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From waste to resource: utilizing chinar leaf litter for oyster mushroom cultivation and pollution mitigation

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ABSTRACT

Biomass burning of horticultural and plantation waste remains a prevalent practice in many developing countries, contributing significantly to air pollution and public health risks. Sustainable waste management strategies, including reuse, recycling, and resource recovery, have gained global attention as alternatives to such harmful practices. This study evaluates the potential of mycoremediation as an eco-friendly approach to managing dry leaf litter, particularly Chinar (*Platanus orientalis*) leaves, by cultivating oyster mushrooms (*Pleurotus ostreatus*). The efficiency of mushroom production was evaluated, and a theoretical framework was used to examine the potential for air pollution mitigation. Our findings indicate that Chinar leaf litter serves as a viable substrate for *Pleurotus ostreatus* cultivation. The complete colonization of the substrate (spawn run) occurred within 26 days, followed by the emergence of pinheads on the 33rd day and full development of fruiting bodies by the 36th day. The mushrooms cultivated on Chinar leaves exhibited high nutritional value, with crude protein content of 25.03±1.12% and crude fiber content of 18.55±1.27%. These results demonstrate that Chinar leaf litter, often discarded and burned, can be transformed into a valuable food resource, reducing environmental pollution. This study is the first to explore the potential of Chinar leaves for *Pleurotus ostreatus* cultivation, providing a novel and sustainable solution to biomass burning.

Keywords: Oyster mushroom, *Pleurotus ostreatus*, chinar leaves, air pollution, biomass burning

Open burning of horticultural and plantation residues is a significant contributor to air pollution, particularly in the Kashmir Valley, where fallen leaves of *Platanus orientalis* (chinar) are traditionally burned to produce charcoal for winter heating in kangris (Islam *et al.*, 2021). This seasonal biomass burning substantially elevates black carbon and particulate matter levels, deteriorating air quality and posing serious public health risks. Studies have reported peak autumn black carbon concentrations of 9.2 µg/m³ in Srinagar (Bhat *et al.*, 2017), while PM10 and PM2.5 levels in the Kashmir Himalayas frequently exceed permissible limits, especially during winter (Jehangir *et al.*, 2011; Romshoo *et al.*, 2021). Given India's high global pollution ranking, the identification of sustainable alternatives to open leaf burning is urgently required.

Eco-friendly management strategies such as composting and vermicomposting of chinar leaf litter have demonstrated potential for improving soil fertility (Divakar and Prasanthrajan, 2019). Vermicomposted mixtures containing chinar leaves have also been identified as viable nutrient sources for agricultural applications (Sheikh *et al.*, 2019). Additionally, *Platanus orientalis* leaves possess documented

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medicinal properties, including anti-inflammatory, anti-nociceptive, and wound-healing activities (Haider *et al.*, 2012; Niknam *et al.*, 2021). Despite these applications, limited research has explored the utilization of chinar leaf litter as a substrate for mushroom cultivation.

Mushroom production represents a sustainable and economically viable approach for converting lignocellulosic waste into nutrient-rich food (Srivastava, 2012; Doroski *et al.*, 2022). Global demand for edible mushrooms has increased substantially in recent years (Liu *et al.*, 2019; Lu, 2020), with projected market growth reaching US$83.7 billion by 2030 (Grimm and Wösten, 2018). Exploring alternative, low-cost substrates can therefore support environmental conservation, waste valorization, and livelihood generation.

Pleurotus ostreatus (oyster mushroom), the second most widely cultivated edible mushroom after *Agaricus bisporus*, is highly efficient in degrading lignocellulosic substrates (Sanchez, 2010). It requires relatively low nitrogen but high carbon content for optimal growth (Dubey, 2019) and is valued for its nutritional and medicinal attributes (Tesfay, 2020). Moreover, the spent mushroom substrate (SMS) generated after cultivation retains beneficial properties and can be further utilized as fertilizer, animal feed, in bioremediation, enzyme recovery, or activated carbon production (Antunes *et al.*, 2020; Niazi and Ghafoor, 2021; Grimm *et al.*, 2023; Boulanger *et al.*, 2024).

This study evaluates the potential of chinar leaf litter as an alternative substrate for *Pleurotus ostreatus* cultivation without nutrient supplementation, comparing its bioefficacy and nutritional profile with conventional wheat straw (Kulshreshtha, 2013). By transforming seasonal leaf waste into a valuable food resource, the approach offers a sustainable waste management strategy that can mitigate air pollution, promote circular bioeconomy practices, and enhance livelihood opportunities.

MATERIALS AND METHODS

Experimental site

Experiment was carried out at Mushroom Research and Training Center (MRTC), SKUAST-Kashmir, Srinagar. Two flushes of mushrooms were taken from each bag for the whole test run with six replications for both the substrates chinar leaves (CL) and wheat straw (WS).

Procurement of spawn

The spawn of *Pleurotus ostreatus* was obtained from spawn production MRTC laboratory, SKUAST-Kashmir.

Collection of the substrate

Chinar leaves (CL) were collected from Naseem Bagh, Hazratbal, University of Kashmir, India. The Naseem Bagh campus has approximately 700 Chinar trees spread across 15.04 hectares of land (diqa.uok.edu.in/files/ssr/7.1.8.1_GA_Report.pdf). The collected CL were first cleaned by washing with tap water to remove any surface impurity. These leaves were then sun dried, cut into small pieces and stored in sterile poly-bags for carrying out experimental work (Fig. 1). Wheat straw used as control in the study was procured from MRTC, SKUAST-K.

The representative samples were taken from each substrate grounded in an electronic blender, powdered, sieved and analyzed for parameters like pH (Hoa *et al.*, 2015) in the 1:10 ratio of sample to distilled water using a digital pH meter. Total nitrogen (Bremner, 1960), organic carbon (Walkley and Black, 1934)

Fig. 1. (a) Collection of chinar leaves from University of Kashmir campus (b) Cleaning of leaves to remove impurities (c) Drying and chopping of leaves (d) Storing of leaves in bags to carry out further research work

were analyzed using standard methods (Jackson, 1958; Gupta, 1999). C: N ratio of both the substrates was calculated. All the results were analyzed in triplicates.

Substrate preparation and cultivation

The substrates (WS and CL) were soaked in water overnight, and then placed in a sieve for the drainage of excess moisture until it reached 60 -70% moisture content (Mensah *et al.*, 2018). For carrying out sterilization process, substrate (1 kg wet weight) was autoclaved at 121^{o}C for 1 hour in autoclavable polypropylene bags (Oliveira do carmo *et al.*, 2021). The bags were inoculated with 2% spawn, under aseptic conditions (Rama *et al.*, 2020) and kept in a room at 25-30°C and relative humidity 70-75% in the dark for spawn run. Fully colonized the substrate bags were exposed to diffused light and the plastic bags were taken off from the substrate. For the initiation of pin heads and subsequent growth of fruiting bodies substrate was placed in a growth environment with a temperature of 15-18°C (Sharma *et al.*, 2013).

