NEWSLETTER OF THE INTERNATIONAL SOCIETY FOR MEDICINAL MUSHROOMS

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News Reports

How the Lowly Mushroom is Becoming a Nutritional Star

By Robert Beelman

Mushrooms are often considered only for their culinary use because they are packed with flavor-enhancers and have gourmet appeal. That is probably why they are the second most popular pizza topping, next to pepperoni.

In the past, food scientists like me often praised mushrooms as healthy because of what they don't contribute to the diet; they contain no cholesterol and gluten and are low in fat, sugars, sodium and calories. But that was selling mushrooms short. They are very healthy foods and could have medicinal properties, because they are good sources of protein, B-vitamins, fiber, immune-enhancing sugars found in the cell walls called beta-glucans, and other bioactive compounds.

Mushrooms have been used as food and sometimes as medicine for centuries. In the past, most of the medicinal use of mushrooms was in Asian cultures, while most Americans have been skeptical of this concept. However, due to changing consumer attitudes rejecting the pharmaceutical approach as the only answer to healing, that seems to be changing.

I study the nutritional value of fungi and mushrooms, and my laboratory has conducted a great deal of research on the lowly mushroom. We have discovered that mushrooms may be even better for health than previously known. They can be excellent sources of four key dietary micronutrients that are all known to be important to healthy aging. We are even looking into whether some of these could be important in preventing Parkinson's disease and Alzheimer's disease.

Four key nutrients

Important nutrients in mushrooms include selenium, vitamin D, glutathione and ergothioneine. All are known to function as antioxidants that can mitigate oxidative stress and all are known to decline during aging. Oxidative stress is considered the main culprit in causing the diseases of aging such as cancer, heart disease and dementia.

Ergothioneine, or ergo, is actually an antioxidant amino acid that was initially discovered in 1909 in ergot fungi. Amino acids are the building blocks of proteins.

Ergo is produced in nature primarily by fungi, including mushrooms. Humans cannot make it, so it must be obtained from dietary sources. There was little scientific interest in ergo until 2005, when pharmacology professor Dirk Grundemann discovered that all mammals make a genetically coded transporter that rapidly pulls ergo into the red blood cells. They then distribute ergo around the body, where it accumulates in tissues that are under the most oxidative stress. That discovery led to a significant increase in scientific inquiry about possible role of ergo in human health. One study led to a leading American scientist, Dr. Solomon Snyder, recommending that ergo be considered as a new vitamin.

The downside of a mushroom. The upside is that it may contain an amino acid that does a lot of important work in your body. basel101658/Shutterstock.com

In 2006, a graduate student of mine, Joy Dubost, and I discovered that edible cultivated mushrooms were extremely rich sources of ergo and contained at least 10 times the level in any other food source. Through collaboration with John Ritchie and post-doctoral scientist Michael Kalaras at the Hershey Medical Center at Penn State, we showed that mushrooms are also a leading dietary source of the master antioxidant in all living organisms, glutathione. No other food even comes close to mushrooms as a source of both of these antioxidants.

I eat mushrooms, ergo I am healthy?

A salad with egg, greens and mushrooms. The author is studying whether mushrooms can prevent neurodegenerative brain diseases. Ekaterina Kondratova/Shutterstock.com

Our current research is centered on evaluating the potential of ergo in mushrooms to prevent or treat neurodegenerative diseases of aging, such as Parkinson’s and Alzheimer’s. We based this focus on several intriguing studies conducted with aging Asian populations. One study conducted in Singapore showed that as people aged the ergo content in their blood declined significantly, which correlated with increasing cognitive impairment.

The authors suggested that a dietary deficiency of ergo might predispose individuals to neurological diseases. A recent epidemiological study conducted with over 13,000 elderly people in Japan showed that those who ate more mushrooms had less incidence of dementia. The role of ergo consumed with the mushrooms was not evaluated but the Japanese are known to be avid consumers of mushrooms that contain high amounts of ergo.

More ergo, better health?

One important question that has always begged an answer is how much ergo is consumed in the diet by humans. A 2016 study was conducted that attempted to estimate the average ergo consumption in five different countries. I used their data to calculate the estimated amount of ergo consumed per day by an average 150-pound person and found that it ranged from 1.1 in the U.S. to 4.6 milligrams per day in Italy.

We were then able to compare estimated ergo consumption against mortality rate data from each country caused by the common neurological diseases, including Alzheimer's, dementia, Parkinson's disease and multiple sclerosis. We found, in each case, a decline in the death rates with increasing estimated ergo consumption. Of course, one cannot assume a cause and effect relationship from such an exercise, but it does support our hypothesis that it may be possible to decrease the incidence of neurological diseases by increasing mushroom consumption.

If you don't eat mushrooms, how do you get your ergo? Apparently, ergo gets into the food chain other than by mushroom consumption via fungi in the soil. The fungi pass ergo on to plants grown in the soil and then on to animals that consume the plants. So that depends on healthy fungal populations in agricultural soils.

This led us to consider whether ergo levels in the American diet may be harmed by modern agricultural practices that might reduce fungal populations in soils. We began a collaboration with scientists at the Rodale Institute, who are leaders in the study of regenerative organic agricultural methods, to examine this. Preliminary experiments with oats have shown that farming practices that do not require tilling resulted in significantly higher ergo levels in the oats than with conventional practices, where tillage of the soil disrupts fungal populations.

