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Distribution, cultivation, nutritional composition, and bioactivities of *Lentinus* (Polyporaceae, Basidiomycetes): A review

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Abstract

Lentinus of the family Polyporaceae is one of the widely distributed and studied mushrooms worldwide. Aside from their reported edibility, species of *Lentinus* are well known for their nutritional and medicinal properties. Accordingly, this review aimed to provide a global checklist of *Lentinus* species, optimal culture conditions with special reference to their nutritional and physical requirements for growth and production, nutritional and bioactive compositions, biological properties, and other applications. A total of 86 *Lentinus* taxa belonging to 26 species were reported in 30 countries in Asia, Central and South America, Europe, and Africa, of which India recorded the highest number of species. *Lentinus tigrinus* was identified as the most widely reported species of the genus. Most *Lentinus* species favor coconut water-based medium for mycelial growth and rice straw and sawdust-based formulated substrate for fruiting body production. *Lentinus* species are rich sources of carbohydrates, crude fiber, 18 amino acids, 16 fatty acids, 14 mycochemicals, and 83 mycocompounds. They are also reported to exhibit several biological activities such as antioxidant, antimicrobial, antiproliferative, anticancer, antihypertensive, anti-ulcer, anti-diabetic, anti-obesity, cytotoxic, and teratogenicity. Moreover, *Lentinus* species are utilized in bioremediation, decolorization of waste dyes, and water purification. The data presented in this review, particularly the cultivation, nutritional, and biological compounds, and bioactivities of *Lentinus* species can be used as benchmark data for the production of *Lentinus*-based products such as nutritious and functional foods, dietary supplements, and pharmaceutical drugs in the global market.

Keywords – anticancer – functional food – mushroom diversity – responsible production

Introduction

Lentinus (Polyporaceae, Agaricomycetes, Basidiomycota) is morphologically characterized by having solid, tough, and round pileus with light brown to black scales, saw-toothed edges, white to yellow underside lamellae with hyaline, ellipsoidal to cylindrical basidiospores, and scaly white stipe (Dulay et al. 2020c). They are saprophytic fungi growing solitary or as a cluster on water-soaked woods, logs, and stumps of different tropical trees. They are widely distributed in tropical regions and thrive in a wide range of temperatures (Karunarathna et al. 2011).

Lentinus has been traditionally considered in the Family Tricholomataceae since it has a white spore print and a lamellate hymenophore (Miller 1973). However, due to the presence of

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dimitic and amphimitic hyphal systems, the group was included in Family Polyporaceae (Pegler 1983, Singer 1986). Molecular evidence also supports the claim that *Lentinus* ancestry is among the Polyporales, demonstrating that *Polyporus arcularius* Batsch: Fr is a near-related outgroup of *Lentinus* (Karunarathna et al. 2011).

Another debatable classification of *Lentinus* is the phylogenetic relationship between *Lentinus* and *Panus* and their allies (Hibbett & Vilgalys 1993). Based on morphology, some mycologists consider *Lentinus* and *Panus* as separate genera (Corner 1981). However, based on the phylogenetic and phylogenomic investigation of Binder et al. (2013), *Lentinus* is grouped in the core polyporoid clade while *Panus* is grouped in the residual polyporoid clade.

The morphogenesis from basidiospore to mycelia, and from mycelia to fruiting bodies of *L. tigrinus*, and *L. swartzii* have been documented (Dulay et al. 2012a, 2020a). The significant developmental stages include basidiospore swelling, elongation and septation, plasmogamy, hyphal branching, mycelial coat thickening, swelling or popcorn stage, browning, and mycelial coat hardening, primordia initiation, stipe elongation, and pileus expansion. The different developmental stages of *Lentinus* are dependent on nutritional and physical factors. Investigations of the morphology, basidiospore germination, morphogenesis, growth and development, and variations are very essential in the selection of strains/species for mass production and mushroom biotechnology research.

Due to the increasing demand and interest for functional food, attention has been paid to the nutritional and pharmacological importance of wild mushrooms including *Lentinus* species. Accordingly, published works on these topics are continuously expanding at the turn of the 21st century. *Lentinus* species have been reported for their cultivation potential and as a natural resource of nutritious food and pharmacologically important compounds for various diseases (Ragasa et al. 2018, Ugbogu et al. 2019, Reena Roy et al. 2020, Adeoye-Isijola et al. 2021). Herein, we reviewed the global records, distribution, cultivation, nutritional and chemical compositions, biological activities, and other applications of *Lentinus* species in order to provide benchmark data for their efficient utilization and conservation.

Distribution of *Lentinus* species

Mushrooms are usually found growing on lignin-cellulosic-rich substrates in forests, grasslands, agricultural, and other areas with favorable environmental conditions. Accordingly, the distribution and abundance of mushrooms in their natural habitat are strongly dependent on nutritional and environmental factors. Members of the Polyporaceae family are widely distributed in tropical, subtropical, temperate, and boreal regions of the world (Senthilarasu 2015). *Lentinus* species in each region may vary depending on the cultural requirements of individual species since each region has distinct environmental conditions.

This review paper listed a total of 86 *Lentinus* mushrooms that have been reported in Asia, Central and South America, Europe, and Africa (Table 1). These *Lentinus* mushrooms belong to 26 species. Among these species, *Lentinus tigrinus* was recorded as the most widely distributed species, which has been reported in 17 countries (Fig. 1). This was followed by *Lentinus crinitus* (9), *Lentinus squarrosulus* (7), *Lentinus sajor-caju* (7), and *Lentinus glabratus* (5). However, among the 30 countries, India recorded the highest number of reported *Lentinus* species (20), followed by Thailand (9), Malaysia and Philippines (6), Nigeria and Costa Rica (4), and USA (3) (Fig. 2). The geographic distribution of the 5 most widely reported *Lentinus* species is shown in Fig. 3.

Table 1 Distribution of different species of *Lentinus* worldwide.

Species of *Lentinus*	**Reported countries**	**References**
L. alopecinus Fr.	India	Fries (1838)
L. badius Berk.	India, Thailand, and Malaysia	Pegler (1983), Karunarathna et al. (2011), Grand et al. (2011)

Table 1 Continued.

Species of *Lentinus*	Reported Countries	References
L. bambusinus Kumar et Manim.	India	Kumar & Manimohan (2005)
L. candidus Graff.	India	Lloyd (1898-1925)
L. cladopus Lev.	Thailand, India, and Philippines	Natarajan 1978, De Leon et al. (2013a), Karunarathna et al. (2011)
L. concentricus	Thailand	Karunarathna et al. (2011)
L. concinnus Pat.	India	Senthilarasu (2015)
L. connatus Berk.	India and Nigeria	Sharma & Atri (2014), Afiukwa et al. (2015)
L. crinitus (Linn.:Fr.)	USA, India, Dominican Republic, Puerto Rico, Venezuela, Brazil, Costa Rica, Belize, and Ecuador	Natarajan & Raman (198), Grand (2004), Grand et al. (2011)
L. dicholamellatus Manim.	India	Manimohan et al. (2004)
L. fasciatus Berk.	Malaysia and India	Pegler (1983), Bolhassan et al. (2012)
L. glabratus Mont.	India, Costa Rica, Philippines, USA, and Cuba	Currey 1874, Grand (2004), Grand et al. (2011), Dulay et al. (2021b)
L. levis (Berk. and Curt.)	Mexico	Sobal et al. (1997)
L. megacystidiatus	Thailand and India	Karunarathna et al. (2011), Senthilarasu (2015)
L. patulus Lev.	India	Mohanan (2011)
L. polychrous Lev.	India, Thailand, and Malaysia	Manimohan et al. (2004), Grand (2004), Bolhassan et al. (2012)
L. prolifer (Pat & Har.) Pegler	India	Natarajan & Raman (1981)
L. roseus	Thailand	Karunarathna et al. (2011)
L. sajor-caju (Fr.) Fr.	Malaysia, Nigeria, Tanzania, Thailand, Philippines, India, and Brazil	Grand (2004), Manimohan et al. (2004), Cuevas et al. (2009), Bolhassan et al. (2012), Afiukwa et al. (2015), Hussein et al. (2016), Finimundy et al. (2018)
L. scleropus (Pers.)	Mexico	Grand et al. (2011)
L. squarrosulus Mont.	China, Philippines, India, Thailand, Nigeria, Ghana, and Japan	Manimohan et al. (2004), Karunarathna et al. (2011), De Leon et al. (2013b), Zhou et al. (2015), Anike et al. (2015), Ugbogu et al. (2020)
L. striatulus Lev.	Costa Rica	Grand et al. (2011)
L. swartzii Berk.	Philippines and Costa Rica	Grand (2004), Dulay et al. (2020a)
L. tigrinus (Bull.) Fr.	Malaysia, Nigeria, India, Turkey, Austria, Argentina, Iran, USA, Philippines, Thailand, Armenia, Mongolia, Azerbaijan, Ukraine, Russia, Czech Republic, and Uzbekistan	Grand (2004), Grand et al. (2011), Mohanan (2011), Karunarathna et al. (2011), Bolhassan et al. (2012), Dulay et al. (2012a), Adejumo & Awosanya (2015), Sevindik (2018)
L. velutinus Fr.	Malaysia and India	Pegler (1983), Bolhassan et al. (2012)
L. villosus Klotzsch	India	Lloyd (1904-1919)
Lentinus sp. 1	Philippines	De Leon et al. (2013a)
Lentinus sp. 2	Philippines	De Leon et al. (2013a)
Lentinus sp. 1	Philippines	Torres et al. (2020)
Lentinus sp. 2	Philippines	Torres et al. (2020)
Lentinus sp.	Philippines	Dulay et al. (2020b)
Lentinus sp.	Philippines	Lazo et al. (2016)
Lentinus sp.	Philippines	Paguirigan et al. (2020)
Lentinus sp.	Philippines	Guerero et al. (2020)
Lentinus sp.	USA	Grand (2004)

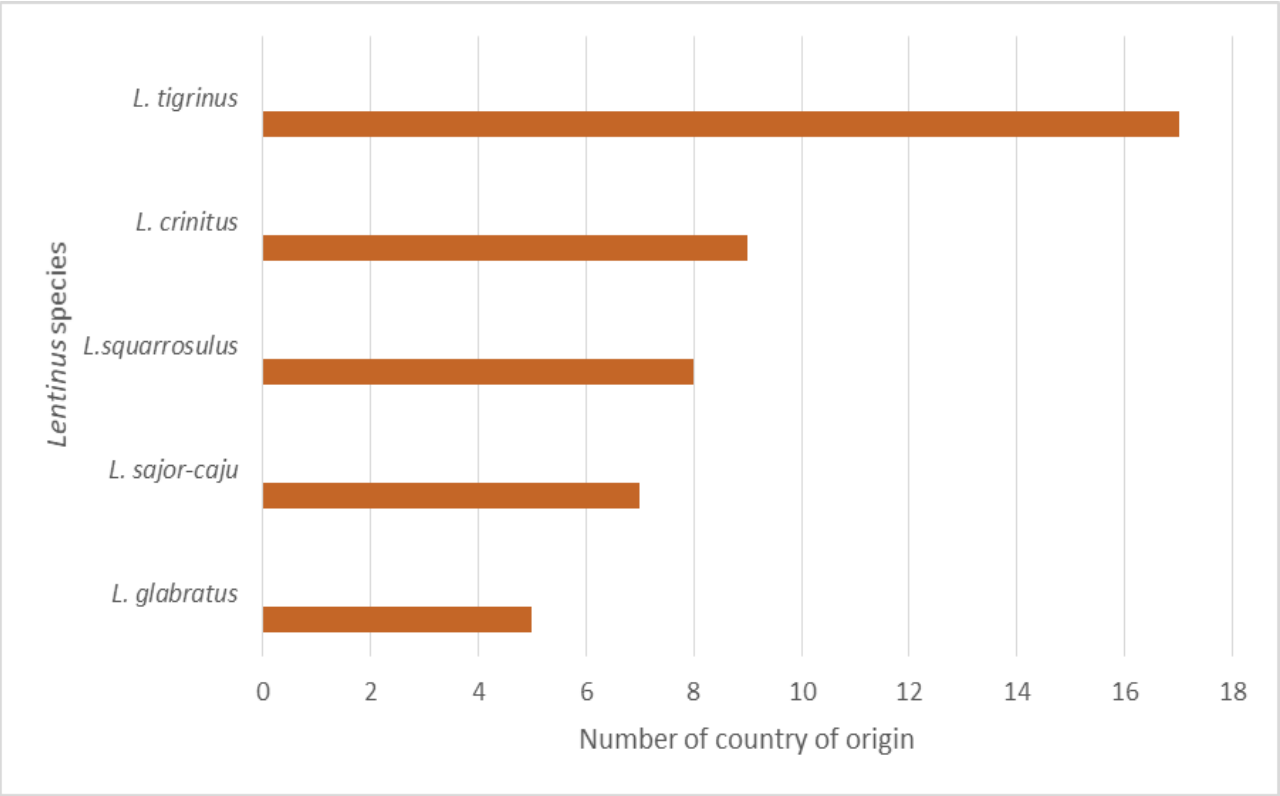


Fig. 1 – Top 5 most widely distributed *Lentinus* species in the world.