During the formation of the pinhead and fruit body, humidity was kept between 80-90% by misting water three times a day over the walls, the floor, and the substrate bags surroundings (Baysal *et al.*, 2003). Mushroom fruiting bodies were harvested on maturity for further analysis. The data concerning mycelia growth, pin head and fruit body formation of

Pluerotus ostreatus was observed and recorded. Immediately following harvest, the fresh weight of mushrooms was recorded.

Biological efficiency (BE) was calculated as given by Liang *et al.* (2019)

$$BE = \frac{\text{Fresh weight of mushrooms}}{\text{Dry weight of substrate}} \times 100$$

Proximate analysis

The proximate contents of air-dried mushroom fruit bodies were determined by the Association of Official Analytical Chemists (AOAC) method. The crude fibre (dilute acid and alkali hydrolysis), ash (muffle furnace ashing), crude protein was calculated from Kjeldahl total nitrogen using the conversion factor 4.38 (% Protein = N× 4.38) (AOAC, 2002; Nakalembe *et al.*, 2015), crude fat (soxhlet method) (AOAC, 2003; Siyame *et al.*, 2021), total carbohydrate content by difference (AOAC, 1996; Oliveira do Carmo *et al.*, 2021) as following;

Crude fiber determination: 2 g of defatted sample was heated with 1.25% H_2SO_4 for 30 minutes, rinsed with hot distilled water to remove acid, while being filtered. The process was repeated by heating with 1.25% NaOH solution, washing it with hot distilled water to remove the alkali, while being filtered. The filtrate was collected in a clean crucible, dried in the oven, and fired in a muffle furnace at 550°C for two hours.

$$\text{Crude fiber (\%)} = \frac{\text{Weight of crucible with fiber} - \text{Weight of empty crucible}}{\text{Weight of sample}} \times 100$$

***Ash content determination*:** For the determination of ash content, 2 g of mushroom sample was taken in a pre-dried, weighted crucible. The sample was heated to 550°C in a muffle furnace for three hours and given time to cool in desiccator before being weighed. The ash-filled crucible's final weight was measured.

$$\text{Ash (\%)} = \frac{\text{Weight of crucible with ash} - \text{Weight of empty crucible}}{\text{Weight of sample}} \times 100$$

***Crude Fat content determination*:** 3 g of mushroom samples were extracted using petroleum ether in the Soxhlet apparatus extraction tube for 6 hours. The extracts were dried in an oven at 105°C for 30 minutes and the weight was recorded after cooling in a desiccator.

$$\text{Crude fat (\%)} = \frac{\text{Weight of flask with sample} - \text{Weight of empty flask}}{\text{Weight of sample}} \times 100$$

***Crude protein determination*:** Crude protein was determined by Kjeldahl method (Bremner, 1960). The sample (0.5 g) was digested in a Kjeldahl flask with 10 ml of concentrated H2SO4 and 5 g of catalyst (K_2SO_4 and $CuSO_4$) at 420°C for 2-3 hours. It was then steam-distilled, and the resulting distillate was titrated against a 0.1N HCL solution until it reached the endpoint. Additionally, a reagent blank assessment was made.

Protein(%)=(14.01×0.1 N×(TV-BV)×100×4.38)/(W×1000)

Where,

14.01 = Nitrogen's Molecular weight

0.1 N= Normality of titration solution

TV = Volume (mL) of 0.1 N HCL used for titrant

BV = Volume (mL) of 0.1 N HCL used for blank

W = Sample weight (g)

4.38= the protein-nitrogen conversion factor

***Total carbohydrate (%) content*:** Total carbohydrate content was computed by deducting the percentage of crude fibre, crude protein, crude fat and ash from 100%

Statistical analysis

For the evaluation of mushroom production, the experiment was run with six replications. Five samples were examined for the nutritional analysis of mushrooms, and each test was carried out three times. The findings were presented as mean values and standard deviation (SD). The statistical software SPSS 16.0 was used to analyze the data collected for this study using the Student's t-test at the 5% level. Data on mushroom production (spawn run, pin head formation, fruit body formation (days)), total yield (grams), biological efficiency (%) and nutritional composition (crude fat, crude protein, ash, crude fibre and total carbohydrates (%)) were analyzed in order to determine the significance of the differences between two substrates (CL and WS).

Mitigation of air pollution through mushroom cultivation

For the purpose of air pollution mitigation through mushroom cultivation, it is important to have the estimates of emissions that are or may be produced by burning the leaf litter of *Platanus orientalis*. Since there are no studies as far our knowledge that have estimated the mitigation of air pollution caused by leaf litter burning through mushroom cultivation, this study is first of its kind and thus a theoretical approach was applied to estimate the total emissions from leaf litter. A reference value of leaf litter was taken from Gonzalez *et al.* (2022) to estimate the per tree leaf litter fall. The study was carried on *Platanus hispanica* (a plant with similar physiological characteristics as that of *Platanus orientalis*) with total leaf litter estimated in the range of 2.5 to 2.66 Mg/ha/yr. Using this reference value in the sampling area, the per tree leaf litter fall was estimated using following equation:

$$TLF_{(kg/tree)} = \frac{l_{kg/ha} \times A_{ha}}{N}$$

Where, $TLF_{(kg/tree)}$ is total annual leaf fall per tree; $l_{(kg/ha)}$ is leaf fall per hectare; A_{ha} is total area in hectares and N is total number of trees present in the study area (A).

RESULTS

Substrate analysis

The pH was found to be 6.4 for WS and 6.2 for CL. The organic carbon and total nitrogen were 44.07 % and 0.88 % for CL respectively with C:N ratio of 50.12. While as the organic carbon and total nitrogen were 48.23 % and 0.53 % for WS, respectively with C:N ratio of 91.19 (Table 1).

