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Studies on some Physiological, Cultural and Postharvest Aspects of Oyster Mushroom, *Pleurotus eous* (Berk.) sacc.

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ABSTRACT. *The physiological studies on Pleurotus eous revealed that the best radial growth was obtained on potato-dextrose agar, whereas the highest mycelial weight was recorded in glucose-asparagine solution. Thiamine (50 ppm), gibberllic acid (0.5 ppm) and copper sulphate (3 ppm) were the best vitamin, growth regulator and trace element, respectively. The modified glucose-asparagine recorded the highest mycelial dry weight. Among the various substrates tried for spawn production, partially-filled paddy grains (PFPg) and sorghum grains were rapidly colonised by P. eous. Horsegram flour 3% was found to be highly favourable. Addition of 1% gypsum in combination with 3% of horsegram flour increased the yield. Among the 17 substrate tested for bed preparation, paddy straw remained the most suitable substrate and unchopped straw of paddy can be used as a substrate for P. eous cultivation. Unchopped straw of White Ponni paddy variety was found to be better than the straw of other varieties. Horsegram flour at 5% level gave higher yield than the other levels tested. Addition of groundnut oil cake at 3% level gave higher yield than that of organic nitrogen supplements. GA at 100 ppm spray was the best in maximising the yield components. Ventilation provided with PVC pipe (12 holes) contributed to higher yield. Refrigeration generally increased the storage life of sporophores (10 d) when compared to room temperature (3 d). Dehydration and canning were observed to give a long storage period (more than 90 d) without any change in quality parameters.*

INTRODUCTION

Many sources of proteins including algae, yeast and leaf protein have been tried in the past, but have been strongly rejected either due to unpalatability or consumer resistance. The new food item should not only be nutritious but should also enjoy the preference of consumers. Mushrooms with their flavour, texture, nutritional value with high productivity level per unit area rightly have been identified as an excellent food source to fight malnutrition in developing countries. In India, the total quality of agricultural by-products and wastes which are cellulose in nature account for nearly 25 million tons per year (Jandaik, 1974), posing problems of disposal. By cultivation of suitable mushroom fungi these wastes can be well utilised, recycled and our environment may not be endangered by pollution. The edible mushrooms *Pleurotus* spp. are well suited for this purpose. Considering obvious potentialities of *Pleurotus*, a systematic study was undertaken to standardize the techniques of preparation of quality spawn and technology of successful cultivation. The present investigation was therefore, undertaken with the following objectives: 1) To elucidate various physiological requirement of *P. eous*, 2) To study the most appropriate cultivation technology for *P. eous*, 3) To ascertain the storage life of *P. eous*.

MATERIALS AND METHODS

Physiological studies

Effect of solid media, incubation period, pH, temperature, carbon sources, nitrogen sources, glucose-asparagine ratio, vitamins, growth regulators and trace elements on the *in vitro* growth of *P. eous* were studied following standard procedure as described by Jandaik and Kapoor (1976).

The effective levels observed with different constituents tried *viz.*, carbon sources, nitrogen sources, vitamins, growth regulators and trace elements were pooled together and a modified medium was tested as below:

Number	Treatment
T_1	Glucose-asparagine broth (basal) (Appendix 1)
T_2	Modified glucose-asparagine broth (Appendix 2)
T_3	T_2 + effective vitamin (thiamine - 50 ppm)
T_4	T_3 + effective growth regulators (GA - 0.5 ppm)

The sterilization, inoculation, determination of mycelial dry weight were done as per standard procedure described (Sivaprakasam, 1980).

Cultivation technology

The cultivation studies of *P. eous* were carried out by varying different factors spawn substrates, bed substrates, nutrient and hormone supplements and aeration of beds considered essential for the cultivation of other *Pleurotus* spp.

Grains spawn preparation

Grains were partially cooked in water for 20 min. After draining excess water, the grains were mixed with 3% calcium carbonate to prevent adhesion of the grains and to maintain optimum pH for the fungal growth. They were filled in 500 ml glucose drip bottle up to three-fourth volume and plugged with non-absorbent cotton and sterilized at 121°C for 2 h. The bottles were inoculated with the pure culture of the fungus and incubated at room temperature (25±3°C) for 10–15 d in order to get complete colonised spawn bottles and such bottles were only used.

Preparation of mushroom bed (modified method)

Cultivation of *Pleurotus* is usually carried out in transparent polythene bags of 60×30 cm size and thickness of 100 gauge. Cylindrical beds were prepared using 0.5 kg of paddy straw on dry weight basis, following layer spawning method as described by

Sivaprakasam (1980) with the modification mentioned below. The unchopped whole straw was made into coils and a layer of coiled paddy straw was placed at the bottom of polythene bags. Over this, a layer of spawn was laid. In this manner 5 layers of coiled paddy straw and 4 layers of spawn were kept in each polythene bag and the bag was tied then at the top (modified cylindrical bed method). Two opposite holes of 1 cm diameter were made in the polythene bags. These mushroom beds (bags) were hung from the ceiling of cropping room by means of ropes (*Uri*-method) instead of the usual method of keeping them in tiers made of bamboo or *casuarina* stacks. The cropping room temperature ranged from 23–28°C and relative humidity from 80–90%. The following yield parameters *viz.*, spawn run, maturity time of sporophores, number of sporophores, weight of sporophores and biological efficiency were studied.

