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Performance of Different Oyster Mushroom Varieties Cultivated on *Eleusine coracana* (Finger Millet) Under High Altitude Condition of Tawang, Arunachal Pradesh, India

Ashok Naglot*, Vijay Pal, Khonamai Sewa Nakhuru and Sanjai Kumar Dwivedi

Defence Research Laboratory (DRL), DRDO, Tezpur - 784001, Assam, India

*Corresponding Author E-mail: naglot_ashok@yahoo.co.in

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ABSTRACT

The aim of the study was to investigate the suitability of locally available substrate Eleusine coracana (finger millet) straw for the cultivation of different Pleurotus species in terms of yield, biological efficiency, nutritional contents and antioxidant properties under the native condition of Tawang, Arunachal Pradesh. Four species of oyster mushroom namely Pleurotus florida, P. ostreatus, P. citrinopileatus and P. erygnii were successfully cultivated on finger millet straw in the native condition of Tawang. P. florida and P. ostreatus showed better results in terms of pin head appearance, fruiting bodies maturation, yield and biological efficiency when compared (P≤0.05) to P. citrinopileatus and P. erygnii. Crude protein, fat, total ash, dietary fiber and total carbohydrate content in respective oyster species were found to be in the ranges of 0.70 – 2.37, 0.16 - 0.19, 0.62 – 1.05, 0.69 – 1.40 and 3.31 to 6.47 g/100g of fresh edible portion (EP) respectively. Whereas the values of calcium, magnesium, zinc and iron in the four oyster species were found to be in the ranges of 11.23 – 12.32, 11.02 – 16.21, 1.45 – 1.97 and 1.46 – 2.89 mg/100g of fresh EP respectively. In addition, the Pleurotus species grown on finger millet also showed good antioxidant activity with DPPH radical scavenging assay and hydroxyl radical scavenging assay. The ethanolic extract of P. florida showed the highest DPPH radical scavenging effect (47.71 ± 0.73%) at 1000 µg/ml concentration and strongest hydroxyl radical scavenging activity (56.75 ± 1.19%) at 2.5 µg/ml concentration when compared to other three Pleurotus species. This is the first study evaluating the suitability of Eleusine coracana (finger millet) straw as a substrate for growing oyster species.

Keywords: *Eleusine coracana (finger millet), Pleurotus spp., Tawang (Arunachal Pradesh), Biological efficiency, Antioxidant activity*

INTRODUCTION

Mushrooms of the genus *Pleurotus* comprise about 40 different species that are commonly referred to as "Oyster mushroom". These edible fungi are cultivated worldwide especially in Southeast Asia, India, Europe and Africa due to their nutritional and medicinal values (Deepalakshmi & Mirunalini, 2014; Uddin et al., 2011).

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Oyster mushrooms are the easiest, fastest and cheapest to grow requiring less preparation time, low demand of resources and production technology. However, the environmental factors like temperature, humidity and raw waste materials play significant role in their production. *Pleurotus* spp. usually grow in wide range of temperature (15°C -30°C) depending upon the species. Nutritionally, oyster mushrooms are rich in fibre, vitamins (niacin, riboflavin, folic acid and vitamin - C) and minerals (calcium, phosphorus and potassium) but low in calories, sodium, fat and cholesterol. Moreover, *Pleurotus* spp contain high protein and thus, are capable of accomplishing the protein malnutrition problem in developing and underdeveloped countries (Rashid et al., 2016). Now a day, oyster mushrooms have become an attractive functional food because of their antioxidant property, helping the human body to reduce oxidative damage without any interference (Cheung et al., 2003). Apart from ascorbic acid, mushrooms accumulate a variety of secondary metabolites including phenolic compounds, polyketides, terpenes and steroid which make them a good source of antioxidants (Wasser et al., 1999).

Tawang is located in a temperate region near to Indo-China border in North East, India. This region is characterized by cold and rainy environment. The average temperature in the month of May to August is usually 18°C ± 2°C which is favourable for the growth of edible macro fungi, oyster (*Pleurotus* spp). The common people of Tawang generally fulfil their protein requirement in the diet by consuming animal flesh. However, due to stringent religious practices and beliefs the residents of Tawang do not sacrifice animals for their diet. In Tawang animal flesh/meat is transported from the lower regions for the consumption but this neither cost effective nor hygienic. Thus, oyster mushrooms being excellent source of proteins and other macronutrients can become an alternative source of diet in Tawang if their cultivation practices are adopted using locally available substrate.

