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Edible Mushroom of *Lentinula* spp.: A Case Study of Shiitake (*Lentinula edodes* L.) Cultivation

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Day by Day, the human is searching about any alternative sources for his nutrition beside the main traditional sources. Edible mushrooms already have been consumed by the human several years ago due to their beneficial for human health. The list of edible mushrooms and their species include many different mushrooms like *Pleurotus*, *Lentinula* and others. The mushroom of shiitake (*Lentinula edodes* L.) is considered the second important cultivated mushroom in the world, which is contributed by more than 25% from the global mushroom consumption. This mushroom has several promising properties, which support their applications in many fields including fresh and functional foods, bioethanol production, bio-control of plant diseases, bioindicator for soil and water pollution, medicinal attributes, and biotechnological application. Several studies have been published on this mushroom in different themes, but there are still many fields need investigations including the green or biosynthesis of nanoparticles using this mushroom beside the myco-nano-remediation of polluted environments.

Keywords: *Lentinula*, *Lentinus*, Nutritional value, Medicinal attributes, Substrate

1. Common species in *Lentinula* and *Lentinus* genera

Mushroom of *Lentinus* is located in the Kingdom of Fungi, Phylum of Basidiomycota, Class of Agaricomycetes, Order of Polyporales, Family of Polyporaceae, and finally its genus is *Lentinus*, whereas the genus of *Lentinula* is a small wood-dwelling fungi, erected by in 1909 by the American mycologist “Franklin Sumner Earle” belongs the family of Omphalotaceae or Marasmiaceae, and order of Agaricales (**Figs. 1 and 2**). The common species in both species are listed in **Tables 1 and 2.** *Lentinula* fungi feed saprobically on the deadwood of broad-leaved trees in the tropical and sub-tropical zones of Asia, Australia, North and South America. In general, the fruiting bodies of these mushrooms are light-colored to black or reddish brown, with a convex to flat cap supported by a fibrous stalk (Soković et al. 2018).

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Table 1. A list of accepted species of the genus of *Lentinus* according to the Global Biodiversity Information Facility (GBIF).