Studies on spawn preparation

To select a suitable substrate for spawn production, 5 cereal grains [pearl millet, maize, partially filled paddy (PFPg), paddy and sorghum], 2 pulses (blackgram and greengram) and other substrates (paddy straw, rice husk and sugarcane bagasse) were used for spawn preparation as detailed earlier. The partially filled paddy grains (PFPg) were separated using winnowing technique. After sterilization, the spawn substrate (bottles) were inoculated with pure culture of the fungus. The bottles were incubated at room temperature (25±3°C) for 10–15 d till complete colonisation took place. The spawn thus prepared was further evaluated for its productivity using steam pasteurised paddy straw. Less expensive and effective PFPg spawn was used for further experiments. PFPg spawn were prepared as detailed earlier. Powdered pulse flours blackgram, greengram, bengalgram, peas, horsegram and redgram were added at 2% level. The supplements were throughly mixed with grains and sterilized before inoculation. Effective supplement (horsegram flour) was further evaluated at graded levels of 1, 2, 3 and 4%. The PFPg spawn supplemented with horsegram (3%) was prepared as stated earlier. Different levels of gypsum at 0.5, 1, 2 and 3% was incorporated separately into the supplemented spawn medium before sterilization.

Different N sources *viz.*, peptone, groundnut oil cake, yeast extract, potassium nitrate, ammonium tartrate and urea were incorporated at 0.2% to PFPg before sterilization and then the spawn was prepared.

The effective levels observed from different experiments tested under the spawn base study were pooled together and a new substrate for spawn base was tried. The treatments used were; T_1 : PFPg + Calcium carbonate (3%), T_2: T_1 + horsegram flour (3%), T_3 : T_2 + gypsum (1%).

Studies on cylindrical bed preparation

To identify best substrate for bed preparation *viz.*, crop residues [bamboo leaves, coir pith, pearl millet stalks, cotton stalks, groundnut haulms, groundnut shell, paddy straw, palm leaves, sorghum stalks, soyabean stalks, sugarcane bagasse, sugarcane trash, tapioca leaves and tapioca *thippi* (residue after extraction of starch)] and weeds (*Croton*

sparsiflorus, Cyperus rotundus and *Parthenium* spp. stalks) were tried. The substrates were cut into pieces (4–6 cm) wherever required and soaked in water for a period of 6 h (Sivaprakasam, 1980). The sterilized substrates were spawned with *P. eous*.

The additives were used at 5% on the basis of wet weight of the substrate. The additives used were rice, wheat, maize, pearl millet, finger millet, horsegram, blackgram, soyabean, groundnut shell and tapioca *thippi* ground into flour and rice bran. The additives were powdered well and sterilized in an autoclave at 121°C for 1 h. They were throughly mixed with sterilized paddy straw before spawning. Paddy straw without any additives served as the control. The additives *viz.*, horsegram flour, rice flour and rice bran which supported significantly good growth were further studied at 3 different levels (3, 5 and 7%).

The effect of various organic nitrogen supplements on the yield performance of *P. eous* was also studied. Powdered oil cakes of groundnut, gingelly, castor and coconut were used as supplements at 1, 3 and 5% of wet weight of the paddy straw substrate. The cakes were sterilized in an autoclave at 121°C for 1 h. The supplements were throughly mixed with sterilized paddy straw before spawning.

Plant hormones, gibberllic acid (GA), indole-3-acetic acid (IAA) and 6-benzyl amino purine (BAP) at 1, 10, 100 and 200 ppm were prepared in double distilled water obtained by using glass apparatus. Ten ml of the concentration of each was applied with atomizer on the surface of the mycelial mat as soon as sporophore initials appeared on beds. Similarly, sporophores initials of 2nd and 3rd crops were also sprayed.

For the purpose of providing ventilation, 45 cm long PVC pipes and papaya petioles (1.5 cm dia.) were used. Equidistant holes with varying diameter were made on tubes. The holes were made in opposite directions. While filling the bags, the tubes were kept at the centre of the bags. Filling and spawning of paddy straw were done as per the standard method (Sivaprakasam, 1980). After filling, the top end of the bag was tied keeping the vent tube slightly projecting outside. The top end of tube was plugged with non-absorbent cotton. The papaya petioles were coated with lime to avoid contamination. The treatments were as follows:

Treatment number		Number of holes in vent tubes	Distance between holes (cm)
Papaya petiole	PVC		
T_1	T_7	20 (10+10)	5
T_2	T_8	18 (9+9)	5
T_3	T_9	16 (8+8)	5
T_4	T_{10}	14 (7+7)	5
T_5	T_{11}	12 (6+6)	6
T_6	T_{12}	10 (5+5)	8
	T_{13}	Control	-