Keeping the above aspect in view and the growing popularity and demand of Oyster mushroom in north east region of India, the study was aimed to evaluate the yield performance, nutritional composition, and antioxidant property of four different *Pleurotus* spp. namely *P. ostreatus*, *P. florida*, *P. eryngii* and *P. citrinopileatus* grown on locally available substrate *Eleusine coracana* (finger millet) straw under the condition of Tawang, Arunachal Pradesh.

MATERIALS AND METHODS

Strains: Cultures of four *Pleurotus* species namely *Pleurotus florida* (strain 3308), *P. citrinopileatus* (strain 4346), *P. eryngii* (strain 3306) and *P. ostreatus* (strain 33834) were obtained from ICAR-Directorate of Mushroom Research, Solan, India. Pure cultures were maintained on potato dextrose agar (PDA, Himedia Laboratories Pvt. Ltd., India) at 4°C until inoculation.

Study area: The study was conducted at Defence Research laboratory (DRL) R & D Centre, Tawang, Arunachal Pradesh, India. The area falls under cool temperate zone. The investigation was executed during May to August, 2019 and the average temperature during this period was 18°C ± 2º C (approx.).

Mother spawn preparation: The whole grains of wheat were soaked for 5-6 hours followed by boiling for 20-25 minutes until the grains get soft. The excess of water was drained off and 2% w/w $CaCO_3$ plus $CaSO_4$ were added. The components were mixed thoroughly and 250gm of treated grains were filled equally into 500 mL wide mouth bottles. The bottles were then plugged with cotton and plug of each bottle was further covered with brown paper. The bottles were then autoclaved at 121°C under atleast 15 psi of pressure for 15 minutes. Each bottle was inoculated with 8 days old culture of respective oyster species and incubated at 25°C for 15 days until the substrate become fully colonized.

Spawn preparation: The wheat grains were processed as described previously and 250gm of treated grains were filled into polypropylene bags of 25 x 17 cm size, and packed tightly.

The neck of each bag was plugged with cotton, covered with brown paper and tied with a rubber band. The packets were then autoclaved for 15 minutes at 121°C under 15 psi of pressure. The packets were inoculated with respective mother culture of the oyster species and incubated for 20 days at 25°C to achieve full growth of the mycelium. The fully colonized packets were used for spawning.

Cultivation: Locally available *Eleusine coracana* (finger millet) straw was used for cultivation. The straw was chopped into 2-4cm length, washed thoroughly and soaked for 10-12 hours in clean water. The straw was then taken out and excess water was drained. The straw was spread on a clean surface for drying in the sunlight until it retains 25-30% moisture. The polypropylene bags of 24 × 36cm size were filled with 1.2 kg (wet weight) substrate. During bagging 13gm spawn of respective *Pleurotus* species was spread evenly after filling one layer of straw. Altogether four layers of straw were filled with three times spawn (13gm per layer) inoculation. The bags were then tied tightly with thin rope and 12-15 small (0.5-1.0cm diameter) holes were created on all around the bags. The spawned bags were kept in a 'dark room' at 18°C±2°C for mycelium growth**.**

Cropping and Harvesting: When the bags were fully covered with respective oyster species mycelium, the bags were then shifted in another room called as 'cropping room'. The room was properly ventilated with 200 lux light intensity (for 6-7 hours) required for pin head appearance and subsequently maturation of them into healthy fruiting bodies. Moreover, the humidity of the room was maintained up to 80-90% by spraying/sprinkling clean water on the floor and walls. After the first harvest, the polythene of each bag was torn apart and the clean water was sprayed thrice a day on the bags to maintain moisture upto 85% to 90%. The bags were retained upto three flushes. The yield parameters recorded during the cultivation period were complete spawn run (days), pin-head formation (days), maturation of fruiting bodies (days), time interval (days) between flushes, total yield (gm) and biological efficiency (%).