Mushroom species name (Year of publication)	Mushroom species name (Year of publication)
Lentinus anastomosans Rick (1938)	*Lentinus luteoapplanatus* Beeli (1928)
Lentinus anthocephalus (Lév.) Pegler (1971)	*Lentinus macgregorii* P.W.Graff (1913)
Lentinus araucariae Har. & Pat. (1903)	*Lentinus martianoffianus* Kalchbr. (1877)
Lentinus arcularius (Batsch) Zmitr. (2010)	*Lentinus melzeri* Velen. (1920)
Lentinus atrobrunneus Pegler (1971)	*L. megacystidiatus* Karun., K. Hyde & Z. Yang (2011)
Lentinus badius (Berk.) Berk. (1847)	*Lentinus metatensis* Bacc. (1917)
Lentinus baguirmiensis Pat. & Har. (1908)	*Lentinus mitissimus* Bigeard & H.Guill. (1913)
Lentinus bambusinus T.K.A. Kumar & Manim. (2005)	*Lentinus mollipes* Pat. (1917)
Lentinus berteroi (Fr.) Fr. (1825)	*Lentinus nigroglaber* Lloyd (1923)
Lentinus brumalis (Pers.) Zmitr. (2010)	*Lentinus nigro-osseus* Pilát (1936)
Lentinus brunneofloccosus Pegler (1971)	*Lentinus ochraceus* Lloyd (1920)
Lentinus caesariatus Pat. (1924)	*Lentinus ochroleucus* Beeli (1928)
Lentinus calyx (Speg.) Pegler (1983)	*Lentinus omphalopsis* Reichert (1921)
Lentinus campinensis Teixeira (1946)	*Lentinus orizabensis* Murrill (1915)
Lentinus candidus P.W. Graff (1913)	*Lentinus palauensis* Imazeki (1941)
Lentinus chordalis Lloyd (1919)	*Lentinus palmeri* (Earle) Sacc. & Traverso (1911)
Lentinus chudaei Har. & Pat. (1912)	*Lentinus papillatus* (Henn.) Henn. (1905)
Lentinus cochlearis (Pers.) Bres. (1903)	*Lentinus pertenuis* Lloyd (1922)
Lentinus concavus (Berk.) Corner (1981)	*Lentinus phillipsii* Van der Byl (1926)
L. concentricus Karun., K. Hyde, Z. L. Yang (2011)	*Lentinus pholiotaeformis* Velen. (1939)
Lentinus concinnus Pat. (1892)	*Lentinus pilososquamulosus* Lj.N.Vassiljeva (1973)
Lentinus connatus Berk. (1842)	*Lentinus piperatus* Beeli (1928)
Lentinus copulatus (Ehrenb.) Henn. (1898)	*Lentinus polychrous* Lév. (1844)
Lentinus cordubensis Speg. (1902)	*Lentinus prancei* Singer (1981)
Lentinus courtetianus Har. & Pat. (1909)	*Lentinus prolifer* (Pat. & Har.) D.A. Reid (1977)
Lentinus crinitus (L.) Fr. (1825)	*Lentinus pulcherrimus* Sumst. (1907)
Lentinus densifolius R. Heim & L. Rémy (1926)	*Lentinus ramosii* Lloyd (1923)
Lentinus dicholamellatus Manim. (2004)	*Lentinus ramosipes* Har. & Pat. (1909)
Lentinus egregius Massee (1910)	*Lentinus retinervis* Pegler (1983)
Lentinus elmeri Bres. (1912)	*Lentinus roseus* Karun., K. Hyde & Z. L.Yang (2011)
Lentinus elmerianus Lloyd (1922)	*Lentinus rubescens* Velen. (1939)
Lentinus erosus Lloyd (1925)	*Lentinus sajor-caju* (Fr.) Fr. (1838)
Lentinus erringtonii Pat. & Har. (1900)	*Lentinus samarensis* Pilát (1941)
Lentinus fasciatus Berk. (1840)	*Lentinus sayanus* Singer (1952)
Lentinus favoloides R. Heim (1964)	*Lentinus sclerogenus* Sacc. (1916)
Lentinus floridanus (Murrill) Murrill (1943)	*Lentinus scleropus* (Pers.) Fr. (1836)
Lentinus fluxus Herp. (1912)	*Lentinus sibiricus* Pilát (1936)
Lentinus freemanii Murrill (1919)	*Lentinus similans* (Earle) Sacc. & Traverso (1911)
Lentinus fuscoexactus Lloyd (1922)	*Lentinus squamosus* Quél. (1888)
Lentinus fuscus Lloyd (1925)	*Lentinus squarrosulus* Mont. (1842)
Lentinus fusipes Cooke & Massee (1887)	*Lentinus striatulus* Lév. (1846)
Lentinus gibbsiae A.L. Sm. (1909)	*Lentinus stuppeus* Klotzsch (1833)
Lentinus glabratus Mont. (1842)	*Lentinus subdulcis* Berk. (1851)
Lentinus gogoensis Har. & Pat. (1909)	*Lentinus subscyphoides* Murrill (1911)
Lentinus goossensiae Beeli (1928)	*Lentinus swartzii* Berk. (1843)
Lentinus graminicola Murrill (1911)	*Lentinus terrestris* Lloyd (1925)
Lentinus huensis Lloyd (1922)	*Lentinus thomensis* Cout. (1925)
Lentinus integrus Reichert (1921)	*Lentinus tigrinoides* Corner (1981)
Lentinus inverseconicus Pat. (1923)	*Lentinus tigrinus* (Bull.) Fr. (1825)
Lentinus isabellina Lloyd (1922)	*Lentinus tuber-regium* (Fr.) Fr. (1836)
Lentinus lagunensis P.W. Graff (1913)	*Lentinus umbrinus* Reichardt (1866)
Lentinus lamelliporus Har. & Pat. (1902)	*Lentinus velutinus* Fr. (1830)

Lentinus lateripes Lloyd (1922)	*Lentinus vestidus* (Earle) Sacc. & Traverso (1912)
Lentinus ledermannii Pilát (1936)	*Lentinus villosus* Klotzsch (1833)
Lentinus lepideus (Fr.) Fr. (1838)	*Lentinus zelandicus* Sacc. & Cub. (1887)
Lentinus levis (Berk. & M.A. Curtis) Murrill (1915)	*Lentinus zenkerianus* Henn. (1905)
Lentinus lividus Beeli (1928)	*Lentinus zeyheri* Berk. (1843)

Source: https://www.gbif.org/species/ accessed on 20.01.2022.

