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A Comparative Approach on the Effects of Organic Wastes for the Cultivation of Wild Edible Mushrooms along with Various Substrate Compositions

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Abstract

Mushrooms are widely valued for their nutritional, medicinal qualities and economic importance. The primary objective of this review work is to compare the available data on the cultivation of mushrooms and to find suitable substrates for the cultivation of wild edible mushrooms. Additionally, this review work includes data on the overall quantity of wild edible mushrooms that have been cultivated globally, as well as the methods utilized for their cultivation. Results showed that waste materials such as industrial, and agricultural, serve as a value-added technique to recycle or use these waste resources effectively to produce edible mushrooms. This study involved the screening of approximately 201 cultivation reports, with 44 reports originating from India and 151 from other countries. The review identified a maximum of 19 species of the genus *Pleurotus* being cultivated on agricultural waste such as paddy and wheat straw, as well as on mixed substrates. Many researchers have pointed out that paddy and wheat straw are particularly effective agricultural wastes for the cultivation of various edible mushrooms. By employing an appropriate standard ratio, this review will be helpful for the people or farmers to cultivate a specific variety of wild edible mushroom on easily accessible substrates more rapidly and productively. Furthermore, understanding the relationship between the active components of cultivated mushrooms and the substrate is key to enhancing productivity.

Keywords – Agro-Industrial Wastes – Cultivation Techniques – Mixed Substrate – *Pleurotus* species

Introduction

All mushrooms are fungi, but not all fungi are mushrooms, and they are called macrofungi with a distinguishable fruiting body that can be either hypoghetic or epighetic, expressive to the eyes, and easy to pick (Chang & Miles 1992). The class Basidiomycetes encompasses mushrooms, which are part of the kingdom of fungi, with the exception of ascomycetous fungi such as truffles and morels (Yun & Hall 2004). Mushrooms have been perceive as important food items since ancient times due to their various uses, and their usage is stepping up day by day for their significant role as a neutraceutical. Mushrooms can produce a vast array of enzymes that digest the

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complicated substrates during growth and consume the soluble compounds for their nutrition (Singh & Prasad 2012). Mushrooms are one of the most important components of the forest ecosystem, and they are an important part of the ecosystem because, without them, the food web would be incomplete (Dighton et al. 2005). Mushrooms, as many people believe, grow in the wild after heavy rainfall (Ibrahim et al. 2017) and in specialised fields like forest beds, fields, woods, water channels, bunds, manure heaps, and grassy grounds (Atkinson 1961). Macrofungi used as essential foodstuffs and possess various medicinal properties throughout the world because they contain different active constituents, such as polysaccharides, selenium oligosaccharides, dietary fibres, triterpenoids, proteins, peptides, alcohol, amino acids, mineral elements, and phenols (Wasser 2010, Wani et al. 2010).

According to Michael et al. (2011), cultivated mushrooms showed different effects on functional, organoleptic, and chemical characteristics. The biological antioxidants are supposed to be very imperative for the human diet, particularly concerning oxidative pressure avoidance. The powerful antioxidant activity and dietary involvement may help to prevent oxidative damage diseases (Roy et al. 2017; Debnath et al. 2017). Cultivated and wild mushrooms are rich in proteins, carbohydrates, fibres, vitamins, and minerals. Edible mushroom has regarded as therapeutic agents for a long time and have no unwanted effects (Debnath et al. 2019). Mushrooms contain several biotransformed components with a wide range of biological properties, including antimicrobial, haematological, antioxidant, anti-inflammatory, hepatoprotective, anti-tumour, antibacterial, antifungal, blood sugar control, reduced platelet aggregation, atherosclerosis, etc. (Wasser 2010). Therefore, the specific goals of this review are to determine the best substrate for the cultivation of wild edible mushrooms, which will be useful for people. This review work will also give brief data on the total number of genus and species of mushrooms cultivated till now throughout the world, with special attention to India, and also study the most cultivated mushroom species along with useful cultivation methods.

Significance of Mushroom Cultivation

Mushroom cultivation did not come into practice until A.D. 600, when *Auricularia auricularia* was first cultivated in China on wood logs, but the biggest advancement in mushroom cultivation came in France about 1600, when *Agaricus bisporus* was cultivated on composted substrates (Chang 2006). Mushroom cultivation is an economically viable biotechnological application that includes the processing of protein-rich food items from natural resources and is a way of addressing food insecurity, a demanding issue in low- and middle-income countries (Imtiaj & Rahman 2008). Mushroom-growing technology is, therefore, a likely contender for combating food insecurity and being environmentally friendly, apart from their neutraceutical value (Beetz & Kustudia 2004). The increased demand by customers over the decades of mushrooms as food and medicine has increased manifold. Mushroom cultivation is an ever-expanding sector that is an extremely efficient method of utilizing agricultural wastes to create nutritious food while mitigating environmental pollution (Atri & Lata 2013). Agricultural production creates large quantities of biomass that is high in lignin, cellulose, and hemicellulose. One of the simplest ways to recycle it for human consumption is through mushroom cultivation (Manimuthu & Rajendran 2015). Mushroom farming has reported as an alternative way of alleviating poverty in developing countries due to its low cost of production, high profit, and quick returns (Masarirambi et al. 2011).

Mushroom cultivation can help reduce malnutrition susceptibility and improve livelihood by generating a fast-producing and nutritious food and a sustainable source of employment (Imtiaj & Rahman 2008, Rachna et al. 2013). This is an agricultural product, cultivated independently without sunshine; it does not require favourable conditions and can be cultivated on a limited scale because it does not include any major investment (Chadha & Sharma 1995). Mushroom cultivation can increase the socio-economic status of villagers and resolve employment issues in both semi-urban and rural areas. Mushroom cultivation also improves women's empowerment because, it is an economical practice where women can take an advantage to utilize their free time and play an important role despite compromising their home commitments (Manju et al. 2012). According to

Celik & Peker (2009), mushroom cultivation techniques gives the employment opportunities in rural areas, and offering small family farms and underprivileged groups with income opportunities and their findings also revealed that the production of mushrooms could also help in water and soil conservation.

Research Findings on Mushroom Cultivation

This review revealed that there are almost 201 reports of mushroom cultivation, represented by 128 research articles. Among them, 30 records of mushroom cultivation were recorded from India and 171 reports from other countries. This review recorded 201 reports on the cultivation of mushrooms, comprising many species. Total 54 species, representing 27 genera, were recorded which were cultivated on different agro-waste substrates. Among them, the genus *Pleurotus* (22 species) was the most frequently cultivated mushroom species, followed by *Agaricus* (6 species) and *Volvallella* (5 species). Out of these 27 genera, 9 were reported from India and 26 from the rest of the world (Fig. 1). Present findings also documented that 195 species of mushrooms were cultivated on different types of agricultural, forest, and industrial waste from India and other countries. This study also showed that the largest number of cultivated species are from the *Pleurotus* genus (22 species), with *Agaricus* following closely behind with six species and *Auricularia* with four species. This study documented 99 reports of *Pleurotus* species cultivation on different biodegradable wastes from all over the world, of which 33 were from India and 66 from other countries. It was observed that the genus *Pleurotus* was most frequently cultivated due to various usages in the fields of medicine, nutrition, bioremediation of contaminated environments, enzyme synthesis, etc. Moreover, many researchers applied various methodologies, and they used decomposing organic matter for growth in a wide variety of alternative substrates for cultivation, including agro-industrial residues, leaves, sawdust, fruit peels, and industrial effluents, according to availability, varying among places. This review effort demonstrated that the total number of farmed mushroom species belong to various genera and comprise a variety of species namely, *Pleurotus* (22 species) followed by *Agaricus* (6 species), *Auricularia* (4 species), *Lentinus* (3 species), *Pholiota* (3 species), *Coprinus* (2 species), *Agrocybe* (2 Species), *Glifola* (2 species), *Volvallela*(2 species), *Hericium* (2 species), *Oudemanisella* (2 species), *Hypsizigus* (1 species), *Cordyceps* (1 species), *Clitocybe* (1 species), *Flammulina* (1 species), *Ganoderma* (1 species), *Lycophyllum* (1 species), *Macrolepiota* (1 species), *Calocybe* (1 species), *Ophiocordyceps* (1 species), *Polyporus* (1 species), *Schizophyllum* (1 species), *Sparassis* (1 species), *Stropharia* (1 species), *Trametes* (1 species), *Tremella* (1 species) and *Tricholoma* (1 species) and all the findings are depicted in Table 1.