Proximate and mineral analysis: Approximately 200gm freshly harvested fruiting bodies of each oyster mushroom species were cut into small pieces with the help of a knife and transported to the Food Quality Control Laboratory, Tezpur University, Assam (India) for the determination of proximate and Mineral analysis (calcium, magnesium, zinc and iron) using following test methods -

SN	Test Parameters	Test method
01.	Moisture	IS 4333(2002) (Reaffirmed 2008)
02.	Crude Protein	IS:7219(1973) (Reaffirmed 2005)
03.	Crude Fat	AOAC 20th edn, 2016 2003.05
04.	Crude Ash	IS:1011:2002 (Reaffirmed 2013)
05.	Crude Fiber	IS:10226:1982 (Reaffirmed 2005)
06.	Carbohydrate	By Subtraction Method
07.	Calcium (Ca)	AAS Method
08.	Magnesium (Mg)	
09.	Zinc (Zn)	
10.	Iron (Fe)	

Antioxidant analysis: The extraction for each test oyster mushroom species was prepared from the dried fruiting bodies using 90% ethanol. Approximately 10gm of dried sample was extracted with 100 ml solvent at room temperature for 24 hours followed by filtration through no. 4 whatman filter paper. The residual material was re-extracted twice and finally the filtrates were combined. The extract was then evaporated almost to dryness in a rotary evaporator (model IKA RV 10 Control) at 60º C. The dried extract was redissolved in

the solvent to a concentration of 2mg/ml and stored at 4ºC for antioxidant evaluation. Antioxidant activity of the ethanolic extracts was determined by 2, 2-diphenyl-1-picryl-hydrazyl-hydrate (DPPH) free radical scavenging (Brand-Williams et al., 1995) and hydroxyl radical scavenging method (Halliwell et al., 1987).

Statistical analysis: All the data was analysed in triplicate (n=3) using Grap Pad InStat version 3.05 by one way Analysis of Variance (ANOVA) followed by Tukey – Kramer multiple comparisons tests. All the statistical analysis was done at the 0.05 significance level. The results were expressed as mean values and standard deviation (SD). Linear regression analysis was used to calculate the IC50 value of the antioxidant activity.

RESULTS

A. Completion of spawn run:

The data shown in table 1 indicates that spawn running phase completed in 32.33, 33.33, 36.66 and 42.33 days for *P. ostreatus*, *P. florida*, *P. citrinopileatus* and *P. eryngii* respectively on finger millet straw. *P. eryngii* took significantly more time in spawn running in comparison (P≤0.05) to other three test species.

B. Pin head appearance, maturation of fruiting bodies and flushing intervals:

The pin head formation was observed after 38.33, 42.66, 52.66 and 55.66 days for *P. ostreatus*, *P. florida*, *P. citrinopileatus* and P. eryngii respectively. Similarly, the maturation of pin heads into the fruiting bodies was noted 46.66, 49.33, 66 and 68.66 days for *P.* ostreatus, *P. florida*, *P. citrinopileatus* and *P. eryngii* respectively. *P. ostreatus* took significantly lesser time to generate pin heads followed by their transformation into the fruiting bodies. Moreover, the data related to flushing intervals revealed that all the test species took almost similar flushing interval period (days) on the finger millet straw (Table1).

Table 1: Days for completion of spawn running, pin heads formation, fruiting bodies maturation and flushing intervals of *Pleurotus* spp. on finger millet

***Pleurotus* spp.**	**Completion of spawn running (days)**	**Pin heads formation (days)**	**Fruiting bodies maturation (days)**	**Flushing intervals (days)**
P. florida	$33.33^{a} \pm 1.52$	$42.66^{a} \pm 2.51$	$49.33^{a} \pm 0.57$	$7^{a} \pm 1$
P. citrinopileatus	$36.66^{ab} \pm 1.52$	$52.66^{b} \pm 1.52$	$66^{b} \pm 1.00$	$7.33^{ab} \pm 1.15$
P. eryngii	$42.33^{c} \pm 1.52$	$55.66^{bc} \pm 0.57$	$68.66^{c} \pm 1.15$	$8.33^{abc} \pm 0.57$
P. ostreatus	$32.33^{abd} \pm 2.51$	$38.33^{ad} \pm 1.52$	$46.66^{d} \pm 1.15$	$7^{abcd} \pm 1$

*****Data presented as mean ± SD of 3 replicates. Values in the same column not sharing common superscript letter(s) are significantly different at P≤0.05 by using Tukey – Kramer multiple comparisons test.

C. Total yield and biological efficiency (B.E %):

The maximum yield (g) on fresh weight basis after three flushes was noted for *P. florida* (626 g) followed by *P. ostreatus* (612 g), *P. citrinopileatus* (572.66 g) and *P. eryngii* (465 g) per 600gm dried weight of the substrate used. The biological efficiency was calculated by the formula given by Chang et al. (1981).

$$\text{B.E\%} = \frac{\text{Fresh weight of fruiting bodies (Accumulation of 3 flushes)}}{\text{Dry weight of substrate taken to prepare the bag}} \times 100$$

The highest biological efficiency was noted for *P. florida* (104.33%) followed by *P. ostreatus* (101.66%), *P. citrinopileatus* (95.50%) and *P. eryngii* (77.83%). *P. eryngii* showed significantly lower B.E in comparison to other three test species on finger millet (Table 2).