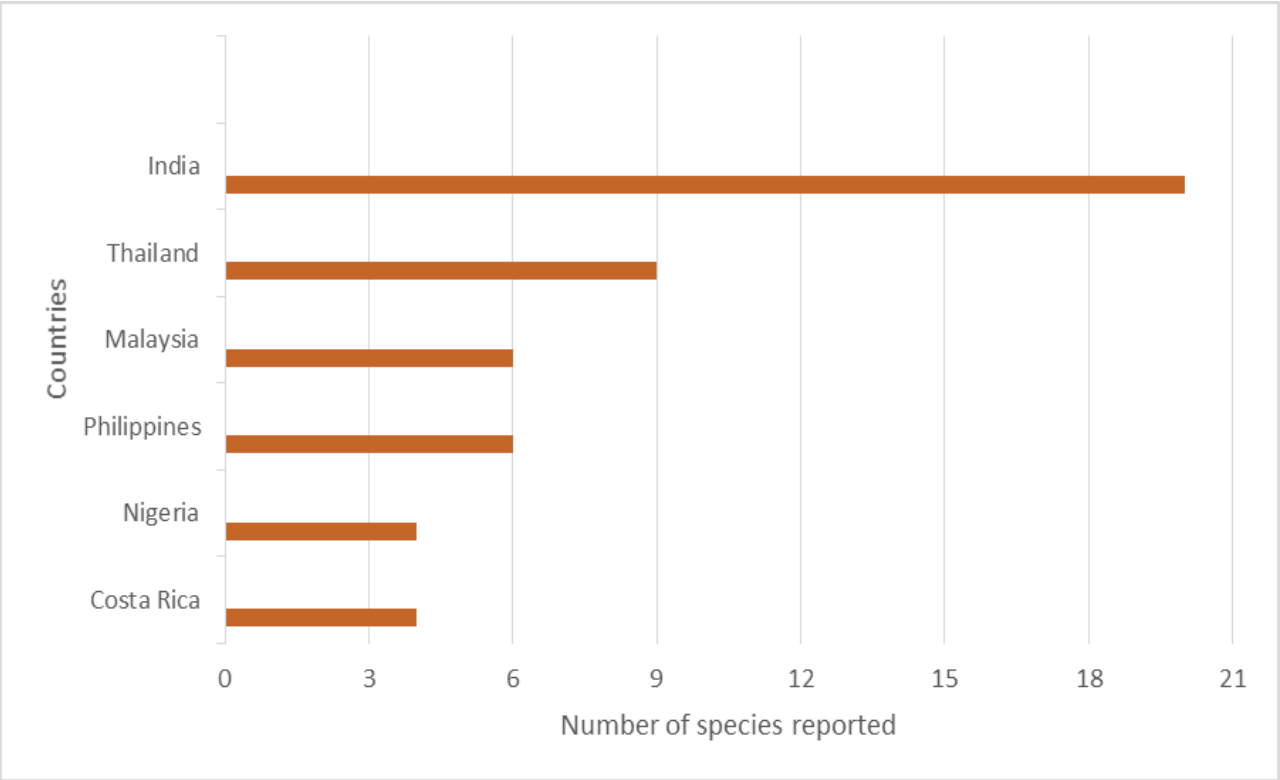


Fig. 2 – Top countries with the greatest number of reported *Lentinus* species.

The number of species reported in this paper is far from the approximate *Lentinus* species (53) reported by Manjunathan & Shymala Gowri (2019). In their review, some *Lentinus* species listed are not mentioned in Species Fungorum such as *Lentinus australia*, *Lentinus aespiticola*,

Lentinus lentinellus, *Lentinus lepidus*, *Lentinus panustigrinus*, *Lentinus cretaceous*, *Lentinus fastigatus*, and *Lentinus edulis*, some others were assigned to other genera such as *Lentinus cyathiformis* (*Neolentinus cyathiformis*), *Lentinus cochleatus* (*Lentinellus cochleatus*), *Lentinus edodes* (*Lentinula edodes*), *Lentinus kauffmanii* (*Neolentinus kauffmanii*), *Lentinus lepideus* (*Neolentinus lepideus*), *Lentinus detonsus* (*Lentinula boryana*), *Lentinus lecomte*i and *Lentinus strigosus* (*Panus neostrigosus*), *Lentinus praerigidus* (*Lentinus polychrous*), *Lentinus strigellus* (*Panus strigellus*), *Lentinus suavissimus* (*Neofavolus suavissimus*), *Lentinus tuber-regium* (*Pleurotus tuber-regium*), and *Lentinus ursinus* (*Lentinellus ursinus*), while the rest are just synonyms of other *Lentinus* species such as *Lentinus praerigidus* (*Lentinus polychrous*), and *Lentinus bertieri*, (*Lentinus berteroi*). Moreover, in comparison with the annotated checklist of *Lentinus* in India by Sharma & Atri (2015), only 20 *Lentinus* species are listed and 21 *Lentinus* species were excluded from Indian records due to either synonym of the other species or grouped into other genera. It is safe to mention, therefore, that our review provided an updated listing of *Lentinus* species worldwide.

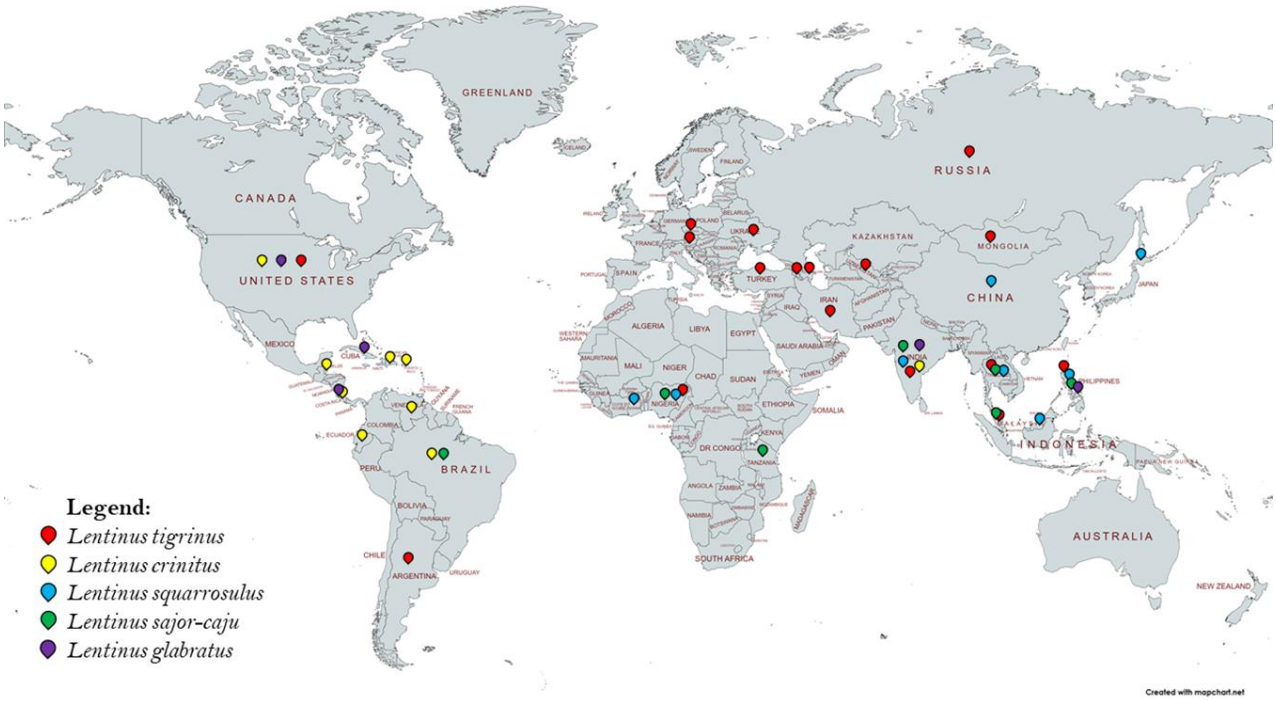


Fig. 3 – Distribution of top 5 *Lentinus* species worldwide – world map was downloaded in www.mapchart.net/world.html and was outlined using Microsoft office power point.

Looking at the top 5 countries with the highest number of reported *Lentinus* species, four are tropical countries from Asia and two from America. Accordingly, in the study by Nacua et al. (2018), they reported that tropical countries in Asia and temperate countries in Central and South America registered a rich fungal diversity of *Lentinus*.

Apart from the climatic conditions of the geographic origin, another important factor to consider is the substratum, which provides the nutrient requirements of *Lentinus* species. Dulay et al. (2020b) reported that the availability of lignin-cellulosic substrates and undisturbed habitat is positively correlated with the macrofungal species composition in a given area. *Lentinus* thrives on old or fallen tree trunks, as well as hidden or exposed roots of decaying deciduous trees, and acts as nutrient recyclers in the form of natural decomposers in various tropical rainforests regions of Africa and Asia (Abiodun et al. 2021). Countries like Thailand, Myanmar, Malaysia, Indonesia, Philippines, and Papua New Guinea, as well as tropical regions in Australia, South America, Central America, and West and Central Africa, are known to have rich tropical rainforests that provide an ideal growing environment for mushrooms (Smith 2019).

Most importantly, the number of mycologists and mycotaxonomists in a country must be considered. Extensive research efforts in mushroom biodiversity, particularly *Lentinus* species, are being done in India which is why most *Lentinus* species are documented in this country. It is interesting to note that in early 1800 to 1900s, identification of *Lentinus* species is being done in India. *Lentinus glabratus* was recorded in India in 1874 (Currey 1874), while in the Philippines the said species was only recorded recently (Dulay et al. 2021b). We believe that there are still more *Lentinus* species in the wild waiting to be discovered and suggest extensive efforts on the mycodiversity assessment coupled with accurate identification and characterization worldwide.

Nutritional and physical requirements for *Lentinus* culture

The intrinsic factors including medium/substrate composition, nitrogen sources, carbon to nitrogen ratio, minerals, organic acid, amino acid, phytohormones, and pH, as well as the extrinsic factors including temperature, luminosity, aeration, and agitation of *Lentinus* species are presented in this review.

Optimal condition for mycelial growth and production

The nutritional content of the organic matter of the substrates influenced the growth of the mycelia, thus nutritional evaluation is necessary for determining the medium which favors the effective growth of the mushroom species (De Leon et al. 2017a)

Accordingly, numerous commercial mycological culture media are commonly utilized in the laboratory for mycelial growth which provides nutrients for mushrooms, such as potato dextrose agar (PDA), malt extract agar (MEA), and Sabouraud dextrose agar (SDA) (Dulay & Garcia, 2017). However, these commercially available culture media are expensive, thus, alternative culture media derived from indigenous sources including coconut water, rice bran, corn grit, sorghum seeds, and potato, among others are introduced, which are cheaper and more advantageous for researchers and mushroom farmers.

In the present review, studies focusing on the optimization of mycelial growth in semi-solid media and submerged culture, and on the fruiting body production of *Lentinus* species were gathered. Table 2 shows the optimal culture condition for secondary mycelial growth of *Lentinus* species. It can be seen that most of the reported optimization studies showed the preference of *Lentinus* species for coconut water agar. However, some species preferred PDA and MEA. The superiority of coconut water could be attributed to its nutrient composition. According to USDA (2019a), coconut water has a variety of nutritional components such as water (95 g), protein (0.22 g), carbohydrates (4.24 g), sugar (3.92 g), sucrose (0.96 g), glucose (0.82 g), fructose (2.14 g), magnesium (6 mg), phosphorus (5 mg), potassium (165 mg), sodium (26 mg) and vitamin C (9.9 mg).

Apart from complex culture media, optimization of the different nutrient sources was also demonstrated in some studies. The optimal specific nutrient source requirements of the *Lentinus* species are presented in Table 3. It can be noticed that each species has a unique nutrient source preference. For instance, *L. swartzii* and *L. tigrinus* mycelia favorably grew on starch and sucrose and ammonium chloride and malt extract at C/N ratios of 10:1 and 40:1, respectively. The most suitable minerals were KH2PO4 for *L. swartzii*, and all minerals tested except CuSO4•5H2O for *L. tigrinus*. Organic acids such as lactic acid, and citric acid also enhanced mycelial growth. Growth-stimulating phytohormone, gibberellic acid (GA), and vitamin, pyridoxine produced superior mycelial growth of the three mushrooms (Dulay et al. 2020c).

Submerged cultivation of *Lentinus* species also received high interest as an alternative technique for the efficient production of biomass and bioactive metabolites. This cultivation technique has a shorter period of incubation and lesser chances of contamination with great advantages of higher mycelial production (Kim et al. 2002). The optimal submerged culture condition for mycelial biomass production of some *Lentinus* species is presented in Table 4. The most widely used media for submerged cultivation of *Lentinus* were coconut water and rice-bran decoction. This is in conformity with the most commonly used indigenous semi-solid medium.

Aside from coconut water, rice bran decoction was also found suitable medium in liquid culture and this could be attributed to a variety of chemical components, such as sources of protein (13.35g), fat (21g), dietary fiber (21g), fructose (0.2g), glucose (0.2g), sucrose (0.5g), carbohydrates (49.69g), and sugar (0.9g) (Dulay et al. 2020c).

The pH of the culture medium is a critical factor in mycelial cultivation as it influences the medium ionic state, mushroom physiology and morphology, and even product development (Dulay et al. 2021b). In this review, it was established that *Lentinus* can grow in a wide pH range from 4.5 to 8 (Tables 2, 3). However, most of the species preferred a slightly acidic medium which showed luxuriant mycelial growth at pH 5 and 6. This pH requirement is similar to other mushrooms such as *Schizophyllum commune*, *Trametes elegans*, *Ganoderma lucidum*, and *Panaelous cyanescens* that also produced luxuriant mycelial growth and biomass in a slightly acidic medium (Bustillos et al. 2014a, Dulay et al. 2015b, Kalaw et al. 2016, Dulay et al. 2021a).