Different Substrates for Mushroom Cultivation

Mushroom farming technology was regarded as the most profitable business, environment-friendly, and short biological process of food protein recovery utilising the degrading capabilities of mushrooms (Philippoussis 2009**)**. Different researchers applied paddy straw as a an agricultural waste product for the cultivation of various *Pleurotus* species, namely *P. sajor-caju* (Hossain 2017; Devi et al. 2015, Dubey et al. 2019), *P. ostreatus* (Sitaula et al. 2018, Debnath et al. 2019), *P. platypus* and *P. eous* (Sathyaprabha et al. 2011), and *Pleurotus* sp. (Nayak et al. 2015), and findings revealed rice straw as a good substrate for cultivation based on their yield and biological efficiency (Table 1). Rice straw was the best substrate for the cultivation of other mushroom genera as well. *Volvariella volvaceae*, *V. diplasia*, *Agrocybe aegerita*, and *Calocybe indica* were reported to be cultivated using paddy straw (Tripathy 2010, Muthu et al. 2014, Bokaria et al. 2014). On the other hand, many researchers reported wheat straw as the best agricultural substrate for the cultivation of edible mushrooms like *P. djamor* (Satpal et al. 2017), *P. eryngii*, *P. ostreatus*, *Agrocybe aegerita* (Philippoussis et al. 2001), *P. ostreatus* (Kumari & Achal 2008), *P. florida* (Elhami & Ansari 2008), and *Calocybe indica* (Vijaykumar et al. 2014) on a large scale. Contrary to the earlier studies on the cultivation of mushroom species on a either single substrate, paddy straw or wheat straw, various authors suggested that a mixture of agricultural waste, mainly rice and wheat straw, with other waste substrates gave a higher yield in comparison to a single substrate. For example, wheat straw supplemented with gram husk and wheat bran used for *P. ostreatus* (Rani 2018), wheat straw with cotton seed meal for *P. pulmonarius* (Pal et al. 2017), wheat straw substrate with soybean flour for *P. sajor-caju* (Singh & Prasad 2012), wheat straw substrate with soybean flour for *P. forida* (Ibrahim et al. 2017), sludge and wheat straw for *P. citrinopileatus* (Kulshreshtha et al. 2013), Olive mill wastewater and wheat straw for *P. sajor-caju* and *P. cornucopiae* (Kalmış & Sargın 2004), wheat straw mixed with date palm at ratio of 25 (date palm): 75 (agro-waste) for *P. ostreatus* (Alananbeh et al. 2014), maize cobs and wheat straw with wheat bran for *Auricularia auricular* (Onyango et al. 2011), paddy straw with wheat bran at a ratio of 3:1 used for *A. polytricha* (Devi et al. 2013), sunflower seed hull with wheat bran for *Schizophyllum commune* (Figlas et al. 2014), sawdust to rice bran at a ratio of 2:1 for *S. commune* (Dasanayaka & Wijeyaratne 2017), rice straw with sawdust for *Lentinus squarrosulus* (De Leon et al. 2013) and rice straw with sawdust used for the cultivation of *L.tigrinus* (De Leon et al. 2013), rice bran with 10% to the paddy straw used for *Agrocybe aegerita* (Muthu et al. 2014), sawdust with wheat straw for *Hericium erinaceus* (Hassan 2007) and paddy straw with palm pressed fiber for *Flammulina velutipes* (Harith et al. 2014).

Other uncommon agricultural and industrial wastes, either alone or in a mixture, were used for the cultivation of various edible and medicinal mushrooms. Different agricultural, industrial and other wastes product were used by the different scientists throughout the world for the successful cultivation of mushrooms by using various substrates like, corncob and sugarcane bagasse (Hoa et al. 2015), corncob (Buah et al. 2010; Shiferaw et al. 2018; Samuel & Eugene 2012; Meng et al. 2019), sugarcane bagasse (Dey et al. 2008), banana leaves (Tirkey et al. 2017, Neupane et al. 2018, Ediriweera et al. 2015), banana pseudostem (Arathy & Das 2016, coffee waste (Tarko & Sirna 2018, Boulware et al. 2014), cotton stalks and leaves (Tupatkar & Jadhao 2006), cottonseed and hull (Emiru et al. 2016, Wang et al. 2015, Xu et al. 2016), cotton waste and coffee pulp (Tsegaye et al. 2017), cotton waste (Philippoussis et al. 2001), dried leaves stalks (Stănescu & Vamanu 2016, Alemu & Fisseha 2015), maize stalk (Adjapong et al. 2015), maize stover and cobs (Dlamini et al. 2012), wheat straw and sunflower shells (Myronycheva et al. 2017, Figlas et al. 2007, 2014), seagrass (Manimuthu & Rajendran 2015), ramie and kenaf stalks (Xie et al. 2017), chickpea straw (Iqbal et al. 2005), sawdust (Islam et al. 2009, Ediriweeraet et al. 2015, Wanget et al. 2016, Win & Ohga 2018), spent mushroom compost (Noonsong et al. 2016), sawdust mixed with ground wax apple branches (Hwang et al. 2015), Tapioca peel (Lalithadevy et al. 2014), soybean straw (Ingale & Patil 2010), defatted pistachio meal (Pardo-Giménezet et al. 2016), chicken manure (Mwita et al. 2010, Magingo et al. 2004, paper waste (Dulay et al. 2012), food waste (Jasińska et al. 2016), coconut leaf and coir dust (Ediriweeraet et al. 2015), pecan wood-chips (Ozcariz-Fermoselleet et al. 2018), tree and grass pruning (Alquatiet et al. 2016), bamboo powder (Ohga 1999), cattail weed, stems and leaves, spikes, whole cattail weed, rhizomes and roots (Mshandete 2011), oil palm fruit fiber (Okhuoya & Okogbo 1991) and cardboard (Owaid et al. 2015).

The present review work revealed that agricultural waste products, especially rice and wheat straw, are widely used by researchers as well as farmers throughout the world due to their availability and high cost-benefit ratio. This study also observed that mixed substrates were very useful for the cultivation of diverse types of edible mushrooms based on productivity and biological efficiency (Hoa et al. 2015, Ibrahim et al. 2017). The highest possible reason behind this may be due to the variation in the physico-chemical constituents present in the substrate, like the ratio of cellulose and lignin, mineral contents, electrolyte conductivity, and pH of the substrate, particularly the ratio of carbon and nitrogen, which enhances the growth of the mushroom species (Hoa et al. 2015). The findings showed that the maximum reports of cultivation of *Pleurotus* species were best in agricultural waste, especially rice and wheat straws, either singly or in mixtures. Another major aspect of the locals selection of different agro-industrial waste products was their availability as substrates that may be applied in any specific region or locality throughout the world. This review also documented that the productivity of mushrooms and their various parameters were affected by diverse factors like the local environment, the type of cultivated species, the quality of the strain, and most importantly, the chemical properties of the substrate.

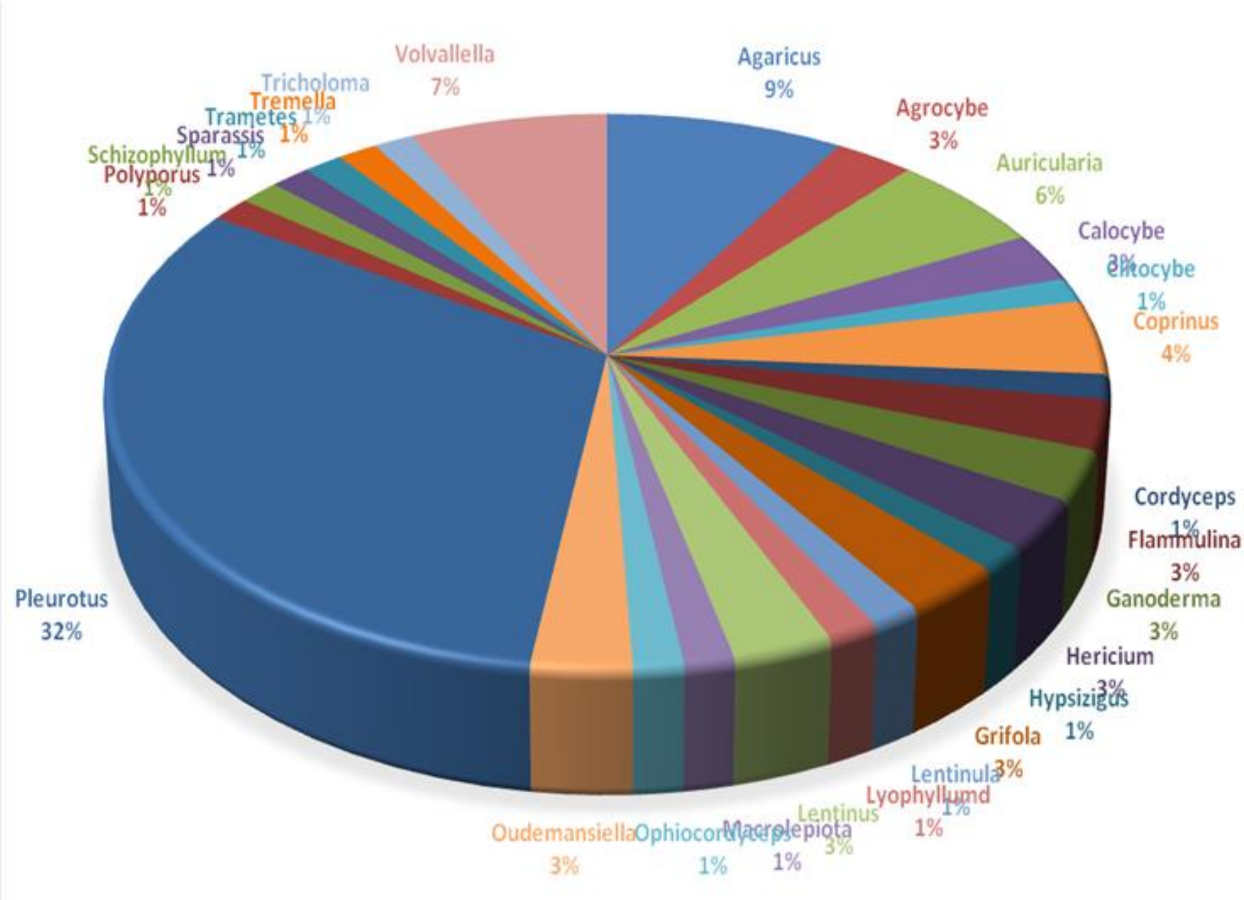

Fig. 1 – Mushroom genera frequency for cultivation.