Table 2: Yield (g) and Biological Efficiency (B.E %) of *Pleurotus* spp. on finger millet

Pleurotus spp.	Yield (g) – accumulation of 3 flushes per 600gm dried wt. of substrate	Biological efficiency (B.E %)
P. florida	626	$104.33^{a} \pm 0.52$
P. citrinopileatus	573	$95.50^{b} \pm 0.76$
P. eryngii	467	$77.83^{c} \pm 1.00$
P. ostreatus	610	$101.66^{ad} \pm 0.71$

* Data presented as mean ± SD of 3 replicates. Values in the same column not sharing common superscript letter(s) are significantly different at (P≤0.05) by using Tukey – Kramer multiple comparisons test.

D. Proximate and mineral analysis: Table 3 depicts the nutritional contents (g/100 g) of different fresh *Pleurotus* species. The moisture contents of *P. florida*, *P. citrinopileatus*, *P. eryngii* and *P. ostreatus* were found 92.96%, 92.09%, 93.10% and 94.18% respectively. The highest crude protein was noted for *P. florida* (2.37 g) followed by *P. eryngii* (2.07 g). The protein content was noted comparatively low for *P. ostreatus* (0.84 g) and *P. citrinopileatus* (0.70 g). The crude fat, total ash and dietary fibre contents were found to be in the range of 0.16 g to 0.19 g, 0.62 g to 1.05 g and 0.69 g to 1.40 g respectively for the different test *Pleurotus* species. Moreover, carbohydrates content was noted highest for *P. citrinopileatus* (6.47 g) followed by *P. florida* (3.76 g) and *P. ostreatus* (3.64 g).

Table 3: Proximate composition of fresh *Pleurotus* spp. (g/100g)

	***Pleurotus* spp.**			
Nutrients	***P. florida***	***P. citrinopileatus***	***P. eryngii***	***P.ostreatus***
Moisture	$92.96^{a} \pm 0.58$	$92.09^{ab} \pm 0.34$	$93.10^{abc} \pm 0.26$	$94.18^{cd} \pm 0.50$
Crude Protein	$2.37^{a} \pm 0.49$	$0.70^{b} \pm 0.05$	$2.07^{ac} \pm 0.27$	$0.84^{bd} \pm 0.08$
Crude Fat	$0.19^{a} \pm 0.01$	$0.19^{ab} \pm 0.01$	$0.17^{abc} \pm 0.01$	$0.16^{abcd} \pm 0.02$
Crude Ash	$0.62^{a} \pm 0.01$	$0.67^{b} \pm 0.01$	$1.05^{c} \pm 0.02$	$0.62^{d} \pm 0.01$
Crude Fiber	$0.69^{a} \pm 0.01$	$1.40^{b} \pm 0.30$	$0.95^{ac} \pm 0.01$	$0.74^{acd} \pm 0.02$
Carbohydrate	$3.76^{a} \pm 0.14$	$6.47^{b} \pm 0.05$	$3.31^{c} \pm 0.03$	$3.64^{ad} \pm 0.02$

***** Data presented as mean ± SD of 3 replicates. Values in the same row not sharing common superscript letter(s) are significantly (P≤0.05) different by using Tukey – Kramer multiple comparisons test.

Table 4 shows the contents of some important minerals in different oyster species. Calcium, magnesium, zinc and iron in different *Pleurotus* species were found to be in the ranges of 11.23 to 12.32, 11.02 to 16.21, 1.45 to 1.97 and 1.46 to 2.89 mg per 100 gram of fresh edible portion respectively.