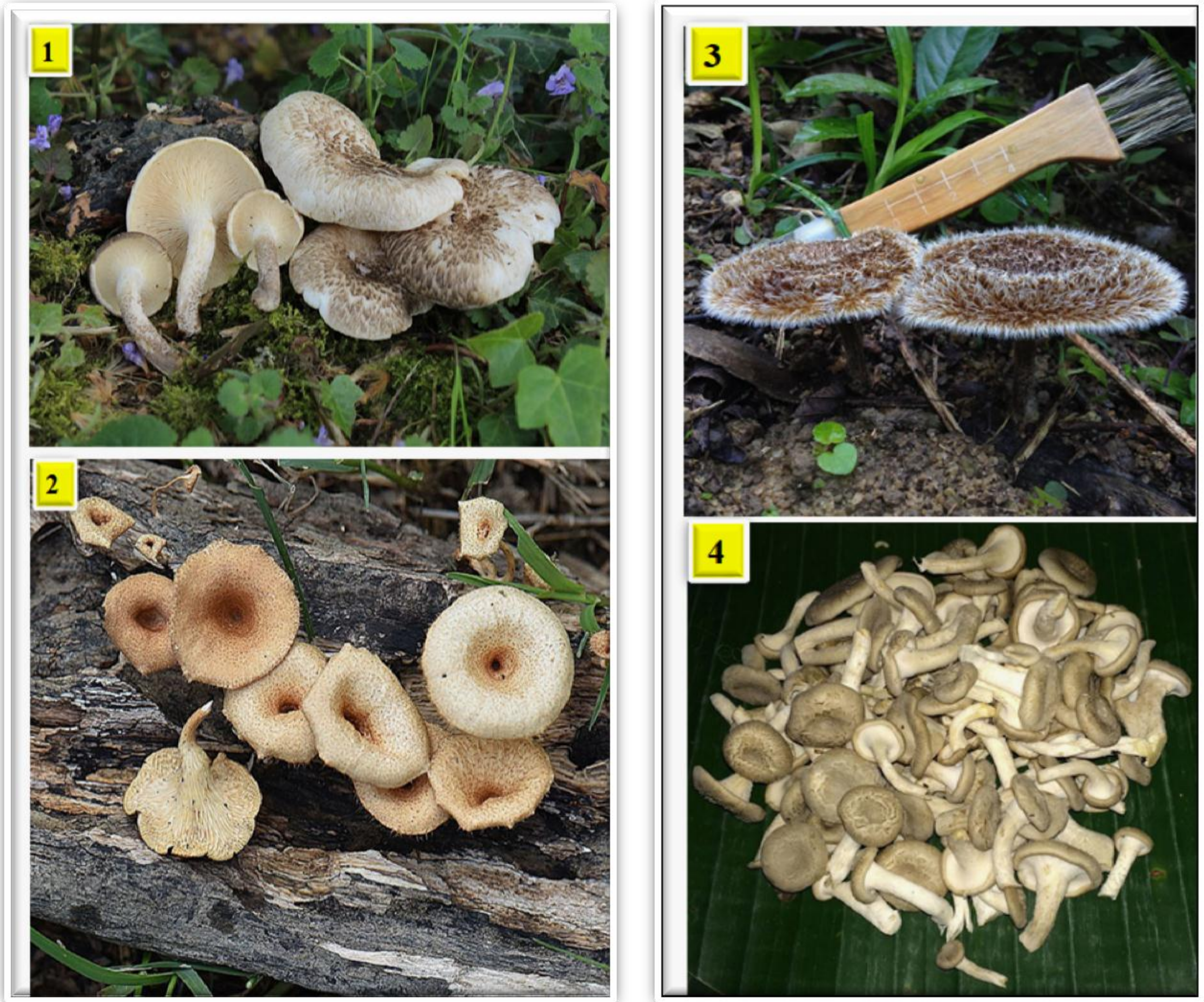

Fig. 1. Some photos of some *Lentinus* spp. including *Lentinus tigrinus* (Bull.) Fr (Photo 1), *Lentinus swartzii* Berk. (Photo 2), *Lentinus berteroi* (Fr.) Fr (photo 3), and *Lentinus squarrosulus* Mont. (Photo 4), the source: https://en.wikipedia.org/wiki/Lentinus accessed on 9.2.2022.

