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Mushroom Cultivation Systems: Exploring Antimicrobial and Prebiotic Benefits

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MUSHROOM farming is the practice of growing and cultivating various species of mushrooms for food, medicinal, or industrial purposes. It involves creating the ideal environment and conditions for the mushrooms to grow and thrive, such as providing a substrate (a nutrient-rich material on which mushrooms grow), controlling temperature and humidity, and ensuring proper ventilation and lighting.Several innovative applications of mushrooms can be noticed in their farming and cultivation. These applications mainly focus on the medicinal and prebiotic attributes, besides their role in producing food and energy. This review is an attempt to highlight the cultivation of mushrooms and their requirements under different kinds of farming. These farming types may include mushroom-worm system, mushroom-bee farming, smart mushroom farming, forest-mushrooms farming, urban mushroom farming, and mushroom-livestock farming. In this study the condition of cultivation of several mushroom species and their edibility is included. Edible/medicinal mushrooms are well-known for their high content of many beneficial bioactive ingredients for human health such as antioxidants, ergosterols, lectins, phenolics/polyphenolics, polysaccharides, and terpenoids. These bioactives of mushrooms have the potential capability to treat and/or prevent several chronic diseases. The medicinal and prebiotic attributes of mushrooms still need more investigation, and this topic of "mushrooms in medicine" still has several open questions are needed to be answered in the future.

Keywords: Mushroom-worm farming, Mushroom-bee farming, Smart mushroom farming, Forest-mushrooms farming, Urban mushroom farming, Mushroom-livestock farming.

1. Introduction

Cultivation of mushrooms is thought to be back over four thousand years of many edible and medicinal mushroom species by the ancient Egyptians, Japan and China (Cotter 2014). The cultivation of mushrooms needs an understanding of all development stages, which include the release of the spores (sporulation), their germination on a suitable

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growing media, colonization as much territory as possible to build up a competitive biomass, complete colonization and primordia formation, and mature mushrooms for producing spores, and the cycle starts again (Cotter 2014). Several reports have been published on mushroom cultivation from different points of view such as the cultivation of mushrooms as a sustainable integrated agriculture model (Ye et al. 2023), for mycoremediation (Sahithya et al. 2022), supporting selenium in removing mercury from soil (Pereira de Oliveira et al. 2023), for biofuel production (Leong et al. 2023), and biosynthesis of nanoparticles for removing organic pollutants (Chauhan et al. 2023).

Mushroom farming could be found in several types including mushrooms for healthy foods (Bell et al. 2022), mushroom-worm farming (Yang et al. 2023), mushroom-bee farming system, smart mushroom farming (Rahman et al. 2022), forest-mushrooms farming (Copena et al. 2022), urban mushroom farming (Dorr et al. 2021), and mushroom-livestock farming (Wang et al. 2022).

Edible mushrooms have unique nutritional attributes that allow use as a source of protein meat analog compared with animal meat and plant-based meat analogs(Wang and Zhao 2023). Many recent studies confirmed the bright side of mushrooms as a future generation healthy food (e.g., Okuda 2022; Bell et al. 2022). Many applications of biotechnology in mushroom farming, which focuses on traditional cultivation include mining biosynthetic gene clusters, precision breeding, developing mushroom chassis cells, and constructing cell factories for high value-added products (Zou et al. 2023). Several mushrooms have a great potential source of active metabolites and medicines (Bhambri et al. 2022).

Therefore, several therapeutic applications of mushroom including edible and medicinal ones were reported (Chugh et al. 2022; Ahmad et al. 2023), which may include more than 130 medicinal activities such as antioxidant, antitumor, cardioprotective and antiviral actions, immunomodulation, and radical scavenging (Chugh et al. 2022).

Therefore, this review presents an overview of the mushrooms and their cultivation and different antimicrobial and prebiotic properties, in addition, different mushroom farming types will be highlighted.

2. Mushroom farming requirements

The cultivation of mushrooms is an important industry, which can gain a potential income. This industry can be carried out indoors or outdoors (in the open field or forests). Due to its importance, mushrooms have a promising strategy in the Nano-Food Lab (Debrecen university), which started several years ago (**Figure 1)**. This plan was successfully translated into many publications and many patents in progress including many research areas such as cultivating edible mushroom in polluted soils (El-Ramady et al. 2021), the green biotechnology of mushrooms (El-Ramady et al. 2022a), the nutritional and medicinal attributes of edible mushrooms (El-Ramady et al. 2022b), the sustainable production of food and energy (El-Ramady et al. 2022c), the sustainable soil nano-management (Elsakhawy et al. 2022), sustainable applications in soil science (Fawzy et al. 2022), and edible mushrooms with focus on *Pleurotus* spp. (Törős et al. 2022), and *Lentinula* spp. (Hajdú et al. 2022).

Pleurotus mushrooms are globally well-cultivated on a large scale, accounting for 27% of their global production (Raman et al. 2021). Several mushrooms can adapt their growing to a wide range of temperatures, at relatively high humidity and high CO_2 levels without requiring specific controlled environmental conditions (Raman et al. 2021). In general, there are seven steps for mushroom cultivation are presented in **Figure 2**, whereas **Figure 3** includes some photos of mushroom farming (*Pleurotus ostreatus*). The main systems of mushroom cultivation could be the following:

I. Outdoor systems (e.g., logs, stumps, and wood chips), and

II. Indoor systems (e.g., bags under greenhouse conditions, bottles of king oyster, bags hung in a wall formation, horizontal shelf with bags, shelf cultivation of mushrooms, a-frame shelf with bags, tray cultivation of mushrooms, and sawdust blocks of mushrooms).

The main types of mushroom spawn include sawdust spawn, grain spawn, plug or dowel spawn, straw spawn, naturalized or wild spawn, and liquid spawn.

The substrate of cultivated mushrooms differs depending on the climate zone of the cultivation area and the system. For example, Cotter (2014) reported that the available substrate under temperate climate (16–29°C) may involve the following systems:

1- Logs and stumps (e.g., beefsteak, birch polypore, black poplar, cauliflower, and chicken of the woods),

2- Wood mulch or chips (e.g., brick top, king Stropharia, and parasol),

3- Composts and livestock waste (e.g., almond portabella, and king Stropharia, parasol, shaggy mane, and composted livestock manure),

4- Agricultural waste, straw, plant debris (e.g., Elm oyster, king Stropharia, parasol, and shimeji),

5- Sawdust (e.g., black poplar, beefsteak, elm oyster, and hairy panus).