The temperature is also an important physical condition that affects the growth of mushrooms. According to Kalaw et al. (2016), the temperature is a crucial environmental factor for the mycelial growth of mushrooms, since temperature extremely influences the survival and distribution of fungal species in nature. All *Lentinus* species preferred room temperature ranging from 28 to 35 °C. In contrast with *Cordyceps militaris* and *Collybia maculate*, the ideal temperature of these mushrooms favors a slightly lower temperature of 20 °C (Park et al. 2001, Lim et al. 2004). The finding of the temperature requirement of *Lentinus* could be a possible reason why most of its species are mostly found in tropical and temperate regions.

Moreover, the illumination condition of *Lentinus* differs from species to species. Some species prefer light conditions, some require dark, and some others prefer both. According to Chang & Miles (1992), most mushrooms are less sensitive to a considerable amount and exposure to light, but light is important for most mushroom development and growth. Thus, it is necessary to define which condition favors the essential growth of *Lentinus* species in terms of illumination conditions. In the study of Damaso et al. (2018) about the effect of color light-emitting diode (LED) on mycelial growth of *Lentinus tigrinus*, the highest mean mycelial diameter was obtained under blue LED. In contrast with the study of Tiniola et al. (2021), they observed the highest mycelial dry weight produced in the liquid culture of *Lentinus swartzii* incubated in red LED.

On the other hand, most of the *Lentinus* species showed efficient growth in either sealed or unsealed conditions, suggesting that aeration is not the major factor to be considered in *Lentinus* semi-solid cultivation, given that it can thrive in either anaerobic or aerobic conditions. But for submerged cultivation, aeration is introduced in the form of agitation. Based on the data, most of the *Lentinus* showed luxuriant mycelial growth in either agitated or static conditions, but most preferably in the static condition. This is because, in submerged cultivation, agitation may damage mycelial hyphae and adversely affect growth and product formation in the cultivation of mycelial organisms (Elisashvili 2012).

Taking all information together, each species of *Lentinus* has a unique preference for the different nutritional and physical factors, which play a crucial role in the growth and development of *Lentinus* mycelia. These important factors are essential in generating technology for the efficient production of mycelial biomass, which can also be considered an important source of quality *Lentinus* mycelial-based products.

Fruiting body production

Aside from mycelial cultivation, fungi (macrofungus) are also cultivated for the production of fruiting bodies especially edible species for the purpose of commercialization. According to Sakamoto (2018), mushrooms are fruiting bodies composed of basidiomycetes and certain ascomycetes that have been consumed fresh or processed and utilized as a delicacy for decades. Most of the commercialized mushroom available in the market utilizes the fruiting body of the mushroom over mycelia because fruiting body cultivation shows a wide array of applications from its edibility to pharmaceuticals applications. However, fruiting body cultivation depends on the substrate formulation as it should favor the effective growth and fruiting of the mushrooms. As a

result, selecting suitable substrates and formulation is a critical component in mushroom production. However, the substrate should be readily accessible locally in sufficient amounts and at an affordable price. Today, numerous mushroom cultivation was already performed utilizing agro-industrial waste such as rice bran, wheat husk, rice hull, and sugarcane bagasse, among others.

In this review, it can be noticed that *Lentinus* showed an excellent biological efficiency in the substrate formulation containing 70% rice straw and 30% sawdust for most of the *Lentinus* species indicating that this formulation is an excellent substrate that can be utilized in mushroom farming, specifically for *Lentinus* fruiting body cultivation (Table 5). These findings are supported by the study of Liwanag et al. (2020) about enriched cultivation of *L. tigrinus*, which revealed that indigenous substrates such as corn grits and rice bran are excellent enrichment materials for mushroom cultivation. A variety of chemical components of rice bran as mentioned before and corn grits, as a source of protein (8.57 g), fat (1.43 g), carbohydrates (77.14 g), fiber (5.7 g), and iron (4.11 mg) efficiently support the mycelial growth of the mushrooms (USDA, 2019b). Moreover, substrates containing rice bran, wheat, and barley can also be utilized in fruiting body cultivation as some of the *Lentinus* species are luxuriantly grown in them. Furthermore, of all the *Lentinus* species cultivated for fruiting body production, the *Lentinus crinitus* showed a very high biological efficiency of 84.2% grown in Cupuacu (*Theobroma grandiflorum*) exo-carp and rice bran substrates and 93.5% grown in Cupuacu exocarp and litter substrates. Generally, the biological efficiency of all the *Lentinus* recorded ranges from 0.87% to 93.5% depending on the composition of substrates used.

In comparison with other Agaricomycetes, *Coprinus comatus, Panaeolus antillarium, Panaeolus djamor, Panaeolus florida, Pleurotus columbinus, Pleurotus ostreatus, Pleurotus pulmonarius*, and *Pleurotus sapidus* where they utilized indigenous substrates in fruiting body production such as mushroom spent, carabao (*Bubalus bubalis carabanesis*)-dung, purely used paper, banana (*Musa acuminate*) leaves, chicken (*Gallus gallus domesticus*) manure, waste paper, agro-residues (wheat straw, rice straw, corn straw), and sisal (*Agave sisalana*) leaf decortications waste (SLDW) also shows high yields and biological efficiency (Dulay et al., 2014c, Bustillos et al., 2014b, Tesfaw et al., 2015, Mohamed et al., 2016, Alvarez & Bautista, 2021, Wu et al., 2019).

Moreover, both the studies of Damaso et al. (2018) and Tiniola et al. (2021) utilized LED in fruiting body production of *L. tigrinus* and *L. swartzii*, respectively. Results showed that the fruiting bags of *L. tigrinus* exposed to the blue LED produced the highest yield of 37.59g, or a biological efficiency of 12.53%, while the highest weight of the fruiting body equivalent to 35.73 g of *L. swartzii* was obtained in fruiting bags exposed to the red LED, corresponding to a biological efficiency of 7.14%.

Overall, the substrate used, substrate ratio formulation, and other extrinsic factors like illumination conditions affect both the yield and biological efficiency of mushrooms. Previously, the rice straw-sawdust formulation shows an excellent yield production for most of the *Lentinus* species, but other substrates are recommended to be utilized to produce higher yields with higher biological efficiency like in the case of *L. crinitus* grown in Cupuacu exo-carp. Therefore, this review employed importance as a source of information for further product development or mushroom utilization particularly of *Lentinus*.

Chemical composition of *Lentinus* species

Lentinus are widely utilized as a source of food and/or traditional medicine worldwide as it was known to have essential nutrients, vitamins, minerals, mycochemicals, and mycocompounds, which are shown to be beneficial to humans health (Dulay et al. 2014b, Srikram & Supapvanich, 2016, Machado et al. 2016). Accordingly, this review shows the chemical composition of *Lentinus* species particularly the proximate composition, amino acid, fatty acid, and mycochemical composition as well as the mycocompounds and their bioactivities.

Table 2 Optimal culture conditions for secondary mycelial growth of *Lentinus* species.

Species	Medium[a]	pH	Temperature (°C)	Illumination	Aeration	References
L. crinitus	2% MEA	4.5-6.5	31-34	n.d	n.d	Colla et al. (2020)
L. sajor-caju	CWG	6	32	Both	n.d.	Kalaw et al. (2016)
L. sajor-caju	CWG	5	28-32	Lighted	Both	De Leon et al. (2017a)
L. sajor-caju 1	CWG	5-5.5	28-30	Both	Both	Kalaw et al. (2021b)
L. sajor-caju 2	CWG	5-6.5	30	Both	Both	Kalaw et al. (2021b)
L. squarrosulus	PSG	6.5-7	32	Alternating light and dark	Sealed	De Leon et al. (2017b)
L. squarrosulus 1	CWG	5-6	28-30	Lighted	Sealed	Kalaw et al. (2021b)
L. squarrosulus 2	CWG	5-8	30	Lighted	Both	Kalaw et al. (2021b)
L. swartzii BIL4618	CWG/PSGPDA	6	32	Dark	Sealed	Dulay et al. (2021a)
L. swartzii	CWG	6-8	30	Both	Both	Kalaw et al. (2021b)
L. tigrinus	CWG	7-8	32	Dark	Both	Dulay et al. (2012b)
L. tigrinus CLSU A	CWG	6	32	Dark	n.d.	Kalaw et al. (2016)
L. tigrinus CLSU B	CWG	6	23	Dark	n.d.	Kalaw et al. (2016)

[a]CWG, coconut-water gulaman; CWA, coconut-water agar; MEA, malt-extract agar; PBSA, potato-broth sucrose agar; PDA potato-dextrose agar; PSG, potato-sucrose gelatin; SDA, sabouraud-dextrose agar n.d., not determined

Table 3 Nutrient source requirements of *Lentinus* species.

Species	Carbon source	Nitrogen source	C/N	Mineral salts	Organic acids	Amino acid	Phytohormones	Vitamins	References
L. swartzii	Starch	Ammonium chloride	10:1	KH_2SO_4	Lactic acid	n.d.	Indole-3-acetic acid (I-3-AA); furfurylaminop-urine (FAP); Gibberellic acid (GA);	Pyridoxine	Dulay et al. (2020c)
L. tigrinus	Sucrose	Malt extract	40:1	K_2HPO_4	Citric acid	n.d.	Gibberellic acid	Pyridoxine	Dulay et al. (2020c)
L. squarosulus 218	Starch/ Dextrose	Yeast extract	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	Anike et al. (2015)
L. squarosulus 339	Starch/ Mannose	Yeast extract	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	Anike et al. (2015)
L. squarosulus 340	Starch/ Mannose	Yeast extract	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	Anike et al. (2015)
L. squarrosulus	Glucose	Yeast Extract	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	Ahmad et al. (2015)

n.d., not determined

Table 4 Optimal submerged culture conditions for mycelial biomass production of *Lentinus* species.

Species	Medium[a]	pH	Temperature (°C)	Illumination	Agitation	References
L. tigrinus DQS75	CW	5	30	Lighted	Both	Dulay et al. (2021b)
L tigrinus BP32	CW	5	30	Lighted	Static	Dulay et al. (2021b)
l. tigrinus AS21	CW	6	30	Both	Both	Dulay et al. (2021b)
L. tigrinus	RBD	n.d.	32	n.d.	n.d.	Dulay et al. (2015a)
L. squarrosulus LSQBot	CW	5	30	Lighted	Agitated (100rpm)	Dulay et al. (2021b)
L. squarrosulus CPS5	CW	5	30	Both	Both	Dulay et al. (2021b)
L. squarrosulus LSQOs	CW	6	30	Lighted	Static	Dulay et al. (2021b)
L. sajor-caju LSCBot	CW	4-5	30	Both	Static	Dulay et al. (2021b)
L. sajor-caju C005	CW	5	30	Lighted	Static	Dulay et al. (2021b)
L. sajor-caju	RBD	n.d.	32	n.d.	n.d.	Dulay et al. (2015a)
L. swartzii CL-02	CW	6	30	Lighted	Both	Dulay et al. (2021b)
L. swartzii BIL4618	CW	5	30	Lighted	Static	Dulay et al. (2021b)
L. glabratus CVS22	CW/RBD	5	30	Lighted	Both	Dulay et al. (2021b)
L. glabratus CVS29	CW/RBD	5	30	Lighted	Both	Dulay et al. (2021b)

[a]CW, coconut water; RBD, rice-bran decoction; SDA, sabouraud- dextrose agar
n.d., not determined

Table 5 Substrate requirement for fruiting body production and biological efficiency of *Lentinus* species.

Species	Substrates	Biological Efficiency (%)	References
L. levis	Barley straw	53.8	Sobal et al. (1997)
L. sajor caju 1	70% composed of rice straw and 30% composed of sawdust	8.8	Kalaw et al. (2021b)
L. sajor caju 2	70% composed of rice straw and 30% composed of sawdust	10.2	Kalaw et al. (2021b)
L. sajor-caju	9:1 ratio of wheat straw and wheat bran with 0% olive mill waste water (OMWW)	70.20	Kalmis & Sargin (2004)
L. sajor-caju	9:1 ratio of wheat straw and wheat bran with 25% olive mill waste water (OMWW)	65.90	Kalmis & Sargin (2004)
L. sajor-caju	9:1 ratio of wheat straw and wheat bran with 50% olive mill waste water (OMWW)	55.80	Kalmis & Sargin (2004)
L. sajor-caju	9:1 ratio of wheat straw and wheat bran with 75% olive mill waste water (OMWW)	34.20	Kalmis & Sargin (2004)
L. swartzii	7:3 ratio of rice straw and sawdust produced	7.40	Dulay et al. (2021a)
L. crinitus DPUA 1535	Cupuacu exo-carp and rice bran (2:1 ratio)	84.2	Machado et al. (2016)
L. crinitus DPUA 1535	Cupuacu exocarp and litter (2:1 ratio)	93.5	Machado et al. (2016)

Table 5 Continued.