Table 2. A list of accepted species of the genus of *Lentinula* according to the Global Biodiversity Information Facility (GBIF).

Mushroom species name (Year of publication)	Mushroom species name (Year of publication)
L. aciculospora J. Mata & R. Petersen (2000)	*Lentinula guarapiensis* (Speg.) Pegler (1983)
L. boryana (Berk. & Mont.) Pegler (1976)	*Lentinula lateritia* (Berk.) Pegler (1983)
L. cubensis (Berk. & M. Curtis) Earle ex Pegler	*L. novae-zelandiae* (G. Stev.) Pegler (1983)
Lentinula detonsa (Fr.) Murrill (1911)	*L. raphanica* (Murrill) Mata & R Petersen (2001)
Lentinula edodes (Beck.) Sing. (1976)	*Lentinula reticeps* (Mont.) Murrill (1915)

Source: https://www.gbif.org/species/ accessed on 10.02.2022.

Fig. 2. Some common mushrooms belong the genus of *Lentinula* including *Lentinula boryana* (photo 1), *Lentinula aciculospora* (photo 2), shiitake mushroom (*Lentinula edodes* L.) (photo 3), and *Lentinula lateritia* (photo 4). Source: https://en.wikipedia.org/wiki/Shiitake#/media/File:Shiitakegr owing.jpg accessed on 9.2.2022.

2. Cultivation of *Lentinula edodes* L.

It is well known that; mushrooms have been gain recently great concern due to their prospects in medicine and nutraceutical production. Mushrooms also have high nutritional values, good organoleptic properties, and a myriad of pharmacological attributes (Elhusseiny et al. 2021). The mushroom of *Lentinula edodes* (Berk.) Singer is called Shiitake in Japanese or Xiang-gu in Chinese and is considered a nutritious edible and medical mushroom (Yu et al. 2022a). These mushrooms can provide human with proteins, dietary fibers, essential amino acids, and many vitamins like B_1, B_2, B_{12}, C, D, and E, as well as many medicinal molecules including lipids, polysaccharides, sterols, and, terpenoids, which possess antioxidant, anti-tumor, anti-viral, anti-hypertensive, and immune-modulatory attributes (Finimundy et al. 2014; Yu et al. 2022a). Shiitake mushroom (*Lentinula edodes* L.) is considered the leading cultivated mushroom in the world, where it contributes by 22% of the world's mushroom supply with an annual production over 7 billion kg (Royse et al. 2017; Yu et al. 2022a). The chemical composition of organic cultivated (bio-cultivation) *L. edodes* in 5 countries in Asia and Europe was evaluated. The results confirmed that organic mushrooms have a higher content of major essential nutrients and less light and heavy rare earth elements compared to the traditional cultivated mushrooms (Siwulski et al. 2021).

The growing of *L. edodes* in early days was usually on natural logs of the “shii tree” (*Castanopsis cuspidate*). In late 1960s in China, the sawdust-based substrate was invented as a breakthrough technique in this mushroom cultivation, which largely increased the production efficiency by improving nutrient utilization and shortening mushroom cycle. This substrate has been upgraded and widely used by several growers in all producing countries (Yu et al. 2022a). Several agricultural wastes or byproducts and forest residues have been used for mushroom cultivation such as hazelnut husk (Ozcelik and Peksen 2007), ground wheat straw (Royse et al. 2007; Baktemur et al. 2020), peanut shell (Baktemur et al. 2020), maize cob and vine pruning waste (Baktemur et al. 2020), which can enable the biotransformation of these wastes (**Table 3**). Different formulas have been reported concerning the substrates for *L. edodes* cultivation including the ground wheat straw with different applied ratio like the formula of wheat straw (8 – 16%) to 44– 32 % oak sawdust, respectively, which their mushroom yields were 11 and 19% higher as compared with reference formula (52% oak sawdust), whereas mushroom sizes were not affected by formula changes (Yu et al. 2022a).

Table 3. The most common substrate that use in cultivation of shiitake mushrooms in different places and different literatures.