Table 1 Different wild edible mushrooms cultivated on various substrates along with substrate composition, their significance, reported country name and cited references.

Name of the mushrooms	Substrate	Substrate composition	Importance of Substrates	Reported from	References
P. ostreatus *P. cystidiosus*	Sawdust, corncob, sugarcane bagasse	1.100%sawdust; 2.100% sugarcane bagasse; 3.50% sawdust+50% sugarcane bagasse 4.100% corncob; 4.50% sawdust+50% corncob; 5.80% sawdust+20% corncob	Corncob and sugarcane bagasse was the most suitable substrates for cultivation of oyster mushrooms	Taiwan, ROC	Hoa et al. (2015)
P. eryngii	Rice straw, wheat straw, cotton straw, tea leaves and banana leaves.	1. Barley straw + wheat bran and wood chips + soybean powder + rice bran treatments; 2. Wheat straw + wheat bran + soybean powder treatment	NA	Noida, India	Kamthan & Tiwari (2017)
P. sajor-caju	Soybean straw, wheat straw and sawdust	1. Soybean straw + wheat straw; 2. soybean straw + sawdust			
P. ostreatus	Corn cob, sugarcane bagasse	Corncob + sugarcane bagasse			
P. cystidiosus	Corn cob, sugarcane bagasse	Corncob + sugarcane bagasse			
Agaricus bisporus	Wheat straw	NA			
Lentinula edodes	Rice bran, coffee pulp				
Volvallella sp.	Tea leaves				
Ganoderma sp.	Sawdust				
Agrocybe cylindracea	Oak sawdust and flax shives	Two types of substrates (marked as A and B) were used in the experiments. Substrate A: was prepared from a mixture of alder and beech sawdust (1:1 v/v) which was additionally supplemented with wheat bran (25%), cornmeal (12%), millet (10%), chalk (2%), gypsum (0.97%), KH_2PO_4 (0.02%) and $MgSO_4$ (0.01%). Substrate B: was prepared from a mixture of oak sawdust and flax shives (1:1 v/v) which was additionally supplemented with ground rye (20%), sorghum (10%), defatted soy flour (10%), oat bran (8%), gypsum (1.97%), KH_2PO_4 (0.02%) and $MgSO_4$ (0.01%).	The significantly higher yield was observed in substrate A	Poznań, Poland	Siwulski et al. (2018)
Clitocybe maxima	Alder and beech sawdust				
Flammulina velutipes	Oak sawdust and flax shives				
Ganoderma lucidum	Alder and beech sawdust				
Lentinula edodes	Alder and beech sawdust				
P. eryngii	Alder and beech sawdust + oak sawdust and flax shives				

Table 1 Continued.

Name of the mushrooms	Substrate	Substrate composition	Importance of Substrates	Reported from	References
P. florida	Wheat, cardboard, banana leaves	NA	Banana leaves can be the best alternative and replacement of traditional substrates	Uttar Pradesh, India	Tirkey et al. (2017)
P. sajor-caju	Rice straw, wheat straw, banana leaves and sugarcane bagasse	Wheat straw, rice straw, banana leaves and sugarcane bagasse which were used as completely Randomized Design (CRD).	Among the treatments, rice straw was found most favourable substrates in terms of yield in comparison to other	Chitwan, Nepal	Dubey et al. (2019)
P. florida	Banana leaves, rice straw, wheat straw, the mixture of rice and wheat straw and sawdust	The experiment was conducted in Completely Randomized Design (CRD)	Banana leaf could be one of the best substrates for the production of *P. florida*	Chitwan, Nepal	Neupane et al. (2018)
Oyster mushroom	Paddy straw, sugarcane bagasse and mustard straw	NA	Sugarcane bagasse performed best	Mymensingh, Bangladesh	Dey et al. (2008)
P. ostreatus	Coffee waste (Cw), sawdust (Sd) and sugarcane bagasse (Sb)	Each substrate, they were combined into different ratio (Cw50%:Sb50%, Cw50%:Sd50%, Sb50%:Sd50%, Cw50%:Sb25%:Sd25%, Sb50%:Cw25%:Sd25% and Sd50%:Cw25%:Sb25%) as growth substrates with 5% animal dung as supplementary substrates. In addition, 1% gypsum was used as additives so as to balance the pH	The highest yield was obtained in pure coffee waste	Tepi, Ethiopia	Tarko & Sirna (2018)
P. ostreatus	Sawdust, grounded corncob	1. Sawdust+ corncob (50+50%); 2. Sawdust + corncob (40+60%); 3. Sawdust + corncob (60+40%); 4. Sawdust (100%); 5. Corncob (100%)	Biological efficiency was higher in corncob substrate	Zaria, Nigeria	Buah et al. (2010)
P. djamor	Wheat straw, paddy straw and chickpea straw	Combination of each other with 1:1 ratio(w/w) for the cultivation	Wheat straw would be recommended as the most suitable substrate for the cultivation of *P. Djamor*	UP and Uttrakhand, India	Satpal et al. (2017)
P. sajor-caju	Wheat and paddy straw, bajara, maize, jowar, cotton, soybean stalks and their leaves and groundnut creepers	1. Wheat straw; 2. Paddy straw; 3. Bajra stalks and leaves; 4. Maize stalks and leaves; 5. Jowar stalks and leaves 6. cotton stalks and leaves; 7. Soybean straw;	The different substrates of cotton stalks and leaves were found significantly higher. The lowest yield was observed in the treatment of groundnut creepers	Pune, India	Tupatkar & Jadhao (2006)

Table 1 Continued.

Name of the mushrooms	Substrate	Substrate composition	Importance of Substrates	Reported from	References
		8. Groundnut creeper plus wheat straw; 9. Soybean straw plus wheat straw; 10. Groundnut creepers			
P. sajor-caju	Paddy straw, wheat straw, banana leaves, sugarcane bagasse, sugarcane leaves, newspapers and maize stalks and leaves	NA	Paddy straw showed the highest yield	Orissa, India	Hossain (2017)
P. ostreatus	Wheat straw, leaves and sawdust	1. Saw + wheat straw; 2. Sawdust + leaves; 3. Saw dust; 4. Wheat straw + leaves; 5. Wheat straw; 6. Leaves	Sawdust produced the highest yield, biological efficiency and number of fruiting bodies	Azad Kashmir, Pakistan	Shah et al. (2004)
P. florida	Five tree sawdust and wheat bran	1. Controlled (Mixer of sawdust) supplemented with 30% wheat bran and 1% lime; 2. Mango tree (*Mangifera indica*) sawdust supplemented with 30% wheat bran and 1% lime; 3. Mahogany tree (*Swietenia mahagoni*) sawdust supplemented with 30% wheat bran and 1% lime; 4.Rain tree (*Albiiasaman*) sawdust supplemented with 30% wheat bran and 1% lime; 5. Teak tree (*Tectona grandis*) sawdust supplemented with 30% wheat bran and 1% lime; 6. Jack fruit tree (*Artocarpus heterophylla*) sawdust supplemented with 30% wheat bran.	Mahogany sawdust supplemented with 30% wheat bran can be further used as a better substrate for *P. florida* production	Dhaka, Bangladesh	Supta et al. (2017)
P. florida	Maize spawn, bajra spawn, paddy spawn, and wheat spawn	1.Maize @ 5%; 2.Maize @ 6%; 3.Bajra @ 5%; 4.Bajra @ 6%; 5.Paddy @ 5%; 6.Paddy @ 6% 7.Wheat; (control) @ 6%	Maximum number of pin head initiation (56.66) were observed in 6% spawn rate of wheat (control)	Uttar Pradesh, India	Kumar et al. (2018)

Table 1 Continued.

Name of the mushrooms	Substrate	Substrate composition	Importance of Substrates	Reported from	References
P. eous	Paddy straw, spent mushroom substrate, banana pseudostem, sawdust, coir pith compost	NA	The banana pseudostem is the best substrate	Kattakada, India	Arathy & Das (2016)
P. ostreatus	Crop residue, maize husk, maize cob, and maize stalk	NA	Maize stalk substrate produced the highest number of fruit bodies	Sunyani, Ghana	Adjapong et al. (2015)
P. ostreatus	Wheat straw, paddy straw, rice bran, sugarcane bagasse supplemented with gram husk and wheat bran	NA	Wheat straw supplemented with gram husk and wheat bran gave maximum yield	Punjab, India.	Rani (2018)
Auricularia polytricha	Sawdust, *Panicum repens, Pennisetum purpureum* and *Zea mays.*	30%, 45% and 60%, respectively used as control.	The yield was highest in substrate containing *Z. mays* stalk	Taiwan, ROC	Liang et al. (2016)
P. ostreatus *P. pulmonarious*	Wheat straw and sunflower shells	NA	NA	USA	Myronycheva et al. (2017)
P. sajor-caju	Wheat straw, paddy straw, sugarcane bagasse, sugarcane leaves, black gram straw, sorghum leaves, maize heart, Ashoka leaves, banana leaves, barley straw, sorghum stalks and t12-mustard straw	NA	The maximum yield was recorded on paddy straw	Samastipur (Bihar), India	Pandey et al. (2008)
P. ostreatus	Sawdust, cassava peel, cotton waste, dry plantain, palm oil chaff and vegetable.	Cotton waste, cassava peel, palm oil chaff, vegetable, sawdust and dry plantain leaf	This observation revealed that more fruit bodies were produced on cotton waste	Nigeria	Amuneke et al. (2011)

Table 1 Continued.