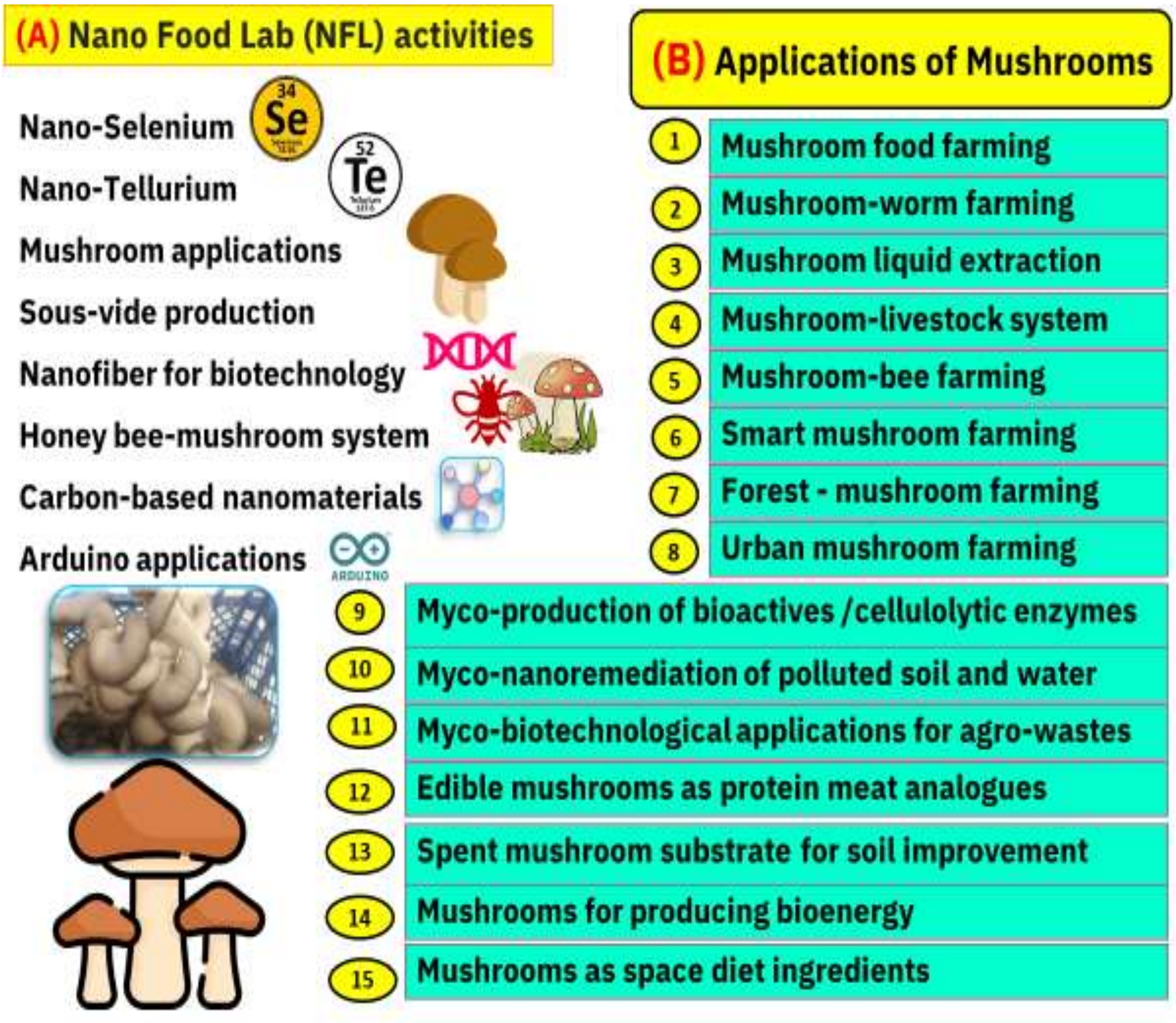


Fig. 1.List of activities of the Nano-Food Lab (Debrecen University, Hungary) in part (A), which includes many applications of mushrooms (part B).

