Mycological Spectrum (e-ISSN:3107-6203)
https://mycologicalspectrum.org/
Published by Association of Fungal Biologists, India

Review Article

The Resource Potential of Mushrooms – A Review

Susanna Badalyan[a*], Mirco Iotti[b] and Alessandra Zambonelli[c]

[a]Laboratory of Fungal Biology and Biotechnology, Research Institute of Biology, Yerevan State University, 1 Alex Manoogian St, 0025, Yerevan, Armenia
[b]Department of Life, Health and Environmental Science, University of L'Aquila, via Vetoio, Coppito 67100, L'Aquila, Italy
[c]Department of Agricultural and Food Science and Technology, University of Bologna, Viale Fanin 44, Bologna, Italy

Corresponding Author: Susanna Badalyan: E-mail: s.badalyan@ysu.am

Abstract

Mushrooms taxonomically belong to the phyla *Basidiomycota* (class *Agaricomycetes*) and *Ascomycota* (class *Pezizomycetes*) of the subkingdom *Dikarya*. They form epigeal and hypogeal sporomata with nutritional and medicinal values. Mushrooms produce various bioactive compounds (polysaccharides, terpenoids, phenolics, polyketides, etc.) with different therapeutic effects (antimicrobial, antioxidant, antitumor, hypocholesterolemic, hypoglycemic, immunomodulatory, neuroprotective, etc.). Currently, about 200 mushroom species are cultivated biotechnologically, and about 50 species are produced commercially. Recent advances in fungal biology and biotechnology are assisting to develop mushroom-derived innovative biotech products for human and animal use. The mushroom growing industry has decreased the costs and increased the availability of mushroom-derived biotech products (MDBP), making them accessible as healthy food obtained from both wild and cultivated samples, as well as mycelial biomass. *Agaricomycetes* species, such as *Coriolus* (= *Trametes*) *versicolor*, *Ganoderma lucidum*, *Grifola frondosa*, *Hericium erinaceus*, and *Lentinula edodes* have been reported as prebiotics that regulate human gut microbiota. Mushroom supplementation of various food products, such as dairy beverages, yogurts, bread, pasta, and beer, significantly enhances their quality and culinary value. Truffles (*Tuber* spp.) and morels (*Morchella* spp.) are considered as highly priced gourmet foods with medicinal effects. Further studies in fungal biology, biotechnology, myco-pharmacology, genomics, metabolomics, and proteomics will contribute to the application of mushrooms in nanobiotechnology and nanomedicine, as well as food safety with positive environmental impacts and human welfare.

Keywords: Biomedicine, Biotechnology, Biotech products, Healthy food, Mushrooms

Citation: Badalyan S, Iotti M, and Zambonelli A.(2026). The Resource Potential of Mushrooms – A Review. *Mycological Spectrum 2(1), 1-17.*

Received: 05 October 2025 | **Accepted**: 17 November 2025 | **Published**: 01January 2026.

Handling Editor: Dr. Shilpa A. Verekar | **Reviewers**: Prof. N.S. Atri and Dr. Sunil K. Deshmukh.

1. Introduction

Basidiomycetes (class *Agaricomycetes*) and *Ascomycetes* (class *Pezizomycetes*) fungi of the subkingdom *Dikarya* develop epigeal and hypogeal sporomata (mushrooms). From an estimated 1.5 to 3.0 million fungal species, approximately 150,000 comprise mushroom-forming fungi. About 50% (80,486 species) belong to class *Agaricomycetes* and 1.8% to *Pezizomycetes*, with over 40% of the taxa being unknown (Hawskworth, 2012; Tedersoo *et. al*., 2014). Within 1.5 million fungal species, about 15,000 species are taxonomically known mushrooms, of which about 7000 are edible, and more than 2000 are considered entirely safe, at least 170 are poisonous to deadly toxic, about 700 possess medicinal properties with 130 described pharmacological effects (Kües & Badalyan, 2017; Badalyan & Zambonelli, 2019, 2023).

Mushrooms are producers of different bioactive compounds (polysaccharides, terpenoids, phenolics, polyketides, alkaloids, lectins, proteins, steroids, etc.) with potential pharmacological effects (antitumor, anti-inflammatory, antioxidant, anti-proliferative, antiviral, hypocholesterolaemic, hypoglycaemic, hypotensive, immunomodulatory, neuroprotective, wound healing, etc.) (Badalyan, 2012; Badalyan & Gharibyan, 2016, 2020; Badalyan & Rapior, 2021; Badalyan & Zambonelli, 2023; Badalyan *et al*., 2021, 2022, 2023; Jayasuriya *et al*., 2017; Lee *et al*., 2020; Peng *et al*., 2015; Saltarelli *et al*., 2015) (Table 1). They have been used for medicinal purposes since ancient times. Among *Agaricomycetes* fungi, polyporoid *Ganoderma* mushrooms (order *Polyporales*, family *Ganodermataceae*), such as *G. lucidum, G. resinaceum,* and *G. adspersum* produce the highest diversity of pharmacologically active molecules (Peng *et al*., 2015; Saltarelli *et al*., 2015; Kües & Badalyan, 2017) (Fig. 1). However, diverse medicinal properties were also reported in edible agaricoid *Pleurotus* species (oyster mushrooms) (*P. cornucopiae*, *P. djamor*, *P. eryngii*, and *P. ostreatus*). They are producers of statins with significant hypoglycaemic and hypocholesterolaemic effects, as well as other bioactive molecules (MDBM) (Jayasuriya *et al*., 2017; Finimundy *et al.*, 2018).

Highly prized hypogeal edible *Pezizomycetes* mushrooms belonging to the genera *Tuber* (the true truffles), *Terfezia* and *Tirmania* (the desert truffles), as well as the epigeal *Morchella* (true morels) genus are biotechnologically cultivated and have economic impact due to their unique gastronomic and medicinal properties (Badalyan & Zambonelli, 2019, 2023).

The pathways and genes responsible for MDBM (terpenoids, phenolics, polysaccharides, polyketides, cyclic peptides, aegerolysins, lectins, ribosome-inactivating proteins, etc.) biosynthesis in edible and medicinal mushrooms are largely understudied. These genes and gene clusters are found in only a restricted number of fungal taxa and species (Kües & Badalyan, 2017). Meanwhile, wild and cultivable, edible and medicinal mushrooms may be considered valuable resources to develop innovative healthcare biotech products, such as pharmaceuticals, nutraceuticals and cosmeceuticals (Chang & Buswell, 1996; Iotti *et al*., 2012; Wu *et al*., 2016; Dissanayake *et al*., 2018; Raethong *et al*., 2020; Rahi *et al*., 2021; Badalyan & Zambonelli, 2019, 2023; Badalyan *et al*., 2023; Łysakowska *et al*., 2023). Advances in fungal biology and introduction of new biotechnological cultivation techniques of selected taxonomic and ecological groups of edible and medicinal mushrooms will further assist in the production of MDBP for human welfare. Biotechnological exploitation of edible and medicinal mushrooms is also directed at environmentally friendly bioprocessing of agro-industrial wastes (Barua *et al*., 2024).

In this review, advancements and new perspectives in mushroom research for their biotechnological cultivation and exploitation are discussed.