Name of the mushrooms	Substrate	Substrate composition	Importance of Substrates	Reported from	References
P. pulmonarius	Wheat straw and sawdust	1. Wheat straw + Sawdust (2:1); 2. Wheat straw + Ammonium nitrate (5g/kg of the wet weight of substrate); 3. Wheat straw + Cottonseed meal (5g/kg of the wet weight of substrate); 4. Wheat straw + CAN (5g/kg of the wet weight of substrate); 5. Wheat straw + Urea (2.5g/ kg of the wet weight of substrate); 6. Wheat straw control	Wheat straw with cottonseed meal resulted in fastest spawn run and higher productivity and biological efficiency	Himachal Pradesh, India	Pal et al. (2017)
P. ostreatus	Sawdust, rice straw, cottonseed hull & maize cob with 100%, 75%, 50% and 25% combination ratios	1. 100% Saw dust (control); 2. 100% Rice straw; 3. 100% Cottonseed hull; 4. 100% Maize cob; 5. 75% Saw dust+25% Rice straw; 6. 75% Saw dust +25% Cottonseed hull; 7.75% Saw dust + 25% Maize cob; 8.50% Saw dust +50% Rice straw; 9.50% Saw dust +50% Cottonseed hull; 10.50% Saw dust +50% Maize cob; 11.25% Saw dust +755 Rice straw; 12.25% Saw dust+75% Cottonseed hull; 13.25% Saw dust +75% Maize cob; 14.75% Cottonseed hull+25% Maize cob; 15.50% Cottonseed hull+50% Maize cob; 16.25% Cottonseed hull+75% Maize cob; 17.75% Rice straw +25% Maize cob; 18.75% Rice straw +25% Cottonseed hull; 19.50% Rice straw +50% Maize cob; 20. 50% Rice straw +50% Cottonseed hull; 21. 25% Rice straw + 75% Maize cob; 22.25% Rice straw + 75% Cottonseed hull; 23.25% Maize cob +25% Rice straw +25% Cottonseed+25% Saw dust	The 100% cottonseed hull substrate was the best substrate for cultivation of *P. ostreatus*	Mekelle, Ethiopia	Emiru et al. (2016)
Volvariella volvaceae	Rice bran, wheat bran, rice straw, sawdust, banana leaf and	1. Wheat %; 2. 50%Wheat + 50% Rice bran; 3. 50%Wheat + 50% Wheat bran;	Paddy straw was the best substrate for cultivation of *V. volvaceae*	Orissa, India	Tripathy (2010)

Table 1 Continued.

Name of the mushrooms	Substrate	Substrate composition	Importance of Substrates	Reported from	References
	sugarcane baggage	4. 50%Wheat + 50% Straw; 5. 50%Wheat + 50% Sawdust; 6. 50%Wheat + 50%Banana leaf; 7. 50%Wheat + 50% Sugarcane baggage			
V. diplasia	Rice bran, wheat bran, rice straw, sawdust, banana leaf and sugarcane baggage	1. Wheat %; 2. 50%Wheat + 50% Rice bran; 3. 50%Wheat + 50% Wheat bran; 4. 50%Wheat + 50% Straw; 5. 50%Wheat + 50% Sawdust; 6. 50%Wheat + 50%Banana leaf; 7. 50%Wheat + 50% Sugarcane baggage	Paddy straw was the best substrate for cultivation of *V. diplasia*	Orissa, India	
P. ostreatus	Sawdust, cow dung, teff straw, corn cob and chat left over	1.cow dung with corn cob; 2.cow dung with sawdust; 3.cow dung with teff straw; 4.corn cob with teff straw; 5.chat leftover with corn cob; 6.chat leftover with cow dung; 7.saw dust with chat leftover; 8.cow dung with teff straw; 9.saw dust with teff straw; 10.teff straw with chat left over	Corn cobs give the highest yield in comparison to other substrates	Jimma, Ethiopia	Shiferaw et al. (2018)
P. ostreatus	Cotton waste, coffee pulps, wood chips and tef straw.	1. Cotton waste + coffee pulp; 2. Cotton waste + tef straw; 3. Coffee pulp + tef straw; 4. Cotton waste + wood chips; 5. Wood chips + tef straw	Combination of cotton waste and coffee pulp was found as the best substrate	Ethiopia	Tsegaye et al. (2017)
P. ostreatus	Maize, wheat and millet grains	Combination of maize, wheat and millet grains.	Maize was found as the best substrate	Eldoret, Kenya	Mbogoh et al. (2011)
P. sajor-caju	Wheat and rice	NA	Findings revealed that rice straw as the best substrate	Manipur, India	Devi et al. (2015)
P. ostreatus	Maize stalk, wheat bran (WB) and maize flour (MF).	Maize stalk substrates were separately supplemented with 8 levels of maize flour and wheat bran, *viz.*; 0%, 2%, 4%, 8%, 12%, 14%, 18% and 20% respectively	It was observed that the productivity (biological efficiency and yield) gradually higher when an increase in the level of supplementation (wheat bran and maize flour) leads	South Africa	Mkhize et al. (2016)

Table 1 Continued.

Name of the mushrooms	Substrate	Substrate composition	Importance of Substrates	Reported from	References
P. sajor-caju	Tissue paper, rice husk ash and rubber sawdust	Tissue paper, rice husk ash and rubber sawdust with rice bran and calcium carbonate ($CaCO_3$)	Tissue paper was one of capable substrate for cultivation of *P. sajor-caju*	Malaysia	Fasehah & Shah (2017)
P. ostreatus	Paddy straw, sugarcane bagasse, sawdust, maize cob.	1. Paddy Straw; 2. Maize cob + Paddy Straw (1:1); 3. Sugarcane+Paddy Straw (1:1); 4. Sawdust+Paddy Straw (1:1)	Paddy straw alone was the best substrate for the growth and development of the *P. ostreatus*	Chitwan, Nepal	Sitaula et al. (2018)
P. sajor-caju	Soybean straw, paddy straw, wheat straw, groundnut straw, sunflower stalk and pigeon pea stalk	Each of the six treatments was replicated three times.	Soybean straw showed the significantly highest yield	Naigaon,Maharashtra, India	Patil (2012)
P. ostreatus *P. eryngii* *P. pulmonarius* *Agrocybeaegerita* *V. volvacea*	Wheat straw, cotton waste and peanut shells	NA	Wheat straw showed the highest yield Wheat straw showed the highest yield Cotton waste showed the highest yield Wheat straw showedthehighest yield Cotton waste showedthehighest yield	Greece	Philippoussis et al. (2001)
P. eous *P. florida* *P. sajor-caju*	Khetki, fairy castle, coconut coir, dharba, banana, lotus, bunny ears and sugarcane	NA	Eight different substrates give high yield than compared to straw	Avadi, Chennai	Masi et al. (2016)
P. ostreatus	Leftover bread (LB)	Wheat bran, crushed, corn seeds, leftover, bread, $CaCO_3$ and sawdust	The highest biological efficiency was determined on the mixtures containing 20% wheat bran, 10% spent brewery grain and 2% $CaCO_3$	Slovenia	Gregori et al. (2008)
P. sajor-caju	Wheat grain along with autoclaving, hot water application, radiation and chemical treatment	Wheat grain along with autoclaving, hot water application, radiation and chemical treatment were assessed	Maximum yield and biological efficiency were observed in chemically treated substrate	India	Siddhant et al. (2014)
P. sajor-caju	Wheat straw, soybean flour and cow dung	1.Wheat straw + wheat brawn@2%; 2.wheat straw + wheat brawn@5%; 3.wheat straw + soybean flour@2%; 4.wheat straw + soybean flour@5%; 5.wheat straw + cow dung@2%; 6.wheat straw + cow dung@5%; 7.wheat straw	The maximum yield was documented in the wheat straw substrate with soybean flour supplement	Azamgarh, U.P., India	Singh & Prasad (2012)

Table 1 Continued.

Name of the mushrooms	Substrate	Substrate composition	Importance of Substrates	Reported from	References
Plurotus forida	Wheat straw, soybean flour andcow dung	1.Wheat straw + wheat brawn@2%; 2.wheat straw + wheat brawn@5%; 3.wheat straw + soybean flour@2%; 4.wheat straw + soybean flour@5%; 5.wheat straw + cow dung@2%; 6.wheat straw + cow dung@5%; 7.wheat straw	The maximum yield was documented in the wheat straw substrate with soybean flour supplement	Azamgarh, U.P., India	Ibrahim et al. (2017)
Agrocybe aegerita	Paddy straw, rice bran, wheat bran and horse gram	1. Paddy straw; 2. Paddy straw + rice bran (5%); 3. Paddy straw + rice bran (10%); 4. Paddy straw + wheat bran (5%); 5. Paddy straw + wheat bran (10%); 6. Paddy straw + horse gram (5%); 7. Paddy straw + horse gram (10%)	The rice bran supplementation of 10% to the paddy straw gave the maximum yield	Tamil Nadu, India.	Muthu et al. (2014)
P. ostreatus	Corn cobs on corn flour T1, Corn cobs on rice bran T2, Iroko on corn flour T3, Iroko on rice bran T4, Eucalyptus on corn flour T5 and Eucalyptus on rice bran T6; supplemented with 1% $CaCO_3$	1. Eucalyptus on corn flour and $CaCO_3$ (tied normally). In the ratio 69:30:1 respectively; 2. Eucalyptus on rice bran and $CaCO_3$ (tied with white thread). In the ratio 69:30:1 respectively; 3. Corn cobs on corn flour and $CaCO_3$ (tied with orange thread). In the ratio 69:30:1 respectively; 4. Corn cobs on rice bran and $CaCO_3$ (tied normally). In the ratio 69:30:1 respectively; 5. Iroko on rice bran and $CaCO_3$ (tied with yellow thread). In the ratio 69:30:1 respectively; 6. Iroko on corn flour and $CaCO_3$ (tied with blue thread). In the ratio 69:30:1 respectively	Eucalyptus on corn flour T5 showed the highest yield	Cameroon	Kinge et al. (2016)
Calocybe indica	Paddy straw, wheat straw, soybean straw, coconut coir pith, cotton waste and sugarcane bagasse	NA	Wheat straw was found as good substrate cultivation of milky mushroom	Navsari, Gujarat, India	Vijaykumar et al. (2014)
Pleurotus sp.	Sea grass	NA	The mushroom was produced from polybag fermentors filled with seagrass in 18th day. The results gave an idea that mushroom cultivation in the coastal area of Tamil Nadu.	Tamil Nadu, India	Manimuthu & Rajendran (2015)

Table 1 Continued.

