *Pleurotus* spp. could not influence the nutrient composition of the fruit bodies. The fruit body of *Pleurotus* spp. cultivated in the present study, contained 90.14–93.08% moisture, 40.13–46.2% carbohydrate, 25.63–44.3% crude protein, 2.98–8.63 mg/g amino nitrogen, 0.95–3.16 mg/g fat, 0.64–2.10 mg/g calcium, 6.1–12.7 mg/g iron, 10.3–33.2 mg/g potassium, 9.40–18.9 mg/g magnesium, 0.78–1.15 mg/g sodium and 118–220 mg/g phosphorous (Table 2). The polymeric substance contents were 27.4–46.2% of cellulose, 23.40–40.30% of hemicellulose, 14.00–20.40% lignin and 11.40–20.48% of crude fibre (Table 3). The fruit bodies of *Pleurotus* spp., especially grown on coir fibre, were rich in carbohydrate, crude fibre, amino nitrogen and sodium; the fat content was very low. Fruit bodies of *P. platypus* contained high amounts of fat, calcium, magnesium, sodium and phosphorous; whereas fruit bodies of *P. citrinopileatus* were rich in potassium. In polymeric substances, *P. sajor-caju* contained comparatively high amounts of cellulose and crude fibre; *P. platypus* was rich in hemicellulose and *P. citrinopileatus* contained high amounts of lignin.

3.4. Energy value of mushrooms and energy recovery of wastes in the fruit bodies of Pleurotus spp.

Based on the crude protein, carbohydrate and fat contents, the energy value of fruit bodies of *Pleurotus* spp. were calculated (Table 4). The energy values of *P. sajor-caju* fruit bodies were observed to be 272, 316, 288, and 304 (k/cal/100 g substrate), respectively, for cotton stalks, coir fibre, sorghum stover and mixed bed. The energy values of *P. platypus* were 280, 298, 287, and 284 (k/cal/100 g substrate); for *P. citrinopileatus* the values were 295, 274, 307, and 325 (k/cal/100 g substrate), respectively. Similarly, the energy values of substrates, based on their contents of cellulose, hemicellulose and lignin, were computed. The energy values of substrates used in the present study were, 406, 378, 413, and 514 k.cal/100 g of substrate, respectively, for cotton stalks, coir fibre, sorghum stover and mixed bed. Based on these two values, the percent energy recovery of the substrates in the fruit bodies were calculated. The highest recovery was obtained in *P. sajor-caju* on cotton stalks (10.12%) followed by *P. platypus* (9.6%); the energy recovery was low in *P. citrinopileatus* (8.9%). Bisaria et al. (1987), reported the recovery of 5.0–10.0% in paddy straw and Ragunathan et al. (1996) reported recovery of 1.1–10.5% in various agro - residues. From the study, it was observed that the *Pleurotus* spp. could

Table 4
Energy recovery of fruit bodies and agro-residues of *Pleurotus* spp.

Substrate	Energy value of substrate (kcal/100 g substrate) (1)	Energy value of mushroom (k/cal/100 mushroom) (2)			Yield of mushroom (kcal/l00 g substrate) (3)			Energy value of mushroom (kcal/100 g substrate) (4) = 2×3/100			Energy value of substrate in mushroom (%) (4)×100/1 (5)		
		Ps	Pp	Pc	Ps	Pp	Pc	Ps	Pp	Pc	Ps	Pp	Pc
Cotton stalk	406	272	280	292	45.5	41.6	37.0	41.2	38.8	36.4	10.1	9.60	8.90
Coir fibre	338	316	298	273	34.2	33.7	32.8	36.0	33.5	30.1	9.52	8.90	7.90
Sorghum sotver	413	288	287	308	41.3	37.9	32.2	39.7	36.1	33.1	9.06	8.80	7.90
Mixed bed	514	304	284	304	40.5	36.9	32.0	41.1	34.9	34.6	7.99	6.80	6.70

Ps, *Pleurotus sajor-caju*; Pp, *Pleurotus platypus*; Pc, *Pleurotus citrinopileatus*.

be cultivated economically on agro-residues. Cotton stalks could be used for cultivation of *P. sajor-caju,* coir fibre for *P.platypus* and sorghum stover for *P. citrinopileatus*. The fruit bodies are rich in nutrients and minerals with low fat content. Moreover, the cultivation of *Pleurotus* spp. on agro-residues helps in effective disposal of these wastes.

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