The country	The used suberates in shiitake mushroom cultivation	References
The USA	Sawdust substrate could be used for 16–20-day spawn run and then browning outside or inside the bag	Royse et al. (2017)
Japan	Nearly 90% of this mushroom production uses the blocks made from solidified woodchips	Ogawa and Yashima (2019)
Japan	Japanese beech (*Fagus crenata*) sawdust mixed with rice bran at ratio 95:5 (w/w) to cultivate shiitake on bed logs	Hiraide (2021)
Brazil	Shiitake could be cultivated on logs of *Eucalyptus* species beside using synthetic bags cultivation with sawdust	Eira and Meirelles (2005)
Sweden	Birch sawdust (28 %) wheat grain (3.5 %), wheat bran (3.5%), and $CaCO_3$ (0.55 %)	Xiong et al. (2019)
Sweden	Birch bark (10-20 %), whey (1-2%), birth stem wood (58-80%), barley grains (10%), and wheat bran (10%)	Chen et al. (2020)
Sweden	Sawdust of species (white birch, alder) were debarked, chipped, dried, ground, beside wheat bran and whey	Chen et al. (2022a)
China	General formula consists of oak sawdust (78%), wheat bran (20%) and gypsum (2%)	Yu et al. (2017)
China	Sawdust (79-89%) was applied (in %) to wheat bran (10-20), rice bran (10), soy bean pulp (10), gypsum (1) and maize meal (10) and bagasse (20) in different formulas	Li et al. (2019)
China	Components in (%) were oak sawdust (20-80), rice straw (80-20), wheat brane (18), lime and saccharose (1%)	Gao et al. (2020)
Korea	Korean substrate includes about oak tree sawdust (80%), and rice or wheat bran (20%); water content (55–60%)	Chung et al. (2020)
China	Modified formula consists of maize cob (20–78 %), oak sawdust (18–78 %), wheat bran (20%), and gypsum (2%)	Yu et al. (2022a)
Malaysia	Modified medium of Shochu distillation lees including hardwood sawdust (71-91%) and nutrient (5-25%)	Azman et al. (2019)
Poland	Beech and oak sawdust (1:1 vol.), wheat bran (25%), corn flour (5%), soy meal (5%) and gypsum (1%)	Gąsecka et al. (2021)
Russia	Sawdust of oak and wheat bran (10%), $CaCO_3$ (0.1%), gypsum (1%) and 70% moisture	Titova (2022)

Usually, the common cultivated method of *Lentinula edodes* is the cut-log cultivation, which requires a long growth period till fruiting bodies of the mushrooms and this leads to the destruction of large forest resources (Li et al. 2019). Based on the advanced in agro-byproducts recycling and the fast development in mushroom cultivation technology, terrible increases in the culture substrate combinations using different materials have been applied for the cultivation of *L. edodes*. The main factor controlling selecting substrate is the suitable sources of both carbon and nitrogen, which could provide adequate nutrients for the fruiting bodies growth. The fruiting bodies quality also depend on these substrates especially the mushroom texture and its flavor (Li et al. 2019). Nam et al. (2021) found that the antioxidant capacity, the bioactive compounds, and metabolic profiles in *Lentinula edodes* cultivated on log vs sawdust substrates were the main differences. In this study, the primary metabolites content was high in *L. edodes* grown on sawdust due to the high growth rate compared to log-cultivated *L. edodes*. Several studies have been published on the cultivation of shiitake and its substrate from different point of view like studying the transfer of some pollutants like cesium using shiitake cultivated in substrate of sawdust of beech (*Fagus crenata*) mixed with rice bran (Hiraide 2021). This study confirmed that the exchangeable Cs (as a pollutant) should be measured as the transfer factor in both shiitake and substrate just before fruiting body development. The genetics and breeding studies on *L. edodes* still few and need more especially, to focus on these properties under pollution conditions like polluted with cadmium (Yu et al. 2022b).