Species	Substrates	Biological Efficiency (%)	References
L. squarrosulus	1:4 ratio of rice straw-sawdust formulation	7.83	De Leon et al. (2013b)
L. squarrosulus	8 parts composted rice straw, 2 parts composed of saw dust enriched with 15% rice bran and 20% rice hull	18.0	De Leon et al. (2017b)
L. squarrosulus	3:1 ratio of *Spondias mombin* log + rice bran supplemented spawn	10.25	Adesina et al. (2011)
L. squarrosulus	3:1 ratio of *Citrus sinensis* log + rice bran supplemented spawn	5.84	Adesina et al. (2011)
L. squarrosulus 1	70% composed of rice straw and 30% composed of sawdust	7.3	Kalaw et al. (2021b)
L. squarrosulus 2	70% composed of rice straw and 30% composed of sawdust	4.7	Kalaw et al. (2021b)
L. tigrinus	Sawdust enriched with wheat bran	56.66	Shahtahmasebi et al. (2017)
L. tigrinus	20% sawdust and 80% rice straw substrate	15.93	Dulay et al. 2012b
L. tigrinus 1	70% composted rice straw and 30% composted sawdust	6.15	Kalaw et al. (2021a)
L. tigrinus 2	70% composted rice straw and 30% composted sawdust	2.86	Kalaw et al. (2021a)
L. tigrinus 3	70% composted rice straw and 30% composted sawdust	4.93	Kalaw et al. (2021a)
L. tigrinus 4	70% composted rice straw and 30% composted sawdust	0.87	Kalaw et al. (2021a)
L. tigrinus 5	70% composted rice straw and 30% composted sawdust	1.47	Kalaw et al. (2021a)
L. tigrinus 6	70% composted rice straw and 30% composted sawdust	16.37	Kalaw et al. (2021a)
L. tigrinus 7	70% composted rice straw and 30% composted sawdust	11.80	Kalaw et al. (2021a)
L. tigrinus 8	70% composted rice straw and 30% composted sawdust	7.30	Kalaw et al. (2021a)
L. tigrinus 9	70% composted rice straw and 30% composted sawdust	5.70	Kalaw et al. (2021a)
L. tigrinus 10	70% composted rice straw and 30% composted sawdust	2.93	Kalaw et al. (2021a)
L. tigrinus 11	70% composted rice straw and 30% composted sawdust	3.10	Kalaw et al. (2021a)
L. tigrinus BAFC 197	77% wheat straw, 20% wheat meal, and 3% $CaCO_3$	62.20	Lechner & Papinutti (2006)
L. swartzii	70% composted rice straw and 30% composted sawdust	6.9	Kalaw et al. (2021b)

Proximate composition of *Lentinus* species

The edibility and nutritional composition of a mushroom are determined by its proximate composition. Accordingly, the proximate composition of *Lentinus* species was observed for both the cultivated and wild fruiting body and the mycelium which shows abundance in terms of nutritional composition, particularly the protein, fat, moisture, fiber, carbohydrates, and ash composition ranging from 40.34%-2.42%, 21.94%-0.2%, 88.6%-1.7%, 24.7%-0.03%, 87.3%-4.39%, and 9.50%-0.7%, respectively (Table 6). Based on the gathered data, carbohydrates account for most of the composition of *Lentinus* followed by protein. According to Mc-Connel & Esselen (1947), in terms of carbohydrates composition, the fresh mushroom contains reducing sugar (0.28%), hemicellulose (0.91%), and mannitol (0.9%), and glycogen (0.59%). On the other hand, mushrooms, in general, have higher protein content than most vegetables, that's why it is recommended for vegetarians as they also contain the protein composition animals have (Wani et al. 2010).

Furthermore, among the *Lentinus* species studied, *Lentinus squarrosulus*, *Lentinus polychrous*, *Lentinus tigrinus,* and *Lentinus crinitus* recorded the highest protein composition (40.34%), highest fat composition (21.94%), highest fiber composition (24.7%), and highest carbohydrates composition (87.3%), respectively. In addition, the moisture composition recorded varies whether the sample type of *Lentinus* was examined in dry weight or fresh weight.

Amino acids of *Lentinus* species

Mushrooms are said to be an excellent source of protein, with some researchers claiming that the amino acid composition of the mushroom protein is equivalent to that of animal protein. In addition, protein is an essential component of mushrooms, and it varies depending on the pileus size, mushroom species, substratum, and even the harvest time (Dulay et al. 2015a). In this review, the fruiting body and mycelium of *Lentinus* presented 18 different amino acids (Table 7), such as alanine, arginine, aspartic acid, glutamic acid, glycine, histidine, isoleucine, leucine, lysine, phenylalanine, proline, serine, threonine, tyrosine, valine, cysteine, methionine, and tryptophan. Among the *Lentinus* species identified, the *Lentinus squarrosulus* shows rich amino acid composition in all 18 amino acids recorded followed by *Lentinus connatus,* and the glutamic acid, leucine, and arginine are the most of the amino acids present in all of the species of *Lentinus.* In the study of Dutta et al. (2013), they employed glutamic acid in a variety of tests, including endogenic anticancer, conjugates to anticancer drugs, and glutamic acid derivatives as potential anticancer agents. On the other hand, leucine (at high dosages) has been shown to enhance muscle protein synthesis (Garlick 2005), and it has also been shown to improve postprandial glycemic management (van Loon 2012). In addition, Arginine is a secretagogue that improves wound healing by promoting the production of growth hormone, insulin, insulin-like growth factor 1, and prolactin. (Scott Lind 2004). Hence, the amino acid present in *Lentinus* can also be utilized for bioactivities due to the diverse array of amino acids present in this mushroom.

Fatty acids of *Lentinus* species

Lentinus' fruiting body and mycelium contained 16 distinct fatty acids as shown in Table 8. The fatty acid present in *Lentinus* is Pelargonic acid, Caproic acid, Lauric acid, Myristic acid, Pentadecyclic acid, Palmitoleic acid, Palmitic acid, Margaric acid, 3-Hydroxy-Margaric acid, Oleic acid, Stearic acid, Nonadecyclic acid, Gadoleic acid, saturated fatty acid, monosaturated fatty acid, and polyunsaturated fatty acid. Among the recorded *Lentinus* species, *L. squarrosulus,* and *Lentinus sajor-caju* show a rich fatty acid composition on most of the 16 different amino acids. According to Venn-Watson et al. (2020), high dietary intakes of heptadecanoic acid (C17:0), pentadecanoic acid (C15:0), and odd-chain saturated fatty acids (OCFAs) are linked to a decreased risk of cardiometabolic illnesses, and higher intakes of OFCAs are linked to a lower risk of death. However, data obtained also show that the two *Lentinus* species contain a very high saturated fatty acid of 57.36%, and 53.89%, respectively. According to Kennedy et al. (2009), saturated fatty acids have an inflammatory and insulin-antagonistic impact, which contributes to metabolic syndrome progression. Nevertheless, even though fats are the least composed found in *Lentinus* compared with carbohydrates and protein, it still has important biological activities that are advantageous for human consumption.

Mycochemicals of *Lentinus* species

According to Bustillos et al. (2014a), mycochemicals are a class of mycological compounds generated primarily by mushrooms to enable metabolic activities and even to protect themselves. The presence of primary metabolites such as carbohydrates, and amino acids can be good nutritional supplements, and the presence of other mycochemical compounds can be beneficial to the pharmaceutical industry (Jakovljevic et al. 2018). In this review, the mycochemicals such as steroids, terpenoids, flavonoids, glycosidase, tannins, saponins, alkaloids, phenols, triterpenes, anthocyanin,

arthrones, anthraquinones, coumarins, and terpenes were found in the fruiting body and mycelium of *Lentinus*, as shown in Table 9. Among all the mycochemicals investigated, terpenoids, alkaloids, flavonoids, and phenols are the abundant mycochemicals among the *Lentinus* species. According to Nobori et al. (1994), toxicity to cells of foreign organisms is one of the most bioactivities of alkaloids, and its potential applicability in the eradication and decrease of human cancer cell lines has been thoroughly examined. Moreover, terpenoids are tested for different bioactivities such as anti-malarial, cancer preventive, and anti-inflammatory (Roslin & Anular 2011), while flavonoids are known as an anti-inflammatory and anti-thrombotic agent (Robak & Gryglewski 1996).

Mycocompound of *Lentinus* species and their bioactivities

The mycocompounds and bioactivities of *Lentinus* species are illustrated in Table 10. Based on the gathered data, there are about 83 mycocompounds present in *Lentinus* (80 in *Lentinus squarrosulus*, and 3 in *Lentinus tigrinus)* which vary on the extracts which serve as the sample type examined. These mycocompounds exhibited different bioactivities, such as auto-immune suppression, anti-inflammatory, antiulcer, antitumor, antioxidant, anti-nephrotoxic antibacterial, analgesic, antiplasmodial, antiobesity, cancer preventive, cytotoxicity, hepatoprotective effects, stimulator of the nervous system, wound healing, pesticide, flavor, immunostimulant, and others. Among the mycocompound identified in *L. squarrosulus*, the n-Hexadecanoic acid, 9,12-octodecadienoic acid, and 2H-2,4a-Ethanonaphthalene, 1, 3, 4, 5, 6, 7-hexahydro-2, 5, 5-trimethyl- shows diverse bioactivities, such as antioxidant, antibacterial, nematicide, anti-inflammatory, hypocholesterolemic, pesticide, lubricant, anti-androgenic, antitumor, cancer preventive, immunostimulant, chemopreventive, 5-α reductase inhibitor, hepatoprotective effect, antihistaminic, antieczemic, antiobesity, antiacne, anti-arthritic, antitumor, radical scavenging activity, antiplasmodial, antityrosinase, platelet aggregation, enhancing percutaneous penetration activity, and wound healing (Pang et al. 2014, Adeoye-Isijola et al. 2018). On the other hand, the *L. tigrinus* mycocompound, specifically the cerevisterol, stellasterol, and ergosterol are known to exhibit bioactivities, such as an anti-inflammatory drug which suppressed the expression of iNOS, COX2, TNF-, and SOCS3 mRNAs and decreased the production of iNOS and COX2 proteins in a dose-dependent way (Lui et al. 2013), exhibited cell cycle arrest against the human cancer cell lines, MCF-7 and SH-SY5Y (Pereira et al. 2014), protect against the development of bladder cancers caused by a variety of promoters found in the environment (Yazawa et al. 2000), respectively. Based on the gathered data, *Lentinus* species has a diverse array of mycocompounds which are known to exhibit different bioactivities ideal for commercial or industrial application. These findings enable further studies that will utilize these mycocompounds identified in *Lentinus* in the production of *Lentinus*-derived products in pharmaceuticals, nutraceuticals, and medical industries.

Biological properties of *Lentinus* species

Of over 40,000 fungal species belonging to Basidiomycota about 660 of them possess medicinal properties from cellular components and secondary metabolites which are tested primarily from the fruiting body, culture mycelium, and culture broth of mushrooms species (Sivanandhan et al. 2017). Accordingly, *Lentinus* is one of the basidiomycete's untapped fungal species that have a lot of potential in the medical, pharmaceutical, and food industries.

The cultivation of *Lentinus* has been practiced worldwide for its medical properties, nutritional attributes, and industrial applications. According to De Leon et al. (2017a), aside from consumptions purpose, the *Lentinus* species are cultivated in the Philippines for their nutritional and medicinal properties. In addition, due to the abundance of proteins, lipids, fats, minerals, dietary fiber, and vitamins, *Lentinus* (*Lentinus squarrosulus*) is a prominent mushroom used for traditional medicine in Nigeria (Adenipekun et al. 2021).

Table 6 Proximate composition of *Lentinus* species.

Species	Sample Type	Proximate Composition (%)						References
		Protein	Fat	Moisture	Fiber	Carbohydrates	Ash	
L. squarrosulus	Cultivated fruiting body	26.32	3.28	2.46	n.d.	20.66	5.70	Zhou et al. (2015)
L. squarrosulus	Wild fruiting body	17.59	5.91	9.85	1.19	62.53	3.03	Ugbogu et al. (2020)
L. squarrosulus	Cultivated fruiting body (fresh weight)	5.61	2.19	86.10	0.39	4.39	1.32	Srikram & Supapvanich (2016)
L. squarrosulus	Cultivated fruiting body (dry weight)	40.34	15.75	86.10	2.80	31.61	9.50	Srikram & Supapvanich, (2016)
L. squarrosulus	Wild fruiting body	27.07	0.85	83.33	8.32	48.84	6.32	Roy Das et al. (2017)
L. tigrinus	Cultivated fresh pileus	3.7	0.2	88.6	2.0	6.8	0.7	Dulay et al. (2014b)
L. tigrinus	Cultivated air-dried pileus	25.9	2.1	12.2	17.4	52.4	7.4	Dulay et al. (2014b)
L. tigrinus	Cultivated stipe	15.7	1.9	10.5	24.7	67.7	4.0	Dulay et al. (2014b)
L. polychrous	Cultivated fruiting body (fresh weight)	2.42	2.91	86.74	0.03	6.60	1.03	Srikram & Supapvanich, (2016)
L. polychrous	Cultivated fruiting body (dry weight)	18.25	21.94	86.74	2.26	49.78	7.77	Srikram & Supapvanich, (2016)
L. crinitus DPUA 1535	Cultivated mycelium in cupuacu exocarp + rice bran substrates	20.00	3.33	n.d.	6.30	53.59	4.90	Machado et al. (2016)
L. crinitus DPUA 1535	Cultivated mycelium in cupuacu exocarp + litter substrates	27.00	4.50	n.d.	11.20	41.41	4.95	Machado et al. (2016)
L. squarrosulus	Wild Stipe (Dry weight)	18.32	6.01	3.83	6.80	65.07	6.62	Nwanze et al. (2006)
L. squarrosulus	Wild Pileus (Dry weight)	27.25	6.56	1.7	8.48	56.23	8.42	Nwanze et al. (2006)
L. sajor-caju	Wild fruiting body (Dry weight except for the moisture)	28.36	2.42	80.29	n.d.	68.24	4.88	Singdevsachan et al. (2013)
L. crinitus U9-1	Cultivated basidiocarp pileus	14.4	0.52	n.d.	n.d.	80.8	4.29	Bertéli et al. (2021)
L. crinitus U9-1	Cultivated basidiocarp stipe	9.5	0.55	n.d.	n.d.	87.3	2.66	Bertéli et al. (2021)
L. squarrosulus "erirokiro"	Wild oven-dried pileus and stipe	31.24	3.71	7.22	9.48	41.27	7.07	Borokini et al. (2016)

n.d., not determined

Table 7 Amino acid composition of *Lentinus* species.