Growth, yield and biological efficiency

Time required by each phase (mycelia growth, pin head and fruit body formation) to complete separately is given in Fig. 2 (a) and Fig. 3. Total mushroom yield and biological efficiency of the two flushes with six replicates is shown in Fig. 2 (b and c). The mycelium colonization in wheat straw substrate took about 23 days while in Chinar leaves, it took about 26 days. On an average pinheads began to appear after 3 days

Table 1. Chemical properties of substrate

Substrate	pH	Carbon (%)	Nitrogen (%)	C:N ratio
Wheat straw	6.44±0.12	48.23±0.90	0.53±0.03	91.19±5.55
Chinar leaves	6.22±0.03	44.07±0.39	0.88±0.03	50.12±1.98

All values are calculated on dry weight basis and are mean ± (standard deviation) SD (*n* =3)

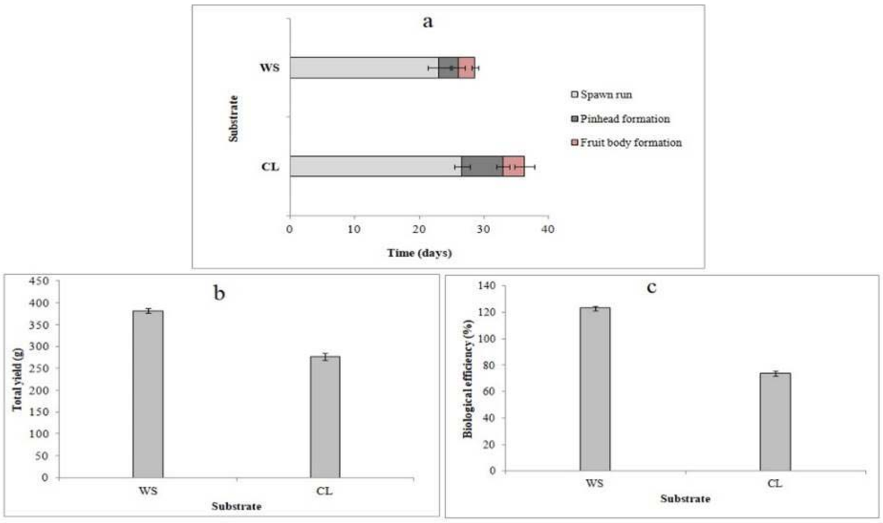

Fig. 2. (a) Time frame for completion of spawn running, pinhead development and fruit body development of *Pleurotus ostreatus* (n=6), (b) Total yield of *Pleurotus ostreatus* on wheat straw and chinar leaves g/kg , (c) Biological efficiency of *Pleurotus ostreatus* on wheat straw and chinar leaves

Fig. 3. (a) Mycelium growth visible in wheat straw. (b) Mycelium growth visible in chinar leaves. (c) Young growing mushroom in wheat straw. (d) Young growing mushrooms in chinar leaves

and 6 days once the bags were opened after spawn run completion i.e., 26th and 33rd days in case of WS and CL, respectively. Pinheads developed in fruit bodies after 2.6 days and 3 days i.e. on the 28.6th day in WS and 36th day in CL, respectively.

Mushrooms yield were taken for two flushes during the cultivation cycle. For both substrates, the yield was considerably higher in the first flush. WS produced the highest mean yield of 381.95 ±5.97g/kg with a biological efficiency of 123.2 ± 1.93% and CL produced the mean yield of 276.42±7.4 g/kg with a biological efficiency of 73.7 ± 1.97%.

Proximate analysis

Crude fiber, crude fat, ash, total carbohydrates and crude protein content of mushrooms cultivated on CL and WS are shown in Table 2. The proximate composition of mushrooms was affected by the two substrates.

The *Pleurotus ostreatus* produced the most crude fibre (18.88±1.6%) when grown on CL, than on WS (15.24±0.63%) and the crude fat content was 3.12±0.58% on CL and 2.73±0.24% on WS (Table 2). Similarly, the ash content was found to be 9.22±1.06% in mushroom fruit bodies cultivated on CL as compared to 6.77±0.40% in mushrooms cultivated on WS However, the mushroom carbohydrate content was 43.72±2.46% and 63.0±1.2% on CL and WS, respectively (Table 2). The protein content of *Pleurotus ostreatus* was higher (25.03±1.12%) when grown on CL than when grown on WS (12.17±1%). Total yield of *P. ostreatus*, cultivated on CL was found to decrease significantly (p<0.05) over control (Fig. 2b). Nutrient analysis of mushrooms, cultivated on CL, revealed a significant increase in crude fibre, crude fat, ash content and crude protein over control (p<0.05) (Table 2). While total carbohydrates was found to decrease significantly in compared to control (p<0.05).

Table 3 presents a comparative analysis of the nutrient composition of *P. ostreatus* mushrooms cultivated on different wastes in the current study. Previous studies also investigated the proximate composition of *P. ostreatus* mushroom grown on different substrate such as bamboo leaves, corn cobs, hardwood sawdust, leftover cotton seeds, soybean straw, and sugarcane bagasse (Table 3). The fat content of the mushrooms cultivated on CL in the current study was determined to be 3.12%, which is similar to those of the studies included in the table. Regarding *Pleurotus ostreatus* cultivated on CL, the total carbohydrate content was similar to that of mushrooms grown on hardwood sawdust and cottonseed waste. The crude fiber content of the mushroom fruit bodies grown on CL in our study was 18.88%, which was greater than in most other studies. Additionally, it was discovered that the ash content matched that of *P. ostreatus* grown on maize cob, hard wood sawdust, and softwood sawdust.

Table 2. Proximate composition of mushroom fruit bodies cultivated on wheat straw and chinar leaves (%)

Substrate	**Crude fiber (%)**		**Crude fat (%)**		**Ash (%)**		**Total carbohydrates (%)**		**Crude protein (%)**	
	Mean[1]±SD	**SEM**	**Mean[1]±SD**	**SEM**	**Mean[1]±SD**	**SEM**	**Mean[1]±SD**	**SEM**	**Mean[1]±SD**	**SEM**
Wheat straw	15.24±0.63	0.16	2.73±0.24	0.06	6.77±0.40	0.11	63.0±1.20	0.33	12.17±1.00	0.26
Chinar leaves	18.88±1.60	0.41	3.12±0.58	0.15	9.22±1.06	0.28	43.73±2.47	0.64	25.03±1.12	0.29
***p*-value**	<0.05		<0.05		<0.05		<0.05		<0.05	

[1]All values are calculated on dry weight basis, mean ± SD (*n*=15)

Table 3. Nutritional composition of *P. ostreatus* grown on different organic substrates