2. Progress in Biotechnological Cultivation of Edible and Medicinal Mushrooms

Currently, more than 2780 listed mushroom species are consumed as food or have medicinal properties. However, only about 2000 could be considered as safe, and only a few dozen are commercially cultivated (Li *et al*., 2021). Among cultivated species, the most popular edible species are *Agaricus bisporus, Flammulina velutipes* and *L. edodes,* as well as *Auricularia*, *Volvariella*, and *Pleurotus* species (Royse *et al*., 2017). The number of species specifically cultivated in Asian countries for their medicinal value is limited and includes *Ganoderma* spp. and *Cordyceps* spp. (Badalyan & Zambonelli, 2019, 2023; Badalyan & Rapior, 2021; Badalyan *et al*., 2023; Raethong *et al*., 2020).

The commercially cultivated mushrooms are mainly saprobic. Their cultivation is achieved by inoculating mycelium in an appropriate substrate, choosing the correct combination of humidity and temperature. The cultivation of edible ectomycorrhizal mushrooms (EEM) with high economic interest (*Boletus edulis*, *Cantharellus cibarius, Lactarius deliciosus,* and *Tuber* spp.) (Zambonelli *et al*., 2021) is more complicated since these species need mutualistic interaction with the roots of a host plant to complete the life cycle. Edible mushrooms are regarded as sources of low-fat, healthy food due to their high-quality protein and essential amino acids, dietary fibre, vitamins, minerals, and unique aroma (Badalyan, 2012; Badalyan & Zambonelli, 2019, 2023). Mycoprotein is also a good solution to animal health and welfare (Badalyan & Zambonelli, 2023).

Several edible species (*A. bisporus*, *L. edodes*, *L. deliciosus*, and *Morchella* spp.) contain bioactive molecules possessing medicinal and cosmetic values (anticancer, antimicrobial, anti-aging, antioxidant, immunomodulatory, hypolipidaemic, etc.) (Wu *et al*., 2016; González *et al*., 2020; Badalyan *et al*., 2023). Although truffles (*Tuber* spp.) have proven to have nutritional and medicinal properties, their consumption is limited due to high price (Iotti *et al*., 2012). The most valuable are the Italian white truffles (*Tuber magnatum*), the Périgord black truffle (*Tuber melanosporum*), the bianchetto truffle (*Tuber borchii*), and the Burgundy truffle (*Tuber aestivum*) (Fig. 1). Among these species, *T. magnatum* is the most expensive (4000 and 6000 €/kg in Italy) due to its unique taste and flavor, the limited geographical distribution, and cultivation difficulties (Bach *et al*., 2021).

The first attempts to cultivate mushrooms date back to the 600 AD when wood-ear *Auricularia* species cultivation was reported in China. Wood was the first substrate used for the cultivation of *L. edodes* and *Auricularia* spp. The soil saprobe species *A. bisporus* was the first mushroom cultivated in compost in France, which marks the beginning era of biotechnological cultivation of mushrooms in 1894. Modern cultivation of EEM species started in the 1960s with the production of the first truffle plants in a greenhouse by using spore and, recently, mycelial inocula (Badalyan & Zambonelli, 2023). Further development of cultivation methods and breeding technologies has enhanced mushroom productivity over the past 50 years (Sánchez, 2004). The multiple health and nutritional benefits of mushrooms have led to a 21-fold increase in their per capita consumption.

In 2025, the global mushroom cultivation market is USD 11.95 billion and is estimated to be USD 19.7 billion in 2034 due to the development and modernization of technologies for mycelium cultivation, as well as increased public understanding of the health benefits of mushroom and MDBP consumption (Badalyan & Zambonelli, 2019, 2023; Barua *et al*., 2024). Moreover, the necessity to find ecologically sustainable and friendly resources of new food and protein is one of the challenges faced by modern mushroom growing industry.

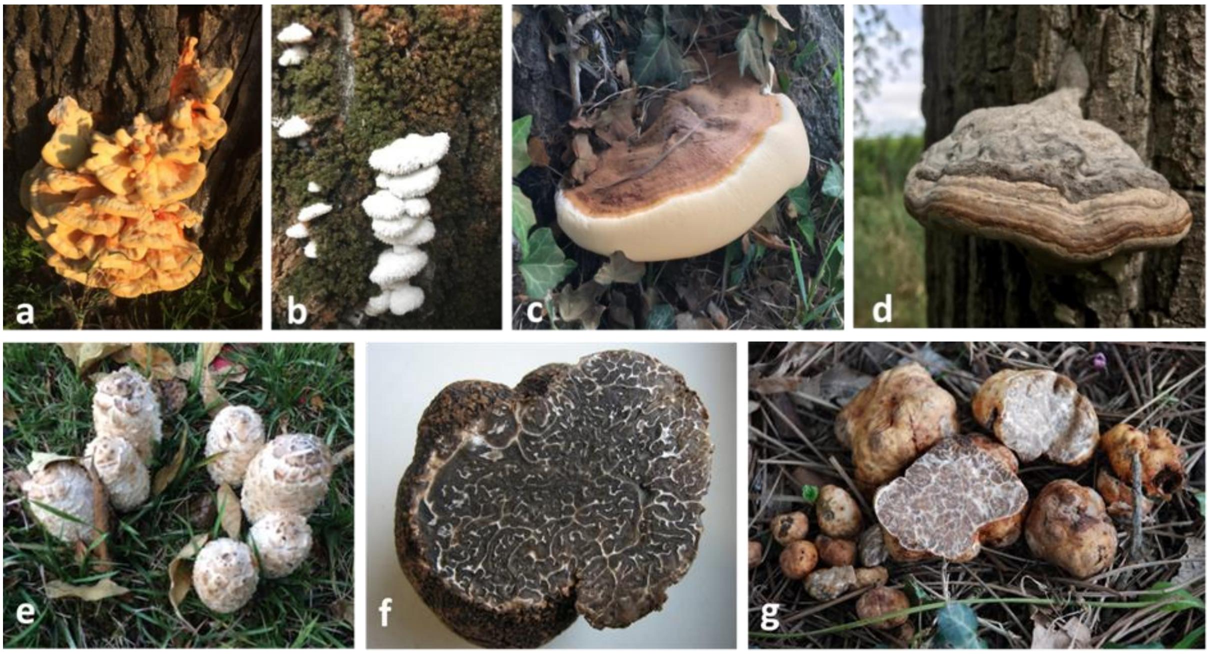

Fig. 1. Fruiting bodies of edible and medicinal agaricomycete and pezizomycete mushrooms: *Laetiporus sulphureus* (a); *Schizophyllum commune* (b); *Ganoderma resinaceum* (c); *Fomes inzengae* (d); *Coprinus comatus* (e) (photos from M. Iotti); *Tuber indicum* (f) and *T. borchii*(g) (photos from A. Zambonelli).

2.1.Cultivation of Saprobic Species

The cultivation of edible and medicinal saprobic species needs a short time, and the first production of mushrooms begins in a few weeks or, maximum several months, depending on the fungal species and the strain, the substrate, and climatic conditions. Moreover, cultivation of saprobic species could utilize different agro-wastes as substrates, contributing to economic development in rural territories (Sánchez, 2004; Royse *et al*., 2017). The characteristic of saprobic species to grow on different wastes makes them ideal candidates for developing a circular bio-economic network. In this process, the use of the digestate, the material remaining after the anaerobic digestion of a biodegradable feedstock, as a substrate for mushroom cultivation is a challenging alternative. The digestate separated mechanically into liquid or solid fractions is commonly used as a fertilizer (Lee *et al*., 2021). However, the solid fraction of digestate from agricultural feed stocks still contains recalcitrant organic compounds prevalent in the ligno-cellulosic components, which are not degraded during the anaerobic fermentation but may be an excellent carbon source for xylotrophic mushrooms. On the other hand, the liquid fraction of digestate is successfully used in spruce sawdust fermentation for the cultivation of Oyster (*Pleurotus ostreatus* and *P. eryngii*) and Reishi (*Ganoderma lucidum*) mushrooms (Brezáni *et al*., 2019).