The effective levels obtained from the different experiments tested under the bed preparation study, were pooled together and a modified paddy straw substrate for bed

preparation was tested again. Temperature and humidity were maintained at optimum levels. The treatments were as follows:

Number	Treatment
T_1	Chopped straw of *White Ponni* (as per standard procedure)
T_2	Unchopped straw of *White Ponni* (as per modified procedure)
T_3	T_2 supplemented with horsegram flour (5%)
T_4	T_3 + groundnut oil cake (3%)
T_5	T_4 + gibberllic acid (100 ppm spray)
T_6	T_4 + PVC vent tubes (12 holes) in beds

Studies on post-harvest technology

The shelf life of freshly harvested sporophores was studied by storing them in different packages such as completely open, completely sealed and completely sealed with perforations (1 cm dia.) of 12, 18 and 24 numbers per packet at room temperature and under refrigeration (0–5°C). Morphological observations were recorded periodically till the sporophore were no longer fit for consumption.

The mushrooms were stored in bottles using different preservatives and stored at 2 different conditions storage at room temperature and under refrigeration and they were subjected to organoleptic evaluation using a questionnaire (Khader and Padmavathi, 1991). The treatments were as follows: 1) Steeping: Mushroom were steeped in a solution of 2.5% sodium chloride, 0.1% ascorbic acid, 0.2% citric acid, 0.1% sodium bicarbonate and 0.1% potassium meta bisulphite. 2) Blanching: The mushrooms were dipped in boiling water for 2–3 min and then transferred to cold water for a few min. The blanched mushrooms were stored in sterilized water. 3) Blanching+Steeping: The blanched mushrooms were steeped in a steeping solution as described earlier. The treated mushrooms were stored. 4) Canning: The trimmed mushrooms were washed gently in water to remove any adhering dust. Later, it was dipped in boiling water for 2–3 min and transferred to cold water. Blanched and cooled mushrooms were filled into the can. Solutions containing 2% common salt, 2% sugar and 0.3% citric acid were prepared, filtered through a piece of cloth and added up to the brim of the can. After closing the lid, the cans were kept in boiling water or steam till the centre reached a temperature of 80–85°C for 1–2 min. Immediately after exhausting, cans were sealed on a seamer to get an air tight seam. The sealed cans were sterilized in an autoclave at 121°C for 25 min. Soon after sterilization, the cans were kept in cold water for cooling. The cans were wiped dry and stored as detailed earlier. 5) Vinegar: The trimmed and washed mushrooms (100 g) were steeped in 300 ml of vinegar (100 g mushroom/300 ml vinegar). 6) Sugar: The trimmed and washed mushrooms (100 g) were steeped in 300 ml of 5% sugar solution and stored. 7) Blanching+Vinegar: The blanched mushrooms (100 g) were steeped in 300 ml of vinegar solutions. They were stored at 2 different conditions. 8) Blanching+Sugar: The blanched mushrooms (100 g) were steeped in 300 ml of 5% sugar solutions and stored. 9) Sugar+Vinegar: The trimmed and washed mushrooms (100 g) were steeped in 300 ml of vinegar solution containing 5% sugar. 10) Blanching+sugar+vinegar: The blanched

mushrooms (100 g) were steeped in 300 ml of vinegar solution containing 5% sugar. 11) Dehydration (sun drying): The mushrooms were dried completely in sunlight for 3–4 days. After complete drying, the mushrooms were packed in perfectly air-tight containers. 12) Dehydrated-cum-powdered mushrooms: The dehydrated mushrooms were powdered well and packed in perfectly air-tight containers and stored.

The fresh mushroom were served as control. The treatments were retained until the sporophores were no longer fit for consumption. The best treatment was maintained up to 100 days and observations were made at 30 day interval. The other treatments were discarded at various periods of observation.

Economic analysis

The net return per bed was calculated by substrating the cost of cultivation from the gross return. Cost- benefit ratio was calculated for different methods, by dividing the gross returns by cost of cultivation.

RESULTS AND DISCUSSION

Physiological studies

Physiological studies not only form the basis for mushroom crop management but are also a prerequisite for effective planning and preparation for successful crop production. It also provides the vital information that has a direct bearing on yield, quality, maturity and other characteristics of sporophores. Among the solid media, significantly faster growth of *P. eous* was obtained on PDA followed by OMA, glucose-asparagine agar and malt extract media. This is in accordance with the findings of Kapoor *et al.* (1997). Maximum mycelial growth on glucose-asparagine solution may be attributed to better utilization of asparagine by the species under study (Mehta and Jandaik, 1986–87). Since glucose-asparagine solution favoured maximum growth of the fungus tested, it was used as basal medium for subsequent experimentation. In the present study, an incubation period of 16 days was observed to be optimum for the growth of *P. eous* the pH of 5.6 resulted in higher growth followed by pH 6.0 and 5.2. The enhanced growth under this pH range might be due to increase in metabolic activity (Kapoor *et al.*, 1997).