Substrate	Crude Protein (%)	Crude Fat (%)	Total Carbohydrate (%)	Crude Fiber (%)	Ash (%)	References
Chinar leaf litter	25.03	3.12	43.72	18.88	9.22	Current study
Banana straw	16.9	5.97	47.0	9.41	5.58	Bonatti *et al.* (2004)
Rice straw	13.1	6.32	47.6	9.86	6.13	
Soybean straw	24.66	2.82	53.20	7.15	6.70	Sopanrao *et al.* (2010)
Rice straw	23.40	2.80	55.33	7.70	6.30	
Wheat straw	21.00	2.60	55.20	7.35	6.35	
Bamboo leaves	31.9	3.3	46.6	6.1	6.3	Yehia (2012)
Sawdust	19.52	1.32	51.26	22.00	5.90	Hoa *et al.* (2015)
Sugarcane bagasse	27.13	2.00	34.94	29.25	6.68	
Corncob	29.70	2.67	30.78	29.75	7.10	
Oat straw	14.7	1.53	78.1	NA	5.69	Fernandes *et al.* (2015)
Softwood sawdust	17.68	1.81	52.04	10.66	9.59	Ogundele *et al.* (2017)
Hardwood sawdust	26.67	1.72	41.57	11.05	9.83	
Cottonseed waste	25.9	2.18	42.14	10.41	10.91	Tolera *et al.* (2017)
Cassava peel only	2.73	0.15	NA	1.69	0.79	Onyeka *et al.* (2018)
Rubber tree sawdust	2.90	NA	7.67	6.19	0.66	Zakil *et al.* (2019)
Sawdust	1.75	0.5	15.68	2.67	8.21	Olujobi *et al.* (2021)
Coconut-Husk	0.88	0.88	22.66	7	7.1	
Maize-cob	0.88	0.75	14.22	5	9.81	
Ground Banana leaves	8.43	2.87	8.01	4.61	2.12	Aguchem *et al.* (2021)
Fibre rejects	22.3-25.2	3-3.5	57.4-61.9	8.1-9.8	7.1-8.6	Grimm *et al.* (2021)

Emission reduction through mushroom cultivation – A theoretical approach

Leaf litter waste used for mushroom cultivation can help reduce carbon and other emissions. The results revealed that approximately 50 kgs of leaf litter is produced by a single fully mature chinar tree annually depending on the various factors like age and size, that if burned may produce a large quantity of particulates and greenhouse gasses. The emission factors (g/kg) from leaf litter burning are given in Table 4.

Table 4. Emission factors (g/kg) from literature and pollution generation through leaf litter burning (g/kg)

Pollutant	Emission factor (EF) (g/kg)	Study
$PM_{2.5}$	28.61 ± 4.90 (smoldering) 10.91 ± 3.32 (blazing) Avg: 19.76	Guo *et al.* 2018
CO	277	Nugraha *et al.* 2023
CO2	1152.5 ±258	Zhang *et al.* 2012

DISCUSSIONS

Evaluation of substrate characteristics is essential, as these factors directly influence mycelial colonization and fruiting development. Among them, pH plays a critical role in fungal growth and metabolic activity (Hoa *et al.*, 2015). In the present study, substrate pH ranged from 6.22 to 6.44, which falls within the acceptable range reported for *Pleurotus ostreatus* cultivation (5.74–8.03) on agricultural wastes mixed with rubber tree sawdust (Zakil *et al.*, 2022). The carbon-to-nitrogen (C:N) ratio is another crucial parameter affecting oyster mushroom production, as accessible nitrogen is required for mycelial growth and fruiting body formation (Miles and Chang, 2004). Since carbon is fundamental for cellular development, an imbalanced or low C:N ratio may negatively affect early mycelial growth (Cueva *et al.*, 2017). In this study, the C:N ratio ranged from 50.12 to 91.19, with the highest value recorded in wheat straw (WS). Previous reports suggest that an optimal C:N ratio for oyster mushroom cultivation lies between 32 and 150 (Miles and Chang, 2004), indicating that both substrates were suitable for growth.

Spawn run was monitored until complete colonization of the substrate bags. Full mycelial colonization occurred within 23–26 days in both substrates, which is comparable to findings by Tavarwisa *et al.* (2021), who reported spawn run completion within 22.8–25.8 days. Similar results were observed by Tahir *et al.* (2021), where 100% colonization occurred within 26–35 days on *Ficus religiosa* leaves mixed with agricultural wastes. Environmental conditions such as temperature, humidity, CO, concentration, and substrate C:N ratio significantly influence colonization duration (Muswati *et al.*, 2021).

Pinhead formation, the second stage of mushroom development, occurred 3 days after full colonization in WS and 6 days in chinar leaves (CL). Comparable pinhead initiation periods ranging from 2.53 to 6 days have been reported in earlier studies (Fufa *et al.*, 2021; Shah *et al.*, 2004; Mondal *et al.*, 2010; Akhter *et al.*, 2022). Fruiting body development followed within 2.6 days (WS) and 3 days (CL), consistent with previous findings of 2–4 days after pinhead formation (Zakil *et al.*, 2019; Tekeste *et al.*, 2020). Variations in fruiting time may be attributed to differences in substrate composition and physiological requirements (Girmay *et al.*, 2016), as well as environmental factors such as temperature and relative humidity (Dunkwal and Jood, 2009).

Biological efficiency (BE) was positively correlated with yield. Both substrates produced higher yields during the first flush compared to the second, likely due to greater nutrient availability during early growth stages (Agba, 2021). Wheat straw recorded a significantly higher total yield (381.95±5.97 g/kg) and BE (123.2%) compared to chinar leaves (276.42±7.4 g/kg; BE 73.7%). The superior performance of WS may be attributed to more readily available sugars in cellulosic substrates (Tavarwisa *et al.*, 2021). The BE observed for WS aligns with previous reports of 97% and 105% (Abou Fayssal *et al.*, 2021). In contrast, BE values reported for leaf-based substrates vary widely (17.65–72.22%) (Aguilar-Rivera *et al.*, 2017). The BE obtained for CL in this study is comparable to banana leaf substrates (75.91%) (Menon *et al.*, 2021). Variations in BE may depend on spawn rate, fungal strain, and supplementation practices (Mandeel *et al.*, 2005).

Nutritional analysis revealed that mushrooms cultivated on CL had higher crude protein, fat, fiber, and ash contents, whereas carbohydrate levels were higher in WS-grown mushrooms. Crude protein content was significantly higher in CL-grown mushrooms (25.03±1.12%) compared to WS (12.17±1%). These findings are consistent with reports of 27.36% protein in mushrooms grown on banana leaves (Reddy *et al.*, 2000). Protein levels reported for WS substrates (14.41–14.96%) (Aguilar-Rivera and Jess-Merales, 2010; Telang *et al.*, 2010) are comparable to the present results. Higher protein content in CL-grown mushrooms may be attributed to nitrogen availability in the substrate (Hoa *et al.*, 2015; Gupta *et al.*, 2013).