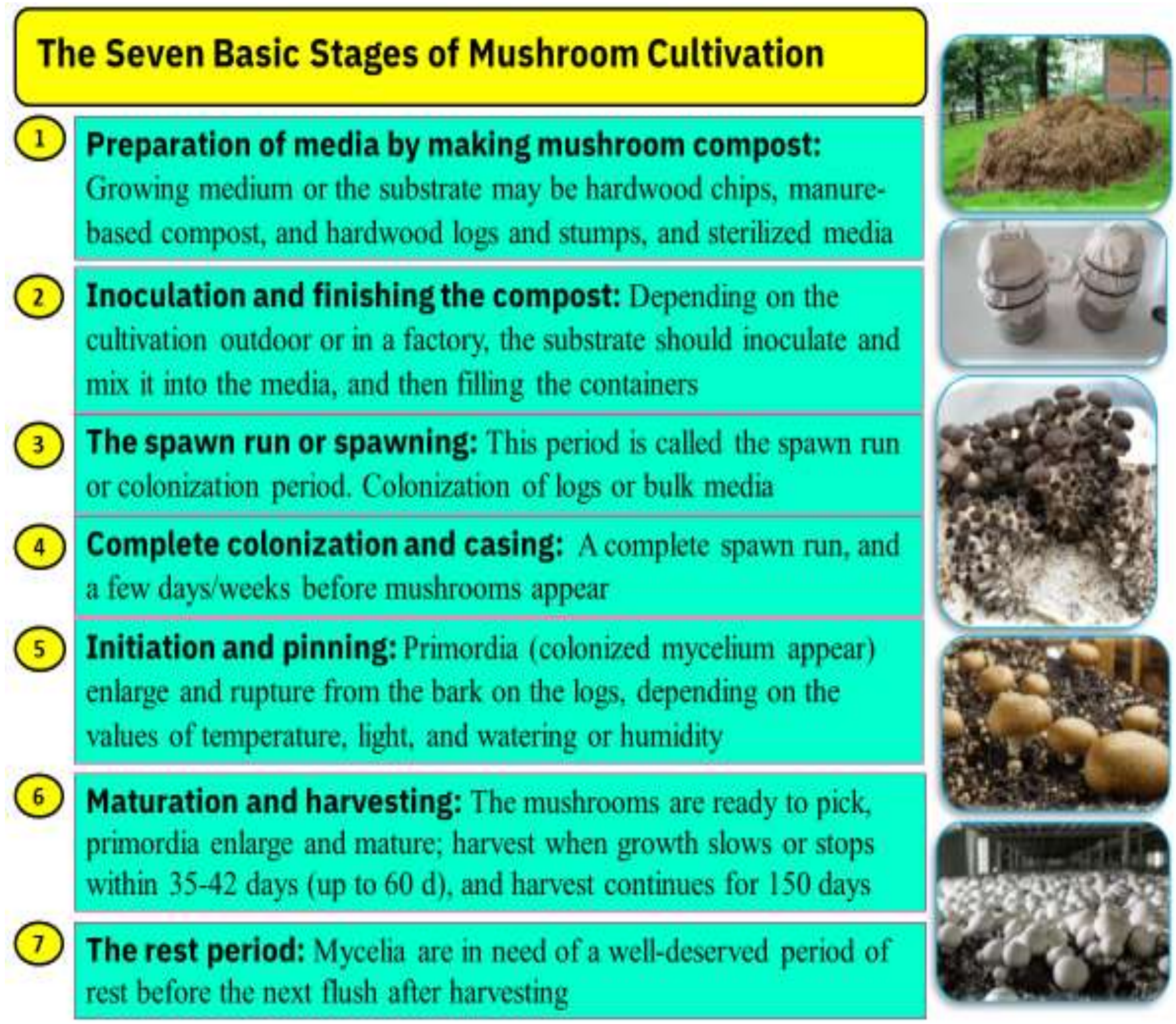
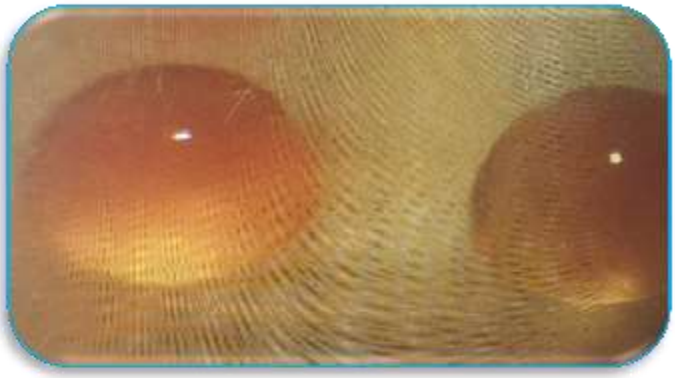


Fig. 2.The main steps in cultivation of mushrooms according to Cotter (2014).

***Pleurotus ostreatus* mycelium on different media (directly after vaccination; room temperature)**

Pleurotus ostreatus **mycelium on different media after 3 days from incubation stage at room temperature**



The microscopic image of secondary metabolit products with orange ball appearance on oyster mycelium

The first harvest of *Pleurotus ostreatus* mushroom grown on corn husks based compost

The first harvest of fresh *Pleurotusostreatus* mushroom as a bouquet grown on corn husks-based compost

Freeze-dried *Pleurotusostreatus* mushrooms, which has been grown on corn husks-based compost

Fresh washed, sliced *Pleurotus ostreatus*

Fig. 3. Some main steps of oyster mushroom cultivation and harvesting from Nano Food Lab (Debrecen University, Hungary). All photos by GrétaTörős.

3. Mushroom farming types

The cultivation of mushrooms under certain conditions is called mushroom farming, and this activity could be performed with or without sharing other agricultural activities like forestry or livestock, the types of farming are presented in**Figure (4)**.Generally, wild mushrooms can grow (up to 10,000 different types of mushrooms), can be classified into 4 categories: parasitic, saprotrophic, mycorrhizal, and endophytic. The consumed mushroom substrate can be used in producing low-carbon biofuel (Leong et al. 2022). Although mushrooms have so many uses, the potential for producing a healthy food is quite important. It is very important to highlight the edibility of many mushrooms in this study as presented in **Table 1**, and they are classified into edible, inedible, toxic, and unknown. The edibility and more growing details besides English and scientific name of these groups of mushrooms are listed as well in Table 1.

Fig. 4.Mushroom farming systems including production of different farming types with focus on foods, livestock, vermicompost, etc.

Table 1.Some common mushrooms in the forestry system with its edibility (adapted from Yan 2023), and the scientific names according to https://www.gbif.org/species.

English name	Scientific name	Edibility and forest growing details
(1) Group of non-edible mushrooms cultivated in forests		
Coral Slime	*Ceratiomyxafruticulose*f. *aurantiaca*Jaap, (1922)	Rotten wood, sometimes on dead leaves. Not Edible
Scrambled Egg Slime	*Fuligoseptica*L. (F.H.Wigg., (1780)	Deciduous forests, on rotten wood, bark, or dead leaves. Not Edible
The Hidden Forest	*Stemonitisaxifera*(Bull.) T.Macbr., (1899)	Rotten Wood. Not Edible
Wolf's Milk Slime	*Lycogalaepidendrum*(L.) Fr., (1829)	Dead/Rotten wood. Not Edible.
Raspberry Slime Mold	*Tubiferaferruginosa*(Batsch) J.F.Gmel., (1792)	Dead wood, dead leaves, or humus. Not Edible
Lemon Drops or Lemon Disco	*Bisporellacitrina*(Batsch) Korf&S.E.Carp. (1974)	Dense colonies on dead branches, rotten wood. Prefers deciduous trees like beech. Not Edible
Canadian Round-headed Cordyceps	*Cordycepscanadensis*Ellis&Everh. (1898)	In humus under pines and deciduous trees. Latches on underground truffles, Not Edible
Adder's Tongue	*Cordycepsophioglossoides*(J.F.Gmel.) Link (1818)	Found in humus of deciduous and mixed forests (birch),latches on to underground truffles, Not Edible.
Black Knot of Cherry	*Dibotryonmorbosum*Schwein. Theiss.	Latches on to cherry trees such as