After mushroom cultivation, the substrate is used as a fertilizer due to its nutrient content and its protective activity against soil-borne diseases. The changes in microbial composition during mycelial growth in the substrate and the subsequent abundance of beneficial microbes improve its suppressive capacity against several pathogens. Alternatively, the used substrate after lignin degradation by mycelium can be reused in plants for biogas production, for the extraction of bioactive molecules, enzymes, and chitin or feeding animals, particularly invertebrates, such as insects or earthworms (Grimm *et al*., 2021).

The new species and varieties of saprobic species are annually added to meet the increasing demand for MDBP. In recent years, the outdoor cultivation of true morels (*Morchella* spp.), particularly *M. importuna*, *M. sextelata* and *M. eximia* has been successful and expanded to a large scale. However, there are also unsuccessful cases of *Morchella* spp. cultivation for still unknown reasons. It may be due to unfavorable soil microbiota (Tan *et al*., 2021), or genetic and biological processes that remain poorly understood. These include several phases of their life cycle, such as the mechanisms of fertilization, the role of asexual mitospores (microconidia), and factors that trigger the development and morphogenesis of microsclerotia and fruiting bodies with mature meiospores. Advancement of fungal biology research is important to fill the knowledge gaps and provide innovative biotechnological progress in *Morchella* cultivation (Sambyal & Singh, 2021).

Entomopathogenic ascomycete *Cordyceps militaris* is a well-known medicinal fungus. In nature, it infects the larvae of lepidopteran hosts. Over the past decade, it has been cultivated in China using artificial nutrient media. Improving the cultivation medium will increase mushroom formation and extend the production of bioactive compounds, such as cordycepin, with significant antitumor and immunomodulatory effects (Raethong *et al*., 2020). The study of biological (morpho-ecological, physiological, and genetic) and growth characteristics of mycelia, as well as *in vitro* development of agaricomycete and pezizomycete fruiting bodies are required to establish the life cycle of these fungi during biotechnological cultivation of new species from different ecological and taxonomic groups.

Currently, about 50 mushroom species are grown commercially and about 200 species, including *G. lucidum*, *G. frondosa*, *H. erinaceus*, *F. velutipes*, *L. edodes*, *P. ostreatus* and *Termitomyces versicolor* are cultivated by submerged or static methods. Submerged mycelium cultivation is the best technique with significant industrial potential and is considered a promising and reproducible alternative to obtain mycelial biomass and sustainable MDBM for human and animal use (Elisashvili, 2012; Bakratsas *et al*., 2021). During submerged cultivation, fungal mycelium is grown in a liquid medium in flasks, fermenters or bioreactors where nutrients are dissolved, and oxygen supply is reinforced by physical (temperature, aeration, agitation, etc.) and chemical (pH, medium composition, etc.) factors to safely control the biomass quality. Currently, the mycelium cultivation industry is progressing, and the production of high-quality mycelium biomass-derived safe biotech products is improving (Bakratsas *et al*., 2021).

2.2. Cultivation of Edible Ectomycorrhizal Mushroom (EEM) Species

The EEM species are culinary valuable and widely used for their unique flavour and texture. However, the biology and the complex lifestyle of EEM create obstacles and complicate their cultivation processes, as well as extend the time of first mushroom production. Among them, *T. melanosporum* was the first species that was successfully cultivated in the early 1800s. The truffle cultivation industry has improved over the last decades due to modern technologies and methods consisting of inoculating seedlings or cuttings with truffles in greenhouses and then transplanting them into suitable sites.

Initially, three different methods of truffle inoculation were proposed: i) spore inoculum, ii) mother plant technique, and iii) mycelium inoculation. Among these, spore inoculum has become the suitable method used by all companies producing *Tuber* mycorrhized plants since it is simple and effective to apply for the most valuable truffle species (Iotti *et al*., 2012). Since the mid-nineties, morphological and molecular methods to identify ascomata and mycorrhizas have been developed (Parladé *et al*., 2016; Zambonelli *et al*., 2000). Recently, the plants obtained through mycelial inoculation yielded their first productive results (Iotti *et al.,* 2016; Parladé *et al*., 2016). Mycelium inoculation enables the selection of strains that produce ascomata with superior aroma profiles or greater adaptability to climatic conditions-traits that appear to be genetically regulated. This technique has also been applied to produce *L. deliciosus* mycorrhizal plants. Cultivation of this species was introduced first in New Zealand in the late 1990s and spread to Europe and China. The ascoma production in New Zealand has been estimated at 1–3 tons per hectare (Wang *et al*., 2021).

2.3. Mushroom-Derived Bioactive Molecules (MDBM) and Mushroom-Derived Biotech Products (MDBP)

A wide spectrum of pharmacological activity of MDBM and recent progress in fungal biology and biotechnology, genomics, proteomics, and myco-pharmacology have contributed in the development of different innovative MDBP from agaricomycete and pezizomycete mushrooms for human and animal use (Kües & Badalyan, 2017; Badalyan & Zambonelli, 2023; Barua *et al*., 2024). The pharmaceutical potential of MDBM from edible and medicinal mushrooms, such as lectins (*A. bisporus*), polysaccharides (*Auricularia auricula-judae*), glifolan (*G. frondosa*), lovastatin (*Pleurotus sajor-caju*), and cordycipin (*Ophiocordyceps sinensis*) has been assessed and several MDBP from these fungi were approved for clinical use (Dissanayake *et al*., 2018; Badalyan & Rapior, 2021; Badalyan *et al*., 2023) (Table 1).

The MDBP are a food or part of the food with nutritional and beneficial health effects and may be used is a preventive and therapeutic strategy to improve the outcome of different diseases without side-effects (Badalyan *et al*., 2023; Łysakowska *et al*., 2023). The mushroom products can be obtained from wild or cultivable fruiting bodies, mycelium biomass, cultural broth and their extracts, as well as from sclerotia and spores (Badalyan & Zambonelli, 2023; Barua *et al*., 2024).

The main groups of MDBP are nutraceuticals and nutriceuticals (dietary supplements and functional food); myco-pharmaceuticals and myco-cosmeceuticals (nutricosmetics and nutracosmetics) (Ahad *et al*., 2016; Wu *et al.,* 2016; Mayolo-Deloisa *et al*., 2020; Raman *et al.*, 2021; Barua *et al*., 2024).

Currently, several mushroom species, such as *Agaricus subrufescens*, *A. bisporus*, *Auricularia* spp., *B. edulis*, *F. velutipes*, *Ganoderma* spp., *G. frondosa*, *H. erinaceus*, *Laetiporus sulphureus*, *L. edodes*, *Morchella esculenta*, *Pleurotus* spp., *T. borchii*, *T. melanosporum*, *Phellinus linteus*, and *Volvariella volvacea* are considered rich sources of bioactive and volatile compounds with nutritional and medicinal properties to be used in the production of innovative MDBP (Badalyan & Zambonelli, 2019, 2023; Badalyan & Rapior, 2021; Badalyan *et al*., 2023; Łysakowska *et al*., 2023; Barua *et al*., 2024). Among these *B. edulis*, *Tuber* spp. and *Morchella* spp. are high-value gourmet dietary food for human well-being (Rapior *et al*., 2000).

