Food Chemistry, Vol. 55, No. 2, pp. 139–144, 1996

0308-8146/96 $15.00+0.00

0308-8146(95)00079-8

Cultivation of *Pleurotus* spp. on various agro-residues

R. Ragunathan, R. Gurusamy, M. Palaniswamy & K. Swaminathan*

Department of Biotechnology, Bharathiar University, Coimbatore 641 046, Tamil Nadu, India

(Received 29 July 1994; revised version received 31 March 1995; accepted 31 March 1995)

Three species of *Pleurotus*, *P. sajor-caju*, *P. platypus* and *P. citrinopileatus*, were cultivated on various agro-residues such as paddy straw, maize stover, sugarcane bagasse, coir pith and a mixture of these wastes. Primordium initiation was observed on 22nd–27th day after spawning. Maximum yield was obtained in *P. sajor-caju* cultivated on paddy straw. *P. platypus* yielded its maximum on coir pith and *P. citrinopileatus* on sugarcane bagasse. The biological efficiency, nutrient composition, energy value and energy recovery of the fruit bodies obtained on these substrates were reported.

INTRODUCTION

Cultivation of speciality mushrooms (non-agaric species) represents a major industry in the countries of South East Asia (Mehta *et al.*, 1990; Chang & Miles, 1991). *Pleurotus* spp. (or oystermushroom) have been preferred by mushroom growers. Production of *Pleurotus* spp. is as high as 900 000 tonnes per year. China alone produces about 800 000 tonnes per year. This genus, because of its flexible temperature and environmental requirements, has more cultivated species than any other mushrooms (Zadrazil & Dube, 1992). In the present study, three species of *Pleurotus*, *P. sajor-caju*, *P. platypus* and *P. citrinopileatus* were cultivated on paddy straw, maize stover, sugarcane bagasse, coir pith and on a mixed bed consisting of equal amounts (w/w) of these substrates in polyethylene bags. The yield of mushrooms, biological efficiency, nutrient composition of the fruit bodies, energy value of the substrates and energy recovery in the mushrooms were analysed.

MATERIAL AND METHODS

The primary inocula of *P. sajor-caju*, *P. platypus* and *P. citrinopileatus* were obtained from the Department of Plant Pathology, Tamilnadu Agricultural University, Coimbatore, Tamilnadu, India and maintained on malt agar medium at 4°C. For inocula multiplication, substrate preparation, inoculation of substrates, maintenance of beds and for harvest, the methods proposed by Marimuthu *et al.* (1993) were followed. Yield of mushrooms and their biological efficiency (yield of mushrooms per 100-g substrate on dry weight basis) were determined.

The fruit bodies were analysed for their moisture content (AOAC, 1990), carbohydrate (Hodge & Hofreiter, 1962), nitrogen (Umbriet *et al.*, 1972), amino-nitrogen (Moore & Stein, 1948), crude protein (Crisan & Sand, 1978), fat (Bligh & Dyer, 1959), minerals (AOAC, 1990), phosphorus (Dyer *et al.*, 1957), cellulose (Updegroff, 1969), hemicellulose, lignin, ash (Thornber & Northcote, 1961) and crude fibre (Maynard, 1970) contents. The energy value of the fruit bodies was calculated on the basis of their content of crude protein, fat and carbohydrate 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 from their contents of cellulose, hemicellulose and lignin by using the factors 4.2, 4.2 and 7.1 kcal/g, respectively (Dent & Brown, 1978).

RESULTS AND DISCUSSION

In *Pleurotus* spp. the primordia initiation was generally observed on the 24th–30th day (Khanna *et al.*, 1992). In the present study it was observed on the 22nd day in *P. sajor-caju* and *P. platypus* and on the 27th day in *P. citrinopileatus*. The yield of mushrooms was reported to be in the range of 0.20–4.79 kg fresh weight per kg of dry substrate (Chang *et al.*, 1981; Bisaria *et al.*, 1987; Chauhan & Pant, 1988; Aslan Azizi *et al.*, 1990; Khanna *et al.*, 1992), with a biological efficiency of 7.66–72.4%. In the present study, maximum yield in *P. sajor-caju* (0.396 kg/kg) was obtained on paddy straw, in *P. platypus* on coir pith (0.327 kg/kg) and in

*To whom correspondence should be addressed.