The vegetative growth of *P. eous* was more at 25°C which was also found to be the best for the other *Pleurotus* species by various workers (Mehta and Jandaik, 1986–87; Bhattacharjee and Samajpati, 1989). Among carbon sources, both glucose and sorbitol resulted in more vegetative growth, while moderate growth was recorded with sucrose and starch. The different response of the species of *Pleurotus* to various carbon sources might perhaps be due to structural variation among the compounds (Steinberg, 1942).

Among organic, inorganic and complex nitrogen sources used for the growth of *P. eous*, the organic N sources asparagine, tyrosine and alanine resulted in the maximum growth. Similar view was reported by Kikon and Rao (1980). The growth of *P. eous* decreased with all vitamins tested except with thiamine which showed an increased growth

compared to the control, implying that the other vitamins were not necessary for normal growth. It has been suggested that the pyrimidine moiety of thiamine is responsible for enhanced growth (Okwujiako, 1990). Among the microelements tried, the growth of *P. eous* was highly influenced by the addition of copper sulphate 3, 4 and 5 ppm followed by boric acid 5 ppm and manganese sulphate 0.5 ppm. Copper is known to be a constituent of a number of enzyme systems. Hence, addition of this element to basal medium might have increased metabolic activity in the fungus resulting in increased growth (Bansal and Singh, 1989).

In general, the modified glucose-asparagine medium developed in this study gave the best mycelial growth. This may be ascribed to the presence of optimum levels of effective constituents (Fig. 1).

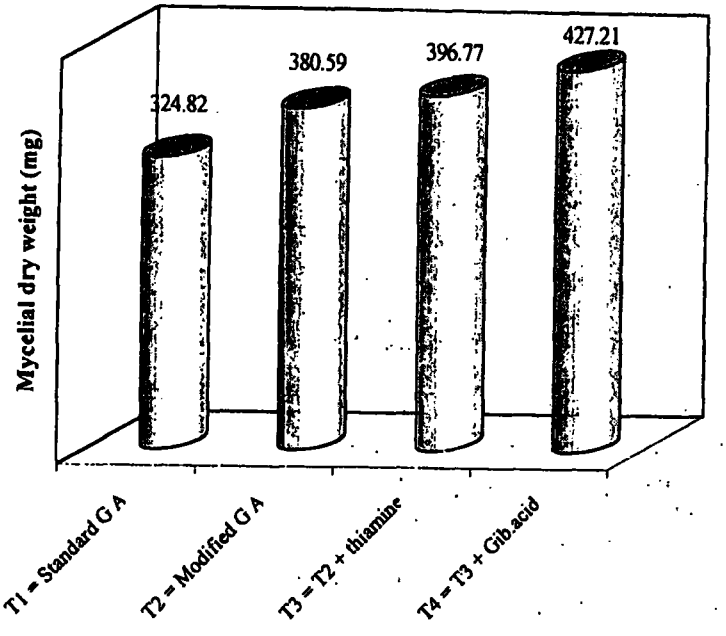

Fig. 1. Evaluation of medium suitable for the *in vitro* growth of *Pleurotus eous*.

Cultivation technology

Spawn preparation

Sorghum and PFPg required the lowest period for complete colonisation on substrate which was followed by chopped paddy straw and rice husk. The variation in colonisation of different substrates could be due to variation in the amount of moisture

absorbed during boiling which is one of the critical factors responsible for mycelial growth (Mehta, 1985).

The stimulation activity of horsegram flour supplements might be due to increase in the activity of beneficial saprophytic bacteria which help in biodegradation of organic substances thereby increasing the nutrient availability in the substrates (Krishnamoorthy and Narasimhan, 1994). In the present study, when attempt were made to further improve the yield by employing graded levels of this cheaper supplement, horsegram flour with different levels of gypsum gave favourable results. Interestingly, the yield per bed progressively increased with increase in the levels of supplement with horsegram and gypsum up to 3% and 1% compared to other treatments (Fig. 2). The best performance of this combination might be due to alteration in the pH and EC.

Addition of nitrogen to the grain spawn base had no influence on the sporophore yield. PFPg supplemented with calcium carbonate, horsegram flour and gypsum has been evaluated as the best substrate since, it is less expensive and may supplement the nutritional and pH requirements of the mushroom fungus.