Name of the mushrooms	Substrate	Substrate composition	Importance of Substrates	Reported from	References
P. eryngii	Ramie stalks, kenaf stalks, cottonseed hulls and bulrush stalks	Ramie stalks, kenaf stalks, cottonseed hull and bulrush stalks were mixed with 1% $CaCO_3$	Ramie stalks and kenaf stalks were found as best substrate	China	Xie et al. (2016)
P. ostreatus (local) *P. ostreatus* (exotic) *P. sajar-caju*	Wheat straw, paddy straw, chickpea straw, sugarcane bags, corn cobs, cotton waste and sunflower heads	NA	The finding showed that the chickpea straw was a better substrate in comparison to other substrates	Pakistan	Iqbal et al. (2005)
P. ostreatus	Paddy straw, wheat straw, bamboo leaves and lawn grasses	Paddy straw, wheat straw, paddy straw 50% + wheat straw 50%, bamboo leaves and lawn grasses	Wheat straw showed better results	Patiala, Punjab, India	Kumari & Achal (2008)
P. flabellatus	Mango sawdust, jackfruit sawdust, kadom sawdust, coconut sawdust, mahogany sawdust, jam sawdust and shiris sawdust	Mango, jackfruit, coconut, jam, kadom, mahogony, shiris sawdust with wheat bran and $CaCO_3$	Mango sawdust and Shiris sawdust were the promising substrates for the cultivation of *P. flabellatus*	Bangladesh	Islam et al. (2009)
Pleurotus sp.	Rice straw, sugarcane bagasse, tea waste and sawdust	NA	Rice straw was found to be a good substrate for cultivation of *P.*sp.	Pondicherry , Chennai, India	Nayak et al. (2015)
P. platypus	Sorghum grain, paddy grain, maize grain, sugar cane trash. teak leaves, black gram pods and banana leaves	NA	Findings revealed that the paddy straw substrate was suitable to cultivate *P. platypus* and *P.eous*	Tamil Nadu, India	Sathyaprabha et al. (2011)
P. eous	Sorghum grain, paddy grain, maize grain, sugar cane trash. teak leaves, black gram pods and banana leaves				
P. florida	Sugarcane bagasse and wheat straw	Sugarcane bagasse, wheat straw with nitrogen doses and manganese doses	Wheat straw substrate showed the highest yield	Ahwaz, Iran	Elhami & Ansari (2008)
Calocybe indica	Sorghum stalks, maize stalks, paddy straw sugarcane bagasse, groundnut haulms.	NA	Paddy straw, maize stalk and sorghum stalk gave significantly higher yields	West Bengal, India and Nepal	Bokaria et al. (2014**)**

Table 1 Continued.

Name of the mushrooms	Substrate	Substrate composition	Importance of Substrates	Reported from	References
P. ostreatus	Banana leaves, sugarcane tops, maize stover, maize stover and cobs	Combination of all substrate in 1:1 ratio.	Maize stover and cobs showed the best performance compared to the other substrates	Swaziland	Dlamini et al. (2012)
Agrocybe cylindracea	Spent mushroom compost, spent mushroom compost and rubber sawdust	1. Spent mushroom compost; 2. Spent mushroom compost: rubber sawdust (3:1); 3. Spent mushroom compost: rubber sawdust (1:1); 4. Spent mushroom compost: rubber sawdust (1:3); 5. Rubber sawdust (control)	Spent mushroom compost alone showed the highest yield	Thailand	Noonsong et al. (2016)
P. ostreatus	Palm cones, corn cobs, sawdust, coffee husk and wheat bran	1. Palm cones (100%); 2.Corn cobs (100%); 3. Corn cobs and Palm cones (1:1); 4. Corn cobs and Palm cones (1:3); 5. Corn cobs and Palm cones (3:1); 6. Sawdust: coffee husk: wheat bran (6:3:1)	The highest biological yield was obtained in corn cones which was much higher than control	Cameroon	Samuel & Eugene (2012)
P. eryngii	Sawdust, wax apple and Indian jujube	1.Sawdust 100%; 2.Wax apple 25%; 3.Wax apple 50%; 4.Indian jujube 25%; 5.Indian jujube 50%	75% sawdust mixed with 25% ground wax apple branches was the best substrate	Taiwan, Republic of China	Hwang et al. (2015)
P. ostreatus	Wheat straw, clover, dried leaves stalks, dried oat, dried sorghum, broken rice and grain	1.Control: 100% wheat straw; 2.100% clover; 3.100% dried leaves stalks; 4.100% dried oat; 5.100% dried sorghum; 2.Formula Experiment 1 supplemented with 10% broken rice; 3.Formula Experiment 1 supplemented with 10% grain	The dried leaves stalk lead to the best productivity	Bucharest, Romania	Stănescu & Vamanu(2016)
P. florida	Fruits and vegetables peel (sweet lime, watermelon, banana, pomegranate, onion, green plantain, potato, tapioca) alone and in the combination of different proportion with paddy straw	1. Paddy straw (control) 100%; 2. Pomegranate peel (100%); 3. Pomegranate: Paddy straw (3:1); 4. Pomegranate: Paddy straw (1:1); 5.Pomegranate: Paddy straw (1:3); 6. Tapioca peel (100%); 7. Tapioca: Paddy straw (3:1); 8. Tapioca: Paddy straw (1:1); 9. Tapioca: Paddy straw (1:3)	Tapioca peel showed the best results	Pondicherry , India.	Lalithadevy et al. (2014)

Table 1 Continued.

Name of the mushrooms	Substrate	Substrate composition	Importance of Substrates	Reported from	References
P. ostreatus	Boobialla leaves, date palm, sawdust, wheat straw	Mixed with date palm leaves at different ratios, with two supplements and three spawn rates were used.	Wheat straw mixed with date palm at the ratio of 25 (date palm): 75 (agro-waste) showed the best results	Saudi Arabia	Alananbeh et al. (2014)
P. djamor	Oak mulch, palm mulch and coffee grounds	The mix of all three substrates	Coffee groundswerethebest substrate for cultivation of *P. djamor*	Orlando, USA	Boulware et al. (2014)
P. ostreatus	Woody substrates *viz*; *Pycnanthusongoleubis*, *Ceiba pentandra* and *Cananium* sp.	NA	*Pycnanthusongoleubis*showed good potential as a substrate for cultivation *P.ostreatus*	Akure, Nigeria	Oyetayo & Ariyo (2013)
P. sajar-caju *P. eous* *P. florida*	Soybean straw, paddy straw and wheat straw	Combination in 1:1	All species showed highest yield when cultivated on the soybean straw	Jalgaon and Amravati, India	Ingale & Patil (2010)
P. ostreatus	Grass (*Digitaria decumbens*) and coffee pulp.	70% grass, 30% coffee pulp with 2% $Ca(OH)_2$	Biological efficiencies were observed between the treatments, composting times and in the interactions between these two factors.	Chiapas, Mexico	Hernández et al. (2003)
Tremella fuciformis	Sawdust, hardwood, rice, wheat bran, cotton-seed hull, soybean powder	Supplemented Sawdust-bran Substrate A: 1. Sawdust, hardwood. 2. rice or wheat bran. 3. gypsum or lime. 4. sucrose. 5. water, approximately. Supplemented Sawdust-bran Substrate B: 1. Sawdust, hardwood. 2. bran. 3. sucrose. 4. gypsum. 5. calcium superphosphate. 6. soybean powder. 7. water Supplemented cotton-seed hull and bran substrate: 1. cotton-seed hull, 2. bran, 3. soybean powder, 4. sucrose, 5. calcium superphosphate and 6. water	Cottonseed hull give the highest yields	Fujian Province, China	Chen & Huang (2001)
Agaricus bisporus *P.ostreatus*	Wheat straw and defatted pistachio meal	NA	Defatted pistachio meal showed best results	Spain, Brazil	Pardo-Giménez et al. (2016)
Auricularia auricula	Grass straw, bagasse, wheat straw and maize cobs	Combination with rice bran and wheat bran	Maize cobs and wheat straw supplemented with wheat bran produced better yield	Kenya	Onyango et al. (2011)
Hericium erinaceus	Sunflower seed hulls	Sunflower seed hulls with wheat bran	Sunflower seed hulls showed the highest yield	Argentina	Figlas et al. (2007)

Table 1 Continued.