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

Substrate	Primordia initiation day (PI)			Total yield*[a] (TY)			Biological efficiency [b] (%) (BE)		
	Ps	Pp	Pc	Ps	Pp	Pc	Ps	Pp	Pc
Paddy straw	28	27	30	0.396 (0.016)	0.312 (0.022)	0.301 (0.040)	46.60 (2.9)	36.78 (3.2)	35.42 (1.8)
Maize stover	27	27	29	0.306 (0.024)	0.251 (0.041)	0.218 (0.000)	35.39 (3.7)	29.40 (1.9)	25.18 (2.2)
Sugarcane bagasse	25	22	27	0.358 (0.030)	0.297 (0.008)	0.335 (0.031)	41.31 (5.2)	34.29 (2.7)	38.63 (4.2)
Coir pith	22	26	27	0.279 (0.042)	0.327 (0.009)	0.252 (0.007)	30.69 (2.8)	35.94 (2.9)	27.79 (3.6)
Mixed bed	29	27	28	0.368 (0.021)	0.262 (0.021)	0.247 (0.012)	41.76 (2.1)	29.63 (1.9)	28.00 (1.8)

*Values are total of four fleshings and mean of five replicates (S.D.).
[a]ANOVA: *F*-value = 1.36; $P = 0.3147$; Barlett's test: Variance = 0.22; $P = 1.00$.
[b]AN0VA: *F*-value = 1.76; $P = 0.2138$; Barlett's test : Variance = 1.17; $P = 0.883$.
Ps: *P. sajor-caju*, Pp: *P. platypus*, Pc: *P. citrinopileatus*.
Chang *et al.* (1981) TY: 4.79 kg/kg paddy straw.
Bisaria *et al.* (1987) TY: 1.24, 0.89 and 0.97 kg/kg, and BE: 11.66,7.66 and 8.33%, respectively for paddy straw, maize stover and sugarcane bagasse.
Chauhan & Pant (1988) TY: 1.026 kg/kg paddy straw.
Aslan Azizi *et al.* (1990) TY: 0.65 and 0.71 kg/kg, respectively for paddy straw and bagasse.
Kumar *et al.* (1990) TY: 0.20–0.54 kg/kg, and BE: 20.02–53.50% for paddy straw.
Khanna *et al.* (1992) PI: on 24th–30th day;TY: 0.20–1.158 kg/kg, and BE: 12.5–72.4%.

P. citrinopileatus on sugarcane bagasse (0.334 kg/kg). In *P. sajor-caju*, straw combination, the biological efficiency was 46.60%, in *P. platypus* and coir pith it was 35.94%, and in *P. citrinopileatus*, sugarcane bagasse it was 38.63% (Table 1). The data revealed that for maximum yield of mushrooms, *P. sajor-caju* and paddy straw combination could be used. But for effective utilization and economical disposal of agro-industrial wastes, coir pith and sugarcane bagasse, *P. platypus* and *P. citrinopileatus*, respectively, are preferred.

The fruit bodies of mushrooms were rich in nutrients such as carbohydrate, protein, amino-nitrogen and minerals, and had low fat content. It has been reported that the fruit bodies contained 82.5–92.2% of moisture, 4.30–50.7% of carbohydrate, 26.6–34.1% crude protein and 1.1–8.0% of fat (Chang *et al.*, 1981; Bisaria *et al.*, 1987; Khanna *et al.*, 1992). In the present study it was observed (Table 2) that the moisture content of the fruit bodies ranged from 84.70 to 91.90% and the carbohydrate content ranged from 40.6 to 46.3%. The crude protein content ranged from 31.9 to 42.5%, 26.9 to 38.8% and 30.0 to 42.5% in *P. sajor-caju*, *P. platypus* and *P. citrinopileatus*, respectively.

The total free aminoacid content of the fruit bodies was estimated as amino-nitrogen. The results showed that *P. sajor-caju* was richer in total free aminoacids than the other two species. The fruit bodies contained very low amounts (1.1–3.8%) of fats.