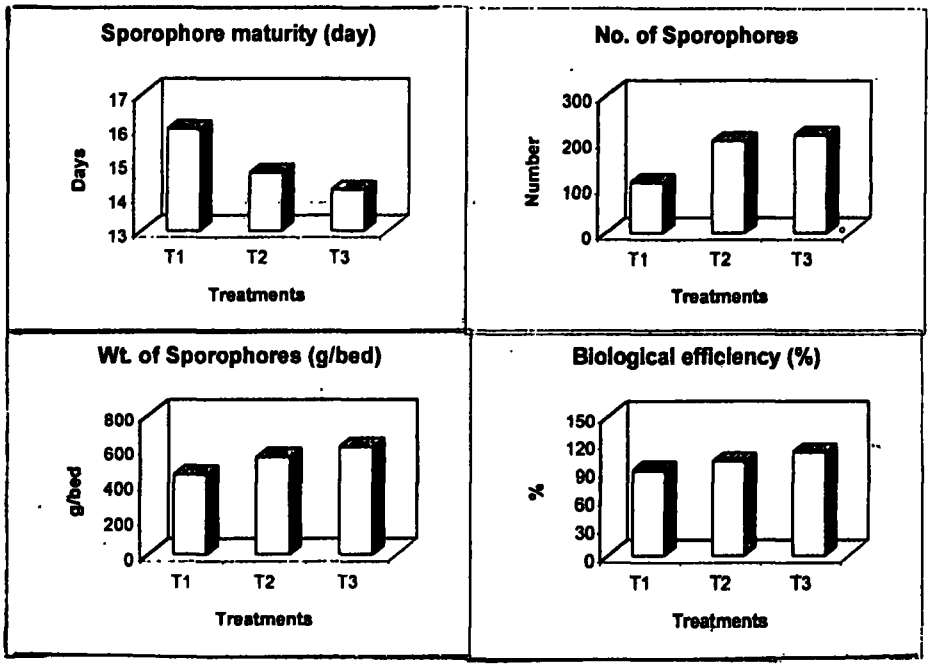

Fig. 2. Evaluation of substrates suitable for spawn preparation.
[Note: T_1 - Partially filled paddy grains, T_2 - Partially filled paddy grains + horsegram (3%) and T_3 - Partially filled paddy grains + horsegram (3%) + Gypsum (1%)].

Cylindrical bed preparation

Pleurotus spp. grew well in varied types of substrate including agricultural wastes (Jandaik, 1974). In the present investigation, *P. eous* was tested for its ability to produce more sporophore in various substrates. Cellulose and lignin in the substrate were important components deciding the yield of sporophore (Zadarzil, 1974). The yield of sporophore was related positively with cellulose content and negatively with lignin and ortho-dihydroxy phenolios content of the substrates (Sivaprakasam, 1980). Paddy straw excelled all other substrate in this study. It is probable that paddy straw substrate provide a more balanced supply of cellulose and nutrients to the mushroom which resulted in the increased biological efficiency (Table 1).

The results indicate that the best performance was observed in unchopped paddy straw compared to chopped straw. The high moisture retention capacity, low aeration and quick rotting habit of chopped straw might be responsible for such inferior performance (Rath, 1976). The best yield parameter were obtained with unchopped straw of paddy varieties *White ponni* and CR 1009 (Table 2). Thus, the study showed that unchopped straw of paddy varieties can be used as a substrate for *Pleurotus* cultivation. An analysis on the economics of the adoptability of modified cylindrical bed preparation method under Annamalainagar conditions supported the findings.

Table 1. Suitability of various substrates for the cylindrical bed preparation for *Pleurotus eous*.

Treatments	Spawn run (days)	Sporophore maturity (days)	Number of sporophores per bed	Weight of sporophores (g/bed)	Biological efficiency (%)
Pearl millet stalks	19.33	23.33	66.67	180.01	36.00
Cotton stalks	16.33	19.33	115.00	369.02	73.80
Groundnut haulms	17.00	21.00	106.00	323.29	64.66
Groundnut shell	23.00	28.67	19.00	36.46	7.29
Paddy straw	11.00	16.33	137.67	481.80	96.36
Sorghum straw	20.00	24.33	80.33	263.82	52.76
Sugarcane bagasse	21.00	25.00	19.67	31.25	6.25
Sugarcane trash	21.00	26.33	26.67	47.30	9.46
Tapioca leaves	23.33	28.33	30.00	56.78	11.36
Tapioca *thippi*	24.67	29.67	44.67	93.92	18.78
Cyperus rotundus	16.00	17.67	125.00	393.27	78.65
SE_D	0.95	1.27	3.33	7.76	5.28
CD (p=0.01)	2.70	3.62	9.47	22.05	14.99

Bamboo leaves, Coir pith, Palm leaves, Soyabean stalks, *Croton sparsiflorus* and *Parthenium* stalks failed to produce sporophore

Addition of various supplements to the substrate was undertaken to enhance the mushroom yield. Among the additives used, horsegram flour significantly increased the growth and yield of *P. eous*. The supremacy of horsegram flour due to induction of cellulase (Ramaswamy and Kandaswamy, 1976) was one of the critical factors responsible for increased yield. Among the organic nitrogen supplements tested, groundnut oil cake at 3% level proved its superiority in increasing the yield of *P. eous*. The days required for spawn run and maturity were reduced with the addition of groundnut oil cake. Much evidences have accumulated in the literature for such beneficial effects of groundnut oil cake (Nita Bahd, 1991; Patra *et al.*, 1997).