Table 4: Mineral content of fresh *Pleurotus* spp. (mg/100g)

	***Pleurotus* species**			
Minerals	***P. florida***	***P. citrinopileatus***	***P. eryngii***	***P.ostreatus***
Calcium	$12.03^{a} \pm 0.20$	$11.23^{ab} \pm 0.46$	$12.32^{abc} \pm 0.33$	$11.33^{abcd} \pm 0.62$
Magnesium	$11.02^{a} \pm 0.20$	$14.16^{b} \pm 0.59$	$16.21^{c} \pm 0.28$	$13.11^{d} \pm 0.27$
Zinc	$1.68^{a} \pm 0.16$	$1.45^{b} \pm 0.02$	$1.85^{ac} \pm 0.04$	$1.97^{cd} \pm 0.02$
Iron	$2.32^{a} \pm 0.38$	$2.03^{ab} \pm 0.07$	$1.46^{c} \pm 0.03$	$2.89^{d} \pm 0.02$

***** Data presented as mean ± SD of 3 replicates. Values in the same row not sharing common superscript letter(s) are significantly (P≤0.05) different by using Tukey – Kramer multiple comparisons test.

E. Antioxidant analysis: Among the 4 *Pleurotus* species, *P. florida* showed highest DPPH radical scavenging effect (47.71 ± 0.73%) at 1000 µg/ml concentration followed by *P. ostreatus* (38.27 ± 0.74%), *P. eryngii* (36.12 ± 0.62%) and *P. citrinopileatus* (30.71 ± 1.37%). Variations in DPPH radical scavenging activities by different test *Pleurotus* species were graphically represented in Fig 1. The IC_{50} value of *P. florida* extract against DPPH radicals was 1053.07 ± 30.49 µg/ml followed by *P. eryngii* (1313.12 ± 17.76 µg/ml), *P. ostreatus* (1415.15 ± 38.91 µg/ml) and *P. citrinopileatus* (1531.59 ± 50.47) [Table 5].