Fat content values were consistent with earlier findings of 2.2% in WS-grown mushrooms (Aguilar-Rivera and Jess-Merales, 2010) and 3.12% in bamboo leaf substrates (Yehia, 2012). Crude fiber content was 15.24±0.63% (WS) and 18.88±1.6% (CL), aligning with previously reported values for various lignocellulosic substrates (Telang *et al.*, 2010; Koutrotsios *et al.*, 2014). Carbohydrate content, though the most abundant nutrient, was lower than values reported by Koutrotsios *et al.* (2014) for WS but comparable to mushrooms grown on bamboo leaves (Yehia, 2012). Ash content in WS-grown mushrooms (6.35%) was similar to earlier findings (Sopanrao *et al.*, 2010), while CL-grown mushrooms (9.22±1.06%) were comparable to those cultivated on date palm leaves and olive mill by-products (Koutrotsios *et al.*, 2014).

Beyond production and nutritional evaluation, this study also assessed the potential of mushroom cultivation as a strategy for air pollution mitigation. Biomass burning is a major global source of carbonaceous aerosols and gaseous pollutants (Wang *et al.*, 2020). On average, burning one kilogram of leaf litter releases approximately 19.76 g of PM2.5 (Guo *et al.*, 2018), 277 g of CO (Nugraha *et al.*, 2023), and 1152.5 g of CO, (Zhang *et al.*, 2012). Redirecting leaf litter toward mushroom cultivation could therefore significantly reduce these emissions.

In addition to environmental benefits, oyster mushroom cultivation offers economic advantages. The market value of fresh oyster mushrooms ranges from 75–250 INR/kg, while dried mushrooms fetch 350–1000 INR/kg (Thakur, 2020; Pipariya *et al.*, 2023). Thus, replacing leaf burning with mushroom cultivation can simultaneously address waste management, air pollution, unemployment, and nutritional security. Overall, this study demonstrates that chinar leaf litter can serve as a sustainable substrate for *Pleurotus ostreatus*, contributing to environmental conservation and socio-economic development.

CONCLUSION

Biomass burning of horticultural and plantation waste is a major contributor to air pollution and associated health risks, highlighting the urgent need for sustainable alternatives. This study is the first to investigate the use of chinar leaves as a substrate for *Pleurotus ostreatus* cultivation, offering an innovative approach to waste valorization and environmental protection. The results demonstrate that chinar leaf litter is a suitable substrate, achieving complete mycelial colonization within 26 days, pinhead formation by day 33, and full fruiting by day 36. Mushrooms cultivated on this substrate showed high nutritional value, containing 25.03±1.12% crude protein and 18.55±1.27% crude fiber. With a biological efficiency of 73.7%, utilizing chinar leaves for mushroom production could prevent the release of approximately 19.76 g PM2.5, 277 g CO, and 1152.5 g CO, per kilogram of leaf litter otherwise burned. Thus, mushroom cultivation presents an effective strategy for air pollution mitigation and sustainable solid waste management by converting organic waste into a nutritionally valuable food resource.

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REFERENCES

1. Abou Fayssal, S, Z El Sebaaly, M.A. Alsanad, R. Najjar, M. Böhme, M.H. Yordanova and Y.N. Sassine. 2021. Combined effect of olive pruning residues and spent coffee grounds on *Pleurotus ostreatus* production, composition, and nutritional value. *PLoS One* **16(9):**

e0255794. https://doi.org/10.1371/journal.pone.0255794.

2. Agba, MIO, A.A. Markson, J.O. Oni and G.A. Bassey. 2021. Growth and yield impact of Oyster mushroom *Pleurotus ostreatus* (Jacq P. Kumm) cultivated on different agricultural wastes. *J Biosci Agri Res* **27(01):** 2225–2233. https://doi.org/10.18801/jbar.270121.272.

3. Aguchem, R. N., C.C. Chibuogwu, B.O. Okolo, U. Oyeagu, V.E. Etim, E.N. Anaele and O.U. Njoku. 2021. Nutrient and Antinutrient Composition of *Pleurotus ostreatus* Grown on Different Substrates. *Biology and Life Sciences Forum* **11(1):** 69. https://doi.org/10.3390/IECPS2021-11955.

4. Aguilar-Rivera, N and J de Jesus-Merales. 2010. Edible mushroom *Pleurotus ostreatus* production on cellulosic biomass of sugar cane. *Sugar Tech* **12(2):** 176–178. https://doi.org/10.1007/s12355-010-0034-4.

5. Aguilar Rivera, N, R.C. Llarena Hernandez, Christian Michel Cuello *et al.* 2017. Competitive edible mushroom production from nonconventional waste biomass. *Future Foods* **1**. https://dx.doi.org/10.5772/intechopen.69071.

6. Akhter, M, R.F. Halawani, F.A. Aloufi, M.A. Taleb, S. Akter and S. Mahmood. 2022. Utilization of Agro-Industrial Wastes for the Production of Quality Oyster Mushrooms. *Sustainability* **14(2):** 994. https://doi.org/10.3390/su14020994.

7. Antunes, F, S. Marcal, O. Taofiq, A. MMB Morais, A.C. Freitas, I. CFR Ferreira and M. Pintado. 2020.Valorization of mushroom by-products as a source of value-added compounds and potential applications. *Molecules* **25(11):** 2672. https://doi.org/10.3390/molecules25112672.

8. AOAC.2002. *Official Methods of Analysis*, 17th edn. Association of Official Analytical Chemist, Maryland.

9. AOAC.2003. *Official Methods of Analysis of AOAC International*, 2nd Revision, AOAC International Gaithersburg, Maryland.

10. AOAC (Ed.).1996. *Official Methods of Analysis of the Association of Official Analytical Chemists*, Sixteenth ed. AOAC International, Gaithersburg, Maryland.

11. Baysal, E, H. Peker, M.K. Yalinkilic and A. Temiz. 2003. Cultivation of oyster mushroom on waste paper with some added supplementary materials. *Biores Technol* **89(1):** 95–97. https://doi.org/10.1016/s0960-8524(03)00028-2.

12. Bhat M.A., S.A. Romshoo and G. Beig. 2017. Aerosol black carbon at an urban site-Srinagar, Northwestern Himalaya, India: Seasonality, sources, meteorology and radiative forcing. *Atmos Environ* **165:** 336–348. https://doi.org/10.1016/j.atmosenv.2017.07.004.

13. Bonatti, M, P. Karnopp, H.M. Soares and S.A. Furlan. 2004. Evaluation of *Pleurotus ostreatus* and *Pleurotus sajor-caju* nutritional characteristics when cultivated in different lignocellulosic wastes. *Food chem* **88(3):** 425–428. https://doi.org/10.1016/j.foodchem.2004.01.050.