Species	Sample Type	Amino acid composition (%)																	References
		Ala	Arg	Asp	Glu	Gly	His	Ile	Leu	Lys	Phe	Pro	Ser	Thr	Tyr	Val	Cys	Met	Trp	
L. squarrosulus	Wild fruiting body	0.09	0.21	0.37	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.06	n.d.	n.d.	0.19	n.d.	n.d.	n.d.	n.d.	Sharma & Atri (2014)
L. squarrosulus	Cultivated fruiting body	2.26	1.98	4.14	6.54	1.86	0.46	1.33	2.74	2.22	1.53	1.35	1.60	3.53	1.30	1.10	n.d.	n.d.	n.d.	Zhou et al. (2015)
L. squarrosulus	Wild fruiting body	3.17	4.75	6.91	10.32	3.11	1.91	3.03	5.18	3.09	3.22	2.84	3.04	2.70	2.10	3.34	0.77	0.76	0.73	Ugbogu et al. (2020)
L. sajor-caju	Wild fruiting body	0.12	0.25	0.33	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.03	n.d.	n.d.	0.16	n.d.	n.d.	n.d.	n.d.	Sharma & Atri (2014)
L. connatus	Wild fruiting body	0.13	0.27	0.28	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.01	n.d.	n.d.	0.19	n.d.	n.d.	n.d.	n.d.	Sharma & Atri (2014)
L. cladopus Lev	Wild fruiting body	0.11	0.24	0.31	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.04	n.d.	n.d.	0.24	n.d.	n.d.	n.d.	n.d.	Sharma & Atri (2014)
L. sajor-caju	Cultivated air-dried sporophores	3.40	n.d.	n.d.	n.d.	0.50	1.28	0.76	1.39	6.66	1.63	n.d.	n.d.	n.d.	0.62	0.43	1.99	0.16	n.d.	Lata & Atri (2017)
L. connatus	Wild fruiting body	3.74	6.39	5.00	11.10	1.55	1.45	1.35	2.29	2.15	1.90	0.31	2.54	2.64	1.43	1.62	0.43	0.55	n.d.	Afiukwa et al. (2015)
L. sajor-caju	Wild fruiting body	3.65	6.22	4.31	10.15	1.55	1.25	1.22	2.27	1.51	1.44	0.41	2.23	2.20	1.03	1.51	0.37	0.59	n.d.	Afiukwa et al. (2015)
L. crinitus DPU1 1535	Cultivated mycelium in cupuacu exocarp + rice bran substrates	0.00111	0.00147	0.00249	0.00400	0.00124	0.00049	0.00065	0.00093	0.00133	0.00077	0.00049	0.00183	0.00096	0.00046	0.00125	0.00004	0.00018	0.00041	Machado et al. (2016)
L. crinitus DPUA 1535	Cultivated mycelium in cupuacu exocarp + litter substrates	0.00178	0.00228	0.00257	0.00441	0.00145	0.00070	0.00127	0.00207	0.00185	0.00128	0.00124	0.00152	0.00130	0.00110	0.00155	0.00015	0.00048	0.00037	Machado et al. (2016)
L. squarrosulus "erirokiro"	Wild oven-dried pileus and stipe	3.23	3.62	7.17	10.00	3.00	1.96	2.85	16.99	2.67	3.37	2.14	2.03	2.53	2.06	3.01	0.60	0.73	n.d.	Borokini et al. (2016)

Ala (Alanine); Arg (Arginine); Asp (Aspartic acid); Glu (Glutamic acid); Gly (Glycine); His (Histidine); Ille (Isoleucine); Leu (Leucine); Lys (Lysine); Phe (Phenylalanine); Pro (Proline); Ser (Serine); Thr (Threonine); Tyr (Tyrosine); Val (Valine); Cys (Cysteine); Met (Methionine); Trp (Tryptophan).
n.d., not determined

In this review, the biological properties and activities of some *Lentinus* species are shown in Table 11. Based on the findings, the most common extracts used in the identification of bioactivities were ethanol and hot water extracts. Moreover, the lipids, peptides, polysaccharides, and hypnophilin (HNP) sesquiterpenes are among the identified bioactive components of the *Lentinus* species. Furthermore, the cultivated and wild fruiting bodies and mycelia of *Lentinus*, especially, *Lentinus tigrinus*, *Lentinus sajor-caju*, *Lentinus squarrosulus*, *Lentinus swartzii*, *Lentinus polychrous*, and *Lentinus crinitus* exhibited biological activities that include antibacterial,

antioxidant, antiproliferative, anticancer, antihypertensive, antiulcer, antidiabetic, antiobesity, cytotoxicity, embryo-toxicity, and teratogenicity.

Table 8 Fatty acid composition of *Lentinus* species.

Species	Sample Type	Fatty acid composition (%)																References
		C9:00	C10:00	C12:00	C14:0	C15:00	C16:01	C16:00	C17:01	C17:03 OH	C18:1 cis9	C18:00	C19:01	C20:01	SFA	MUFA	PUFA	
L. squarrosulus	Wild fruiting body	0.75	1.64	n.d.	n.d.	5.82	1.71	45.13	2.01	1.45	23.38	4.02	n.d.	n.d.	57.36	27.1	1.45	Sharma & Atri (2014)
L. squarrosulus	Wild fruiting body	n.d.	2.87	n.d.	4.44	n.d.	n.d.	8.05	n.d.	n.d.	12.45	11.28	n.d.	n.d.	n.d.	n.d.	n.d.	Ugbogu et al. (2020)
L. sajor-caju	Wild fruiting body	0.99	0.26	n.d.	n.d.	4.41	0.63	41.29	0.69	1.31	13.9	6.94	1.05	n.d.	53.89	16.27	1.37	Sharma & Atri (2014)
L. connatus	Wild fruiting body	3.47	1.79	n.d.	n.d.	2.03	2.05	14.25	0.69	0.7	23.38	5.51	6.6	2.41	27.05	32.72	0.70	Sharma & Atri (2014)
L. cladopus	Wild fruiting body	n.d.	0.21	n.d.	n.d.	1.69	1.53	22.79	1.02	0.76	47.87	2.07	16.93	n.d.	26.76	67.35	0.76	Sharma & Atri (2014)

C9:00 (Pelargonic acid); C10:00 (Caproic acid); C12:00 (Lauric acid); C14:00 (Myristic acid); C15:00 (Pentadecyclic acid); C16:01 (Palmitoleic acid); C16:00 (Palmitic acid); C17:01 (Margaric acid); C17:03 OH (3-Hydroxy-Margaric acid); C18:1 *cis9* (Oleic acid); C18:00 (Stearic acid); C19:01 (Nonadecyclic acid); C20:01 (Gadoleic acid); SFA (saturated fatty acid); MUFA (monosaturated fatty acid); PUFA (polyunsaturated fatty acid)
n.d., not determined

Table 9 Mycochemical composition of *Lentinus* species.

Species	Extraction	Mycochemicals (+, present; -, absent)														References
		Ste	Terd	Fla	Gly	Tan	Sap	Alk	Phe	Tri	Atc	Atr	Atq	Cou	Ter	
L. sajor-caju	Hot water extract of mycelia	-	+	-	+	-	+	+	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	De Leon et al. (2017a)
L. squarrosulus	Petroleum ether extract of fruiting body	+	+	+	+	n.d.	-	+	-	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	Reena Roy & Krishnappa (2018)
L. squarrosulus	Chloroform extract of fruiting body	+	+	+	+	n.d.	-	+	+	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	Reena Roy & Krishnappa (2018)
L. squarrosulus	Ethanol extract of fruiting body	+	+	+	+	n.d.	-	+	+	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	Reena Roy & Krishnappa (2018)
L. squarrosulus "erirokiro"	Wild oven-dried pileus and stipe	-	+	+	n.d.	+	+	-	n.d.	n.d.	n.d.	n.d.	-	n.d.	n.d.	Borokini et al. (2016)
L. squarrosulus	Ethanol extract of fruiting body	+	n.d.	+	+	+	+	+	n.d.	n.d.	n.d.	n.d.	+	n.d.	+	Adeoye-Isijola et al. (2021)

Table 9 Continued.

Species	Extraction	Mycochemicals (+, present; -, absent)														References
		Ste	**Terd**	**Fla**	**Gly**	**Tan**	**Sap**	**Alk**	**Phe**	**Tri**	**Atc**	**Atr**	**Atq**	**Cou**	**Ter**	
L. squarrosulus	Aqueous extract of fruiting body	n.d.	n.d.	+ 0.38%	n.d.	+ 0.38%	+ 1.36%	+ 0.42%	+ 1.22%		+ 0.14%	n.d.	n.d.	n.d.	n.d.	Ugbogu et al. (2020)
L. swartzii	Ethanol extract of mycelia and fruiting body	n.d.	n.d.	+	n.d.	+	n.d.	n.d.	+	+	n.d.	n.d.	n.d.	n.d.	n.d.	Austria et al. (2021)

Ste (Steroids); Terd (Terpenoids); Fla (Flavonoids); Gly (Glycosidase); Tan (Tannins); Sap (Saponins); Alk (Alkaloids); Phe (Phenols); Tri (Triterpenes); Atc (Anthocyanin); Atr (Arthrones); Atq (Anthraquinones); Cou (Coumarins); Ter (Terpenes)
n.d., not determined

Table 10 Mycocompounds and bioactivities of of *Lentinus* species.

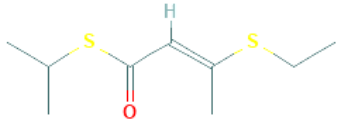
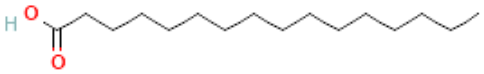
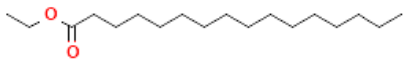
Species	Sample Type	Name of Compound	Chemical Structure	References
L. squarrosulus	Ethanolic extract	2-Butenethioic acid, 3-(ethylthio)-, S(1-methylethyl) ester	 PubChem CID: 5371702	Adeoye-Isijola et al. (2018)
		n-Hexadecanoic acid (Palmitic acid)	 PubChem CID: 985	Adeoye-Isijola et al. (2018)
		Hexadecanoic acid ethyl ester (palmitic acid ester)	 PubChem CID: 12366	Adeoye-Isijola et al. (2018)

Table 10 Continued.

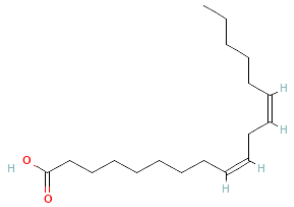
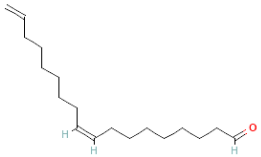
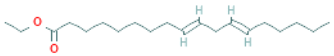
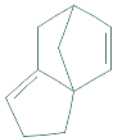
Species	Sample Type	Name of Compound	Chemical Structure	References
		9,12-octadecadienoic acid (Conjugated Linoleic acid)	 PubChem CID:5280450	Adeoye-Isijola et al. (2018)
		9,17-Octadecadienal, (Z)-	 PubChem CID:5365667	Adeoye-Isijola et al. (2018)
		9,12-Octadecadienoic acid, ethyl ester (Linolelaidic acid ethyl ester)	 PubChem CID:5365672	Adeoye-Isijola et al. (2018)
		3a,6-Methano-3aH-indene,2,3,6,7 tetrahydro	 PubChem CID:576007	Adeoye-Isijola et al. (2018)

Table 10 Continued.

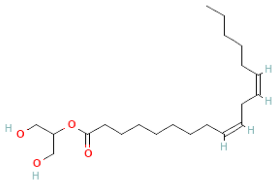
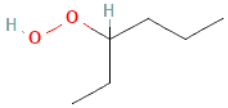
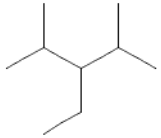
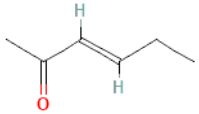
Species	Sample Type	Name of Compound	Chemical Structure	References
		9,12-Octadecadienoic acid (Z, Z)-2 hydroxy-1-(hydroxymethyl) ethyl ester (2-monolinolein)	 PubChem CID:5365676	Adeoye-Isijola et al. (2018)
		Hydroperoxide, 1-ethylbutyl	 PubChem CID:141085	Reena Roy et al. (2020)
		3-ethyl-2, 4-dimethylpentane	 PubChem CID:14040	Reena Roy et al. (2020)
		3-Hexen-2-one	 PubChem CID:5367744	Reena Roy et al. (2020)

Table 10 Continued.

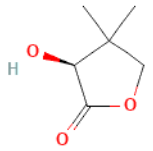
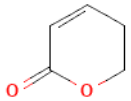
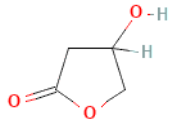
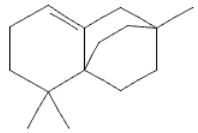
Species	Sample Type	Name of Compound	Chemical Structure	References
		2(3H)-Furanone, dihydro-3-hydroxy-4,4-dimethyl-, (R)-	 PubChem CID:736053	Reena Roy et al. (2020)
		2H-Pyran-2-one, 5,6-dihydro-	 PubChem CID:520660	Reena Roy et al. (2020)
		2(3H)-Furanone, dihydro-4-hydroxy-	 PubChem CID:95652	Reena Roy et al. (2020)
		2H-2,4a-Ethanonaphthalene, 1, 3, 4, 5, 6, 7-hexahydro-2, 5, 5-trimethyl-	 PubChem CID:600220	Reena Roy et al. (2020)
		1-Dodecanol	 PubChem CID:8193	Reena Roy et al. (2020)

Table 10 Continued.