Increased number and weight of sporophores and biological efficiency were observed when GA (100 ppm) was applied. The stimulating action of GA might be due to increase in cell division and cell elongation.

Provision of vent tubes with several holes increased the yield of sporophores of *Pleurotus* spp. The yield obtained from all the treatments was higher than control. Increased air circulation obtained by the provision of vent tubes in cylindrical beds resulted in higher yield realization. The number of holes per vent tube was also found to have a profound influence on yield parameters. The highest sporophores weight was obtained when PVC pipes were used with 12 holes, compared to other treatments (data not given). However, excessive air circulation resulted in drying up of the bed, thereby exposing the fungus to moisture stress.

Table 2. Suitability of chopped and unchopped paddy straw from different paddy varieties for the cylindrical bed preparation for *Pleurotus eous*.

Treatments		Spawn run (days)	Sporophore maturity (days)	Number of sporophores per (day)	Weight of sporophores (g/bed)	Biological efficiency (%)
IR 50	Unchopped	11.33	17.00	119.00	453.00	90.60
	Chopped	11.70	17.67	104.00	405.00	81.00
IR 72	Unchopped	11.00	16.33	137.33	469.77	93.95
	Chopped	11.67	17.00	110.00	413.57	82.71
TKM 9	Unchopped	12.67	17.00	108.67	408.95	81.79
	Chopped	13.00	17.33	92.33	388.27	77.65
PY 5	Unchopped	12.67	17.67	90.67	365.89	73.18
	Chopped	13.33	19.00	76.67	343.41	68.68
White Ponni	Unchopped	9.67	14.33	167.67	524.34	104.87
	Chopped	10.67	15.67	128.00	464.39	92.88
CR 1009	Unchopped	10.33	15.33	141.67	479.78	95.96
	Chopped	11.00	16.67	122.33	441.79	88.36
SE_D		0.24	0.67	2.98	12.32	4.41
CD (p = 0.01)		0.66	1.88	8.35	34.52	12.34

Though chopped paddy straw (4–5 cm long) has been the traditional method used by the mushroom growers of this region for over a decade, the possibility of preparation of cylindrical bed with unchopped straw of *White Ponni* with supplements of horsegram flour (5%), groundnut oil cake powder (3%), spraying of beds with GA (100 ppm) and provision of PVC vent tubes (12 holes) (Fig. 3) in the new method of bed preparation has maximised production. The modified cylindrical bed preparation method registered highest net return and cost-benefit ratio (Table 3). The higher net return and cost benefit ratio in this method could be attributed to the greatest availability of more balanced nutrients. The cost- benefit ratio was more than the standard method which was due to lower both cost of cultivation and higher level of production.

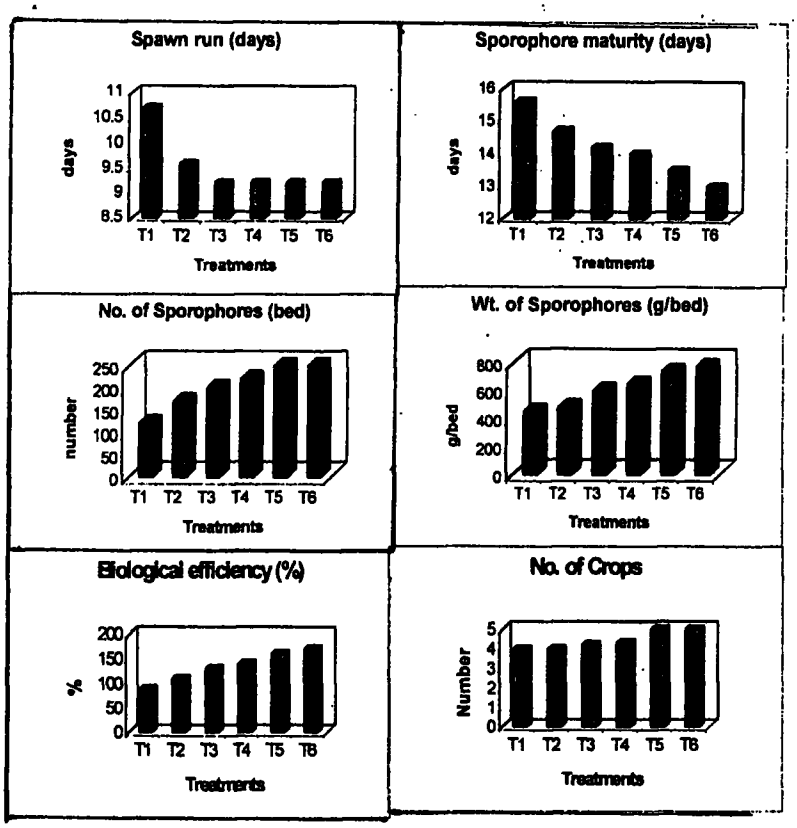

Fig. 3. Evaluation of substrate suitable for cylindrical bed preparation.
[Note: T1 - Standard method, T2 - Modified method, T3 - T2 + horsegram (5%), T4 - T3 + Groundnut oil cake (3%), T5 - T4 + GA (100 ppm spray), T6 - T5 + provision of PVC vent tubes (12 holes)].