	& Syd. (1915)	*Prunusvirgiana;Prunuspensylvanica*. Not Edible.
Agassiz's Lachnella	*Lachnellulaagassizii*(Berk. &M.A.Curtis) Dennis (1962)	In dense colonies on dead conifer bark, especially fir. Not edible.
Hairy Earth Tongue	*Trichoglossumhirsutum*(Pers.) Boud. (1907)	On humus or rotten wood. Not edible.
Dead Man's Fingers	*Xylariapolymorpha*(Pers.) Grev. (1824)	On dead branches, trunks, or logs. Even on live trees, especially on deciduous trees such as beech. Not edible.
Black Witche's Butter	*Exidiaglandulosa*(Bull.) Fr. (1822)	On dead branches from deciduous trees. Not edible.
White Coral Jelly Fungus	*Tremellareticulata*(Berk.) Farl. (1908)	On ground or on rotten wood or leaves. Especially in maple/oak forests. Not edible.
Perennial Polypore	*Coltriciaperennis*(L.) Murrill (1903)	On the ground in disturbed forests such as clear cuts or wildfire mainly in coniferous forests with birch and aspen. Not Edible.
Woolyvelvet polypore or Velvet Rosette	*Onniatomentosa*(Fr.) P.Karst. (1889)	On buried roots in coniferous forests. Not Edible.
Winter Polypore	*Polyporusbrumalis*(Pers.) Fr. (1818)	On dead wood, especially birch wood. Not edible.
Variegated Polypore	*Polyporusvarius*(Pers.) Fr. (1821)	On dead wood in deciduous forests. Not Edible.
Reddish Brown Crust	*Hymenochaetetabacina*(Sowerby) Lév. (1846)	On dead branches and trunks, in deciduous forests. Not edible.
Red Tree Brain	*Peniophorarufa*(Fr.) Boidin (1958)	In dense colonies, on dead branches, trunks of quaking aspen, or willow. Not Edible.
Reddish Brown Crust	*Hymenochaetetabacina*(Sowerby) Lév. (1846)	On dead branches and trunks, in deciduous forests. Not edible.
Hairy Parchement	*Stereumhirsutum*(Willd.) Pers. (1800)	On dead wood of deciduous trees, such as oak, maple, and beech. Not edible.
Milk-white Toothed Polypore	*Irpexlacteus* (Fr.), Fr. (1828)	On dead branches and trunk of deciduous trees. Not Edible.
Tin Maze Flat Polypore	*Daedaleopsisconfragosa*(Bolton) J.Schröt. (1888)	On dead trunks of deciduous trees, mainly on beech, birch, willows,alders. Not Edible.
Mossy Maze Polypore	*Cerrenaunicolor*(Bull.) Murrill (1903)	In large colonies on dead wood, or even living deciduous trees. Not edible.
Split-gilled Bracket	*Schizophyllum commune* Fr. (1815)	Dead branches of deciduous trees. Not Edible.
Rusty-gilled Polypore	*Gloeophyllumsepiarium*(Wulfen) P.Karst. (1882)	On dead trunks, or logs of coniferous trees. Not edible.
Timber Polypore	*Fomesfomentarius* (L.), Fr. (1849)	On trunks of living or dead deciduous trees, such as birch. Not edible.
Red-belted Polypore/ Red-Banded Polypore	*Fomitopsispinicola*(Sw.) P.Karst. (1881)	On dead trunks, mostly on conifers. Not Edible.
Artist's Conk	*Ganodermaapplanatum*(Pers.) Pat. (1887)	On trunks of dead deciduous trees. Not edible.
Resinous Polypore	*Ischnodermaresinosum*(Schrad.) P.Karst. (1879)	On logs, and trunk of dead, deciduous trees. Not edible.
Scaly Polypore	*Polyporussquamosus*(Huds.) Quélet (1886)	On trunks and logs of wounded deciduous trees. Not Edible.
False Timber Polypore	*Phellinus cinereus*Niemelä	On stumps, mostly of birch trees. Not edible.
Birch Polypore	*Piptoporusbetulinus*(Bull.) P.Karst. (1881)	On dead birch trees. Not edible.
Turkey Tail Polypore	*Trametesversicolor*(L.) Lloyd (1921)	On stumps, trunks, logs, or branches of deciduous trees. Not edible, but Medicinal.
Cinnabar-red Plypore (Cinnabar Bracket)	*Pycnoporuscinnabarinus*(Jacq.) P.Karst. (1881)	On stumps, logs, or trunks of deciduous trees, commonly on cherry. Not edible.
Parchment Bracket or Violet-toothed polypore	*Trichaptumbiforme*(Fr.) Ryvarden (1972)	On stumps, trunks, and logs of deciduous trees, sometimes covering the whole surface.