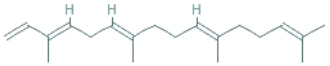
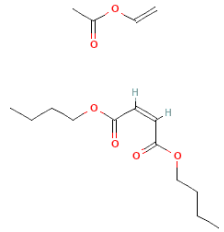
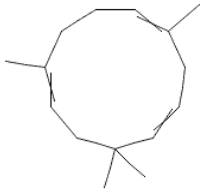
Species	Sample Type	Name of Compound	Chemical Structure	References
		Tetradecane	 PubChem CID:12389	Reena Roy et al. (2020)
		(E,E,E)-3,7,11,15-Tetramethylhexadeca-1,3,6,10,14-pentaene	 PubChem CID:5365883	Reena Roy et al. (2020)
		2-Butenedioic acid (Z)-, dibutyl ester	 PubChem CID:6441450	Reena Roy et al. (2020)
		alpha-Caryophyllene	 PubChem CID:23204	Reena Roy et al. (2020)

Table 10 Continued.

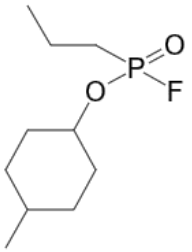
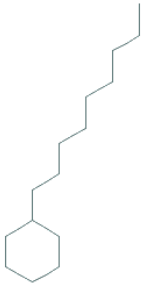
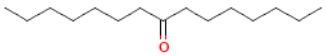
Species	Sample Type	Name of Compound	Chemical Structure	References
		Propylphosphonic acid, fluoroanhydride, 4-methylcyclohexyl ester	 ChemSpider CSID 505335	Reena Roy et al. (2020)
		1-Pentadecene	 PubChem CID:25913	Reena Roy et al. (2020)
		n-Nonylcyclohexane	 PubChem CID:17900	Reena Roy et al. (2020)
		8-Pentadecanone	 PubChem CID:13162	Reena Roy et al. (2020)

Table 10 Continued.

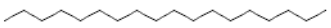
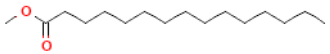
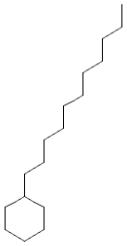
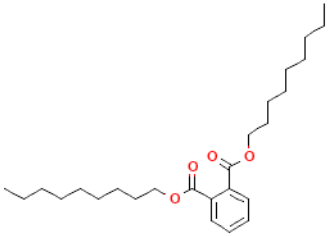
Species	Sample Type	Name of Compound	Chemical Structure	References
		Octadecane	 PubChem CID:11635	Reena Roy et al. (2020)
		Pentadecanoic acid-methyl ester	 PubChem CID:23518	Reena Roy et al. (2020)
		Cyclohexane, undecyl-	 PubChem CID:40997	Reena Roy et al. (2020)
		1,2-Benzenedicarboxylic acid, dinonyl ester	 PubChem CID:6787	Reena Roy et al. (2020)

Table 10 Continued.

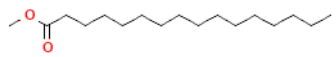
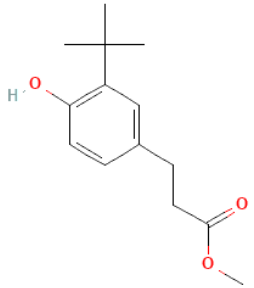
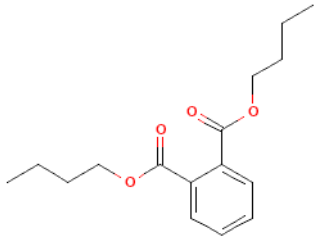
Species	Sample Type	Name of Compound	Chemical Structure	References
		Hexadecanoic acid, methyl ester (Methyl palmitate)	 PubChem CID:8181	Reena Roy et al. (2020)
		Benzenepropanoic acid, 3,5-bis(1,1-dimethylethyl)-4-hydroxy-, methyl ester	 PubChem CID:3084638	Reena Roy et al. (2020)
		Dibutyl phthalate	 PubChem CID:3026	Reena Roy et al. (2020)

Table 10 Continued.

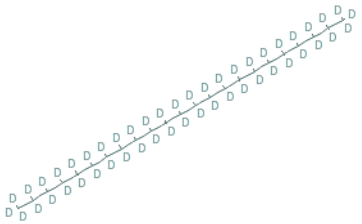
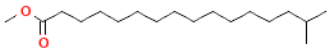
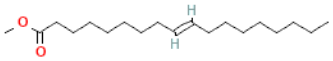
Species	Sample Type	Name of Compound	Chemical Structure	References
		1-Heptadecene	 PubChem CID:23217	Reena Roy et al. (2020)
		n-Tricosane	 PubChem CID:102602136	Reena Roy et al. (2020)
		7-Hexadecenoic acid, methyl ester, (Z)-	 PubChem CID:543305	Reena Roy et al. (2020)
		Hexadecanoic acid, 15-methyl-, methyl ester	 PubChem CID:522345	Reena Roy et al. (2020)
		9-Octadecenoic acid, methyl ester	 PubChem CID:5280590	Reena Roy et al. (2020)

Table 10 Continued.

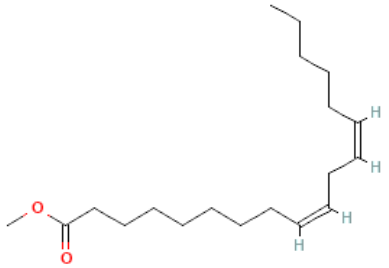
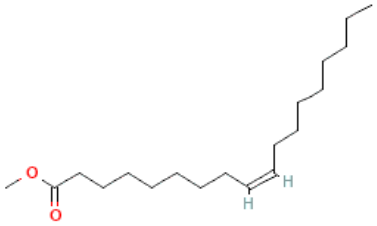
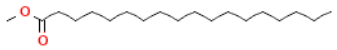
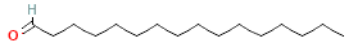
Species	Sample Type	Name of Compound	Chemical Structure	References
		Methyl linoleate	 PubChem CID:5284421	Reena Roy et al. (2020)
		9-Octadecenoic acid (Z)-, methyl ester	 PubChem CID:5364509	Reena Roy et al. (2020)
		Octadecanoic acid, methyl ester	 PubChem CID:8201	Reena Roy et al. (2020)
		Hexadecanal	 PubChem CID:984	Reena Roy et al. (2020)

Table 10 Continued.

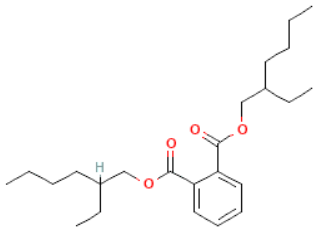
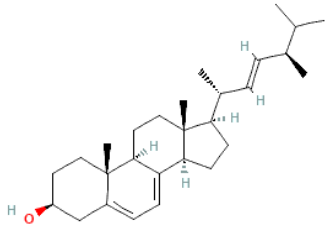
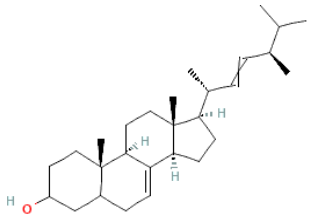
Species	Sample Type	Name of Compound	Chemical Structure	References
		1,2-Benzenedicarboxylic acid, bis(2-ethylhexyl) ester	 PubChem CID:8343	Reena Roy et al. (2020)
		Ergosterol	 PubChem CID:444679	Reena Roy et al. (2020)
		Ergosta-7,22-dien-3-ol, (3.beta.,5.alpha.,22E)-	 PubChem CID:125947	Reena Roy et al. (2020)

Table 10 Continued.

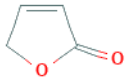
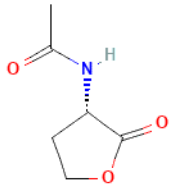
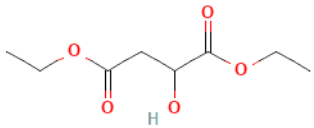
Species	Sample Type	Name of Compound	Chemical Structure	References
		Ethane, Fluoro	 PubChem CID:9620	Adeoye-Isijola et al. (2021)
		2(5H)-Furanone	 PubChem CID:10341	Adeoye-Isijola et al. (2021)
		L-Homoserine lactone, N, N-dimethyl-	 PubChem CID:10012012	Adeoye-Isijola et al. (2021)
		Butanedioic acid, hydroxy-, diethyl ester	 PubChem CID:24197	Adeoye-Isijola et al. (2021)

Table 10 Continued.

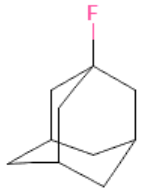
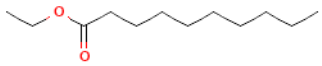
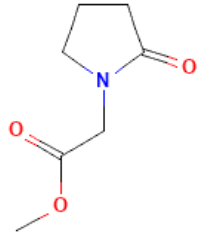
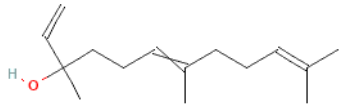
Species	Sample Type	Name of Compound	Chemical Structure	References
		1-Fluoroadamantane	 PubChem CID:136608	Adeoye-Isijola et al. (2021)
		Decanoic acid, ethyl ester	 PubChem CID:8048	Adeoye-Isijola et al. (2021)
		Methyl 2-oxo-1-pyrrolidine acetate	 PubChem CID:108835	Adeoye-Isijola et al. (2021)
		1,6,10-dodecatrien-3-ol,3,7,11-trimethyl-,(E)-	 PubChem CID:8888	Adeoye-Isijola et al. (2021)

Table 10 Continued.

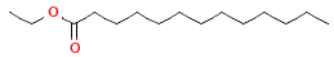
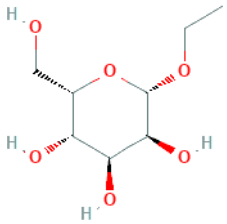
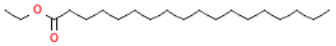
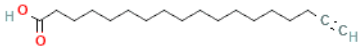
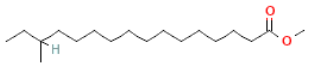
Species	Sample Type	Name of Compound	Chemical Structure	References
		Ethyl tridecanoate	 PubChem CID:119908	Adeoye-Isijola et al. (2021)
		Ethyl alpha-d-glucopyranoside	 PubChem CID:91694274	Adeoye-Isijola et al. (2021)
		Octadecanoic acid, ethyl ester	 PubChem CID:8122	Adeoye-Isijola et al. (2021)
		17-octadecynoic acid	 PubChem CID:1449	Adeoye-Isijola et al. (2021)
		Ethyl 14-methyl-hexadecanoate	 PubChem CID:520159	Adeoye-Isijola et al. (2021)

Table 10 Continued.

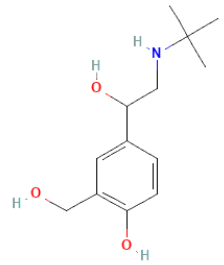
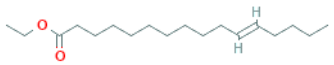
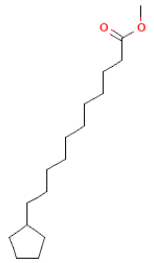
Species	Sample Type	Name of Compound	Chemical Structure	References
		Albuterol	 PubChem CID:2083	Adeoye-Isijola et al. (2021)
		E-11-hexadecenoic acid, ethyl ester	 PubChem CID:5364484	Adeoye-Isijola et al. (2021)
		Cyclopentaneundecanoic acid, methyl ester	 PubChem CID:535041	Adeoye-Isijola et al. (2021)

Table 10 Continued.

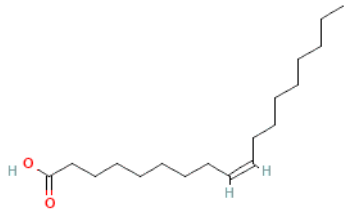
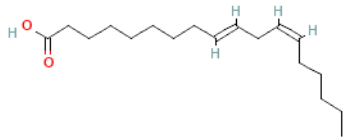
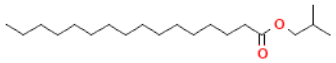
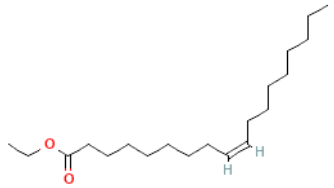
Species	Sample Type	Name of Compound	Chemical Structure	References
		Oleic acid	 PubChem CID:445639	Adeoye-Isijola et al. (2021)
		9,12-octadecadienoic acid (E,Z)-	 PubChem CID:5282798	Adeoye-Isijola et al. (2021)
		Hexadecanoic acid, 2-methylpropyl ester	 PubChem CID:66967	Adeoye-Isijola et al. (2021)
		Ethyl oleate	 PubChem CID:5363269	Adeoye-Isijola et al. (2021)

Table 10 Continued.

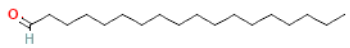
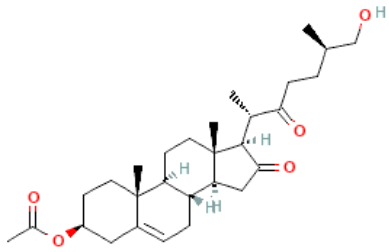
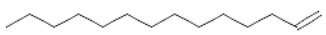
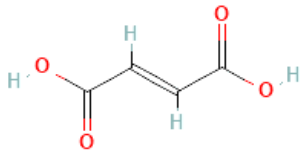
Species	Sample Type	Name of Compound	Chemical Structure	References
		Octadecanal	 PubChem CID:12533	Adeoye-Isijola et al. (2021)
		Cholest-5-ene-16,22-dione,3 beta 26-dihydroxy-, 3-acetate, (20S, 25R)-	 PubChem CID:91691791	Adeoye-Isijola et al. (2021)
		Ethyl stearate, 9,12-diepoxy	 PubChem CID:91205583	Adeoye-Isijola et al. (2021)
	Aqueous extract	1-Tetradecene	 PubChem CID:14260	Ugbogu et al. (2019)
		Fumaric acid, monochloride, 6-ethyloct-3-yl ester	 PubChem CID:444972	Ugbogu et al. (2019)

Table 10 Continued.