Post-harvest technology

Fresh sporophore of *P. eous* were stored at both room temperature and under refrigeration following different packing methods. Periodic observations revealed that under room temperature, either the sporophore should be stored in open trays or completely sealed on polythene packets (without perforations) to attain a maximum storage period of 3 days. Similarly, in respect of storing the freshly harvested sporophores of *P. eous* at refrigeration, best results were obtained in completely sealed packets where the sporophores were soft, spongy and followed by dried and frozen condition in fully exposed trays after 10 days of storage. On the whole, all these sporophores could be categorized as edible up to 50 days of storage with a moderate change in colour as well as drying up of pileus. The general increase in shelf life at refrigerate could be due to reduction in moisture loss, growth of microorganisms, post-harvest metabolic activity and chemical reactions associated with colour degradation, autolysis and liquefaction of tissues.

Table 3. Economics of *Pleurotus eous* cultivation under Annamalainagar conditions.

S. No.	Particulars	Standard method	Modified method
1	Paddy straw quantity required (kg)	105	66
2	Quantity of spawn required (kg)	2.10	1.32
3	Total cost of paddy straw @ Rs. 1 kg^{-1}	105.00	66.00
4	Addition cost required for the supplementation and provision of inputs *viz.*, horsegram flour (5%), groundnut oil cake (3%), GA (100 ppm) and PVC vent pipe	-	200.00
5	Total cost of spawn		
	a. Standard method (sorghum grains + $CaCO_3$ as spawn base	100.00	-
	b. Modified method [PFPg + $CaCO_3$ + horsegram flour (3%) + gypsum (1%) as spawn base]	-	50.00
6	Labour required (man days)	32	14
7	Total labour cost at Rs. 50 / man day	1600.00	700.00
8	Total cost of polythene bags at Rs. 260 kg^{-1}	750.00	550.00
9	Rent of mushroom house	300.00	300.00
10	Miscellaneous charges for electricity, water, pesticides *etc.*,	500.00	400.00
11	Total cost of cultivation	3355.00	2306.00
12	Total price of 100 kg at Rs. 40 kg^{-1}	4000.00	40000.00
13	Net return (in Rs)	645.00	1694.00
14	Cost-benefit ratio	1:1.19	1:1.73
15	Percentage increased over net return of the standard method (in Rs.)	-	163.00

a - Biological efficiency (%) : Standard method : 96, Modified method : 150.
b - Sporophore maturity time (days) : Standard method : 16, Modified method : 14.

Among treatments, dehydration (sun drying) and dehydrated cum powered had the highest score for colour, odour, appearance and taste (score of over 4 out of six) followed by canning (score of about 3). All the other treatments had poor storage life (scores less than one; data not shown). Refrigeration always improve the quality of *Pleurotus eous*. From the results, it could be assessed that the treatments, sugar+vinegar, vinegar, sugar, blanching+vinegar, blanching+sugar had poor storage life. The poor storage life of mushroom stored at room temperature was due to higher rate of metabolic activity. The initial bacterial population at harvest is an important factor in the deterioration of fresh mushrooms during storage (Beelman, 1987). The browning of mushroom during storage is a result of the combination of auto enzymatic breakdown and microbial action on the tissue (Fordyce, 1968).

The dehydration in mushroom increased the shelf-life as compared to all other treatments tested. The main objective of drying in the present study was to reduce water content in the harvested sporophore in order to check the biochemical and microbial activity. Sun drying is an appropriate technology for our country because of free source of energy and minimum investment in capital cost (Lal and Sharma, 1997).

CONCLUSIONS

Studies have shown that *P. eous* can be cultured easily on modified glucose-asparagine medium with considerable increase in the mycelial yield. Partially filled paddy grains incorporated with calcium carbonate (3%), horsegram flour (3%) and gypsum (1%) can be utilised as the new spawn base. The modified cylindrical bed preparation method using unchopped paddy straw with addition of horsegram flour (5%), groundnut oil cake powder (3%), spraying of gibberellic acid (100 ppm), provision of PVC vent tubes (12 holes) and *uri* method has given encouraging results. This simple modified technique holds promise as a viable and low cost technique for increasing mushroom yield to some extent and may be considered as an efficient and eco-friendly method of supplying balanced nutrients to mushroom for yield maximisation with good scope for effective disposal and utilization of agricultural and industrial wastes.

The freshly harvested sporophores can easily be stored in scaled polythene bags upto 72 h (maximum) at room temperature and in refrigerating temperature upto 50 days. Dehydration (sun drying) and dehydrated-cum-powdered were observed to give a long term storage period (more than 100 days) without any change in quality parameters.