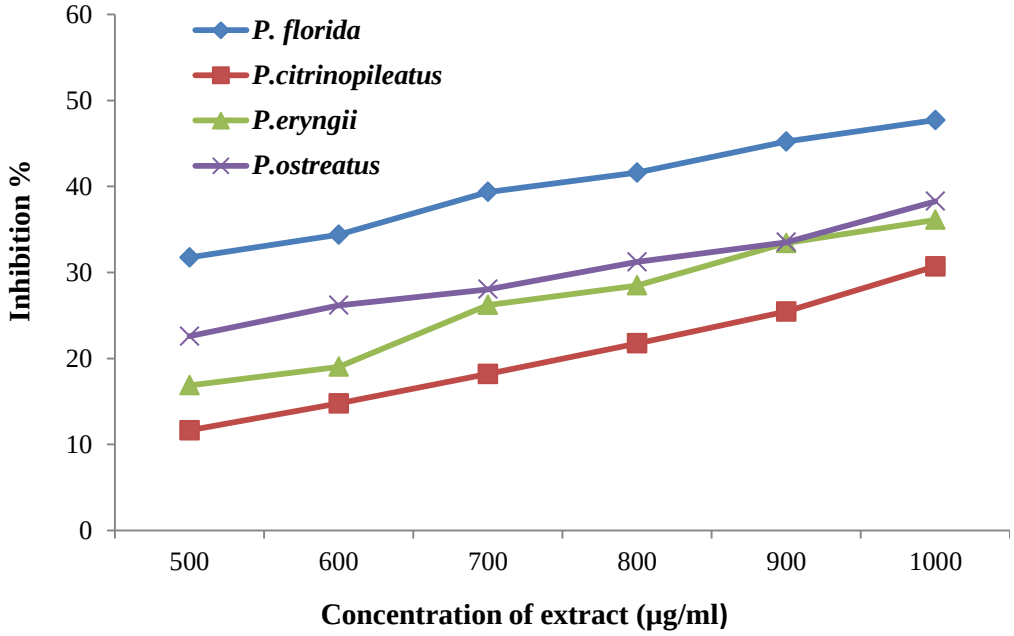

Fig. 1: DPPH radical scavenging activity of different *Pleurotus* species

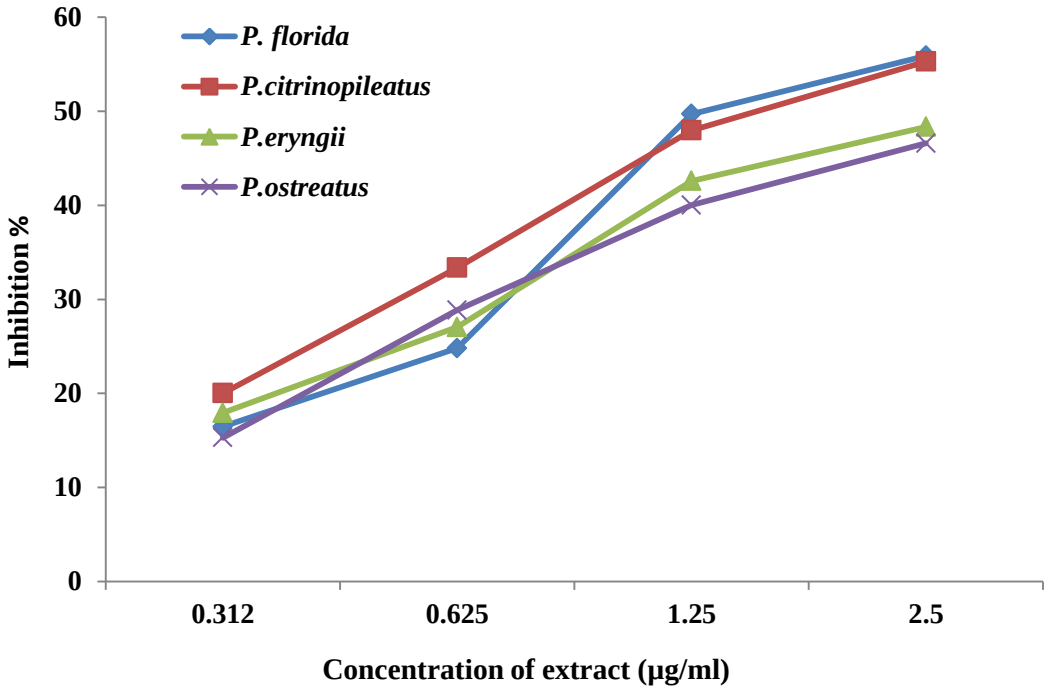

Fig. 2: Hydroxyl radical scavenging activity of different *Pleurotus* species

The hydroxyl radical scavenging effects of ethanol extracts of four *Pleurotus* species were determined using deoxyribose assay in the concentrations ranging from 0.312 µg/ml to 2.5 µg/ml. The strongest hydroxyl radical scavenging activity was observed in *P. florida* (56.75 ± 1.19%) at 2.5 µg/ml concentration. The other three oyster species viz., *P. citrinopileatus*, *P. eryngii* and *P. ostreatus* showed 55.29 ± 0.77%, 48.35 ± 0.40% and 46.60 ± 0.17% antioxidant activity respectively at 2.5 µg/ml (Fig 2).The strongest IC_{50} of hydroxyl radical scavenging activity was noted for *P. florida* at 1.5 ± 0.38µg/ml concentration followed by *P. citrinopileatus* (1.7 ± 0.05 µg/ml), *P. eryngii* (2.17 ± 0.04 µg/ml) and *P. ostreatus* (2.27 ± 0.01µg/ml) [Table 5].

Table 5: IC_{50} (µg /ml) values of ethanol extracts of *Pleurotus* spp. against DPPH and OH radicals

***Pleurotus* spp.**	**IC_{50} (µg /ml)**	
	DPPH radical	**Hydroxyl radical**
P. florida	1053.07±30.49	1.58±0.38
P. citrinopileatus	1531.59±50.47	1.78±0.05
P. eryngii	1313.12±17.76	2.17±0.96
P. ostreatus	1415.15±38.91	2.27±0.96

DISCUSSION

The present study revealed that all the four test *Pleurotus* species can be cultivated successfully on locally available finger millet (*Eluesine coracana*) straw in a cool temperate climate of Tawang, Arunachal Pradesh. The time taken for complete colonization of the substrate by the *Pleurotus* spp. ranged from 32.33 – 42.33 days. *P. ostreatus*, *P. florida* and *P. citrinopileatus* showed faster growth rate of mycelium as compared to *P. eryngii* (Table 1). Iqbal et al. (2016) reported that fastest spawn running occurred in wheat straw (26 days) followed by sorghum straw (34 days) and paddy straw (37 days) while the lowest spawn running was recorded for maize straw (39 days) and sugarcane bagasse (40 days). Tan (1981) stated that *P. ostreatus* took 21 days for complete spawn running on cotton waste. However, some researchers (Jiskani et al., 1999; Patra & Pani, 1995) reported shorter spawn running time for *Pleurotus* spp. on paddy straw. The colonization rate and time needed for complete spawn running depend not only on the nutritional value of the substrate (Kimenju et al., 2009) but also on the purity and quality of spawn (Nita Bahl, 1984). Besides this, the inherent temperature (optimum 20ºC±2), humidity (60%) and CO_2 concentration (10,000 ppm or 10%) are the critical factors which regulate the vegetative phase of mushroom cultivation.