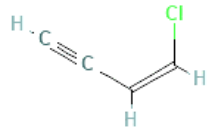
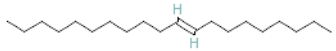
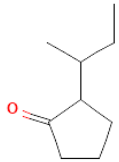
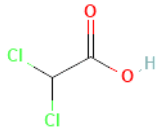
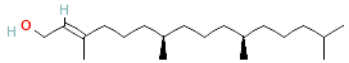
Species	Sample Type	Name of Compound	Chemical Structure	References
		1-Buten-3-yne, 1-chloro-, (Z)-	 PubChem CID:5364314	Ugbogu et al. (2019)
		9-Eicosene, (E)-	 PubChem CID:5365037	Ugbogu et al. (2019)
		Cyclopentanone, 2-(1-methylpropyl)	 PubChem CID:558511	Ugbogu et al. (2019)
		Dichloroacetic acid	 PubChem CID:6597	Ugbogu et al. (2019)
		Phytol	 PubChem CID:5280435	Ugbogu et al. (2019)

Table 10 Continued.

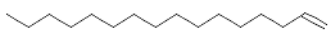
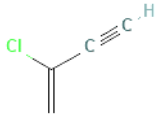
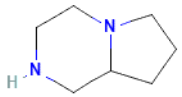
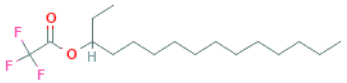
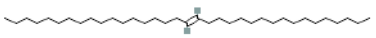
Species	Sample Type	Name of Compound	Chemical Structure	References
		Cetene	 PubChem CID:12395	Ugbogu et al. (2019)
		1-Buten-3-yne, 2-chloro	 PubChem CID:559395	Ugbogu et al. (2019)
		Octahydropyrrolo[1,2-a]pyrazine	 PubChem CID:558578	Ugbogu et al. (2019)
		3-Trifluoroacetoxypentadecane	 PubChem CID:534406	Ugbogu et al. (2019)
		17-Pentatriacontene	 PubChem CID:5365022	Ugbogu et al. (2019)

Table 10 Continued.

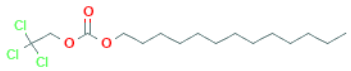
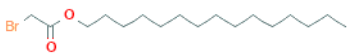
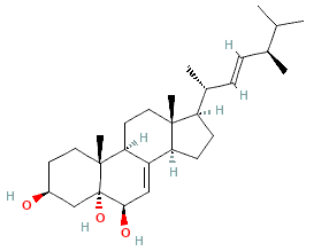
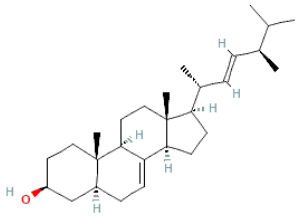
Species	Sample Type	Name of Compound	Chemical Structure	References
		Carbonic acid, tridecyl 2,2,2-trichloroethyl ester	 PubChem CID:6421316	Ugbogu et al. (2019)
		Bromoacetic acid, pentadecyl ester	 PubChem CID:537044	Ugbogu et al. (2019)
L. tigrinus	Dichloromethane extract	Cerevisterol	 PubChem CID:10181133	Ragasa et al. (2018)
		Stellasterol	 PubChem CID:5283628	Ragasa et al. (2018)

Table 10 Continued.

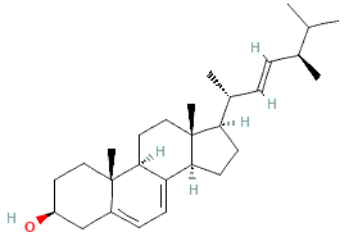
Species	Sample Type	Name of Compound	Chemical Structure	References
		Ergosterol	 PubChem CID:444679	Ragasa et al. (2018)

Table 11 Biological properties of *Lentinus* species.

Species (mushroom sample)	Extracts	Bioactive components	Findings	References
L. tigrinus (cultivated air-dried fruiting body)	Acetonitrile	Lipids	Exhibited antibacterial activity against *S. aureus* at an extract concentration of 75 mg/ml.	Dulay et al. (2017)
L. tigrinus (cultivated air-dried fruiting body)	Acetonitrile	Lipids	Exhibited 39.2% radical scavenging activity against 2,2-diphenyl-1-1picrylhydrazyl (DPPH)	Dulay et al. (2017)
L. tigrinus (freeze-dried fruiting body)	Polyethylene glycol	n.d.	Killed about 45.00% and 70.00% of MCF-7 and PC3 cancer cell lines, respectively, inducing apoptosis at an LTPp concentration of 70µg/ml. LTPp demonstrated a greater anti-proliferative and cytotoxic action against PC3 cells than MCF-7 cells.	Mohammadnejad et al. (2019)
L. tigrinus (culture spent and mycelia)	Ethyl acetate	n.d.	Exhibited 18.94% radical scavenging activity against DPPH	Dulay et al. (2015a)
L. tigrinus Kaya 7454 (cap and stipe)	Chloroform, acetone, and n-hexane	n.d.	IC_{50} values of 0.376mg/ml of acetone, 0.434mg/ml of hexane, and 2.854mg/ml of chloroform extracts have a significant degree of growth inhibitory potential over hepatocellular carcinoma cells (HepG2 cells)	Sadi et al. (2015)
L. tigrinus Kaya 7454 (cap and stipe)	Water, n-hexane, chloroform, acetone, and methanol	n.d.	Exhibited antibacterial activity against *B. subtilis, E. coli, S. aureus, A. tumefaciens and B. licheniformis* at extract concentration of 40µg/ml.	Sadi et al. (2015)
L. tigrinus (cultivated air-dried fruiting body)	Hot water	n.d.	Showed delayed development prior to severe malformation in the treated zebrafish embryo 0.5-10% extract concentration.	Dulay et al. (2014a)
L. sajor-caju (culture spent and mycelia)	Ethyl acetate	n.d.	Exhibited 16.94% radical scavenging activity against DPPH	Dulay et al. (2015a)

Table 11 Continued.

Species (mushroom sample)	Extracts	Bioactive components	Findings	References
Lentinus sajor-caju (wild fruiting body)	n-hexane	n.d.	Demonstrated the maximum cytotoxicity activity against colorectal cancer HCT116wt cells, with an IC_{50} value of 0.05mg/ml. Also, PSC-hex compounds have altered the p21/p53 cell cycle regulation system.	Finimundy et al. (2018)
L. sajor-caju (air-dried fruiting body)	Hot water extract	n.d.	Exhibited antihypertensive and was found to lower systolic blood pressure, diastolic blood pressure, and heart rate in spontaneously hypertensive rats (SHR) at extract concentrations 3.87 and 7.70 mg/ml. Also, reduced triglycerides, blood urea nitrogen, and creatinine, while significantly increasing total cholesterol, high-density lipoprotein-cholesterol, and albumin-to-globulin ratio (A/G ratio) in SHR at an extract concentration of 38.5mg/ml.	Eguchi et al. (2014)
L. sajor-caju (wild air-dried fruiting body)	Ethanol	n.d.	Zebrafish embryo treated with *L. sajor-caju* extract at 5% concentration showed 83.33% mortality from 36h-48h of exposure to the ethanolic extract. Also, at 5% concentration, there is 0% hatchability, 100% delayed growth, and 83.33% tail malformation recorded.	De Castro & Dulay (2015)
L. sajor-caju FCL237 (mycelia)	Roswell Park Memorial Institute (RPMI) 1640	n.d.	In LS 180 and SW948 human colon cancer cells, pro-apoptotic levels were determined to be about 18.8±11.8% and 14.7±8.0%, respectively, and the cancer cells' viability was decreased to 60.0±6.68% on HT-29 cells and 40.0±8.6% on SW948 human colon cancer cells. In addition, the extracts' NO-secreting effects are around 2-fold higher.	Zajac et al. (2021)
L. squarrosulus (fruiting body)	Aqueous	Peptide	In H460, H292, and H23 lung cancer cells, the IC_{50} of partly purified peptide extracts from *L. squarrosulus* was found to be around 26.84±2.84µg/ml, 2.80±2.14µg/ml, and 18.84±0.00µg/ml, respectively. The extracts caused apoptosis by decreasing Bcl-2 protein (~0.5-fold reduction) and increasing BAX (~4.5-fold increase) at a concentration of 20µg/ml. At the same extract concentration, the cellular level of the death receptor inhibitor c-FLIP was likewise reduced (~0.6-fold).	Prateep et al. (2017)
L. squarrosulus (cultivated mycelia broth)	Hot water	n.d.	Exhibited radical scavenging activity equivalent to 14.29 mg/mL against DPPH	Abdullah et al. (2011)
L. squarrosulus (cultivated mycelia broth)	Hot water	n.d.	In ethanol-induced rats, 250 mg/kg of *L. squarrosulus* mycelia extract hastened the healing of stomach ulcers.	Abdullah et al. (2011)
L. squarrosulus (cultivated mycelia)	Cold water, hot water, ethanol	Polysaccharide	IPS HWE inhibits the development of A549 lung cancer cells with a 43% cell viability and an IC_{50} of 56 µg/mL. Also, the IPS HWE, IPS CWE, and EPS WE reduced cell viability, and the IC_{50} were 26 µg/mL, 43.5 µg/mL, and 65 µg/mL, respectively.	Ahmad et al. (2015)
L. swartzii (cultivated air-dried mycelia)	Ethanol	n.d.	Exhibited scavenging activity equivalent to 35.29% and 36.04% against DPPH and nitric oxide, respectively	Austria et al. (2021)

Table 11 Continued.

Species (mushroom sample)	Extracts	Bioactive components	Findings	References
L. swartzii (cultivated air-dried mycelia)	Ethanol	n.d.	Exhibited anti-diabetic activity and showed 81.89% inhibitory activity against α-amylase.	Austria et al. (2021)
L. swartzii (cultivated air-dried fruiting body)	Ethanol	n.d.	Exhibited scavenging activity equivalent to 43.69% and 31.75% against DPPH and nitric oxide, respectively.	Austria et al. (2021)
L. swartzii (cultivated air-dried fruiting body)	Ethanol	n.d.	Exhibited anti-diabetic activity and showed 71.08% inhibitory activity against α-amylase	Austria et al. (2021)
L. polychrous (cultivated oven-dried mycelia)	Ethanol	Polysaccharide	Exhibited scavenging activity comparable to 497µg extract/ml and 123µg extract/ml, respectively against DPPH and 2,2-azino-bis-3-ethylbenzthiazoline-6-sulphonic acid (ABTS).	Thetsrimuang et al. (2011)
L. polychrous (cultivated fresh fruiting body)	Ethanol	Polysaccharide	Exhibited scavenging activity equivalent to 3078µg extract/ml, and 432µg extract/ml against DPPH and ABTS, respectively.	Thetsrimuang et al. (2011)
L. polychrous (cultivated oven-dried fruiting body)	Ethanol	Polysaccharide	Exhibited scavenging activity equivalent to 1660µg extract/ml, and 237µg extract/ml against DPPH and ABTS, respectively.	Thetsrimuang et al. (2011)
L. polychrous (cultivated fresh fruiting body)	Ethanol	Polysaccharide	At 1 mg/ml extract concentration, the A549 non-small cell lung adenocarcinoma cell line had 76% cell viability, SK-Hep-1 hepatocellular carcinoma cell line had 65% cell viability, and MCF-7 human breast adenocarcinoma cell line had 62 % cell viability.	Thetsrimuang et al. (2011)
L. polychrous (cultivated oven-dried fruiting bodies)	Ethanol	Polysaccharide	At 1 mg/ml extract concentration, the A549 non-small cell lung adenocarcinoma cell line had 85% cell viability, SK-Hep-1 hepatocellular carcinoma cell line had 60% cell viability, and MCF-7 human breast adenocarcinoma cell line had 55% cell viability.	Thetsrimuang et al. (2011)
L. crinitus U9-1 (cultivated dried basidiocarp pileus)	Methanol	n.d.	Exhibited scavenging activity equivalent to 99mg/ml, and 35.4µmol Fe^{+2}/g of a sample against DPPH and ferric reducing antioxidant power (FRAP), respectively.	Bertéli et al. (2021)
L. crinitus U9-1 (cultivated dried basidiocarp stipe)	Methanol	n.d.	Exhibited scavenging activity equivalent to 197mg/ml, and 26.1µmol Fe^{+2}/g of a sample against DPPH and FRAP, respectively.	Bertéli et al. (2021)

n.d., not determined

Most of the studies about *Lentinus* bioactivity focused on the antibacterial, and antioxidant activity of this mushroom. However, recent studies showed the potential of the *Lentinus* species as an anticancer, antihypertensive, and antiobesity agent. The anticancer mechanism exhibited by *Lentinus* species, particularly *L. tigrinus, L. sajor caju,* and *L. squarosulus* is demonstrated in the study of Mohammadnejad et al. (2019), Finimundy et al. (2018) and Ahmad et al. (2015), respectively. According to Mohammadnejad et al. (2019), *L. tigrinus* precipitated with polyethylene glycol (LTPp) demonstrated a significant inhibitory effect on MCF-7 and PC3 cancer cell lines at concentrations less than 1000µg/ml, and further microscopic investigation confirmed that LTPp-induced morphological alterations in both