REFERENCES

Bansal, R.K. and Singh, R.D. (1989). Comparative growth of two species of *Volvariella* on trace elements deficient media. Indian J. Mushrooms. 15: 29-30.

Beelman, R. (1987). Factors influencing the post-harvest quality and shelf life of fresh mushrooms. Mushroom News. 35: 12-18.

Bhattacharjee, M.K. and Samajpati, N. (1989). Optimization of mycelial growth of *Pleurotus sajor-caju* in relation to some physical and nutritional factors. Indian J. Mycol. Res. 27: 59-65.

Fordyce, C. Jr. (1968). Microorganisms associated with market deterioration of the cultivated mushroom, *Agaricus bisporus*. Plant Dis. Reptr. 52: 712-714.

Jandaik, C.L. (1974). Artificial cultivation of the mushroom *Pleurotus sajor-caju* (Fr.) Singer. Mushroom J. 2: 405.

Jandaik, C.L. and Kapoor, S. (1976). Effect of carbon and nitrogen nutrition on growth of *Pleurotus sajor-caju*. Indian Phytopath. 29: 327-329.

Jandaik, C.L. (19970. History and development of *Pleurotus* cultivation in the world and future prospects. pp. 81-192. *In*: Rai, R.D., Dhar, B.L. and Verma, R.N. (Eds). Abs: Advances in Mushroom Biology and Production, MSI, Solan, India.

Kapoor, S., Sharma, A., Phutela, R.P. and Sodhi, H.S. (1997). Physiological studies on *Pleurotus fosualtus*. *In*: Abs. No. 4.01, Indian Mushroom Conference '97, Sep. 10-12, 1997, NCMRT, Solan, India.

Khader, V. and Padmavathi, S. (1991). Studies on oyster mushroom (*Pleurotus* spp) at different stages of maturity and standardization of three recipes from matured mushroom. Indian Mushrooms. 8: 21-224.

Kikon, Z. and Rao, A.V. (1980). Physiological studies of the strains of edible mushroom, *Pleurotus ostreatus* (Jacq.) Fr.. Indian J. Mushrooms. 6: 24-27.

Krishnamoorthy, A.S. and Narasimhan, V. (1994). Influence of organic supplements on yield and protein content of oyster mushroom. Mushroom Res. 3: 62.

Lal, B.B. and Sharma, K.D. (1997). Post-harvest technology in mushroom. Present Scenario. pp. 349-35. *In*: Advances in mushroom biology and production, MSI, Solan, India.

Mehta, K.B. (1985). Studies on physiology and cultivation of *Pleurotus sapidus* (Schulzer) Kalch. Ph.D. thesis, HPKVV, COA, Solan, India.

Mehta, K.B. and Jandaik, C.L. (1986-87). Temperature and media requirements for the mycelial growth of *Pleurotus sapidus* (Schulzer) Kalchor. Indian J. Mushrooms. 7-8: 54-56.

Nita, B. (1991). Mushroom, a better source of vegetable protein. pp. 224-226. *In*: Proc. Natl. Stmp. Mush., Thiruvanathapuram.

Okwujiako, I.A. (1990). The effect of vitamins on the vegetative growth and fruit body formation of *Pleurotus sajor-caju* (Fr.) Singer. Mushroom J. Tropics. 10: 35-39.

Patra, A.K., Pani, B.K. and Panda, S.N. (1997). Effect of leaf and oilcake amendments of paddy straw on the sporophore yield of *Pleurotus sajor-caju* (Fr.) Singer. *In*: Abs. No. 2.14, Indian Mushroom Conference '97, Sep. 10-12, 1997, NCMRT, Solan, India.

Ramaswamy, K. and Kandaswamy, T.K. (1976). Effect of certain amendments of cellulase(s) and yield of straw mushroom. Indian J. Mushrooms. 11: 8-11.

Rath, G.C. (1976). Suitability of straw of high yielding paddy for the cultivation of paddy straw mushroom. Indian J. Mushrooms. 2: 16-17.

Sivaprakasam, K. (1980). Studies on oyster mushroom *Pleurotus sajor-caju* (Fr.) Singer. Ph.D. thesis, TNAU, India.

Steinberg, R.A. (1942). The process of amino acid formation from sugars in *Aspergillus niger*. J. Agric. Res. 64: 615-33.

Zadrazil, F. (1974). Ubersetzt ins Chinesische von Chin-Piau Chiang. The research cultivation of *Pleurotus florida* povose. J. Hort. Soc. China. 20: 1-5.

APPENDICES

Appendix 1. Glucose-asparagine medium.

Glucose	- 30 g
Asparagine	- 1 g
$MgSO_4$	- 0.5 g
K_2HPO_4	- 1.5 g

Appendix 2. Modified glucose-asparagine medium.

Glucose	- 40g
Asparagine	- 1 g
$MgSO_4$	- 0.5 g
$CuSO_4$	- 3 ppm
K_2HPO_4	- 1.5 g
Thiamine	- 50 ppm
Gibberllic acid	- 0.5 ppm