		Not edible.
Northern Tooth	*Climacodonseptentrionalis*(Fr.) P.Karst. (1881)	On trunks of dead or living deciduous trees such as elm and maple. Not edible.
Fragrant Hydnum (SweetgrassHydnellum)	Hydnellumsuaveolens(Scop.) P.Karst. (1879)	On mossy forest floor, lichen or needle covered soil. Not edible.
Flat Crep	*Crepidotusapplanatus*(Pers.) P.Kumm. (1871)	Dispersed on dead wood in deciduous forests. Not edible.
Bear Lentinus	*Lentinellusursinus*(Fr.) Kühner, (1926)	On dead wood in deciduous forests. Not edible.
Luminescent Panellus	*Panellusstypticus*(Bull.) P.Karst. (1879)	In bunches, on rotten wood of deciduous forests. Not edible.
Orange Mock Oyster	*Phyllotopsisnidulans*(Pers.) Singer (1936)	In bunches, on dead wood of coniferous and deciduous forests. Not edible.
Pinwheel Marasmius	*Marasmiusrotula*(Scop.) Fr. (1838)	In bunches on rotten wood, or on dead leaf litter, or within stacks of twigs in deciduous forests. Not edible.
Bleeding Mycena or Bleeding Fairy Helmet	*Mycenahaematopus*(Pers.) P.Kumm. (1871)	In bunches on rotten wood of deciduous trees. Stem bleeds a blood-colored latex. Not Edible.
Wrinkled Mycena	*Mycenagalericulata*(Scop.) Gray (1821)	In bunches on rotten wood of deciduous trees. Not edible.
Pink Mycena	*Mycenapura*-(Pers.) P. Kumm. (1871)	On humus in coniferous, mixed, or deciduous forests. Not Edible.
Orange Mycena	*Mycenaleaiana*(Berk.) Sacc. (1891)	In bunches on dead logs of deciduous trees. Not edible.
Fuzzy Foot	*Xeromphalinacampanella*(Batsch) Kühner&Maire (1953)	In dense clusters on stumps, and trunks of rotten coniferous trees. Not edible.
Scaly Stropharia	*Strophariasquamosa* var. thrausta (Kalchbr.) Massee	On buried wood, in forests or fields. Not Edible.
(2) Group of edible mushrooms cultivated in forests		
Orange PeelFungus	*Aleuriaaurantia*(Pers.) Fuckel	Bare, usually sandy soil. Edible
False Morel	*Giromitraesculenta*(Pers. ex Pers.) Fr. (1849)	Open, sandy soils, in coniferous forests, particularly white pine,and mixed forests. Edible for some, but not recommended.
Lobster Mushroom	*Hypomyceslactifluorum*Schwein.,Tul. &C.Tul. (1860)	Latches on to russula, and lactarius mushrooms. In coniferous or mixed forests. Edible, with great texture.
Common Jelly Baby	Leotialubrica	In dense colonies on rotten wood/ directly on the ground. Edible, but glutinous.
Black Morel	*Morchellaelata* Pers. Fr. (1822)	Deciduous forests, especially under poplar, but also in mixed forests. Edible, tasty, but better blanch them first.
Yellow Morel	*Morchellaesculenta*(L.) Pers. (1801)	Deciduous forests, especially under elms, and poplars. Edible, one of the tastiest, but better blanch them first.
Irregular Mitrula or Irregular Earth Tongue	*Neolectairregularis*(Peck) Korf&J.K.Rogers (1971)	On moss, or forest litter such as needles, in coniferous or mixed forests. Edible.
Bay Peziza or bay cup	*Pezizabadia*Pers. (1800)	In deciduous or mixed forests, often found on sandy soil. Edible.
Scarlet Cup	*Sarcoscyphaaustriaca*(Beck ex Sacc.) Boud. (1907)	On the soil, in burrowed wood, in deciduous forests such as maple forests. Edible.
Fairy Butter	*Dacrymyceschrysospermus*Berk. &M.A.Curtis (1873)	On dead wood of conifers. Edible.
Tree Ear	*Auriculariaauricula-judae*(Bull.) Quél. (1886)	On dead wood, especially on conifers like fir and spruce. Edible.
Toothed Jelly Fungus	*Pseudohydnumgelatinosum*(Scop.) P.Karst. (1868)	On rotten wood in coniferous forests. Edible, but not particularly tasty.
Fake Coral Fungus	*Tremellodendron pallidum* Burt. (1915)	On ground in deciduous or mixed forests. Edible.

Apricot Jelly Fungus	*Tremiscushelvelloides*(DC.) Donk (1958)	On ground, or rotten wood in coniferous or mixed forests. Edible, but more decorative than tasty.
Sheep Polypore	*Albatrellusovinus*(Schaeff.) Kotl. &Pouzar (1957)	Under fir or spruce forests. Edible, quite tasty.
Chaga	*Inonotus obliquus*(Fr.) Pilát (1942)	Latches on exclusively on birch trees. Highly medicinal, can be used as coffee alternative. Edible
Chicken of the Woods	*Laetiporussulphureus*(Bull.) Murrill (1920)	On trunks and logs of deciduous trees. Edible, but with variety of results.
Comb Tooth	*Hericiumcoralloides*(Scop.) Pers. (1794)	On trunk of dead or living deciduous trees. Edible.
Sweet Tooth (Wood Hedgehog)	*Hydnumrepandum*L. (1753)	In mixed, deciduous or coniferous forests. Edible, very tasty.
Fairy Fingers	*Clavariafragilis*Holmsk. (1790)	In dense groups on the ground within herbs, and humus, in deciduous forests. Edible.
Purple coral, or the purple fairy club	*Clavariapurpurea*(Fr.) Dentinger&D.J.McLaughlin (2007)	In colonies on the ground, within herbs, orhumus, in coniferous forests. Edible.
Whitecoral fungus or the crested coral fungus	*Clavulinacristata*(Holmsk.) J. Schröt. (1888)	On the ground within moss, and humus, in coniferous or mixed forests. Edible.
Crown-tipped Coral or Candelabra Coral	*Clavicoronapyxidata*(Pers.) Doty (1947)	On rotten wood of deciduous trees, mainly willow, or aspen. Edible, but mediocre.
Spindle-shaped Clavaria	*Clavulinopsis fusiformis*(Sowerby) Corner (1950)	In dense clusters within herbs, or on bare soil, within coniferous or mixed forests. Edible.
Chanterelle	*Cantharelluscibarius* Fr. (1821)	In coniferous, and mixed forests, and more rarely in deciduous forests. Edible, tasty.
Appalachian Chanterelle	*Cantharellusappalachiensis*R.H. Petersen (1971)	In deciduous forests, often under oaks, and beech. Edible, tasty.
Cinnabar Chanterelle	*Cantharelluscinnabarinus*(Schwein.) Schwein. (1832)	On the forest floor, within moss, or along paths, in deciduous forests, often under oaks. Edible, tasty.
Black Trumpet	*Craterellusfallax*A.H.Sm. (1968)	In deciduous, and mixed forests. Edible, tasty.
Trumpet Chanterelle or Yellowfoot	*Craterellustubaeformis*(Fr.) Quél. (1888)	In coniferous, or mixed forests. In moist areas such as peat bogs, in sphagnum moss. Edible, tasty.
Oyster Mushroom	*Pleurotusostreatus*(Jacq. ex Fr.) P.Kumm. (1871)	In bunches, on living or dead deciduous trees, especially on maple, oak, beech, and birch. Edible, tasty.
Angel's Wings	*Pleurocybellaporrigens*(Pers.) Singer (1947)	In bunches, on rotten wood of conifers. Edible, tasty.
Summer or pale Oyster	*Pleurotuspulmonarius*(Fr.) Quél. (1872)	In bunches, on living or dead deciduous trees, such as maple, beech, oaks, and birch. Edible, tasty.
Late Fall Oyster	*Sarcomyxaserotina*(Pers.) P. Karst. (1891)	In bunches, on dead deciduous trees. Edible, tasty.
Golden Waxy Cap	*Hygrocybechlorophana*(Fr.) Wünsche (1877)	In coniferous, mixed, or deciduous forests. Edible, but not recommended.
Chanterelle or Goblet Waxy Cap	*Hygrocybecantharellus*(Schwein.) Murrill (1911)	On extremely rotten wood covered in moss, and on sphagnum moss within humid peat bogs. Edible
Scarlet Waxy Cap	*Hygrocybecoccinea*(Schaeff.) P. Kumm. (1871)	On the forest floor in deciduous, and mixed forests. Edible.
Witch's Hat or Blackening Waxcap	*Hygrocybeconica*(Schaeff.) P.Kumm. (1871)	On the forest floor in deciduous, mixed, or coniferous forests; or in open meadows, and groves. Edible, but not recommended.
Virginal Hygrophorus	*Hygrocybevirginea*(Wulfen) P.D.Orton& Watling (1969)	On poorly drained soil, sometimes withing sphagnum, in coniferous, and mixed forests,