14. Boulanger, N, A.V. Talyzin, S. Xiong, M. Hultberg and A. Grimm. 2024. High surface area activated carbon prepared from wood-based spent mushroom substrate for supercapacitors and water treatment. *Colloids and Surfaces A: Physicochemical and Engineering Aspects* **680:** 132684. https://doi.org/10.1016/j.colsurfa.2023.132684.

15. Bremner, J.M. 1960. Determination of nitrogen in soil by the Kjeldahl method. *J Agri Sci* **55(1):** 11–33. https://doi.org/10.1017/S0021859600021572 .

16. Cueva, M.B., A.V. Hernandez and Z. Nino-Ruiz. 2017. Influence of C/N ratio on productivity and

the protein contents of *Pleurotus ostreatus* grown in differents residue mixtures. *Revista De La Facultad De Ciencias Agrarias* **49(2):** 331–344.

17. Divakar, M and M. Prasanthrajan. 2019. Composting of tree leaf litter using fruit based effective microorganisms. *J. Pharmacognosy Phytochem* **8(4):** 2663–2667.

18. Doroski, A, A. Klaus, A. Rezek Jambrak and I. Djekic.2022. Food Waste Originated Material as an Alternative Substrate Used for the Cultivation of Oyster Mushroom (*Pleurotus ostreatus*): A Review. *Sustainability* **14(19):** 12509. https://doi.org/10.3390/su141912509 .

19. Dubey, D., B. Dhakal, K. Dhami, P. Sapkota, M. Rana, N. Poudel, N. Sharma and L. Aryal. 2019. Comparative study on effect of different substrates on yield performance of oyster mushroom. *Global Journal of Biology, Agriculture, Health Sciences* **8(1):** 1–7.

20. Dunkwal, V and S. Jood. 2009. Effect of substrates on nutrient composition of Oyster mushroom (*Pleurotus sajor caju*). *J Dairy Foods Home Sci* **28:** 132–136.

21. Fernandes, A, L. Barros, A. Martins, P. Herbert and I.C. Ferreira. 2015. Nutritional characterisation of *Pleurotus ostreatus* (Jacq. ex Fr.) P. Kumm. produced using paper scraps as substrate. *Food Chem* **169:** 396–400. https://doi.org/10.1016/j.foodchem.2014.08.027.

22. Fufa, B.K., B.A. Tadesse and M.M. Tulu. 2021. Cultivation of *Pleurotus ostreatus* on Agricultural Wastes and Their Combination. *Int J Agrono*: https://doi.org/10.1155/2021/1465597.

23. Girmay, Z, W. Gorems, G. Birhanu and S. Zewdie. 2016. Growth and yield performance of Pleurotus ostreatus (Jacq. Fr.) Kumm (oyster mushroom) on different substrates. *AMB Express* **6(1):** 1–7. https://doi.org/10.1186/s13568-016-0265-1.

24. Gonzalez, I, H. Sixto, R. Rodriguez-Soalleiro, I. Canellas, A. Fuertes and N. Oliveira. 2022. How can leaf-litter from different species growing in short rotation coppice contribute to the soil nutrient pool?. *Forest Ecology and Management* **520:** 120405. https://doi.org/10.1016/j.foreco.2022.120405.

25. Grimm, A, G.S. dos Reis, S.G. Khokarale, S. Ekman, E.C. Lima, S. Xiong and M.Hultberg. 2023. Shiitake spent mushroom substrate as a sustainable feedstock for developing highly efficient nitrogen-doped biochars for treatment of dye-contaminated water. *Journal of Water Process Engineering* **56:** 104435. https://doi.org/10.1016/j.jwpe.2023.104435

26. Grimm, A, L. Eilertsen, F. Chen, R. Huang, L. Atterhem and S. Xiong.2021. Cultivation of *Pleurotus ostreatus* mushroom on substrates made of cellulose fibre rejects: product quality and spent substrate fuel properties. *Waste and Biomass Valorization* **12:** 4331–4340. https://doi.org/10.1007/s12649-020-01311-y.

27. Grimm, D and H.A.B. Wosten. 2018. Mushroom cultivation in the circular economy. *Applied Microbiology and Biotechnol* **102:** 7795–7803. https://doi.org/10.1007/s00253-018-9226-8.

28. Guo, F, Y. Ju, G. Wang, E. C. Alvarado, X. Yang, Y. Ma and A. Liu. 2018. Inorganic chemical composition of PM2. 5 emissions from the combustion of six main tree species in subtropical China. *Atmospheric Environment* **189:** 107–115. https://doi.org/10.1016/j.atmosenv.2018.06.044.

29. Gupta, A, S. Sharma, S. Saha and S. Walia.2013.Yield and nutritional content of *Pleurotus sajor caju* on wheat straw supplemented with raw and detoxified mahua cake. *Food Chem* **141(4):** 4231–4239. https://doi.org/10.1016/J.foodchem.2013.06.126.

30. Gupta, P.. K. and P. Gupta. 1999. *Soil, plant, water and fertilizer analysis*, Agro Botanica.

31. Haider, S, S. Nazreen, M.M. Alam, H. Hamid and M.S. Alam. 2012.Anti-inflammatory and anti-nociceptive activities of *Platanus orientalis* Linn. and its ulcerogenic risk evaluation. *Journal of Ethnopharmacology* **143(1):** 236–240. https://doi.org/10.1016/j.jep.2012.06.029.

32. Hoa, H.T., C.L. Wang and C.H. Wang. 2015. The Effects of Different Substrates on the Growth, Yield, and Nutritional Composition of Two Oyster Mushrooms (*Pleurotus ostreatus* and *Pleurotus cystidiosus*). *Mycobiology* **43(4):** 423. https://doi.org/10.5941/MYCO.2015.43.4.423.

33. Islam, M.A., P.A. Khan and T. Arjumand. 2021. Traditional use of Chinar (*Platanus orientalis* L.) Leaf Litter for Charcoal Making: A Case Study of Kashmir Himalaya. *Asian J Agric Ext Economics Sociol* **39(12):** 241–247. https://doi.org/10.9734/ajaees/2021/v39i1230827.

34. Jackson, M.L. 1958. *Soil Chemical Analysis Englewood Cliffs*. NT Prentice Hall Inc.

35. Jehangir, A., N.A. Dar, A.R. Yousuf and A.H. Sofi. 2011. Air quality at Sonamarg-a tourist hill station in Kashmir valley, India. *Journal of Experimental Sciences* **2(6):** 18–22.