Name of the mushrooms	Substrate	Substrate composition	Importance of Substrates	Reported from	References
H. erinaceus	Sawdust, rice straw, wheat straw	1.Sawdust; 2. Rice straw; 3. Wheat straw; 4. Sawdust+ rice straw; 5. Sawdust+ wheat straw; 6. Rice straw+ wheat straw	Sawdust with wheat straw showed the highest yield	Giza, Egypt	Hassan (2007)
Coprinus cinereus	Sisal waste substrates	Sisal waste substrates supplemented with chicken manure	Chicken manure was the best substrate for cultivation *C. cinereus* and also increased the production of active secondary metabolites	Tanzania	Mwita et al. (2011)
Schizophyllum commune	Banana stalk	NA	NA	Pakistan	Irshad & Asgher (2011)
S. commune	Sugarcane bagasse	NA	NA	Malaysia	Kam et al. (2016)
S. commune	Sunflower seed hull	sunflower seed hull with barley, wheat bran, sunflower or olive oil	The sunflower seed hull with wheat bran significantly improved the mushroom yield	Argentina	Figlas et al. (2014)
Auricularia polytricha	Sawdust, oil palm frond, spent grain, empty fruit bunch, palm pressed fibres	1.Sawdust (100); 2.palm pressed fibres (100); 3.oil palm frond(100); 4.empty fruit bunch(100) 5. sawdust + palm pressed fibres (90:10); 6. Sawdust + oil palm frond (90:10); 7. Sawdust + empty fruit bunch (90:10); 8. Sawdust + palm pressed fibres (80:20); 9. Sawdust + oil palm frond (80:20); 10. Sawdust + empty fruit bunch (80:20); 11. Sawdust + palm pressed fibres (70:30); 12. Sawdust + oil palm frond (70:30); 13. Sawdust + empty fruit bunch (70:30); 14. Sawdust + palm pressed fibres (50:50); 15. Sawdust + oil palm frond (50:50); 16. Sawdust + empty fruit bunch (50:50)	Palm oil waste was used by local growers for the cultivation of *A. polytricha*. The addition of spent grain and rice bran in the substrates proved to be beneficial in the growth and development	Malaysia	Abd Razak et al. (2012)
Coprinus cinereus *P.flabellatus* *Volvariella volvacea*	Sisal decortications residue	NA	Non-composted sisal decortications residue showed the highest yield	1.Tanzania 2. USA.	Mshandete & Cuff (2008)

Table 1 Continued.

Name of the mushrooms	Substrate	Substrate composition	Importance of Substrates	Reported from	References
Trametes versicolor	Breadcrumb	NA	NA	Ukraine	Ivanova et al. (2014)
Schizophyllum commune	Breadcrumb	NA	NA		
P. ostreatus	*Ficus vasta*leaves	80 % of *Ficus* leaves with- 1. 10% Chicken manure, 8% Wheat bran and 2% wood ash. 2. 10% Cow dung, 8% Wheat bran and 2% wood ash. 3. 18% Wheat bran and 2% wood ash. 4. 18% Cow dung and 2% wood ash. 5. 18% Chicken manure and 2% wood ash	*Ficus* leaf was the best substrate for cultivation of *P. ostreatus*	Ethiopia	Alemu & Fisseha (2015**)**
Schizophyllum commune	Different plant wood substrates (sawdust)	The wood substrate with coir dust, rice bran, dried IpilIpil leaves and used tea leaves	Rice bran promoted the mushroom production and sawdust to rice bran ratio 2:1 gave the highest yield	Sri Lanka	Dasanayakaand& Wijeyaratne (2017)
Coprinus comatus	Pulp and paper wastes (Fine gray paper pulp (FGPP), Coarse gray paper pulp (CGPP), Light blue paper pulp (LBPP), Brown paper pulp (BPP)	1.Fine gray papar pulp (pure), 2.coarse gray paper pulp (pure), 3.light blue paper pulp (pure), 4.BRPP (pure), 5.fine gray paper pulp + rice bran, 6.coarse gray paper pulp + rice bran, 7.light blue paper pulp + rice bran, 8.BRPP + Rice bran	Light blue paper waste + 10% rice bran were the most suitable substrate	Philippines	Dulay et al. (2012)
S. commune	Banana leaves, coconut leaves, paddy straw, coir dust and sawdust	To each substrate, 10% (w/w) rice bran, 2% (w/w) $CaCO_3$ and 0.2% (w/w) $MgSO_4$ were added	Coconut leaf and coir dust containing mixtures was the best substrate	Sri Lanka	Ediriweera et al. (2015)
Auricularia polytricha			Banana leaves containing substrate gave the highest yield		
Lentinus squarrosulus			Rubber sawdust showed the highest yield		
Flammulina velutipes	Empty fruit bunches (EFB), palm pressed fiber (PPF), and paddy straw (PS)	1.sawdust+empty fruit bunches (50:50); 2.sawdust+paddy straw (50:50); 3.paddy straw+empty fruit bunches (25:75); 4.Sawdust + palm pressed fiber (75:25); 5.paddy straw+palm pressed fiber (50:50); 6.empty fruit bunches+palm pressed fiber (25:75); 7.palm pressed fiber (100)	Combination of substrates, sawdust + palm pressed fiber (75:25), paddy straw + palm pressed fiber (50:50) and sawdust + paddy straw (50:50) showed higher mycelial growth rates	Kuala Lumpur, Malaysia	Harith et al. (2014)
Auricularia auricula	*Mansoniaaltissima*sawdust(Brewer's grain (BG), Corn chaff (CC), Oil palm fibre (OPF),	*Mansoniaaltissima*sawdust with 1.5% Brewer's grain; 2.10% Brewer's grain; 3.20% Brewer's grain;	The addition of additives to sawdust; brewer's grain, corn chaff, wheat bran, oil palm fruit fibre and sorghum chaff significantly increased the mycelia	Nigeria and the USA	Adenipekun et al. (2015)

Table 1 Continued.

Name of the mushrooms	Substrate	Substrate composition	Importance of Substrates	Reported from	References
	Sorghum bicolour chaff (SC) and Wheat bran (WB)	4.5% Corn chaff; 5.10% Corn chaff; 6.20% Corn chaff; 7.5% oil palm fibre; 8.10% oil palm fibre; 9.20% oil palm fibre; 10.5% Sorghum bicolor chaff; 11.10% Sorghum bicolor chaff; 12.20% Sorghum bicolor chaff; 13.5% Wheat bran; 14.10% Wheat bran; 15.20% Wheat bran	extension, density and yield of *A. auricula*		
Ganoderma lucidum	Sawdust of *Alnusnepalensis*, *Shorearobusta* and *Dalbergia sisoo*	Sawdust with rice bran, wheat bran, cornflour and gram flour	*Alnus nepalensis*sawdust supplemented with gram flour showed higher yield	Nepal	Gurung et al. (2012)
P. citrinopileatus	Bean straw (*Phaseolus vulgaris*), sawdust of African mahogany (*Khaya anthotheca*), rice straw, maize cobs, wheat straw, sugarcane bagasse and banana leaves	NA	Bean straw substrate showed superior result on cultivated *P. citrinopileatus.*	Kenya	Musieba et al. (2012)
Auricularia polytricha	Good lumber sawdust, rice bran, coconut peat, coconut lumber sawdust, coconut husk and banana leaves	1.Good lumber sawdust + rice bran + lime 2.coconut peat + rice bran + lime 3.coconut lumber sawdust + rice bran + lime 4.coconut husk + rice bran + lime 5.Banana leaves + rice bran + lime 6.Rice straw + rice bran + lime	Sawdust, rice bran and lime had the fastest mycelial run, highest growth rate, yield and biological efficiency	Philippines	Zurbano (2018)
Ganoderma lucidum	Sawdust, tea waste and wheat bran	1.80%sawdust+25%wheat bran 2.75%sawdust+25%tea waste 3.80%sawdust+20%tea waste 4.85%sawdust+15%tea waste 5.90%sawdust+10%tea waste	80% sawdust + 20% tea waste substrate and 75% sawdust + 25% tea waste were the best substrate for cultivation of *G. lucidum*	Turkey	Peksen & Yakupoglu (2009)

Table 1 Continued.