		in pastures, and meadows. Edible.
Larch Waxy Cap	*Hygrophorusspeciosus*Peck, (1878)	Associates with larch trees in humid, coniferous forests. Found in peat bogs, and in sphagnum. Edible.
Dark Honey Fungus	*Armillariaostoyae*(Romagnesi) Herink (1973)	In dense bunches on tree stumps, roots, or dead trunks in deciduous or coniferous forests. Edible.
Grayling or the Humpback	*Cantharellulaumbonata*(J.F.Gmel.) Singer (1936)	On mossy forest floors, in meadows, or groves of coniferous or mixed forests. Edible, tasty.
Club Foot	Clitocybeclavipes (Pers.) P.Kumm. (1871)	Mostly in coniferous, but sometimes in deciduous forests. Edible, but mediocre. Not to mix with alcohol.
Funnel Clytocybe	*Clytocybegibba*(Pers.) P. Kumm. (1871)	On dead leaves, in deciduous or mixed forests. Edible, tasty.
Anis-scented Clitocybe	*Clitocybeodora*(Bull.) P.Kumm. (1871)	On leaf litter in deciduous or mixed forests. Edible, and aromatic.
False Chanterelle	*Hygrophoropsisaurantiaca*(Wulfen) Maire ex Martin-Sans (1921)	In little groups on the group or on rotten wood in mixed or coniferous forests. Edible, tasty.
Pungent Cystoderma	*Cystodermaamianthinum* var. rugosoreticulatum(F.Lorinser) Bon (1999)	On forest floor covered with moss, and conifer needles. Edible, but not recommended.
Bicolored Laccaria	*Laccariabicolor*(Maire) P.D.Orton (1960)	On the floor, or within moss under conifers, especially pine. Edible.
Iris-scented Lepista	*Lepistairina*(Fr.) H.E.Bigelow (1959)	In deciduous, mixed, or coniferous forests, within herbs on open ground. Edible, may cause gastrointestinal problems.
Fetid Tricholoma or booted knight	*Tricholomafocale*(Fr.) Ricken (1914)	In coniferous forests, as well as deciduous, and mixed. Edible, but not great.
Canary Trich or Yellow Knight	*Tricholomaequestre*(L.) P.Kumm. (1871)	In coniferous or mixed forests, often under pine trees. Edible, but eat in small quantity
Shingled Trich	*Tricholomaimbricatum* (Fr.) P.Kumm. (1871)	In bunches, within coniferous, or mixed forests, especially near jackpine. Edible, but eat in small quantities.
Sticky GrayTrich or Coalman	*Tricholomaportentosum*(Fr.) Quél. (1873)	In coniferous forests, but sometimes under beech trees. Edible, tasty.
Soapy Trich	*Tricholomasaponaceum*(Fr.) P.Kumm. (1871)	In coniferous forests, often under spruce, but also in deciduous or mixed forests. Edible, but not recommended.
Brownish-yellow Tricholoma	*Tricholomatransmutans* (Peck) Sacc. (1887)	In coniferous, or mixed forests, often under birch trees, or growing alongside moss. Edible, but mediocre.
Fibril Trich	*Tricholomavirgatum*(Fr.) P.Kumm. (1871)	In coniferous, or mixed forests, often growing alongside moss. Edible (mediocre)
Russet-scaly Trich	*Tricholomavaccinum* (Schaeff.) P.Kumm. (1871)	In coniferous or mixed forests. Edible, but mediocre.
Oak-loving Collybia	*Gymnopusdryophilus*(Bull.) Murrill (1916)	On humus in deciduous, mixed, coniferous forests, especially near oak trees. Edible.
Lawn Mower's Mushrooms	*Panaeolusfoenisecii* (Pers.) J.Schröt. (1926)	On lawns, and in prairies. Edible, but contains low amounts of psilocybin.
(3) Group of toxic mushrooms		
Eastern American Jack O'Lantern	*Omphalotusilludens*(Schwein.) Bresinsky&Besl	In bunches on trunks, or roots of oak trees. Extremely toxic.
Red-brown TrichorTacked Knight	*Tricholomapessundatum*(Fr.) Quél. (1872)	In coniferous forests. Not edible, toxic.
Red-gilled Cort or Surprise Webcap	*Cortinariussemisanguineus* (Fr.) Gillet (1876)	In coniferous, mixed, or oak forests. Not edible, dangerous.
Poison Pie	*Hebelomacrustuliniforme* (Bull. ex	In deciduous, or coniferous forests. Also on