Mushroom-derived supplementation of dairy products, yogurts, bread, pasta, beer, and beverages increases their quality, as well as dietary, culinary and medicinal values (Chang *et al.*, 1996; Finimundy *et al.*, 2018; Bakratsas *et al.*, 2021).

Enzymes derived from filamentous fungi (amylase, cellulase, xylanase, pectinase, lipase, and protease) are widely used in food production, including baking, brewing, dairy and fruit juice products, as well as in meat and fish processing industry. Edible and medicinal mushroom-derived enzymes, particularly laccases have a potential to improve the quality of food and beverages (Mayolo-Deloisa *et al.*, 2020; Sun *et al.*, 2021). Several white-rot agaricoid, polyporoid, hymenochaetoid and russoloid *Agaricomycetes* fungi are used in the production of functional food, nutraceuticals and cosmeceuticals, as well as for stabilization and delignification of feed supplies (Wu *et al.*, 2016; Rahi *et al.*, 2021). Moreover, *T. versicolor*, *G. lucidum*, *G. frondosa*, *H. erinaceus*, *Inonotus obliquus* and *L. edodes* have been reported as prebiotics due to fungal glucans regulating gut microbiota in the host (Nowak *et al.*, 2018). Cosmeceuticals are the products between cosmetics and pharmaceuticals containing bio-ingredients with anti-aging, anti-inflammatory, antioxidant and anti-UV effects. Currently, the cosmetic industry is in a constant search for anti-aging biomolecules (anti-collagenase, anti-elastase, anti-hyaluronidase, and anti-tyrosinase). Wild or cultivable edible and medicinal mushroom species (*A. subrufescens*, *A. bisporus*, *Auricularia auricula-judae*, *O. sinensis*, *Ganoderma lingzhi*, *G. lucidum*, *G. frondosa*, *Hypsizygus ulmarius*, *I. obliquus, L. edodes*, *Polyporus* spp., *Phellinus* spp., *Schizophillum commune*, *T. versicolor*, *Tremella fuciformis* and *Tuber* spp.) are producers of bioactive phenolics, glucans, polysaccharides and terpenoids which are valuable bio-ingredients in the formulation of skin and hair care organic cosmetic products (nutricosmetics and nutracosmetics).

Mushrooms and their extracts are incorporated in the formulation of several innovative cosmetic products (Wu *et al.*, 2016; Badalyan & Zambonelli, 2019; Badalyan *et al.*, 2022). Mushroom-derived nutricosmetics (creams, lotions, and ointments applied topically) and nutracosmetics (administered *per os*) are currently in high demand due to minimal safety regulation compared to traditional cosmetic products. Many companies, such as La Roche (Basel, Switzerland), Nu-Derm and SensiClear (USA) used mushrooms as natural ingredients to develop organic cosmetic products (Wu *et al.*, 2016; Badalyan *et al.*, 2022).

Edible and medicinal mushrooms, as an organic food supplement, are used in animal alimentation to prevent cancer and support immunity (Chuang *et al.*, 2020; Badalyan & Zambonelli, 2023). *Ganoderma* spp. and *Pleurotus* spp. may successfully be used in poultry diets for improving the performance of broilers. These products possess immunomodulatory, antibacterial, antiviral and anti-parasitic activities and are suggested as an alternative to antibiotics. Edible mushroom-derived dietary supplements have improved the poultry meat quality, as well (Vargas-Sánchez *et al.*, 2018).

Table 1. Bioactive compounds with medicinal and cosmetic values isolated from several edible and medicinal mushrooms.

Species	**Bioactive compound**	**Medicinal and cosmetic values**	**References**
Agaricus bisporus	Alkaloids, polysaccharides, tannins, polyphenols, proteins, caffeic,	Antimicrobial, anti-inflammatory, antioxidant,	Badalyan & Rapior (2021), Badalyan and Zambonelli (2023),

	cinnamic, ferulic, gallic, p-hydroxybenzoic, p-coumaric and protocatechuic acids	anticancer, neuroprotective	Badalyan *et al*. (2022), Wu *et al*. (2016)
Amanita muscaria	Muscimol, β-D-glucan, FMG	Neuroprotective	Badalyan & Rapior (2021), Badalyan *et al.* (2022)
Antrodia cinnamomea	Polysaccharides, terpenoids, benzenoid aromatic compound coenzyme Q_{10}	Anti-inflammatory, antibacterial, antioxidant, neuroprotective	Badalyan & Rapior (2021), Badalyan *et al.* (2022, 2023), Kües & Badalyan (2017)
Auricularia auricula-judae	Polysaccharides, proteins	Antitumor, anti-coagulant, antiviral, hypoglycemic, hypolipidemic, anti-inflammatory, cardioprotective	Badalyan (2012), Badalyan & Rapior (2021), Badalyan *et al.* (2021, 2022), Dissanayake *et al*. (2018)
Boletus badius	Polysaccharides, polyphenolics, N-ethyl-g-glutamine	Antimitotic, antitumor, immunomodulatory, antioxidant, neurotrophic	Badalyan (2012), Badalyan & Rapior (2021)
Boletus edulis	Lectin, polysaccharides, polyphenols, ergothioneine, glutathione	Antitumor, immunomodulatory, antimicrobial, antiviral, anti-inflammatory, antioxidant, mitogenic, neurotrophic, cardioprotective	Badalyan (2012), Badalyan & Rapior (2021), Badalyan *et al.* (2021, 2022)
Cantharellus cibarius	Polysaccharides, cibaric acid, phenolic compounds	Antioxidant, antimicrobial, antifungal, insecticidal, nematicidal, neuroprotective, cardioprotective	Badalyan (2012), Badalyan & Zambonelli (2023), Badalyan & Rapior (2021), Badalyan *et al*. (2021)
Coprinus comatus	Polysaccharides, alkaloids, phenolics, proteins, unsaturated fatty acids, coprinol, comatin, tocopherols (vitamin E)	Antitumor, antimicrobial, anti-inflammatory, anti-obesity, antioxidant, hypoglycemic, neuroprotective, hypocholesterolemic, cardioprotective, anti-UV	Badalyan & Rapior (2021), Badalyan *et al.* (2021, 2022), Badalyan & Zambonelli (2023)
Coprinopsis cinerea	Lagopodin, coprinastatins, coprinol, copsin, polysaccharides, lectins, galectins,	Antimicrobial, antitumor, antioxidant, fibrinolytic	Kües & Badalyan (2017), Badalyan & Zambonelli (2023)