The results also indicated the difference in time period in the formation of pin heads of respective *Pleurotus* species on the finger millet straw. *P. ostreatus* (38.33 days) and *P. florida* (42.66 days) showed earlier appearance of pin heads as compared to other two *Pleurotus* species (Table 1). The findings with respect to variance in time period for pin heads appearance of different oyster species are well documented with majority of studies conducted by many workers (Iqbal et al., 2005; Kathiravan & Krishnakumari, 2016; Khan et al. 1981; Paul & Ngozika, 2017; Ramzan et al., 1982). The differences in pin head formation time may be attributed to the ability of the respective species to secrete a wide range of hydrolyzing and oxidizing enzymes which break complex lignocellulosic waste into soluble compounds (Yolisa, 1997). Moreover, Kimenju et al. (2009) reported that the substrates having higher lignin and cellulose contents took longer time to initiate pinning compared to substrates with lower contents of lignin and cellulose. Moreover, the present findings showed that both *P. ostreatus* (46.66 days) and

P. florida (49.33 days) took minimum number of days from appearance of pin heads to the maturation of fruiting bodies (Table 1) on the substrate. Many investigators in the past reported the difference in time period for the transformation of pinheads into fruiting bodies. Khanna & Garcha (1981) noted 20 - 24 days for fruiting bodies formation on paddy straw. Similarly, Iqbal et al. 2016 reported maturity time of pin heads of *P. florida* on wheat straw (30 days), sorghum straw (42 days), rice straw (39 days), sugarcane bagasse (41 days) and maize straw (42 days). The transformation of pin heads into healthy fruiting bodies mostly depends on critical factors like O_2 concentration, CO_2 concentration (1000 ppm or 1%), humidity (80-90%) and light (200 lux intensity) which must be maintained in the cropping room. There was no significant difference noted regarding the flushing intervals of *Pleurotus* spp. (7-8 days) on finger millet straw in the current study (Table1). Iqbal et al. (2005) showed that *P. ostreatus* and *P. sajarcaju* took 6.3 and 6 days respectively for flushing on paddy straw. Similarly, Bhatti (1984) reported that different flushes of oyster species on suitable substrate can be obtained with an interval of 5-6 days. Our study suggests that the time interval between flushes may be reduced or maintained to an optimum range (6-8 days) irrespective of the agro waste utilized as substrate by proper and timely (3 - 4 times) spraying of mushroom bags. Such practice ensures adequate range of humidity i.e., 80 to 90% which supports formation and maturation of fruiting bodies.

According to Table (2) the highest yield and biological efficiency (B.E %) were obtained for *P. florida* followed by *P. ostreatus* and *P. citrinopileatus* in finger millet straw. The B.E% was noted in the range of 77.50 – 104.33% for the test *Pleurotus* spp. The results are well correlated with Jiskani et al. (1999), who reported that 1 kg of dry substrate can produce 1 kg of fresh mushroom which is the 100% substrate of dry weight. However, the yield and B.E% of a particular oyster species depend on the physiochemical and nutritional content of the substrate. Many researchers in the past, reported significant differences in B.E% while studying use of different substrates for *Pleurotus* spp. cultivation (Das & Mukherjee, 2007; Iqbal et al., 2016; Kathiravan & Krishnakumari, 2016; Kimenju et al., 2009; Moonmoom et al., 2010; Nunez & Mendoza, 2002; Paul et al., 2017).

Our study revealed that protein content was recorded highest for *P. florida* followed by *P.ostreatus* and *P. citrinopileatus* cultivated on finger millet straw (Table 3). The protein content usually ranges between 20-30% on a dry weight basis in oyster mushroom spp. Although, the protein concentration in *Pleurotus* species usually vary depending upon the physio-chemical composition of the substrate used (Akyuz & Kirbag, 2010). Zahid et al. (2010) reported that protein content did not differ significantly between the species. However, the current study revealed that *P. eryngii* showed significantly less protein content in comparison to other three test species (Table 3). Similar findings were observed by Wang et al. (2014) who concluded that protein content in oyster mushroom vary among species and the difference is attributed to the environmental factors and stage of fruiting body maturity. The fat content recorded in the present study for the *Pleurotus* spp. in finger millet straw is in accordance with the previous studies (Rashidi & Yang, 2016; Zahid et al., 2010). Similarly, the ash content of the studied oyster species ranged between 0.62 g - 1.05 g per 100 gm of fresh mushroom. The amount of ash in mushroom depends on salt content in the substrate (Pomeranz & Meloan, 2000). Thus, it can vary as per the choice of substrate used. The dietary fibre content in the three oyster species viz., *P. florida*, *P. eryngii* and *P. ostreatus* was found to be in the comparable range whereas the content in *P. citrinopileatus* appeared relatively high (1.40 g /100 gm). The results are in accordance with the findings of Zahid et al. (2010). However, some researchers like Iqbal et al. (2016) and Rashidi & Yang (2016) reported 3.5 % and 17.27% fibre content respectively in oyster species