	St.Amans.) Quél.	lawns, and other open areas. Toxic.
Straw-coloredFiber Head or Split Fibrecap	*Inocyberimosa* (Bull.) P.Kumm. (1871)	In deciduous, mixed, or coniferous forests. Toxic.
White Fiber Head	*Inocybegeophylla* (Bull.) P. Kumm. (1871)	On the ground in deciduous, mixed, or coniferous forests. Toxic.
MarginateGalerina	*Galerinamarginata* (Batsch) Kühner (1935)	In bunches on trunk of rotten deciduous, and coniferous trees.Toxic, DEADLY.
Laughing Mushroom or Yellow Gymnopilus	*Gymnopilusluteus*(Peck) Hesler (1969)	In dense bunches, on trunk and logs of dead deciduous, and coniferous trees. Not edible, contains hallucinegonic toxins.
Shaggy-stalked Lepiota	*Lepiotaclypeolaria* (Bull.) P.Kumm. (1871)	In coniferous or mixed forests. Toxic.
Rosy Entoloma or Wood Pinkgill	*Entolomarhodopolium*(Fr.) P. Kumm. (1871)	On forest floors. Toxic.
Lead Poisoner or Livid Pinkgill	*Entolomasinuatum*(Bull.) P. Kumm. (1871)	On forest floors. Highly Toxic.
Destroying Angel	*Amanita virosa*Bertill. (1866)	In mixed forests, especially under birch. Toxic, Deadly.
Poison Paxillus	*Paxillusinvolutus* (Batsch) Fr. (1838)	On forest floors of coniferous, mixed or deciduous forests. Toxic.
Common Scleroderma or common earthball	*Scleroderma citrinum*Pers. (1801)	Near stumps, rotten wood, in forests or open grounds. Not edible, toxic.
(4) Group of unknown edibility mushrooms		
OcellateCollybia	*Clitocybula oculus* (Peck) Singer (1962)	On trunks, and logs of dead deciduous trees, often covering large surfaces. Unknown.
Smeared Cort	*Cortinariustrivialis* J.E. Lange (1940)	In deciduous, coniferous, or mixed forests. Unknown.
Variable Cort	*Cortinariusmultiformis*Fr. (1838)	In mixed, or coniferous forests. Unknown.
PungeantCort or Gassy Webcap	*Cortinariustraganus*(Fr.) Fr. (1838)	In mixed, or coniferous forests. Unknown.
Violet Cort or Violet Webcap	*Cortinariusviolaceus*(L.) Gray (1821)	In mixed, or coniferous forests, often near birch trees. Unknown.
Maple Agrocybe	*Agrocybeacericola* (Peck) Singer (1950)	On wood chips, and rotten wood of deciduous trees. Unknown.
Lemon-yellow Pholiota	*Pholiotalimonella* (Peck) Sacc. (1887)	In bunches on rotten wood and wounds of deciduous trees. Unknown.
Dark-centeredLactarius or Eye Spot Milky	*Lactariusoculatus* (Peck) Burl. (1907)	In small bunches on humid soils, along moss in coniferous or mixed forests. Unknown.
Common Lactarius or Tacked Milkcap	*Lactariustrivialis*(Fr.), Fr. (1838)	In coniferous forests. Unknown.

4.Mushroom antimicrobial and prebiotic attributes

No doubt that edible mushrooms can be considered an important source for healthy food forthe next-generation. These edible mushrooms have a great nutritional value due to their rich in ash (7-17%), dietary fiber (16–20%), proteins (30-48%), fat (1–4%), carbohydrate (12.5– 40%), minerals, and vitamins like B_1, B_2, B_{12}, C, D, and E (Raman et al. 2021; Bhambri et al. 2022), as well as other bioactive components including alkaloids, lactones, polyphenolic compounds, polysaccharides, sesquiterpenes, sterols, and terpenoids (El-Ramady et al. 2022b). These bioactive ingredients are considered health-promoting supplements when extracted from edible mushrooms and appliedto human foods. Several human diseases have been treated using edible mushroom extracts due to their biological impacts particularly antidiabetic, anticancer, hepatoprotective, antiviral, antioxidant, immune-potentiating, and hypo-cholesterol impacts (Chugh et al. 2022). The health benefits of some common mushrooms were listed in **Figure (5).** Mushroom protein can be considered a novel protein alternative (Ayimbila and Keawsompong 2023).Concerning the prebiotic properties of mushrooms, they exhibited distinguished influence as prebiotic properties due to their high content of many prebiotic components (e.g., chitin, hemicellulose, β and α-glucans, mannans, xylans, galactans, and inulin) as reported by many studies (e.g., Jayachandran et al. 2017; Moumita and Das 2022; Zhang et al. 2022). The prebiotic action of mushrooms may express as a stimulator of the growth of gut microbiota, conferring health benefits to the host.

Horse Mushroom
Agaricusarvensis L. (Schaeff.) 1774
Uses: cancer, cardiovascular disease, immune diseases, lower back pain

Champignon, Button Mushroom, Portobello
Agaricusbisporus L. (J.E.Lange) Imbach (1946)
Cancer, antioxidant, antimicrobial, cognitive function, cardiovascular disease, age, gut health

Field Mushroom
Agaricuscampestris L.
Diabetes, cancer, antimicrobial, antioxidant, lung cancer, fatigue

Almond Mushroom
*Agaricussubrufescens*L. Peck (1893)
Cancer, allergies, diabetes, dermatitis, hepatitis, infections, tumors, inflammation, high cholesterol

Jelly Ear Fungus
Auriculariaauricula-judae(Bull.) Quél. (1886)
Inflammation, sore throat, fever, healthy blood, antioxidant,tumor, anticoagulant

Turkey Tail
Coriolus versicolor L. (Quél.) (1886)
Immune System, cancer, diabetes

Enokitake, Enoki
Flammulinavelutipes(Curtis) Singer (1951)
Cancer, immune system, antimicrobial, antioxidant, neurodegenerative diseases, high cholesterol, inflammation, aging

Birch Polypore
Fomitopsisbetulina(Bull.)B.K.Cui et al. (2016)
Antibiotic, purgative, inflammation, viruses, styptic, antiseptic, cancer, HIV