The fruit bodies contained minerals such as calcium, iron, potassium, magnesium, sodium and phosphorus in the range of 0.189–0.362, 0.052–0.115, 21.3–24.00, 1.432–1.88, 1.58–2.56, and 5.87–8.40 mg/g dry weight of the fruit bodies, respectively (Chang *et al.*, 1981). But the results of the present study (Table 2) showed that the three species of *Pleurotus* under study contained higher amounts of minerals than reported by Chang *et al.* (1981). The fruit bodies contained 0.75–2.45 mg/g of calcium, 5.10–12.2 mg/g of iron, 8.18–18.8 mg/g of potassium, 9.2–14.3 mg/g of magnesium, 0.02–1.32 mg/g of sodium and 113–218 mg/g of phosphorous. *P. citrinopileatus* was rich in minerals. The fruit bodies of *P. sajor-caju* contained 28.4–44.8% of cellulose, 28.5–41.2% of hemicellulose, 13.0–17.0% lignin, 14.1–19.2% of crude fibre and 5.7–6.5% of ash. *P. platypus* contained these components in the ranges 33.6–43.2, 27.3–39.3, 14.0–20.0, 15.6–20.2, and 5.1–6.3%, respectively, and *P. citrinopileatus* had 33.6–43.2, 27.3–39.3, 14.0–20.0, 15.6–20.2, and 5.1–6.3%, respectively (Table 3).

The energy values of the substrates used in the present study were 424, 424, 405, 386 and 507 kcal/100 g of substrate, respectively for the paddy straw, maize stover, sugarcane bagasse, coir pith and mixed bed. The energy values of *P. sajor-caju* (kcal/100 g mushroom) were observed to be 267, 292, 308, 285 and 329, respectively for paddy straw, maize stover, sugarcane bagasse, coir pith and mixed bed, showing a similarity to the results observed by Bisaria *et al.* (1987). The yield was in the order of 46.40, 35.59, 41.31, 30.69, and 41.76 g/100 g substrate. Similar results were observed with *P. platypus* and *P. citrinopileatus* grown on various agro-residues. Among the three species tested, *P. sajor-caju* showed maximum energy recovery (10.5%) followed by *P. platypus* (9.2%). Energy recovery was low in *P. citrinopileatus* (7.7%). In *P. sajor-caju*, energy recovery was

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

Component	Substrates: Paddy straw			Maize stover			Sugarcane bagasse			Coir pith			Mixed bed			ANOVA		Barlett's Test	
	Ps	Pp	Pc	Ps	Pp	Pc	Ps	Pp	Pc	Ps	Pp	Pc	Ps	Pp	Pc	*F value*	*P*	*Variance*	*P*