3. Applications of *Lentinula edodes* L.

Shiitake mushroom (*Lentinula edodes* L.) is considered the 2nd most cultivated edible mushrooms all over the world because of its high protein, low lipid content, and its vital source for the minerals and vitamins (Spim et al. 2021). *Lentinula edodes* may has several applications including bioethanol production (Xiong et al. 2019; Chen et al. 2022b), its spent mushroom compost has nematicidal activity against nematodes like *Panagrellus* spp. (Ferreira et al. 2022), improving the utilization of wheat in poultry production by enzymes of xylanase (Liu et al. 2022), bioindicator for soil pollution (Chung et al. 2020; El-Ramady et al. 2021; Yu et al. 2020, 2021), medicinal attributes (Muszyńska et al. 2020; Elhusseiny et al. 2021), in biotechnology due to their preventing the chronic diseases, especially diabetes and hypercholesterolemia (Spim et al. 2021), as a source of Bio-elements (Muszyńska et al. 2020), and in bio-controlling plant-diseases like strawberry leaf spot caused by *Xanthomonas fragariae* (Rodrigues et al. 2021). This mushroom has many morphologically distinct virus-like particles or mycovirus (Guo et al. 2021). This mushroom has a nutritional complexity, which could be developed as functional food (like functional bars), due to its low-cost of production, stability and the flexibility to add the functional ingredients, easy transportation, and good acceptance (Hadi et al. 2018; Spim et al. 2021). The shiitake mushroom could be consumed as fresh fruiting bodies in different varieties of cooked dishes and as dried fruiting bodies, which have toast-like or garlic-like aromas (Li et al. 2019).

This is a call for submission articles on this important mushroom including reviews, mini-reviews, original articles, short communication. Any further study to focus on different applications of shiitake mushroom and their cultivation. The environmental issues are most welcome from different angles on this mushroom. The EBSS journal strongly encourages all researchers all over the world to submit their work on this mushroom or any edible mushroom to change the global culture of human diets. The negative sides of consumption of shiitake particularly when this mushroom is grown in polluted environments also are more than welcome.

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4. References

Azman NF, Yamauchi M, Yamada M, Ikeda S, Yamaguchi T, Yagi F, Hara H (2019). Utilization of distillation waste of sweet potato Shochu lees for Lentinula edodes cultivation. Journal of Material Cycles and Waste Management 21, 336–344. https://doi.org/10.1007/s101 63-018-0795-5.

Baktemur, G., Elik, Z.D., Kara, E., Takn, H. (2020). The effect of different agricultural wastes on aroma composition of shiitake (*Lentinula edodes* (berk.) pegler) mushroom. Turk. J. Agric. 8(7), 1540–1547

Chen F, Xiong S, Gandla ML, Stagge S, Martín C (2022b). Spent mushroom substrates for ethanol production – Effect of chemical and structural factors on enzymatic saccharification and ethanolic fermentation of Lentinula edodes-pretreated hardwood. Bioresource Technology 347, 126381. https://doi.org/10.1016/j.biortech.2021.126381

Chen, F., Martín, C., Lestander, T.A., Grimm, A., Xiong, S (2022a). Shiitake cultivation as biological preprocessing of lignocellulosic feedstocks – Substrate changes in crystallinity, syringyl/guaiacyl lignin and degradation-derived by-products. Bioresource Technol. 344, 126256. https://doi.org/10.1016/j.

Chung I-M, Kim S-Y, Han J-G, Kong W-S, Jung MY, Kim S-H (2020). Fatty Acids and Stable Isotope Ratios in Shiitake Mushrooms (Lentinula edodes) Indicate the Origin of the Cultivation Substrate Used: A Preliminary Case Study in Korea. Foods, 9, 1210; doi:10.3390/foods9091210

Eira F, Meirelles W (2005). Shiitake production in corncob substrates. Revista Brasileira de Milho e Sorgo 4(02), 141– 148. https://doi.org/10.18512/1980-6477/rbms.v4n2p 141-148

Elhusseiny SM, El-Mahdy TS, Awad MF, Elleboudy NS, Farag MMS, Yassein MA, Aboshanab KM (2021). Proteome Analysis and In Vitro Antiviral, Anticancer and Antioxidant Capacities of the Aqueous Extracts of Lentinula edodes and Pleurotus ostreatus Edible Mushrooms. Molecules, 26, 4623. https://doi.org/10.3390/molecules26154623

El-Ramady H, Llanaj X, Prokisch J (2021). Edible Mushroom Cultivated in Polluted Soils and its Potential Risks on Human Health: A short communication. Egypt. J. Soil Sci. 61 (3), 381 – 389. DOI: 10.21608/ejss.2021.106452.1478

Ferreira JM, Braga FR, Soares FEF (2022). Nematicidal activity of the *Lentinula edodes*’ spent mushroom compost. South African Journal of Botany 146, 101-102.