Agarikon
Fomitopsisofficinalis(Vill.) (1941)
Pulmonary diseases, rheumatism, asthma, viruses, antibacterial, tuberculosis

Red-Banded Polypore
Fomitopsispinicola(Sw.) P.Karst. (1881)
Headaches, laxative, inflammation, antimicrobial, styptic

Reishi
Ganodermalucidum (Curtis) P.Karst. (1881)
Inflammation, cancer, respiratory issues, asthma, insomnia, arthritis, allergies

Maitake,Hen of the woods
Grifolafrondosa(Dicks.) Gray (1821)
Cancer, diabetes, tumors

Lion's Mane
Hericiumerinaceus(Bull.) Persoon (1797)
Memory, cognitive health, strength, vigor digestion, inflammation,Alzheimer's, anxiety

Chicken of the Woods
Laetiporussulphureus
Cancer, hypoglycemia, inflammation, antioxidant, antimicrobial, high cholesterol, anticoagulant

Devil's Tooth
*Hydnellumpeckii*Banker (1912)
Anticoagulant, Antibacterial

Chaga
Inonotuus obliquus (Ach. ex Pers.) Pilát (1942)
Cancer, tumors, wounds, swelling, diabetes, antioxidant, antimicrobial,HIV, Hepatitis C

Shiitake
Lentinula edodes(Berk.) Pegler (1976)
High cholesterol, antimicrobial, tumor, immune system, cancer

Tiger's Milk
Lignosus rhinoceros(Cooke) Ryvarden (1972)
Neurodegenerativediseases, fever, Itching, asthma, Cancer

Chinese Caterpillar Fungus
Ophiocordycepssinensis(Berk.) (2007)
General health, endurance, stamina, immune issues, fatigue, Progesterone, kidney function

Bitter Oyster Mushroom
Panellusstipticus (Bull.) P.Karst. (1879)
Hemorrhaging

Black Hoof Mushroom
Phellinus linteus(Berk. MACurtis) Teng (1963)
Cancer, menstruation& gastrointestinal issues, antioxidant, diabetes, antimicrobial, viruses, Inflammation,Myocardial ischemia reperfusion

Oyster Mushroom
Pleurotusostreatus(Jacq.) P. Kumm. 1871
Diabetes, hyperlipidemia, cancer, infections, high cholesterol, fungal diseases, tumors, antioxidant, anti-aging

Horn of Plenty
Pleurotuscornucopiae (Paulet) Rolland (1910)
High Blood Pressure

Kingtuber mushroom
Pleurotus tuber-regium (Rumph. ex Fr.) Singer 1951
Cold, fever

Abalone
Pleurotuscystidiosus O.K. Mill. (1969)
Diabetes

Matsutake
Tricholomamatsutake
Antimicrobial, Anti-inflammatory

Stout Camphor Fungus
Taiwanofunguscamphoratus Wu et al. (2004)
Cancer, Allergies, Fatigue,Liver Issues, Antioxidant,Diabetes, Hepatitis B

NOT available English name
*Tolypocladiuminflatum*W. Gams (1971)
Immunosuppressant, inflammation, fungal diseases, Psoriasis,Eczema, Crohn's Disease,Diabetes

Fig. 5. Some common mushrooms and their medical use https://www.gbif.org/species and photos from https://www.pexels.com/ and Wikipedia accessed on 18.04.2023.

AccordingtoBhambri et al. (2022), the suggested mechanism of such medicinal mushroomspresented as follows:

1- Anti-cancer of *Agaricus*spp. by inhibiting cell proliferation of some cancer cell lines, antioxidant activities, and anti-inflammatory due to many metabolite components such as phenolic, sterols, indole compounds and nutraceuticals (Usman et al. 2021),

2- Antitumor, antioxidative, hypolipidemic, and antibacterial effects of *Coprinus* spp. by regulating the blood glucose level, hypoglycemic and antioxidative homeostasis due to forming carbohydrates, dietary fibers, and phenolic compounds (Stilinovic et al. 2020),

3- Anti-inflammatory, antitumor activity against both ascites as well as solid tumors of ethanolic extracts, and high antioxidant activity of *Morchella* spp. by increasing the cytotoxic effect and as immune-modulator because of organic acids, free fatty acids, flavonoids, triglycerides, and sterols (Dissanayake et al. 2021),

4- Antioxidant, antihyperglycemic, antimicrobial, iron-chelation, wound healing, cytotoxicity, anti-hypoxic, anti-acid inflammatory of *Cortinarius* spp. by inhibiting protein synthesis due to presence of amino acids, and orellanine (Meena et al. 2020), and

5- Antitumor, anti-inflammation, antivirus, antidiabetic, antioxidation, anti-hypertensive, immune-enhancing, immunomodulation, hyperlipidemia and hyperglycemia by *Grifola* spp. as an immunomodulator by the action of glucans, sesquiterpenes, and glycoproteins (Su et al. 2020).

Is the world of mushroom a real treasure for the scientific research? The answer simply is yes. This can explain in only one sentence that several mushrooms have a great potential as nutritional, pharmaceutical, and medicinal impacts. Regarding the nutritional value of mushrooms, they have enough and high values of many essential nutritional compounds like fiber, protein, carbohydrates and vitamins. Concerning the pharmaceutical attributes of mushrooms, they contain several metabolite compounds that can exhibit the pharmaceutical behavior in human like antifungal, antibacterial, antiviral, and tumor attenuating. Mushrooms are promising prebiotic agents due to their stimulation of the growth of gut microbiota, which confer health benefits to the host.

5. Conclusions

It could conclude that mushrooms have a distinguished nutritional value, due to their enough and high values of many essential nutritious compounds like protein, fiber, carbohydrates and vitamins. Mushrooms also have pharmaceutical and medicinal attributes, because ofthemcontainmany metabolite compounds, which can exhibit the pharmaceutical behavior in human like antifungal, antibacterial, antiviral, and tumor attenuating. Mushrooms are promising prebiotic agents due to their stimulation of the growth of gut microbiota, which confer health benefits to the host. Therefore, it is expected that enormous of research are needed to be carried out on different edible and medical mushrooms to discover more and more benefits of this treasure.

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