	sesquiterpenes, peptid fungalysins, fatty acids, volatiles		
Cordyceps militaris	Cordycepin	Antitumor, anti-inflammatory, hypolipidemic, immunomodulatory, anti-pigmentation, anti-collagenase, anti-tyrosinase, anti-elastase	Raethong *et al*. (2020), Badalyan *et al*. (2022, 2023)
Fomes fomentarius	Exopolysaccharides, triterpenoids, phenolics, flavonoids, ketones, proteases	Antitumor, antimicrobial, antioxidant, anti-parasitic, antiviral, hepatoprotective, hypoglycemic, hypocholesterolemic, cardioprotective	Badalyan & Gharibyan (2016), Badalyan *et al*. (2021, 2022, 2023), Wu *et al*. (2016)
Fomes inzengae	Fatty acids, polysaccharides,	Antifungal, antibacterial	Gharibyan *et al*. (2024, 2025)
Fomitopsis officinalis	Polysaccharides, lanostane triterpenoids, officimalonic and eburicoic acids, flavonoids, coumarins, phenolics	Antioxidant, anti-inflammatory, neuroprotective, anti-epileptic, neuroregenerative, antidepressant	Badalyan & Rapior (2021), Badalyan *et al*. (2023)
Fomitopsis pinicola	Protoilludene, barbatenes, cadinenes, copaenes, sterols, polysaccharides, triterpenoids, flavonoids, proteases	Antimicrobial, cytotoxic, antitumor, anti-inflammatory, cardioprotective	Badalyan & Rapior (2021), Badalyan *et al*. (2021, 2023)
Ganoderma lucidum	Polysaccharides, triterpenes, aromatic meroterpenoids, proteins, peptides, sterols	Antioxidant, antitumor, analgesic, sedative, neuroprotective, antidepressant, antiepileptic,anti-tyrosinase, cardioprotective	Badalyan (2012), Badalyan & Zambonelli (2023), Saltarelli *et al*. (2015), Badalyan & Rapior (2021), Badalyan *et al*. (2021, 2022, 2023), Wu *et al.* (2016)
Ganoderma resinaceum	Mannogalactan and highly branched β-D-glucans	Antitumor, immunomodulatory	Saltarelli *et al*. (2015), Badalyan & Gharibyan (2016), Badalyan & Rapior (2021), Badalyan *et al*. (2023)
Grifola frondosa	Grifolan, lectin, protein-bound polysaccharide (PGM), extracellulare polysaccharides, β-glucan, gallic	Antitumor, antioxidant, anti-depressant, neuroprotective, enhance microglial amyloid-β clearance,	Badalyan & Zambonelli (2023), Badalyan & Rapior (2021), Badalyan *et al*. (2022, 2023), Dissanayake *et al*. (2018), Wu *et al*. (2016)

	and tannic acids, ergothioneine	stimulation of collagen biosynthesis, anti-melanogenesis	
Hericium erinaceus	Polysaccharides, cyathane diterpenoids, meroterpenoids, hericenones, herinase, erinacines, erinacerins, erinaceolactones, hericenones	Antioxidant, memory-enhancing, neuroprotective, neurotrophic, cardioprotective	Badalyan & Zambonelli (2023), Badalyan & Rapior (2021), Badalyan *et al*. (2021, 2023)
Inonotus obliquus	Polysaccharides, trametenolic acids, phenolics, melanin, xylogalactoglucan, terpenoids, lanostan-type triperpenoids, inotodiol, sterins, styrylpyrones, steroids, flavonoids, agaricine A	Antitumor, anti-proliferative, antioxidant, anti-inflammatory, cytotoxic, immunomodulatory, dermatoprotective, wound-healing, cardioprotective	Badalyan & Gharibyan (2020), Badalyan & Rapior (2021), Badalyan *et al*. (2023)
Lactarius deliciosus	Sesquiterpenoids, lectin, phenolics	Antibacterial, antifungal, cytotoxic, anti-inflammatory, insecticidal, nematocidal, antioxidant	Badalyan (2012), Badalyan & Zambonelli (2023), Wang *et al*. (2021)
Lactarius necator	Alkaloids necatorin andnecotoron	Antibacterial, antifungal	Badalyan (2012), Wang *et al*. (2021)
Laetiporus sulphureus	Lectin, exo- and endopolysaccharides, latiglucans, volatile compounds, fatty acids, sterols, eburicoic and laetiporic acids, phenolics	Antitumor, antifungal, antioxidant, hypoglycemic, immunomodulatory, haemolytic, antimicrobial	Badalyan & Gharibyan (2016), Sułkowska-Ziaja *et al*. (2018), Sevindik (2021)
Lentinus edodes	L-ergothioneine, flavonoids, glycosides, phenolics, proteins, tannins, ergosterol, β-glucanlentinan, eritadenine, phenolics, tocopherols	Antioxidant, anti-inflammatory, antidepressant, neuroprotective, antitumor, immunomodulatory, antimicrobial, moisturizing, anti-aging, anti-tyrosinase	Badalyan (2012), Badalyan & Zambonelli (2023), Badalyan & Rapior (2021), Badalyan *et al*. (2022, 2023), Barua *et al*. (2024), Wu *et al*. (2016)
Lignosus rhinocerotis	Glucans, proteins, proteases, phenolics	Anti-inflammatory, antioxidant, neuroprotective, neuroregenerative	Badalyan & Rapior (2021)
Lyophyllum decastes	(1-3)- and (1-6)-beta-D-glucans, phenolics	Antitumor, antibacterial, antioxidant	Badalyan (2012)

		hypocholesterolemic, hypoglycemic, hypotensive, anti-inflammatory, immunomodulatory	
Morchella esculenta	Galactomannan (a-D-glucan)	Immunomodulatory, antimicrobial	Badalyan (2012)
Ophiocordyceps sinensis	Cordymin, cordycepin, adenosine, β-(1-3)-D-glucan, ergosterol	Hypoglycemic, antitumor, anti-inflammatory, antioxidant, antimicrobial	Badalyan *et al*. (2023)
Pleurotus ostreatus	Polysaccharides, lovastatin, alkaloids, polysaccharides, phenolics, saponins, gallic and protocatechuic acids, formononetin, fatty acids, steroids, tocopherols, vitamins	Antioxidant, antimicrobial, anti-inflammatory, immunomodulatory, hypocholesterolemic, hypoglycemic, hypotensive, anti-pigmentation, cardioprotective	Brezáni *et al*. (2019), Badalyan & Zambonelli (2019), Jayasuriya *et al.* (2015), Badalyan *et al*. (2021, 2022), Finimundy *et al*. (2018), Wu *et al*. (2016)
Phellinus (=Tropicoporus) linteus	Phenolic acids, polysaccharides, hispidin, phelligridin, davallialactone, hypholomine B, interfungin A, inoscavin A, inotodiol	Antitumor, antiviral, immunosuppressive, immunomodulatory, anti-inflammatory, antibacterial, antioxidant, anti-dementia, anti-mutagenic, cytotoxic, hepatoprotective, anti-diabetes, anti-diarrhea	Badalyan & Gharibyan (2020), Badalyan & Rapior (2021), Badalyan *et al*. (2023)
Piptoporus betulinus	Piptolinic acid A	Cytotoxic	Badalyan *et al*. (2023)
Russula delica	Lectin	Anti-proliferative, antiviral	Badalyan (2012), Badalyan & Zambonelli (2019)
Schizophyllum commune	Phenolics, glucans, polysaccharide, schizophyllan, terpenoids	Antitumor, immunomodulatory, antioxidant	Kumar *et al*. (2022)
Suillus granulatus	Tetraprenylphenols	Antitumor, antioxidant	Badalyan (2012)
Suillus luteus	Phenolics, polysaccharides	Antifungal, antioxidant, immunomodulatory	Badalyan (2012)
Trametes versicolor	Polysaccharides, krestin, proteins SIRT1, musarin, phenolic acids	Antioxidant, anti-dementia, anti-inflammatory, antitumor, antiviral, antifungal, anti-proliferative, cytotoxic, antibacterial,	Badalyan & Zambonelli (2019), Badalyan & Gharibyan (2016), Badalyan & Rapior (2021), Badalyan *et al.* (2021, 2022, 2023), Wu *et al.* (2016)