Finimundy TC, Dillon AJP, Henriques JAP, Ely MR (2014). A review on general nutritional compounds and pharmacological properties of the Lentinula edodes mushroom. Food Nutr. Sci. 05(12), 1095–1105. https://doi.org/10.4236/fns.2014.512119

Gao S, Huang Z, Feng X, Bian Y, Huang W, Liu Y (2020). Bioconversion of rice straw agro-residues by *Lentinula edodes* and evaluation of non-volatile taste compounds in mushrooms. Sci Rep. 10: 1814. doi: 10.1038/s41598-020-58778-x

Gąsecka M, Siwulski M, Budzyńska S, Magdziak Z, Niedzielski P, Budka A, Kalač P, Mleczek M (2021). The importance of Cu× Pb interactions to *Lentinula edodes* yield, major/trace elements accumulation and antioxidants. European Food Research and Technology 247, 2799–2812. https://doi.org/10.1007/s00217-021-03833-8

Guo M, Shen G, Wang J, Liu M, Bian Y, Xu Z (2021). Mycoviral diversity and characteristics of a negative-stranded RNA virus LeNSRV1 in the edible mushroom *Lentinula edodes*. Virology 555 89–101. doi:10.1016/j. virol.2020.11.008.

Hadi V, Norouzy A, Tehrani MM, Nematy M, Hadi S (2018). Properties of compact food bars: a review study. JNFH 6:125-131.

Hiraide M (2021). Factors affecting the cesium transfer factor to shiitake (*Lentinula edodes*) cultivated in sawdust medium. e J Wood Sci 67, 17. https://doi.org/10.1186/s10086-021-01949-9.

Li, W, Wang, J, Chen, W, Yang, Y, Zhang, J, Feng, J, Yu, H, Li, Q (2019). Analysis of volatile compounds of Lentinula edodes grown in different culture substrate formulations. Food Research International, 125, 108517. doi:10.1016/j.foodres.2019.108517.

Liu C, Zhang W, Li Y, Pan K, Yang KO, Song X, Xiong X, Zang Y, Wang L, Qu M, Zhao X (2022). Characterization of yeast cell surface displayed *Lentinula edodes* xylanase and its effects on the hydrolysis of wheat. International Journal of Biological Macromolecules 199, 341-347. https://doi.org/10.1016/j.ijbiomac.2021.12.178.

Muszyńska MB, Kała K, Włodarczyk A, Krakowska A, Ostachowicz B, Gdula-Argasińska J, Suchocki P (2020). *Lentinula edodes* as a Source of Bioelements Released into Artificial Digestive Juices and Potential Anti-inflammatory. Biological Trace Element Research 194, 603-613. https://doi.org/10.1007/s12011-019-01782-8.

Nam M, Choi JY, Kim M-S (2021). Metabolic Profiles, Bioactive Compounds, and Antioxidant Capacity in *Lentinula edodes* Cultivated on Log versus Sawdust Substrates. Biomolecules, 11, 1654. https://doi.org/10.3390/biom11111654.

Ogawa, K., Yashima, T. (2019). MRI visualization of shiitake mycelium growing in woodchip blocks used for shiitake mushroom cultivation. Magn. Reson. Imaging 58, 90–96. https://doi.org/10.1016/j.mri.2019.01.004.

Ozcelik, E., Peksen, A (2007). Hazelnut husk as a substrate for the cultivation of shiitake mushroom (*Lentinula edodes*). Bioresour. Technol. 98(14), 2652–2658. https://doi.org/10.1016/j.biortech. 2006.09.020

Rodrigues B, Coqueiro DSO, Di Piero RM (2021). Propolis and *Lentinula edodes* extracts can control the angular leaf spot of strawberry by different mechanisms. Journal of Plant Pathology 103, 799–808. https://doi.org/10.1007/s42161-021-00763-y.