Moisture[a]	91.1 (10.6)	85.6 (9.4)	88.9 (12.3)	89.1 (10.1)	90.2 (11.7)	90.3 (12.4)	91.1 (16.3)	91.9 (8.3)	91.3 (7.4)	90.1 (10.0)	85.9 (9.8)	89.2 (11.3)	84.7 (8.7)	91.2 (13.4)	92.1 (12.4)	0.77	0.5693	8.33	0.0802
Carbohydrate[b]	40.6 (3.5)	42.8 (5.2)	42.5 (9.2)	43.2 (4.4)	45.0 (6.4)	44.4 (8.1)	43.4 (2.1)	43.1 (6.4)	45.6 (2.1)	45.6 (3.7)	43.9 (9.1)	43.2 (8.8)	45.0 (9.3)	46.3 (4.3)	45.5 (7.6)	4.19	0.0302	1.00	0.9091
Crude protein[b]	33.1 (4.7)	38.8 (6.1)	30.0 (4.0)	38.8 (4.9)	32.5 (6.3)	39.8 (5.2)	31.9 (2.8)	26.9 (7.2)	42.5 (9.1)	42.5 (8.4)	33.1 (4.0)	31.9 (3.8)	40.6 (3.5)	27.5 (3.7)	40.6 (1.4)	0.16	0.9523	1.21	0.8770
Amino nitrogen[c]	9.4 (0.83)	6.8 (1.3)	3.3 (1.0)	8.0 (2.6)	6.3 (1.9)	5.5 (1.7)	4.0 (0.3)	5.4 (1.7)	2.7 (0.9)	10.9 (3.4)	7.1 (1.9)	1.5 (0.4)	1.6 (0.9)	5.4 (1.0)	5.5 (1.2)	0.67	0.6302	3.95	0.4131
Fat[b]	1.1 (0.02)	2.1 (0.1)	2.2 (0.9)	1.1 (0.08)	3.6 (0.11)	3.2 (0.90)	1.8 (0.04)	2.8 (0.7)	2.1 (0.3)	1.2 (0.09)	3.2 (0.8)	2.8 (0.8)	4.0 (1.2)	3.8 (0.7)	3.1 (0.09)	1.85	0.1959	2.91	0.5730
Calcium[c]	0.8 (0.00)	2.2 (0.08)	0.8 (0.05)	1.2 (0.08)	1.2 (0.04)	1.0 (0.06)	2.5 (0.12)	1.2 (0.11)	1.7 (0.19)	1.5 (0.14)	1.3 (0.12)	0.7 (0.07)	1.3 (0.08)	1.0 (0.06)	1.1 (0.09)	0.94	0.4794	7.58	0.1082
Iron[c]	5.1 (1.1)	8.2 (2.4)	5.9 (1.7)	10.0 (2.7)	11.0 (2.4)	7.2 (1.6)	6.7 (2.9)	8.3 (1.4)	15.2 (2.8)	11.2 (1.2)	10.2 (3.7)	8.8 (2.1)	6.7 (0.8)	11.2 (2.9)	12.5 (1.9)	1.02	0.4413	3.59	0.4647
Potassium[c]	17.8 (2.5)	11.2 (1.6)	16.2 (2.9)	15.2 (3.4)	13.2 (2.9)	16.6 (3.4)	11.8 (2.8)	14.0 (3.9)	13.8 (2.1)	18.8 (1.7)	15.0 (3.7)	11.6 (4.2)	13.8 (2.8)	0.49 (1.9)	0.7425 (2.1)	0.49	0.7425	1.22	0.8749
Magnesium[c]	9.2 (1.6)	12.4 (2.9)	10.2 (1.9)	14.1 (3.0)	14.1 (3.1)	12.1 (2.6)	13.2 (1.9)	12.1 (2.9)	9.4 (1.3)	10.5 (2.2)	13.3 (3.1)	11.1 (2.6)	9.3 (1.1)	11.2 (1.7)	14.3 (2.2)	0.97	0.4668	1.15	0.8866
Sodium[c]	0.9 (0.00)	1.3 (0.2)	0.9 (0.07)	0.7 (0.05)	1.1 (0.1)	0.7 (0.0)	0.6 (0.02)	0.8 (0.03)	0.7 (0.0)	0.7 (0.02)	0.7 (0.01)	0.6 (0.0)	1.3 (0.1)	0.5 (0.0)	1.2 (0.2)	1.36	0.3147	8.36	0.0791
Phosphorus[c]	143 (11.6)	119 (9.6)	118 (12.3)	214 (14.1)	163 (9.7)	163 (11.4)	114 (17.3)	119 (11.7)	218 (21.1)	184 (12.6)	218 (18.3)	163 (9.7)	113 (12.2)	163 (11.4)	163 (15.3)	1.60	0.2496	3.25	0.5171