		antioxidant, cardioprotective, hypocholesterolemic, hypoglycemic, hepatoprotective, anti-tyrosinase, anti-hyaluronidase	
Tremella fuciformis	Fatty acids, proteins, polysaccharides, enzymes, phenolics, flavonoids, mannose, uronic acid	Antioxidant, anti-aging, dermato-protective, neuroprotective, neurotrophic	Badalyan (2012), Badalyan & Zambonelli (2023), Badalyan & Rapior (2021), Badalyan *et al*. (2022), Wu *et al*. (2016), González *et al*. (2020)
Tricholoma matsutake	a-D-glucan	Immunomodulatory	Badalyan (2012)
Tuber aestivum	Phenolics, flavonoids, ergosteryl ester, polysaccharides, volatile compounds	Antioxidant, antimicrobial, wound-healing	Badalyan (2012), Badalyan & Zambonelli (2019, 2023), Lee *et al*. (2020), Badalyan *et al*. (2022)
Tuber borchii	Lectins cyanovirin-N (CVN) and TBF-1, polysaccharides, volatiles	Antiviral, anti-inflammatory, wound-healing	Badalyan (2012), Badalyan & Zambonelli (2019, 2023), Lee *et al*. (2020), Badalyan *et al*. (2022)
Tuber indicum	Phenolics, flavonoids, ergosterol, volatiles polysaccharides	Antioxidant, anti-inflammatory, antimicrobial, wound-healing	Badalyan (2012), Badalyan & Zambonelli (2019, 2023), Lee *et al*. (2020), Badalyan *et al*. (2022)
Tuber melanosporum	Phenolics, ergosterol, volatiles	Antioxidant, antimicrobial, neurotropic, regenerative	Badalyan (2012), Badalyan & Zambonelli (2019, 2023), Lee *et al*. (2020), Badalyan *et al*. (2022)

3. Conclusion

Edible and medicinal mushrooms belonging to classes *Agaricomycetes* (*Basidiomycota*) and *Pezizomycetes* (*Ascomycota*) are a source of multifunctional bioactive compounds with broad spectrum of nutritional, pharmacological and cosmetic values which may be used to develop innovative MDBP (pharmaceuticals, nutriceuticals, nutraceuticals and cosmeceuticals). Recent progress in fungal biology and biotechnology, myco-pharmacology, genomics, proteomics and metabolomics, as well as mushroom cultivation technologies are directed to further use of genetic resources of edible and medicinal mushrooms. The development of mushroom growing industry will have a significant impact on agriculture and environment promoting economic growth of the society and improving human welfare.

Advances in fungal genomics, metabolomics, and proteomics will contribute to the application of mushrooms in nanobiotechnology and nanomedicine. Further myco-pharmacological studies and clinical trials will expand our knowledge for sustainable manufacturing of high-quality standardized MDBP for human and animal use.

Acknowledgements

This work arises from a longtime collaboration between the authors in the fields of fungal biology and biotechnology supported by bilateral collaboration between Yerevan State University, Armenia and University of Bologna, Italy. The authors are grateful to all colleagues for their contribution in mushroom research. The work was partially supported by the Higher Education and Science Committee of Armenia (HESC).

Conflict of interest

There is no conflict of interest.

References

Ahad, S., Tanveer, S., & Malik, T. A. (2016). Anticoccidial activity of aqueous extract of a wild mushroom (*Ganoderma applanatum*) during experimentally induced coccidial infection in broiler chicken. *Journal of Parasitic Diseases, 40*(2), 408–414. https://doi.org/10.1007/s12639-014-0518-3

Bach, C., Beacco, P., Cammaletti, P., Babel-Chen, Z., Levesque, E., Todesco F., Cotton C., Bruno Robin B., & Murat M. (2021). First production of Italian white truffle (*Tuber magnatum* Pico) ascocarps in an orchard outside its natural range distribution in France. *Mycorrhiza, 31*(3), 383–388. https://doi.org/10.1007/s00572-020-01013-2

Badalyan, S. M. (2012). Medicinal aspects of edible ectomycorrhizal mushrooms. In: A. Zambonelli & G. Bonito (Eds.), *Edible Ectomycorrhizal Mushrooms: Current Knowledge and Future Prospects.* Vol. 34, (pp. 317–334). Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-642-33823-6_18

Badalyan, S. M., & Gharibyan, N. G. (2016). Diversity of polypore bracket mushrooms, Polyporales (*Agaricomycetes*) recorded in Armenia and their medicinal properties. *International Journal of Medicinal Mushrooms, 18*(4), 347–354. https://doi.org/10.1615/IntJMedMushrooms.v18.i4.80

Badalyan, S. M., & Gharibyan, N. G. (2020). Pharmacological properties and resource value of hymenochaetoid fungi (*Agaricomycetes*) distributed in Armenia: Review. *International Journal of Medicinal Mushrooms, 22*(12), 1135–1146. https://doi.org/10.1615/IntJMedMushrooms.2020037092

Badalyan, S. M., & Rapior, S. (2021). The neuroprotective potential of macrofungi. In: D. C. Agrawal & M. Dhanasekaran (Eds.), *Medicinal Herbs and Fungi: Neurotoxicity vs. Neuroprotection.* (pp. 37–77). Springer Nature, Singapore. https://doi.org/10.1007/978-981-33-4141-8_2

Badalyan, S. M., & Zambonelli, A. (2019). Biotechnological exploitation of macrofungi for the production of food, pharmaceuticals, and cosmeceuticals. In: K. R. Sridhar & S. K. Deshmukh (Eds.), *Advances in Macrofungi: Diversity, Ecology and Biotechnology.* (pp. 199–230). CRC Press, Boca Raton. https://doi.org/10.1201/9780429504075.

Badalyan, S. M., & Zambonelli, A. (2023). The potential of mushrooms to develop healthy food and biotech products. In T. Satyanarayana & S. K. Deshmukh (Eds.), *Fungi and Fungal Products in Human Welfare and Biotechnology*. (pp. 307–344). Springer Nature, Singapore. https://doi.org/10.1007/978-981-19-8853-0_11

Badalyan, S. M., Barkhudaryan, A., & Rapior, S. (2021). The cardioprotective properties of Agaricomycetes mushrooms growing in the territory of Armenia (Review). *International Journal of Medicinal Mushrooms, 23* (2), 21–31. https://doi.org/10.1615/IntJMedMushrooms.2021038280

Badalyan, S.M., Barkhudaryan, A., & Rapior, S. (2022). Medicinal macrofungi as cosmeceuticals: A review. *International Journal of Medicinal Mushrooms, 24*(4), 1–13. https://doi.org/10.1615/IntJMedMushrooms.2022043124

Badalyan, S. M., Morel, S., Barkhudaryan, A., & Rapior, S. (2023). Mushrooms as promising therapeutic resources: Review and future perspectives. In: D. C. Agrawal & M. Dhanasekaran (Eds.), *Mushrooms with Therapeutic Potentials: Recent Advances in Research and Development*. (pp. 1–54). Springer Nature, Singapore, https://doi.org/10.1007/978-981-19-9550-7_1