cultivated on different substrates. Similarly, the total carbohydrate content of *P. citrinopileatu*s (6.47 g) was found highest followed by *P. florida* (3.76 g) and *P. ostreatus* (3.64 g) on finger millet in the present study (Table 3). Patil et al. (2010) reported that carbohydrate content of *P. ostreatus* (jacq. Fr.) Kumm ranged from 50.50 to 55.33% grown on paddy straw, soybean straw and wheat straw. However, Sharma et al. (2013) recorded 30.24 to 42.26% carbohydrate content in *P. ostreatus* grown on different substrates. This suggests that substrates nutritional composition play important role in framing the content of individual nutrition in the cultivated oyster species.

According to Table (4) the calcium and magnesium contents in the respective oyster species grown on finger millet straw were found to be in the lower ranges of 11.23 - 12.32 and 11.02 – 16.21 mg per 100 g of fresh edible portion respectively as compared to the previous findings of the researchers (Alam et al., 2007; Bhattacharjya et al., 2015; Hoa et al., 2015; Mattila et al., 2001). However, Museiba et al. (2013) reported 1.78 mg calcium and 7.74 mg magnesium content per 100 g of edible oyster. Similarly Roy et al. (2015) revealed much lower concentration of these two minerals in *P. citrinopileatus*. However, the amount of zinc and iron in the present study was similar with the findings of earlier reports (Alam et al., 2007; Roy et al., 2015; Zahid et al., 2010). Thus, concentration of these nutrients may vary depending on the substrate used for cultivation.

The DPPH radical scavenging assay of ethanolic extracts of Pleurotus species represented in Fig 1 revealed the percentage of inhibition in a dose dependent manner. Highest DPPH radical scavenging activity was shown in *P. florida* extract due to higher content of phenolic acids and flavonoids than the other species, as these had a high hydrogen-donating capacity to scavenge DPPH radicals (Boonsong et al., 2016). The hydroxyl radical scavenging assay (Fig 2.) also depicted the ability of extracts of *Pleurotus* species to quench hydroxyl radicals at 2.5 µg/ml. The inhibitory activity of the *Pleurotus* species was directly related to their concentrations. The antioxidant activity of extracts of *P. florida*, *P. ostreatus*, *P. eryngii and P. citrinopileatus* was reported by other researchers in the past also by virtue of their scavenging hydroxyl and DPPH radicals (Fasoranti et al., 2019). However, the present study has showed the antioxidant activity of the *Pleurotus* species cultivated on finger millet straw under cool temperate condition. The validation of antioxidant activity of the oyster varieties was important because composition of natural antioxidants in oyster mushrooms is dependent on number of factors such as mushroom strain/species, time of harvest, management techniques, average temperature during the cultivation period and most importantly the type of substrate used for cultivation.

CONCLUSION

Eleusine coracana (finger millet) straw, available locally in the Tawang, Arunachal Pradesh is found suitable for the cultivation of oyster species. The substrate supported the growth of *Pleurotus florida*, *P. ostreatus*, *P. citrinopileatus* and *P. erygnii* and produced a significantly higher yield and biological efficiency. It is also proved to be good source of macronutrients like protein, carbohydrate, fat, dietary fibers, calcium and magnesium for the cultivated oyster species. Moreover, the *Pleurotus* species also showed good antioxidant activity. Thus, *Eleusine coracana* (finger millet) straw is a best alternative source of substrate for cultivation of oyster mushrooms in the native condition of Tawang, Arunachal Pradesh, and can popularize the oyster mushroom cultivation technology among the local famers. To best of our knowledge, it is the first study on the suitability of *Eleusine coracana* (finger millet) straw as a substrate for cultivation of *Pleurotus* spp and that too under the high altitude condition of Tawang, Arunachal Pradesh.

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