Values are means of three replicates; [a]% fresh weight of the fruit body; [b]% dry weight of the fruit body; [c]mg/g dry weight of the fruit body.
Chang *et al.* (1981) Moisture content 90.9%, carbohydrate 50.7%, crude protein 26.60%, fat 2.0%, Ca 0.1896–0.362%; Fe 0.052–0.115%.
Bisaria *et al.* (1987) Moisture content 90.2%, carbohydrate 43.3–45.1%, crude protein 31.6–34.1%, fat 1.55–1.80%.
Khanna *et al.* (1992) Moisture content 90.8%, carbohydrate 44.8–53.3%, crude protein 27.3–32.0%, fat 5.8–8.0%.

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

Component	Substrates																	
	Paddy straw			Maize stover			Sugarcane bagasse			Coir pith			Mixed bed			ANOVA		Barlett's Test	
	Ps	Pp	Pc	Ps	Pp	Pc	Ps	Pp	Pc	Ps	Pp	Pc	Ps	Pp	Pc	*F*-value	*P*	Variance	*P*
Cellulose	43.2 (10.6)	33.6 (9.3)	38.4 (9.7)	44.8 (6.4)	36.8 (5.7)	43.2 (5.9)	40.0 (3.8)	35.2 (4.2)	32.0 (2.9)	28.4 (3.8)	36.8 (8.7)	44.8 (10.1)	41.6 (10.8)	43.2 (9.4)	40.0 (8.8)	0.88	0.5096	3.67	0.4526
Hemicellulose	35.2 (7.4)	38.8 (4.9)	39.2 (3.6)	28.5 (3.6)	31.2 (4.2)	30.5 (5.1)	35.2 (6.2)	32.8 (4.4)	33.8 (7.2)	30.2 (2.9)	27.3 (4.9)	28.1 (5.1)	41.2 (7.9)	39.3 (4.6)	40.3 (0.8)	37.08	0.0001	2.86	0.5818
Lignin	15.0 (2.1)	19.0 (3.7)	19.0 (2.1)	14.0 (1.8)	14.0 (3.9)	18.0 (4.1)	13.0 (2.0)	17.0 (1.9)	15.0 (1.5)	17.0 (2.8)	20.0 (3.1)	17.0 (3.2)	17.0 (1.7)	20.0 (2.7)	18.0 (1.9)	1.86	0.1945	0.42	0.9810
Crude fibre	15.0 (3.2)	15.8 (4.6)	14.8 (2.9)	15.5 (3.1)	15.6 (4.2)	16.1 (5.5)	19.2 (4.3)	20.2 (2.1)	12.8 (1.6)	18.2 (2.1)	16.8 (2.2)	17.7 (3.1)	14.1 (2.2)	18.3 (3.4)	15.9 (2.2)	0.76	0.5755	12.02	0.0172
Ash	6.2 (1.6)	5.4 (1.8)	6.1 (0.9)	5.9 (1.7)	5.1 (0.9)	5.4 (1.6)	5.7 (1.3)	6.3 (1.7)	6.9 (1.1)	6.2 (1.6)	6.1 (0.9)	5.8 (0.9)	6.5 (1.4)	5.8 (1.3)	5.5 (1.0)	1.33	0.3226	1.81	0.7707

Values are means of three replicates and expressed as % dry weight of the fruit body.

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

Substrate	Energy value of substrate (kcal/100 g substrate) (1)	Energy value of mushroom (kcal/100 g mushroom) (2)			Yield of mushroom (g/100 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)			Bisaria *et al.* (1987)				
		Ps	Pp	Pc	Ps	Pp	Pc	Ps	Pp	Pc	Ps	Pp	Pc	1	2	3	4	5
Paddy straw	424 (93.2)	267 (31.2)	298 (28.6)	277 (30.6)	46.6 (6.4)	36.8 (7.4)	35.4 (2.9)	41.5 (4.4)	36.5 (2.9)	32.7 (4.8)	9.7 (1.8)	8.7 (2.6)	7.7 (1.9)	373	294	11.6	34.3	9.2
Maize stover	424 (81.6)	292 (26.4)	302 (25.4)	319 (32.4)	35.6 (5.2)	29.4 (2.5)	25.1 (1.6)	34.7 (9.1)	29.6 (3.4)	26.8 (2.9)	8.2 (2.1)	6.9 (1.7)	6.3 (0.6)	344	288	7.7	21.6	6.3
Sugarcane bagasse	405 (98.7)	308 (37.5)	286 (34.5)	269 (16.5)	41.3 (5.2)	34.3 (4.2)	38.7 (7.4)	42.3 (8.2)	32.7 (4.1)	25.8 (3.6)	10.5 (3.2)	8.1 (1.1)	6.4 (1.2)	330	280	8.3	23.3	7.1
Coir pith	386 (60.4)	285 (19.8)	291 (10.8)	313 (19.2)	30.7 (4.9)	35.5 (6.1)	27.8 (5.4)	29.2 (3.7)	35.4 (2.9)	28.9 (2.5)	7.6 (1.8)	9.2 (2.2)	7.5 (1.4)	—	—	—	—	—
Mixed bed	507 (43.8)	329 (32.4)	293 (14.7)	327 (27.5)	41.8 (8.4)	29.7 (2.5)	28.0 (2.9)	45.8 (5.2)	28.9 (4.7)	30.5 (4.8)	1.1 (2.5)	5.7 (0.9)	6.0 (1.0)	—	—	—	—	—
ANOVA																		
F-value			2.08			1.73			0.54			0.84						
P			0.1586			0.2194			0.7129			0.5325						
Barlett's Test: Variance			0.44			1.16			2.52			2.03						
P			0.9790			0.8842			0.6416			0.7340						

more in sugarcane bagasse (10.5%) and paddy straw (9.7%), in *P. platypus* it was highest in coir pith (9.2%) and in paddy straw (8.7%), and in *P. citrinopileatus* it was highest in paddy straw (7.7%) and coir pith (7.5%) (Table 4). The results of the present study reveal that the species of *Pleurotus* could be cultivated economically on agro-wastes. Paddy straw favours the growth of *P. sajor-caju*, coir pith favours *P. platypus* and sugarcane bagasse, *P. citrinopileatus*. The fruit bodies are rich in nutrients and minerals and have low fat content. Apart from providing energy and nutrient-rich food material, cultivation of *Pleurotus* spp. on agro-residues helps in effective disposal of these wastes.