Name of the mushrooms	Substrate	Substrate composition	Importance of Substrates	Reported from	References
Ganoderma lucidum	Pecan shells (PS100), Pecan peri-carp (PP100), Pecan wood-chips (PB100)	1. Pecan shells (PS100); 2. Pecan peri-carp (PP100); 3. Pecan wood-chips; 4. Pecan shells50 + pecan pericarp50; 5.pecan wood-chips50 + pecan shells50; 6.pecan wood-chips50 + pecan pericarp50	The mushroom yield in the substrates containing pecan wood-chips (PB) was significantly high	Spain, Mexico and Portugal	Ozcariz-Fermoselle et al. (2018)
Agaricus subrufescens	Wheat straw and horse manure	NA	NA	Thailand, China and France	Thongklang et al. (2014)
A. flocculosipes	Wheat straw and horse manure	NA	NA		
Ganoderma lucidum	Tree pruning, Grass pruning, Eucalyptus sawdust	1.100% tree pruning; 2.100% grass pruning; 3. 75% tree pruning + 25% grass pruning; 4. 50% tree pruning + 50% grass pruning; 5 .25% tree pruning + 75% grass pruning; 6. Witness (100% eucalyptus sawdust)	Pruning substrates trees and grasses have varied low to medium fungal biomass conversion potential	Brazil	Alquati et al. (2016)
Oudemansiella canarii	Cottonseed hull, sawdust and corncob	1.80% cottonseed hull; 2.80% sawdust; 3.40% sawdust +40% cottonseed hull; 4.40% sawdust + 40% corncob	The mixed substrate of 80% cottonseed hull, 18% wheat bran and 2% lime showed superior results	China	Xu et al. (2016)
Ganoderma lucidum	*Artocarpus heterophyllus* as sawdust	NA	NA	Tamil Nadu, India	Rani et al. (2015)
Oudemansiella tanzanica	Paddy straw, sisal waste, sawdust, rice bran and chicken manure	Sawdust, paddy straw, sisal waste with chicken manure	The most suitable substrate was sawdust supplemented with 5% chicken manure	Tanzania, Sweden	Magingo et al. (2004)
P. citrinopileatus	*Panicum repens*(PRS), *Pennisetum purpureum*(PPS) and *Zea mays*(ZMS)	1. 90% sawdust; 2. 30% *P. repens* stalk + 60% sawdust; 3. 45% *P. repens* stalk + 45% sawdust; 4. 60% *P. repens* stalk + 30% sawdust; 5. 30% *P. purpureum* stalk; + 60% sawdust; 6. 45% *P. purpureum* stalk + 45% sawdust; 7. 60% *P. purpureum* stalk +30% sawdust; 8. 30% *Z. mays* stalk + 60% sawdust; 9. 45% *Z. mays* stalk + 45% sawdust; 10. 60% *Z. mays* stalk + 30% sawdust	The average mushroom weight of the first five flushes observed in the mixture of 30% *Panicum repens* stalk + 60% sawdust (largest weight of 36.2 g)	Taiwan	Liang et al. (2009)

Table 1 Continued.

Name of the mushrooms	Substrate	Substrate composition	Importance of Substrates	Reported from	References
P. citrinopileatus	Wheat straw, handmade paper and cardboard industrial waste	1.100% wheat straw (control); 2.100% Handmade paper industries; 3.50% Handmade paper industries waste + 50% Wheat straw; 4.100% cardboard industries waste; 5.50% cardboard industries waste + 50% wheat straw	The mixture of sludge and wheat straw increased the biological efficiency	India	Kulshreshtha et al. (2013)
Hericium abietis	Conifer sawdust	NA	NA	Canada	Xiao & Chapman (1997)
Grifola gargal	Nothofagus, beech, hardwood and sugi	1.Nothofagus; 2.Beech; 3. Sugi:Hardwood 1:4 (v/v) 4. Sugi:Hardwood 2:3 (v/v) 5. Sugi:Hardwood 3:2 (v/v) 6. Hardwood:sugi, 4:1 (v/v) 7.Sugi	NA	Japan	Harada et al. (2015)
Pholiota nameko	Eucalyptus shaving, cordial shaving, coffee husk, Pinus shaving, cottonseed and teff straw	Wheat bran (WB) was used as an additive material 100:10 and 100:30 (w:w) of the main material	Eucalyptus shaving (*Eucalyptus globules*), Cordia shaving (*C. africana*) and cottonseed (*Gossypium* spp.) were best substrates for the cultivation of *P. nameko*	Ethiopia	Gizaw (2015)
P. citrinopileatus *P.salmoneo-stramineus*	Spent coffee grounds, sawdust wood, shavings wood straw, crushed grain corn, wheat bran and crushed oilseed cake.	1. Substrate I: 38% (w/w) sawdust, 5% (w/w) wood shavings, 20% (w/w) wood straw, 18% (w/w) crushed grain corn, 13% (w/w) wheat bran, 6% (w/w) crushed oilseed cake with 68% (w/w) water content 2. Substrate II: 50% (w/w) of substrate 1 and 50 % (w/w) sterilized cold spent coffee grounds.	Total yield was best in both the substrates I and II Total yield was best the substrates I	Portugal	Freitas et al. (2018)
Lentinula edodes *Grifola frondosa* *Pholiota nameko* *Flammulina velutipes* *Hypsizigus marmoreus* *P. ostreatus* *P. eryngii*	*Phyllostachys pubescens*(bamboo) powder	NA	The bamboo powder was a suitable substrate for cultivation of the studied mushrooms and the yield of fruit bodies on the test substrate was significantly higher than the control	Japan	Ohga (1999)

Table 1 Continued.

Name of the mushrooms	Substrate	Substrate composition	Importance of Substrates	Reported from	References
P. abalonus *Agrocybe cylindracea* *Agrocybe cylindricaa* *Auricularia fuciformis* *Auricularia polytricha* *Cordyceps militaris* *Flammulina velutipesa* *Ganoderma lucidum* *Glifola frondosa* *Hericium erinaceus* *Hypsizygus marmoreusa* *Lentinula edodes* *Ophiocordyceps sinensis* *Pholiota adiposa* *Pholiota microspora* *P. cornucopiae* *P. diamor* *P. eryngiia* *P. ostreatusa* *P. cystidiosus subsp. Abalonusa* *P. eringi var. tuolienensisa* *Sparassiscrispa*	Sawdust (*Fagus crenata*), wheat bran and rice bran	Mixtures of sawdust, wheat bran and rice bran with the ratio of 8:1:1	The result indicated that 11 species responded well with the ceramic bead substrate when compared to the traditional sawdust substrate with *A. cylindrica* and *P. ostreatus* performed the best adding 70 g more of the fruit bodies. Conversely, nine species responded poorly with the ceramic beads substrate with *A. polytricha* performed the worst losing 120 g	Japan	Huang & Ohga (2017)
P. sajor-caju *P. cornucopiae*	Olive mill wastewater (OMWW) and wheat straw	Wheat straw with different OMWW: tap water mixtures.	Mixtures containing 25% and 50% OMWW was found as a suitable substrate	Turkey	Kalmış & Sargın 2004)

Table 1 Continued.

Name of the mushrooms	Substrate	Substrate composition	Importance of Substrates	Reported from	References
P.HK-37 *P. sapidus*	Cattails weed botanical fractions namely, stems and leaves, spikes, rhizomes and roots and whole cattail weed	NA	Whole cattail weed was found to be a suitable substrate Rhizomes and roots were found to be a suitable substrate	Tanzania	Mshandete (2011)
Flammulina velutipes	Fermented Apple Pomace (FAP)	1. Corncob; 2. Fermented Apple Pomace; 3. Rice bran; 4. Cottonseed hull; 5. Wheat bran; 6. Sugar beet powder; 7. Soy pulp	FAP was an alternative substrate for *F. velutipes* as raw material	Japan	Hiramori et al. (2017)
Lyophyllum decastes	Culture wastes of *P.ostreatus* and *Pholiotanameko*	A mixture composed of bark compost (sawdust used for cultivating *P. ostreatus* and *P. nameko* were from softwood (*Cryptomeria japonica*) and hardwood (not identified), respectively. The culture wastes were piled and left outdoors under natural conditions.) and rice bran (10:1, v/v)	The results showed that outdoor treatment of culture waste is useful for producing *L. decastes* fruit bodies	Japan	Akamatsu (1998)
P. tuber-regium	Cassava (*Manihot* sp.) peelings corn (*Zea*sp.) straw oil palm fruit fibre rice (*Oryza* sp.) and straw wild grass (*Pennisetum* sp.)	NA	Oil palm fruit fibre substrate was the most suitablesubstrate	Nigeria	Okhuoya & Okogbo (1991)
Ganoderma lucidum	Waste, oat straw, bean straw, brachiaria grass straw, Tifton grass straw and eucalyptus straw	1.Tyfton straw 0% of wheat bran; 2. Tyfton straw 20% of wheat bran; 3.Brachiaria straw 0% of wheat bran; 4.Brachiaria straw 20% of wheat bran; 5.Oat straw 0% of wheat bran; 6.Oat straw 20% of wheat bran; 7.Bean straw 0% of wheat bran; 8.Bean straw 20% of wheat bran; 9.Eucalyptus sawdust 0% of wheat bran; 10.Eucalyptus sawdust 20% of wheat bran	Brachiaria straw showed the greater yield	Brasil	Carvalho et al. (2015)

Table 1 Continued.

Name of the mushrooms	Substrate	Substrate composition	Importance of Substrates	Reported from	References
Ganoderma lucidum	*Pennisetum purpureum* (napier or elephant grass); *Brachiariabrizantha*cv. Marandu (marandu); *Brachiariabrizantha*cv. Aruana (aruana); *Panicum maximum* cv. Massai(massai); *Panicum maximum* cv. Mombaça (mombaça); *Brachiaria Decumbens*cv. Basilisk (brachiaria); *Brachiariahumidicola*c Humidícola (humidícola); *Brachiariabrizantha*cv. Xaraés (xaraés); *Cynodon*spp. cv. tifton 85 (tifton 85 or Bermuda grass); *Brachiariabrizantha*cv. Piatã (piatã); (Control) *Eucallyptus*spp. (eucalyptus sawdust)	80% of grass, 18% of wheat bran and 2% of limestone	*B. brizantha*cv. Aruana (aruana) and *Cynodon*spp. cv. tifton 85 (tifton) were the most suitable substrate for the cultivation of *G. lucidum*	Brazil	André et al. (2017)
Agaricus arvensis *Agaricus bitorquis* *A. subrufescens*	Straw paper, chicken manure, anaerobic and digestate	NA	Yields was higher in the paper-digestate based on conventional compost	Poland, Norway	Jasińska et al. (2016)
Macrolepiota procera	Wheat straw, oak leaves, peat and the mixtures of these materials at different ratios	1. Straw; 2. Straw: Peat (1:1); 3. Straw: Peat (2:1); 4. Commercial compost; 5. Commercial compost: Peat (1:1); 6.Commercial compost: Peat (2:1)	Fruiting bodies has not been obtained	Turkey	Pekşen & Kibar (2017)

Table 1 Continued.