Bakratsas, G., Polydera, A., Katapodis, P., & Stamatis, H. (2021). Recent trends in submerged cultivation of mushrooms and their application as a source of nutraceuticals and food additives. *Future Foods, 4*, 100086. https://doi.org/10.1016/j.fufo.2021.100086

Barua, R. C., Coniglio, R. O., Molina, M. A., Díaz, G. V., & Fonseca, M. I. (2024). Fungi as biotechnological allies: exploring contributions of edible and medicinal mushrooms. *Journal of Food Science, 89,* 6888–6915. https://doi.org/10.1111/1750-3841.17390

Brezáni, A., Svobodova, K., Jablonský, I., & Tlustoš, P. (2019). Cultivation of medicinal mushrooms on spruce sawdust fermented with a liquid digestate from biogas stations. *International Journal of Medicinal Mushrooms, 21*(3), 215–223. https://doi.org10.1615/IntJMedMushrooms.2019030022

Chang, S.T., & Buswell, J. A. (1996). Mushroom nutriceuticals. *World Journal of Microbiology and Biotechnology, 12*(5), 473–476. https://doi.org/10.1007/BF00419460

Chuang, W. Y., Hsieh, Y. C., & Lee, T. T. (2020). The effects of fungal feed additives in animals: A review. *Animals, 10*(5), 805. https://doi.org/10.3390/ani10050805

Dissanayake, A.A., Zhang, C.R., Mills, G.L., & Nair, M.G. (2018). Cultivated Maitake mushroom demonstrated functional food quality as determined by in vitro bioassays. *Journal of Functional Foods, 44*, 79–85. https://doi.org/10.1016/j.jff.2018.02.031

Elisashvili, V. (2012). Submerged cultivation of medicinal mushrooms: Bioprocesses and products (review). *International Journal of Medicinal Mushrooms, 14*(3), 211–239. https://doi.org/10.1615/IntJMedMushr.v14.i3.10

Finimundy, T.C., Barros, L., Calhelha, R.C., Alves, M J., Prieto, M. A., Abreu, R. M. V., Dillon, A. J. P., Henriques, J. A. P., Roesch-Ely, M., & Ferreira, I. C. F. R. (2018). Multifunctions of *Pleurotus sajor-caju* (Fr.) Singer: A highly nutritious food and a source for bioactive compounds. *Food Chemistry, 245*, 150–158. https://doi.org/10.1016/j.foodchem.2017.10.088

Gharibyan, N. G., Barkhudaryan, A. L., & Badalyan, S. M. (2025). Study of antibacterial activity of mycelia bracket fungi *Fomes fomentarius s.s.* and *F. inzengae* (*Polyporales*, *Agaricomycetes*). In: Advances in Medical Mycology, Ed. Sergeev YV. Proceed. International Mycological Forum. Moscow, Russia, National Academy of Mycology. Moscow, Russia. *27*(9): 318–322. https://doi.org/10.14427/amm.2025.xxvii.01

Gharibyan, N. G., Gasparyan, A. K., & Badalyan, S. M. (2024). Study of antifungal activity of mycelia of Armenian collections of polypore mushroom *Fomes inzengae* (*Agaricomycetes*) toward dermatophytes. In: Advances in Medical Mycology. Ed. Sergeev YV. Proceed. International Mycological Forum, Moscow, Russia, National Academy of Mycology. *26*(1), 20–22. https://doi.org/10.14427/amm.2024.xxvi.01

González, A., Cruz, M., Losoya, C., Nobre, C., Loredo, A., Rodríguez R., Contrerasa J., & Belmares R. (2020). Edible mushrooms as a novel protein source for functional foods. *Food & Function, 11*(9), 7400–7414. https://doi.org/10.1039/D0FO01746A

Grimm, D., Kuenz, A., & Rahmann, G. (2021). Integration of mushroom production into circular food chains. *Organic Agriculture, 11*(2), 309–317. https://doi.org/10.1007/s13165-020-00318-y

Hawskworth, D. L. (2012). Global species numbers of fungi: are tropical studies and molecular approaches contributing to a more robust estimate? *Biodiversity and Conservation.21*, 2425–2433. https://doi.org/10.1007/s10531-012-0335-x

Iotti, M., Piattoni, F., & Zambonelli, A. (2012). Techniques for host plant inoculation with truffles and other edible ectomycorrhizal mushrooms. In: A. Zambonelli & G. M. Bonito (eds.), *Edible Ectomycorrhizal Mushrooms: Current Knowledge and Future Prospects*. Vol. 34. (pp. 145–161). Springer. Berlin, Heidelberg. https://doi.org/10.1007/978-3-642-33823-6_9

Iotti, M., Piattoni, F., Leonardi, P., Hall I. R., & Zambonelli, A. (2016). First evidence for truffle production from plants inoculated with mycelial pure cultures. *Mycorrhiza*, *26*, 793–798 https://doi.org/10.1007/s00572-016-0703-6

Jayasuriya, W. B., Wanigatunge, C. A., Fernando, G. H., Abeytunga, D. T., & Suresh, T. S. (2015). Hypoglycaemic activity of culinary *Pleurotus ostreatus* and *P. cystidiosus* mushrooms in healthy volunteers and type 2 diabetic patients on diet control and the possible mechanisms of action. *Phytotherapy Research, 29*(2), 303–309. https://doi.org/10.1002/ptr.5255

Kües, U., & Badalyan, S.M. (2017). Making use of genomic information to explore the biotechnological potential of medicinal mushrooms. In: Agrawal, D. C., Tsay, H. S., Shyur, L. F., Wu, Y. C. & Wang, S. Y. (Eds.). *Medicinal Plants and Fungi: Recent Advances in Research and Development.* (pp. 397–458). Springer Nature, Singapore. https://doi.org/10.1007/978-981-10-5978-0_13

Kumar, A., Bharti, A. K., & Bezie, Y. (2022). *Schizophyllum commune*: a fungal cell-factory for production of valuable metabolites and enzymes. *BioResources 17*(3), 5420–5436. https://doi.org/10.15376/biores.17.3.Kumar

Lee, H., Nam, K., Zahra, Z., & Farooqi, M. Q. U. (2020). Potentials of truffles in nutritional and medicinal applications: A review. *Fungal Biology and Biotechnology, 7*, 9. https://doi.org/10.1186/s40694-020-00097-x

Lee, M. E., Steiman, M. W., & Angelo, S. K. (2021). Biogas digestate as a renewable fertilizer: Effects of digestate application on crop growth and nutrient composition. *Renewable Agriculture and Food Systems, 36*(2), 173–181. https://doi.org/10.1017/S1742170520000186

Li, H., Tian, Y, Menolli Jr N., Ye, L., Karunarathna, C. S., Perez-Moreno, J., Rahman, M. M., Rashid, M. H., Phengsintham, P., Rizal, L., Kasuya, T., Lim Y. W., Dutta, A. K., Khalid, A. N., Huyen, L. T., Balolong, M. P., Baruah, G., Madawala, S., Thongklang, N., Hyde, K. D., Kirk, P. M., Xu, J., Sheng, J., Boa, E., & Mortimer, P. E. (2021). Reviewing the world's edible mushroom species: A new evidence-based classification system. *Comprehensive Reviews in Food Science and Food Safety, 20*(2), 1982-2014. https://doi.org/10.1111/1541-4337.12708