REFERENCES

AOAC, 1990. *Official Methods of Analysis*, 15th edn. Association of Official Analytical Chemists, Arlington.

Aslan Azizi, K., Shamala, T. R. & Sreekantiah, K. R. (1990). Cultivation of *P. sajor-caju* on certain agro-industrial wastes and utilization of the residues for cellulase and D-xylanase production. *Mush. J. Tropics*, **10**, 21–6.

Bisaria, R., Madan, M. & Bisaria, V. S. (1987). Biological efficiency and nutritive value of *Pleurotus sajor-caju* cultivated on different agro-wastes. *Biol. Wastes*, **19**, 239–55.

Bligh, E. G. & Dyer, W. J. (1959). A rapid method for total lipid extraction and purification. *Can. J. Biochem. Physiol.*, **37**, 911–17.

Chang, S. T. & Miles, P. G. (1991). Recent trends in world production of cultivated mushrooms. *Mushroom J.*, **503**, 15–18.

Chang, S. T., Lau, D. W. & Cho, K. Y. (1981). The cultivation and nutritional value of *Pleurotus sajor-caju*. *Eur. J. Appl. Microbiol. Biotech.*, **12**, 58–62.

Chauhan, S. & Pant, D. C. (1988). Effect of spawn substrates and storage conditions on sporophore production in *Pleurotus sajor-caju*. *Indian J. Mycol. Pl. Pathol.*, **3**, 231–4.

Crisan, E. V. & Sand, A. (1978). Nutritional value of edible mushrooms. In *The Biology and Cultivation of Edible Mushrooms*, eds S. T. Chang & W. A. Hayes. Academic Press, New York, pp. 137–68.

Dent, J. B & Brown, W. A. N. (1978). *Alcohol Fuels*. Institute of Chemical Engineers, NSW Group, Sydney, Australia.

Dyer, R. L., Tammers, A. R. & Routh, J. I. (1957). The determination of phosphorous and phosphatase with *N*-phenyl-*p*-phenylanediamine. *J. Biol. Chem.*, **225**, 177–83.

Hodge, J. E. & Hofreiter, B. T. (1962). Determination of reducing sugars and carbohydrates. *Methods Carbohyd. Chem.*, **1**, 380–94.

Khanna, P. K., Bhandari, R., Soni, G. L. & Garcha, H. S. (1992). Evaluation of *Pleurotus* spp. for growth, nutritive value and antifungal activity. *Indian J. Microbiol.*, **32**, 197–200.

Kumar, S. M., Shukla, C. S. & Dixit, A. K. (1990). Modified hot-water substrate treatment for better yield of oyster mushrooms (*Pleurotus sajor-caju* (Fr) Singer). *Indian Mycol. Pl. Pathol.*, **20**, 154–5.

Marimuthu, T. S., Krishnamoorthy, A. S., Sivaprakasham, K. & Jeyarasan, R. (1993). *Cultivation of Oyster Mushroom*. TNAU Publication, Coimbatore, Tamil Nadu, p. 120.

Maynard, A. J. (1970). *Methods in Food Analysis*. Academic Press, New York, p. 176.

Mehta, V., Gupta, J. K. & Kaushal, S. C. (1990). Cultivation of *Pleurotus florida* mushroom on rice straw and biogas production from the spent straw. *World J. Microbiol. Biotech.*, **6**, 366–70.

Moore, S. & Stein, W. H. (1948). Photometric ninhydrin method for use in the chromatography of amino acids. *J. Biol. Chem.*, **176**, 367–88.

Thornber, J. P. & Northcote, D. H. (1961). Changes in the chemical composition of a cambial cell during its differentiation into xylem and phloem tissue in trees. *Biochem. J.*, **81**, 449–55.

Umbriet, W. W., Burris, R. H. & Staffer, J. F. (1972). *Monometric and Biochemical Techniques*, 5th edn. Burgess Publ. Co., Minnesota, p. 387.

Updegroff, D. M. (1969). Semi-micro determination of cellulose in biological materials. *Anal. Biol. Chem.*, **32**, 420–4.

Zadrazil, F. & Dube, H. C. (1992). The oyster mushroom: importance and prospects. *Mushroom Res.*, **1**, 25–32.