36. Koutrotsios, G, K.C. Mountzouris, I. Chatzipavlidis and G.I. Zervakis. 2014. Bioconversion of lignocellulosic residues by Agrocybe cylindracea and *Pleurotus ostreatus* mushroom fungi – Assessment of their effect on the final product and spent substrate properties. *Food Chem* **161:** 127–135. https://doi.org/10.1016/J.foodchem.2014.03.121.

37. Kulshreshtha, S, N. Mathur, P. Bhatnagar and S. Kulshreshtha. 2013. Cultivation of *Pleurotus citrinopileatus* on handmade paper and cardboard industrial wastes. Ind. *Crops Prod* **41:** 340–346. https://doi.org/10.1016/j.indcrop.2012.04.053.

38. Liang, C.H., Wu, C.Y., Lu, P.L., Kuo, Y.C., Liang, Z.C. 2019. Biological efficiency and nutritional value of the culinary-medicinal mushroom *Auricularia* cultivated on a sawdust basal substrate supplement with different proportions of grass plants. *Saudi J Biol Sci* **26(2):** 263–269. https://doi.org/10.1016/j.sjbs.2016.10.017.

39. Liu, D., Yu-Qing Chen, Xiao-Wei Xiao, Ru-Ting Zhong, Cheng-Feng Yang, Bin Liu, and Chao Zhao. 2019. Nutrient Properties and Nuclear Magnetic Resonance-Based Metabonomic Analysis of Macrofungi. *Foods* **8(9):** https://doi.org/10.3390/foods8090397.

40. Lu, H., H. Lou, J. Hu, Z. Liu and Q. Chen. 2020. Macrofungi: A review of cultivation strategies, bioactivity, and application of mushrooms. Comp. Rev. *Food Sci Food Safety* **19(5):** 2333–2356. https://doi.org/10.1111/1541-4337.12602.

41. Mandeel, Q.A., A.A. Al-Laith and S.A. Mohamed. 2005.Cultivation of oyster mushrooms (*Pleurotus* spp.) on various lignocellulosic wastes. *World J Microboi Biotechol* **21(4):** 601–607. https://doi.org/10.1007/s11274-004-3494-4.

42. Menon, S, S. Ayesha and K. Pavithra. 2021. Growth and nutritional indices of oyster mushroom (pleurotus ostreatus) on different substrates. *Current Trends in Biotechnology and Pharmacy* **15(5):** 365–372. https://doi.org/10.5530/ctbp.2021.3s.27 .

43. Miles, P.G. and S.T. Chang. 2004.Mushrooms: *Cultivation, Nutritional Value, Medicinal Effect, and Environmental Impact (2nd ed.)*. CRC Press. https://doi.org/10.1201/9780203492086.

44. Mondal, S.R., J. Rehana, M.S. Noman, S.K and Adhikary. 2010. Comparative study on growth and yield performance of oyster mushroom (*Pleurotus florida*) on different substrates. *J Bang Agricul Uni* **8(2):** 213–220. https://doi.org/10.3329/jbau.v8i2.7928.

45. Muswati, C, K. Simango, L. Tapfumaneyi, M. Mutetwa and W. Ngezimana. 2021.The Effects of Different Substrate Combinations on Growth and Yield of Oyster Mushroom (*Pleurotus ostreatus*). *Int J Agrono* 2021. https://doi.org/10.1155/2021/9962285.

46. Nakalembe, I, J.D. Kabasa and D. Olila. 2015.Comparative nutrient composition of selected wild edible mushrooms from two agro-ecological zones, Uganda. *Springer Plus* **4(1):** 1–15. https://doi.org/10.1186/s40064-015-1188-z.

47. Mensah Narh ,D.L., P. Addo, M. Dzomeku and M. Obodai. 2018. Bioprospecting of powdered pineapple rind as an organic supplement of composted sawdust for *Pleurotus ostreatus* mushroom cultivation. *Food Science and Nutrition* **6(2):** 280–286. https://doi.org/10.1002/fsn3.551.

48. Niazi, A.R. and A. Ghafoor. 2021. Different ways to exploit mushrooms: A review. *All life* **14(1):** 450–460. https://doi.org/10.1080/26895293.2021.1919570.

49. Niknam, S, A. Rastegari, M. Bozorgi, Y. Vahedi-Mazdabadi, M. Saeedi and T. Akbarzadeh. 2021. *In vivo* evaluation of wound healing properties of *Platanus orientalis* L. *Pharmaceutical Sciences* **28(2):** 275–284. https://doi.org/10.34172/PS.2021.50.

50. Nugraha, M.G., E.D. Mozasurya, M. Hidayat and H. Saptoadi. 2023. Evaluation of combustion characteristics in biomass residues open burning. *Materials Today* **87:** 45–50. https://doi.org/10.1016/j.matpr.2023.02.098.

51. Ogundele, G.F., S.W. Salawu, I.A. Abdulraheem and O.P. Bamidele. 2017. Nutritional composition of oyster mushroom (*Pleurotus ostreatus*) grown on softwood (*Daniella oliveri*) sawdust and hardwood (*Anogeissus leiocarpus*) sawdust. *Br J Appl Sci Technol* **20(1):** 1–7. https://doi.org/10.9734/BJAST/2017/28160.

52. Oliveira do Carmo, C, R. Mota da Silva, M. de Souza Rodrigues and A.C. Fermino Soares. 2021. Bioconversion of sisal agro-industrial waste into high protein oyster mushrooms. *Biores Technol Reports* **14:** 100657. https://doi.org/10.1016/J.biteb.2021.100657.

53. Olujobi, O.J. and E.A. Adeniji. 2021. Evaluation of Yield and Nutritional Composition of Oyster Mushroom (*Pleurotus ostreatus*) Grown on Different Substrates. *Nig J Basic Appl Sci* **29(1):** 63–70. https://doi.org/10.4314/njbas.v29i1.8.

54. Onyeka, E.U., E. Udeogu, C. Umelo and M.A. Okehie. 2018. Effect of substrate media on growth, yield and nutritional composition of domestically grown oyster mushroom (*Pleurotus ostreatus*). *Afr J Plant Sci* **12(7):** 141–147. https://doi.org/10.5897/ajps2016.1445.

55. Pipariya D, A. Nasit and S. Mistry. 2023. Low-cost oyster mushroom house preparation technology. *Krishi science – eMagazine for Agricultural Sciences* **4:** 2583–4150.

56. Raman, J, K.Y. Jang and Y.L. Oh .2020. Cultivation and Nutritional Value of Prominent *Pleurotus* spp.: An Overview. *Mycobiology* **49(1):** 1–14. https://doi.org/10.1080/12298093.2020.1835142.