Łysakowska, P., Sobota, A., & Wirkijowska, A. (2023). Medicinal mushrooms: Their bioactive components, nutritional value and application in functional food production — A review. *Molecules, 28*(14), 5393. https://doi.org/10.3390/molecules28145393

Mayolo-Deloisa, K., González-González, M., & Rito-Palomares, M. (2020). Laccases in food industry: Bioprocessing, potential industrial and biotechnological applications. *Frontiers in Bioengineering and Biotechnology, 8*, 222. https://doi.org/10.3389/fbioe.2020.00222

Nowak, R., Nowacka-Jechalke, N., Juda, M., & Malm, A. (2018). The preliminary study of prebiotic potential of Polish wild mushroom polysaccharides: The stimulation effect on *Lactobacillus* strains growth. *European Journal of Nutrition, 57*(4), 1511–1521. https://doi.org/10.1007/S00394-017-1436-9

Parladé, J., De la Varga, H., & Pera, J. (2016). Tools to trace truffles in soil. In: A. Zambonelli, M. Iotti, & C. Murat (Eds.). *True Truffle (Tuber* spp.*) in the World, Soil Biology 47.* (pp. 249–266). Springer International Publishing, Cham, Switzerland. https://doi.org/10.1007/978-3-319-31436-5_15

Peng, X. R., Liu, J. Q., Xia, J. J, Wang, C. F., Li, X. Y., Deng Y. Y., Bao N. M., Zhang Z. R., & Qiu M. H. (2015). Lanostane triterpenoids from *Ganoderma hainanense* J. D. Zhao. *Phytochemistry, 114*, 137–145.https://doi.org/10.1016/j.phytochem.2014.10.009.

Raethong, N., Wang, H., Nielsen, J., & Vongsangnak, W. (2020). Optimizing cultivation of *Cordyceps militaris* for fast growth and cordycepin overproduction using rational design of synthetic media. *Computational and Structural Biotechnology Journal, 18*, 1–8. https://doi.org/10.1016/j.csbj.2019.11.003

Rahi, D. K., Rahi, S., & Chaudhary, E. (2021). White-rot fungi in food and pharmaceutical industries. In: K. R. Sridhar & S. K. Deshmukh (eds.), *Advances in Macrofungi: Industrial Avenues and Prospects.* (pp. 175–206). CRC Press, Boca Raton. https://doi.org/10.1201/9781003191278-14

Raman, J., Jang, K.Y., Hyun-Jae, S., Kong, W. S., & Lakshmanan, H. (2021). Industrial and biotechnological applications of *Pleurotus.* In: K. R. Sridhar & S. K. Deshmukh (Eds.), *Advances in Macrofungi: Industrial Avenues and Prospects*. (pp. 89–107). CRC Press, Boca Raton. https://doi.org/10.1201/9781003096818-9

Rapior, S., Mauruc, M. J., Guinberteau, J., Masson, C. L., & Bessière, J. M. (2000). The volatile composition of *Gyrophragmium dunalii*. *Mycologia*, *92*(6), 1043–1046. https://doi.org/10.2307/3761469

Royse, D. J., Baars, J., & Tan, Q. (2017). Current overview of mushroom production in the world. In: C. Z. Diego & A. J. Pardo-Giménez (Eds.). *Edible and Medicinal Mushrooms: Technology and Applications.* (pp. 5–13). Wiley-Blackwell, Oxford. https://doi.org/10.1002/9781119149446.ch1

Saltarelli, R., Ceccaroli, P., Buffalini, M., Vallorani, L., Casadei, L., Zambonelli, A., Iotti, M., Badalyan, S. & Stocchi, V. (2015). Biochemical characterization, antioxidant and antiproliferative activities of different *Ganoderma* collections. *Journal of Molecular Microbiology and Biotechnology, 25*(1), 16–25. https://doi.org/10.1159/000369212

Sambyal, K., & Singh, R. V. (2021). A comprehensive review on *Morchella importuna*: Cultivation aspects, phytochemistry, and other significant applications. *Folia Microbiologica, 66* (2), 147–157.https://doi.org/10.1007/s12223-020-00849-7

Sánchez, C. (2004). Modern aspects of mushroom culture technology. *Applied Microbiology and Biotechnology, 64* (6), 756–762. https://doi.org/10.1007/s00253-004-1569-7

Sevindik, M. (2021). Biological activities of *Laetiporus* species as a functional food. *Journal of Mycology & Mycological Sciences, 4*(1), 1–5. https://doi.org/10.23880/oajmms-16000138.

Sułkowska-Ziaja, K., Muszyńska, B., Gawalska, A., & Sałaciak, K. (2018) *Laetiporussulphureus*– chemical composition and medicinal value. *Acta Sci. Pol. HortorumCultus, 17*(1), 89–98. https://doi.org/10.24326/asphc.2018.1.8

Sun, K., Li, S., Si, Y., & Huang, Q. (2021). Advances in laccase triggered anabolism for biotechnology applications. *Critical Reviews in Biotechnology, 41*(7), 969–993. https://doi.org/10.1080/07388551.2021.1895053

Tan, H., Liu, T., Yu, Y., Tang, J., Jiang, L., Martin, F. M, & Peng, W. (2021). Morel production related to soil microbial diversity and evenness. *Microbiology Spectrum, 9*(2), e00229-21. https://doi.org/10.1128/Spectrum.00229-21

Tedersoo, L., Bahram, M., Põlme, S., Kõljalg, U., & et. al. (2014). Global diversity and geography of soil fungi. *Science, 346*, 1256688. https://doi.org/10.1126/science.1256688

Vargas-Sánchez, R. D., Torrescano-Urrutia, G. R., Ibarra-Arias, F. J., Portillo-Loera, J. J., Ríos-Rincón, F. G., & A. Sánchez-Escalante. (2018). Effect of dietary supplementation with *Pleurotus ostreatus* on growth performance and meat quality of Japanese quail. *Livestock Science, 207*, 117–125. https://doi.org/10.1016/j.livsci.2017.11.015

Wang, D., Zhang, J. L., Wang, Y., Zambonelli, A., Hall, I. R., & Xiong, W. P. (2021). The cultivation of *Lactarius* with edible mushrooms. *Italian Journal of Mycology, 50*, 63–77. https://doi.org/10.6092/issn.2531-7342/12908

Wu, Y., Choi, M. H., Li, J., Yang, H., & Shin, H. J. (2016). Mushroom cosmetics: The present and future. *Cosmetics, 3*(3), 22. https://doi.org/10.3390/cosmetics3030022

Zambonelli, A., Iotti, M., Puliga, F., & Hall, I. R. (2021). Enhancing white truffle (*Tuber magnatum* Picco and *T. borchii* Vittad.) cultivation through biotechnology innovation. In: J. M. Al-Khayri, S. M. Jain, & D. V. Johnson (Eds.). *Advances in Plant Breeding Strategies: Vegetable Crops*. (pp. 505–532). Springer, Cham. https.//doi.org/10.1007/978-3-030-66969-0_14

Zambonelli, A., Rivetti, C., Percudani, R., & Ottonello, S. (2000). TuberKey: A DELTA-based tool for the description and interactive identification of truffles. *Mycotaxon, 74*(1), 57–76.