Royse DJ, Baars J, Tan Q (2017). Current overview of mushroom production in the world. edible and medicinal mushrooms: technology and applications, 1st Ed. John Wiley & Sons Ltd. https://doi.org/10.1002/9781119149446.ch2.

Royse DJ, Sanchez JE (2007). Ground wheat straw as a substitute for portions of oak wood chips used in shiitake (*Lentinula edodes*) substrate formulae. Bioresour. Technol. 98(11), 2137–2141. https://doi.org/10.1016/j.biortech.2006.08.023

Siwulski M, Budka A, Budzynska S, Gąsecka M, Kalac P, Niedzielski P, Mleczek M (2021). Mineral composition of traditional and organic-cultivated mushroom *Lentinula edodes* in Europe and Asia – Similar or different? LWT 147, 111570. https://doi.org/10.1016/j.lwt.2021.111570

Soković M, Glamočlija J, Ćirić A, Petrović J, Stojković D (2018). Mushrooms as Sources of Therapeutic Foods. In: Alina Maria Holban and Alexandru Mihai Grumezescu (Eds.) Therapeutic Foods Handbook of Food Bioengineering, Pp: 141-178. https://doi.org/10.1016/B978-0-12-811517-6.00005-2

Spim SRV, Castanho NRCM, Pistila AMH, Jozala AF, Junior JMO, Grotto D (2021). *Lentinula edodes* mushroom as an ingredient to enhance the nutritional and functional properties of cereal bars. J Food Sci Technol 58(4), 1349–1357. https://doi.org/10.1007/s13197-020-04646-5

Titova JA (2022). Spent Mushroom Substrates Valorization via Brand New Multirecycled Polyfunctional Biologics Producing on Them. Waste and Biomass Valorization 13, 1089–1100. https://doi.org/10.1007/s12649-021-01552-5

Wei, Panpan; Li, Yimei; Lai, Deqiang; Geng, Lili; Liu, Chunqin; Zhang, Jie; Shu, Changlong; Liu, Rongmei (2020). *Protaetia brevitarsis* larvae can feed on and convert spent mushroom substrate from *Auricularia auricula* and *Lentinula edodes* cultivation. Waste Management, 114, 234–239. doi:10.1016/j.wasman.2020.07.009

Xiong S, Martín C, Eilertsen L, Wei M, Myronycheva O, Larsson SH, Lestander TA, Atterhem L, Jönsson LJ (2019). Energy-efficient substrate pasteurisation for combined production of shiitake mushroom (*Lentinula edodes*) and bioethanol, Bioresource Technology 274, 65-72, https://doi.org/10.1016/j.biortech.2018.11.071

Yu H, Li Q, Shen X, Zhang L, Liu J, Tan Q, Li Y, Lv B and Shang X (2020). Transcriptomic Analysis of Two Lentinula edodes Genotypes With Different Cadmium Accumulation Ability. Front. Microbiol. 11:558104. doi: 10.3389/fmicb.2020.558104

Yu H, Shen X, Chen H, Dong H, Zhang L, Yuan T, Zhang D, Shang X, Tan Q, Liu J, Lv B, Li Y (2021). Analysis of heavy metal content in Lentinula edodes and the main influencing factors. Food Control 130, 108198. https://doi.org/10.1016/j.foodcont.2021.108198

Yu H, Zhang D, Zhang L, Li Q, Song·C, Shang X, Bao D, Tan Q, Chen H, Lv B (2022a). Corncob as a Substrate for the Cultivation of *Lentinula edodes*. Waste and Biomass Valorization 13, 929–939. https://doi.org/10.1007/s12649-021-01575-y

Yu H, Zhang L, Shang X, Peng B, Li Y, Xiao S, Tan Q, Fu Y (2022b). Chromosomal genome and population genetic analyses to reveal genetic architecture, breeding history and genes related to cadmium accumulation in Lentinula edodes. BMC Genomics 23, 120. https://doi.org/10.1186/s12864-022-08325-x

Yu, H., Gao, C., Wang, Q., Zhang, L., Shang, X., Song, C., Zhang, M., Li, Y., Zhou, F., Tan, Q (2017). Effects of sawdust particle size on selected growth parameters of a Lentinula edodes cultivar. Acta Edulis Fungi 24(2), 5–9. https://doi.org/10.16488/j.cnki.1005-9873.2017.02.02