cell lines. LTPs also yielded IC_{50} values of 193.5±25µg/ml and 33.60±9.0µg in MCF-7 and PC3 cells, respectively. Furthermore, co-staining of V-FITC/P1 demonstrated that after 6 hours of treatment, LTPp at 70µg/ml killed about 45.00% and 70.00% of MCF-7 and PC3 cells, respectively, via inducing apoptosis. Thus, the LTPp demonstrated a greater anti-proliferative and cytotoxic action against PC3 cells than MCF-7 cells. On the other hand, the study of Finimundy et al. (2018) about *L. sajor-caju* n-hexane extract (PSC-hex) demonstrated the maximum cytotoxicity activity against colorectal cancer $HCT116^{wt}$ cells, with an IC_{50} value of 0.05mg/ml. The cytotoxicity was then linked to the pathways that promote apoptosis and cell cycle arrest. PSC-hex caused apoptosis by breaking down the mitochondrial membrane potential and releasing reactive oxygen species (ROS). This is confirmed by the lack of cytotoxicity in $HTC116^{-p53}$ and $HTC116^{-Bax}$ cells, as well as increased expression of p53, Bax, and Caspase-3, showing that the proapoptotic impact is likely produced by the p53-related pathway. Therefore, the PSC-hex caused cell cycle arrest at G2/M in $HCT116^{wt}$ cells in $HTC116^{-p21}$ cells without producing cytotoxicity. Likewise, the study of Ahmad et al. (2015) about *L. squarrosulus*, showed that three (3) crude extracts from water extraction the intracellular polysaccharide hot water extract (IPS HWE), intracellular polysaccharide cold water extract (IPS CWE), and exopolysaccharide water extract (EPS WE) displayed antiproliferative activity against lung cancer carcinoma cell lines (A549). Among all the extracts, only IPS HWE inhibits the development of A549 lung cancer cells with a 43% cell viability and an IC_{50} of 56 µg/mL after a 24-hour incubation period.

Furthermore, Eguchi et al. (2014) demonstrated the antihypertensive activity of *L. sajor-caju.* The hot water extract of *L. sajor-caju* (WELS) was found to lower systolic blood pressure (SBP), diastolic blood pressure (DBP), and heart rate in spontaneously hypertensive rats (SHR). WELS' antihypertensive effects were also proven by enhanced metabolic activities, as evidenced by blood chemist clearance. Furthermore, at 28.5 mg/ml or higher concentrations, WELS significantly reduced triglycerides (TG), blood urea nitrogen (BUN), and creatinine (Cre), while significantly increasing total cholesterol (T-Cho), high-density lipoprotein-cholesterol (HDL-C), and albumin-to-globulin ratio (A/G ratio) in SHR.

The recent findings on the bioactivities of the top two *Lentinus* species, the *L. tigrinus* and *L. squarrosulus* are presented in Fig. 4. The different extracts such as water, ethanol, methanol, chloroform, acetone, and n-hexane from both species exhibit different bioactivities such as antibacterial, anticancer, antioxidant, antiulcer, and teratogenic activity. In addition, the bioactive components, polysaccharides, and lipids of *L. squarrosulus* extract and polyethylene glycol extracts of *L. tigrinus* show promising potential as an anticancer agent against A549 lung cancer cell, human breast cancer (MCF-7), and human prostate cancer (PC3).

These findings suggested that consumption of *Lentinus* can be advantageous as it exhibits different bioactivities that provide medical and nutraceutical benefits. Moreover, aside from edibility, *Lentinus* can also be employed in the industry as it shows great potential as an anticancer, antibacterial, antiulcer, antihypertensive, and antiobesity agent. In conformity with *Lignosus rhinocerotis*, the status review of Nallathamby et al. (2018) also shows a wide array of bioactivities similar to *Lentinus*, suggesting that it can be used as an alternative and natural medication. We believe that more research on *Lentinus* will uncover new biological applications. However, both the chemical and biological features of *Lentinus* can already be utilized in the industry with comprehensive validation studies, including human clinical trials of the bioactive components found in *Lentinus* for the production of *Lentinus*-based products.

Applications of *Lentinus* species

Aside from the nutritional benefits of mushrooms, numerous studies were conducted maximizing the application of mushrooms in the industry, such as in pharmaceuticals, dietary supplements, functional food, biofuel, biocatalyst, and bioremediation. In the proceeding section, the chemical and

biological properties of *Lentinus* were illustrated, and through that, extensive research was conducted utilizing *Lentinus* in the industry. The other application of *Lentinus*, primarily bioremediation is illustrated in Table 12.

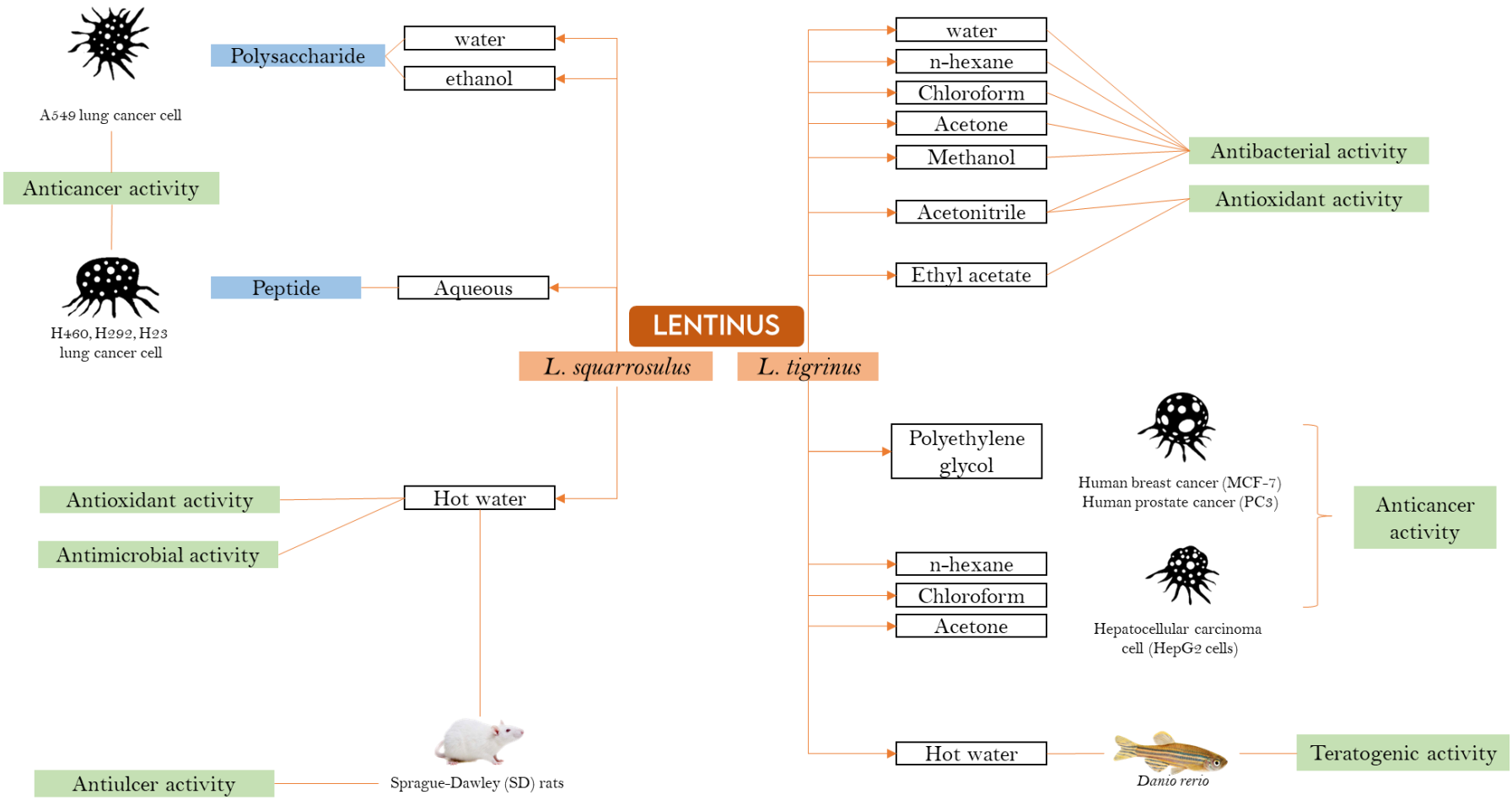


Figure 4 – An overview of the recent findings on the bioactivities of *Lentinus* species.

Based on the recent works, the *Lentinus tigrinus*, and *Lentinus squarrosulus*, show positive results in bioremediation. The *L. tigrinus* bioaugmentation using maize stalk-immobilized mycelium might be beneficial in the rehabilitation of polychlorobiphenyls (PCB) contaminated soils (Federici et al. 2012). Furthermore, *Lentinus crinitus* and *Lentinus polychrous* show decolorization potential for the

treatment of waste dyes, and the results showed that the *L. crinitus* crude enzymatic extract was more successful in decolorizing azo dyes (RB220 and RB5), with over 90% decolorization compared to 77% for anthraquinone dye (Tavares et al. 2020), and *L. polychrous* enzyme laccase and the availability of this fungus has a strong potential for the treatment of waste dyes (Suwannawong et al. 2010). In addition, *Lentinus sajor-caju* exhibits bioabsorbent activity, where the biosorbents were subjected to six biosorption-desorption cycles, and no significant decline in biosorption capacity was detected (Bayramoğlu et al. 2006), while the *Lentinus squarrosulus* water purification activity reduced the turbidity, total heterotrophic count, and total coliform count significantly, making it a potential water purifying agent (Glorialkechi-Nwogu et al. 2020).

Table 12 Applications of *Lentinus* species.

Species	Application	References
L. squarrosulus	Mineralization of mono-nitrophenols	Tripathi et al. (2011)
L. squarrosulus	Purification of untreated drinking water	Glorialkechi-Nwogu et al. (2020)
L. tigrinus	Bioaugmentation of historically contaminated soil	Federici et al. (2012)
L. squarrosulus	Bioremediative potential on sawdust contaminated with crude oil	Bassey & Oshomoh (2020)
L. sajor-caju	Accumulation of uranium from aqueous solution	Bayramoğlu et al. (2006)
L. polychrous	Decolorization of rhodamine B and congo red by partially purified laccase from *L. polychrous*	Suwannawong et al. (2010)
L. tigrinus	Augmentation of historically contaminated soil	Federici et al. (2011)
L. crinitus	Decolorization of azo and anthraquinone dyes	Tavares et al. (2020)

These findings on the capability of *Lentinus* as a bioremediation agent boosted the importance of mushrooms in addressing organopollutants due to industrialization. Accordingly, the white-rot fungus, like *Lentinus* has altered a variety of environmental organopollutants, including pesticides, polychlorinated biphenyls, polycyclic aromatic hydrocarbons, wood preservatives, synthetic dyes, and waste materials from paper manufacturing companies, thus it is being utilized in the food, textile, pharmaceuticals, chemicals, and paper industries (Gloriaikechi-nwogu et al. 2020).

In this review, both biological and chemical properties of *Lentinus* show a diverse array of nutraceuticals composition as rich in carbohydrates, dietary fibers, proteins, fatty acids, and mycochemicals, as well as pharmacological, and biological activities, such as antitumor, antidiabetic, antihypertensive, antibacterial, antiviral, antioxidant, and among others suggesting that genus *Lentinus*, like other mushrooms, can be considered as functional foods. According to Karunarathna et al. (2011), except for those with a tough texture, practically all of the members of *Lentinus* are edible. Accordingly, we believe that *Lentinus* species are not fully studied in comparison with other mushrooms, like *Lentinula edodes* that have been commercialized in the market. However, data for the nutraceuticals compositions and bioactivities of *Lentinus* has great potential when employed in the production of *Lentinus*-based products like biosupplements, food additives, pharmaceutical drugs, and *Lentinus* food products.

Concluding remarks and future perspective

This review highlighted the distribution, cultivation, chemical, and biological composition as well as the application of *Lentinus* species worldwide. Specifically, this review provides a global checklist of 26 *Lentinus* species and the optimal nutritional and physical factors for mycelial growth and fruiting body production. This review also provides the chemical and biological properties of *Lentinus* species, which are essential for various applications. Accordingly, *Lentinus* species have

diverse mycocompounds, however, only two species were exhaustively elucidated. The biological activities of *Lentinus* species were also determined, but limited only to antimicrobial, antioxidant, antiproliferative, antiobesity, anticancer, antihypertensive, antiulcer, antidiabetic, cytotoxicity, and teratogenicity. With the reported values of *Lentinus* species, *Lentinus*-based products are still lacking.

Based on the gathered information presented in this review, the following must be considered for future investigations; (a) extensive studies in the identification and domestication of *Lentinus* species in other countries and/or other *Lentinus* species worldwide, especially for those countries with ideal growing environment favoring the growth of *Lentinus* through comprehensive taxonomic and phylogenetic investigations utilizing modern molecular methods to outline the unique genomic profile and find new *Lentinus* species, (b) commercial cultivation of *Lentinus* species using agro-industrial wastes and other locally-available, cost-effective, alternative medium, and using the generated technologies established in optimization studies, (c) isolation, characterization and identification of chemical composition of other species of *Lentinus*, particularly the newly recorded species, (d) evaluation of the other functional activities in various biological systems or models and elucidation of their mechanism of action, (e) development of *Lentinus*-based based products such as nutritious and functional foods, dietary supplements and pharmaceutical drugs.

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