Name of the mushrooms	Substrate	Substrate composition	Importance of Substrates	Reported from	References
P. ostreatus	Wheat straw and cardboard	1. 100% wheat straw 2. 100% cardboard 3.50% wheat straw and 50% cardboard 4.30% wheat straw and 70% cardboard	Used cardboard increased the yield, fruits size and also provided more biological efficiency	Iraq	Owaid et al. (2015)
Agaricus bisporus *A. bitorquis*	Supplemented wheat straw and sugar cane bagasse	NA NA	NA NA	Central America	De Leon et al. (2003)
Lentinula edodes	Sawdust from oak and rubber trees	NA	NA		
Pleurotus. sp	Wheat straw, coffee pulp, corn-cobs	NA	NA		
Pholiota microspora	Corn stalks and sawdust	1.38% wood chips and 38% corn stalks 2.19% corn stalks	The mixture of corn stalks and sawdust was a novel, inexpensive and high-yield alternative for the cultivation of *P. microspora*	China	Meng et al. (2019)
Auricularia delicata	Rubberwood sawdust, wheat bran, maize powder, cottonseed hull and soybean powder	1. Rubberwood sawdust, wheat bran, maize powder. 2. Rubberwood sawdust, wheat bran, maize powder, cottonseed hull. 3. Rubberwood sawdust, wheat bran, maize powder, soybean powder. 4. Rubberwood sawdust, wheat bran, soybean powder. 5. Rubberwood sawdust, wheat bran, maize powder, cottonseed hull.	Rubberwood was found better substrate for mushroom cultivation	Portugal	Xing-Hong et al. (2016)
Auricularia polytricha	Paddy straw, wheat bran and rice bran.	1.Paddy straw; 2.Paddy straw + wheat bran(3:1); 3.Paddy straw + rice bran(3:1); 4.Paddy straw + saw dust (3:1); 5.Paddy straw + wheat bran(1:1); 6.Paddy straw + rice bran(1:1); 7.Paddy straw + saw dust (1:1)	Paddy straw + wheat bran (3:1) found as better substrate	India	Devi et al. (2013)
Lentinus tigrinus (ZB12MF03) *Lentinus tigrinus* (ZB12MF06) *Lentinus tigrinus*	Rice straw, sawdust and rice bran	8 parts rice straw + 2 parts sawdust formulation with 1.25 Rice bran; 2.50 Rice bran; 3.75 Rice bran;	Agricultural wastes could be used as a supplement to improve the production of mushrooms	Philippines	De Leon et al. (2013)

Table 1 Continued.

Name of the mushrooms	Substrate	Substrate composition	Importance of Substrates	Reported from	References
(ZB12MF05)		4.100 Rice bran; 5.25 Rice grits; 6.50 Rice grits; 7.75 Rice grits; 8.100 Rice grits			
Lentinus tigrinus	Wheat straw, sawdust and wheat bran.	1.Wheat straw + wheat bran 2.Sawdust + wheat bran	The best yield of *L. tigrinus*was obtained with a mixture of Sawdust + wheat bran	Iran	Shahtahmasebi et al. (2017)
Agrocybe cylindracea *P. cystidiosus* *P. eryngii* *P. ostreatus* *P. pulmonarius*	Two-phase olive mill waste.	1. Two-phase olive mill waste 20%; 2. Two-phase olive mill waste 40%; 3. Two-phase olive mill waste60%; 4.Composted Two-phase olive mill waste 20%; 5. Composted Two-phase olive mill waste 40%; 6. Composted Two-phase olive mill waste 60%.	The productivity of all four mushroom species examined was found to be the highest when wheat straw was supplemented with 20-40% composted	Greece	Zervakis et al. (2013)
Agaricus blazei	Sawdust, woodchips and corncob	In the ratio of 25%, 50%, 75% and 100% (by weight) (e.g. compost/sawdust 1:3, 1:1, 3:1, and 1:0). Rice bran and wheat bran were used as supplementary	Compost (100%), woodchips (25%) and corncob (25%) produced better yields	Japan	Win & Ohga (2018)
Tricholoma lobayense	*Chamaecristarotundifolia* hay powder and wheat bran	Six treatments were set up by substituting wheat bran with various proportions of *C. rotundifolia* hay powder in the basic formula of culture substrates, i.e., No wheat bran replaced (WBR0), 20% wheat bran replaced (WBR20), 40% wheat bran replaced (WBR40), 60% wheat bran replaced (WBR60), 80% wheat bran replaced (WBR80), and 100% wheat bran replaced (WBR100).	Replacing 40% of wheat bran with *C. rotundifolia* hay powder in the traditional formula led to 76.92% increase of the biological efficiency and 29.14% increase of total yield compaired to the other treatments	China	Weng et al. (2013)
Polyporus tenuiculus	Wheat straw and willow sawdust	1. Wheat straw (98); 2. Wheat straw (78); 3. Willow sawdust (98); 4. Willow sawdust (78); 5. Willow sawdust (73)	The highest yields were obtained on sawdust with 25% of supplements	Argentina	Omarini et al. (2009)
P.ostreatus	Sawdust and paddy straw	NA	Paddy straw was the best substrate for cultivation of *P. ostreatus*	Tripura, India	Debnath et al. (2019)
Agaricus bisporus	Vine shoots, grape stalks, grape pomace	cereal straw,poultry manure and urea as nitrogen supplements, andgypsum as a structure corrector), was used as a control.Three alternative substrates were made in which strawwas entirely substituted	The greatest number ofmushrooms was obtained with the conventional indoorsubstrate and the 1:1 shoot/stalk combination (766 and796 mushrooms m-	Spain	Pardo et al. (2007)

Table 1 Continued.

Name of the mushrooms	Substrate	Substrate composition	Importance of Substrates	Reported from	References
		by different combinations (3:1,1:1 and 1:3, w/w) of vine shoots and grape stalks.	2respectively). However, the bestyield per unit area and the greatest biological effi-ciency were obtained with the control indoor substrate (18.28 kg m-2and 90.0 kg 100kg-1compost		
Agaricus blazei	cattle compost,sugarcane compost, sawdust, rice bran.	Sawdust and rice bran were chosen as supplementary substances to increase mushroom yields and to achieve faster growth. The compost was mixed with sawdust rates of 0%, 10%, 20%, 30%, 40%, 50%, and 100%. Each mixture of the substrate was supplemented with rice bran 20% of the total weight.	New sugarcane compost substrates, the highest yield was 29.56g on 60% compost followed by 27.82g on 50% compost, 26.30g on 80% compost, 25.08g on 70% compost, and 24.30g	Japan	Horm & Ohga (2008)
Agaricus subrufescens	Sugar cane bagasse, Massai straw, oat straw, Aruana straw, soybean meal	NA		Iran	Zied et al. (2012).
Ganoderma lucidum	Sawdust, malt extract, and wheat bran	Three kinds of sawdust (beech, poplar, and hornbeam)	The highest fruiting body yield and BE were found using hornbeam sawdust	NA	Azizi et al. (2012)
Ganoderma lucidum	Various kinds of sawdust and bran	NA	sawdust, bran and mixtures both in yield and biological efficiency. The highest yield and BE were obtained from oak sawdust	Turky	Erkel (2009)
Ganoderma lucidum	Poplar sawdust and wheat bran	Poplar sawdust and wheat bran were mixed at a ratio of 4:1 based on their dry weight (w/w)	1% molasses and corn gluten meal dosages sigificantly affected on the yield and BE. The highest yield was obtained by in substrates added with 1% molasses and gluten meal than that of other dosages.	Turky	Erkel (2019)
P. ostreatus	Coffea arabica and Ficus sycomorus leaves	Coffea arabica (coffee leaf) and Ficus sycomorus (Sholla) leaf and other additive like cow dung	cultivation of P. ostreatus shows that sholla leaves led to the best growth	Ethiopia	Alemu (2013)
P. sajor-caju	Substrate: Sugar cane bagasse	NA	Washed fresh sugarcane bagasse is viable as a substrate for the production of the mushroom P. sajor-caju, especially in view of its low contamination and of a reduction in substrate disinfection costs	Brasil	Moda et al. (2005)

NA=Not applicable

Conclusion

This review work established brief data on cultivated wild edible mushroom species on different types of easily available substrates, like agricultural waste products, forest waste products, and industrial products. Based on the present documentation, it can be suggested that agricultural waste is more useful for the cultivation of Oyster mushrooms (*Pleurotus*) on a large scale in comparison to industrial or other waste products. People from different countries of the world cultivate Oyster mushrooms (*Pleurotus*) by using different biodegradable waste as substrate. This review work will be helpful for rural people to cultivate a specific type of wild edible mushroom on an easily accessible substrate for a short period with higher productivity by using a standard ratio. This review also revealed that different cultivation techniques have already been developed by various researchers from different parts of the world for the cultivation of the edible mushroom *Pleurotus*. Therefore, more research will be necessary to develop the standard cultivation techniques of other highly edible mushrooms throughout the world. On the other hand, further research is also necessary to unearth the relationship between the active components of cultivated mushrooms and substrates for better productivity.

Compliance with ethical standards

Conflict of interest

The authors declare that there is no conflict of interest with this review work.

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Not required

Accessibility of data

Not required

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