57. Reddy, G.V., I.L. Kothari, A. Mishra and C.R. Patel.2000. Biotransformation of banana waste into protein by *Pleurotus sajor-caju*. *Indian J Exp Bio* **38(8):** 845–848.

58. Romshoo, S.A., M.A. Bhat and G. Beig.2021. Particulate pollution over an urban Himalayan site: Temporal variability, impact of meteorology and potential source regions. *Science of the Total Environment* **799:** 149364. https://doi.org/10.1016/j.scitotenv.2021.149364.

59. Sanchez, C. 2010. Cultivation of *Pleurotus ostreatus* and other edible mushrooms. *Applied Micro Biotech* **85(5):** 1321–1337. https://doi.org/10.1007/s00253-009-2343-7.

60. Shah, ZA, M. Ashraf and M. Ishtiaq .2004. Comparative study on cultivation and yield performance of oyster mushroom (*Pleurotus ostreatus*) on different substrates (wheat straw, leaves, saw dust). *Pakistan J Nutrition* **3(3):** 158–160. https://doi.org/10.3923/pjn.2004.158.160.

61. Sharma, S, R.K.P. Yadav and C.P. Pokhrel .2013. Growth and yield of oyster mushroom (*Pleurotus ostreatus*) on different substrates. *J New Bio Rep* **2(1):** 03–08.

62. Sheikh, T, Z. Baba, R. Bhat, W. Raja, M.A. Bhat, A. ul Haq and M. Nazir .2019. Nitrogen Recovery and Reproductive Performance of Eisenia fetida through Composting of Biowastes under Himalayan Ecosystem. *Int J Curr Microbiol App Sci* **8(12):** 2812–2820. https://doi.org/10.20546/ijcmas.2019.812.329.

63. Siyame, P, N. Kassim and E. Makule. 2021. Effectiveness and suitability of oyster mushroom in improving the nutritional value of maize flour used in complementary foods. *International Journal of Food Science* **(1):** 8863776. https://doi.org/10.1155/2021/8863776.

64. Sopanrao, P.S., A.S. Abrar, T.S. Manoharrao and B.M.M. Vaseem.2010. Nutritional value of *Pleurotus ostreatus* (Jacq: Fr) Kumm cultivated on different lignocellulosic agro-wastes. *Innovative Romanian food biotech* **7:** 66–76.

65. Srivastava, A.K., P.K. Soreng .2012. An effort to domesticate wild edible mushrooms growing in the forest of Jharkhand. Inter. *J Recent Trends Sci Technol* **3(3):** 88–92.

66. Tahir, A., N. Khan, M. Mansha, I. Kamran, H. Akhtar, H.M.U. Aslam, H. Aatif, C.H. Muhammad, S. Hanif, M. Ashfaq, A. Khan, Y. Muhammad. 2021. Yield analysis of oyster mushroom (*Pleurotus ostreatus*) on *Ficus religiosa* leaves in combination with agricultural waste materials. *Pure Applied Bio* **10(1):** https://doi.org/10.19045/bspab.2021. 100002.

67. Tavarwisa, D.M., C. Govera, M. Mutetwa and W. Ngezimana. 2021. Evaluating the suitability of baobab fruit shells as substrate for growing oyster mushroom (*Pleurotus ostreatus*). *Int J Agrono* **7**. https://doi.org/10.1155/2021/6620686.

68. Tekeste, N, K. Dessie, K. Taddesse and A. Ebrahim. 2020. Evaluation of Different Substrates for Yield and Yield Attributes of Oyster Mushroom (*Pleurotus ostreatus*) in Crop-livestock Farming System of Northern Ethiopia. *Open Agri J* **14(1):** 30–35. https://doi.org/10.2174/1874331502014010030.

69. Telang, S.M., S.S. Patil and M.M.V. Baig. 2010. Comparative study on yield and nutritional aspect of *Pleurotus ostreatus* mushroom cultivated on different substrate. *Food Sci Res J* **1:** 60–63.

70. Tesfay, T., T. Godifey, R. Mesfin and G, Kalayu. 2020. Evaluation of waste paper for cultivation of oyster mushroom (*Pleurotus ostreatus*) with some added supplementary materials. *AMB Express* **10(1):** 1–8. https://doi.org/10.1186/S13568-020-0945-8.

71. Thakur, M.P. 2020. Advances in mushroom production: Key to food, nutritional and employment security: A review. *Indian*

Phytopathology **73:** 377–395. https://doi.org/10.1007/s42360-020-00244-9.

72. Tolera, K.D. and S. Abera. 2017. Nutritional quality of oyster mushroom (*Pleurotus ostreatus*) as affected by osmotic pretreatments and drying methods. *Food Sci Nutr* **5(5):** 989–996. https://doi.org/10.1002/fsn3.484.

73. Walkley, A and C.A. Black (1934) An examination of the Degtijarcft method for determining soil organic matter and proposed modification of chromic acid titration method. *Soil Sci* **37:** 29–38. http://dx.doi.org/10.1097/00010694-193401000-00003.

74. Wang, Y, M. Hu, N. Xu, Y. Qin, Z. Wu, L. Zeng and L .He (2020) Chemical composition and light absorption of carbonaceous aerosols emitted from crop residue burning: influence of combustion efficiency. *Atmospheric Chemistry and Physics* **20(22):** 13721–13734. https://doi.org/10.5194/acp-20-13721-2020.

75. Yehia, R.S. 2012. Nutritional value and biomass yield of the edible mushroom *Pleurotus ostreatus* cultivated on different wastes in Egypt. Innov. *Rom Food Biotechnol* **11**. http://www.bioaliment.ugal.ro/ejournal.htm.

76. Zakil, F.A., M.S.M. Sueb and R. Isha. 2019. Growth and yield performance of *Pleurotus ostreatus* on various agro-industrial wastes in Malaysia. *AIP Conference Proceedings* **2155(1):** 020055. https://doi.org/10.1063/1.5125559.

77. Zakil, F.A., L.H. Xuanand N. Zaman. 2022. Growth performance and mineral analysis of *Pleurotus ostreatus* from various agricultural wastes mixed with rubber tree sawdust in Malaysia. *Biores Technol Rep* **17:** 100873. https://doi.org/10.1016/j.biteb.2021.100873.

78. Zhang, Y, M. Shao, Y. Lin, S. Luan, N. Mao, W. Chen and M .Wang. 2012. Emission inventory of carbonaceous pollutants from biomass burning in the Pearl River Delta Region, China. *Atmospheric environment* **76:** 189–199. https://doi.org/10.1016/j.atmosenv.2012.05.055.