In 1928 Alexander Fleming accidentally discovered penicillin produced from a fungal contaminant in a petri dish. This discovery was pivotal to the start of a revolution in medicine that saved countless lives from bacterial infections. Perhaps fungi will be key to a more subtle, but no less important, revolution through ergo produced by mushrooms. Perhaps then we can fulfill the admonition of Hippocrates to "let food be thy medicine."

Source: https://theconversation.com/

Some Mushrooms Glow in the Dark – here's why

By Mike Hale

Glowing fungi with an on-off system synchronised to their daily rhythms? It sounds implausible but it's true.

Some mushrooms evolved the ability to glow in the dark in order to attract insects to spread their spores, according to new research in the journal Current Biology.

Fungi are peculiar beings at the best of times. Once believed to be closely related to plants, they are now understood to be more closely related to animals.

Mushrooms, or fungal fruit bodies – the bit you see above ground – may be familiar to us all as food but in the real world mushroom-forming fungi only produce these fruit bodies under special conditions. The main body of the fungus exists largely out of sight as a colony of white thread-like hyphae growing through a food source such as a piece of wood or leaf litter.

In some instances fungal colonies can be old and very large. A colony of Armillaria solidipes in the US is estimated to cover 9.6km2 and be thousands of years old.

Fungal fan Mike Hale inspects some Armillaria. Mike Hale, Author provided

Fruit bodies and sexual progeny

Fruit bodies are produced to disperse their sexual progeny as spores. Many fungi shoot spores into the air from the underside of the mushrooms, relying on moving air currents to passively distribute the spores over a wide area.

If the fungus is several metres up the trunk of a tree, this method is ideal. But wind speed is often either minimal or non-existent on the underside of logs or at the ground level in a dense forest or even underground, where truffles are produced.

So if air movement isn't effective how can spores be dispersed far and wide? One option is through aroma. Truffles, the fruiting body of the Ascomycete fungi, use their smell to attract fungivores such as pigs or squirrels who eat them and leave spores behind in their waste. Stinkhorn mushrooms have a foul-smelling slime which attracts flies and other insects. The flies eat the slime and unwittingly spread the spores elsewhere.

Luminosity

Light is also attractive to many insects. Indeed a number of fungi bioluminesce, emitting a pale green light. One of the first mycology texts I read as a teenager devoted a whole chapter to "luminosity", mentioning various fungi including some honey fungi (Armillaria), Jack O'lantern (Omphalotus olearius, pictured at the top of this article) and a number of Mycena.

Mycena chlorophos – a fungus found in subtropical Asia.
lalalfdfa, CC BY-NC-SA

In the new study, a team of Brazilian and American researchers looked at the pale green light emission from fungi, to assess whether it attracted insects and whether brighter light conferred a selective advantage for spore dispersal.

The researchers looked at Neonothopanus gardneri, a particularly intense emitter found at the base of coconut palms in Brazil. It was previously thought their light was emitted continuously as a byproduct of some other round-the-clock metabolic process.

However, the study found the fungus glows only at night, and so is energy efficient; during daytime the light emission would be too faint to be visible. In any case, the best conditions for spore germination in canopy forests are found at night, when it is more humid. If the mushrooms glow only at night then the bioluminescence must serve some purpose.

The beetles will never figure this one out.
Oliviera et al

Camera observations showed the glowing fruit bodies became infested by rove beetles. But these beetles may have been attracted by something else – smell, perhaps.

To specifically test the glowing effect, experimental "mushrooms" made from clear acrylic resin were built. They were equipped with a light emitting diode which operated at a similar wavelength to the mushrooms. To the beetles, the light would have looked the same.

The glowing plastic mushrooms attracted these and various other insects sensitive to green light, while fewer were attracted to non-illuminated controls. From this we can conclude that for these fungi there is a selective advantage to glowing in the dark.

Up-coming Events

2023 International Shiitake Industry Innovation Expo First Round Notice

The 2023 International Shiitake Industry Innovation Expo will be held on June 10-11, 2023 at Zibo Convention and Exhibition Center in Shandong, China. The theme of the conference will be "Opening the era of Shiitake globalization". During the event, professional exhibition, main conference, visit and business negotiation will be organized, representatives from Southeast Asia, Japan, Korea, Europe (Germany, Poland, Netherlands, Belgium, Italy, France), the United States and Canada and other major exporting countries and regions of Chinese edible mushrooms will be invited to participate in this event, to gather wisdom and strength to promote the high-quality development of Shiitake industry.

CONFERENCE DATES

June 10-11, 2023

CONFERENCE VENUE

Zibo Convention and Exhibition Center AB Hall

Address: No. 310, Lian Tong Road, Zhang Dian District, Zibo City, Shandong Province, China

THEME OF THE CONFERENCE

Opening the era of Shiitake globalization

CONFERENCE ORGANIZATION

China Chamber of Commerce for Import and Export of Foodstuffs, Native Produce and Animal By-Products
International Joint Research Center for the Creation of New Germplasm Resources of Edible Mushrooms
Shanghai Academy of Agricultural Sciences
Shandong Academy of Agricultural Sciences
Mycological Society of China

MAIN CONTENTS OF THE CONFERENCE:

Part I: The 1st International Shiitake Mushroom Industry Conference

Domestic and foreign academic experts and related teams will be invited to make macro policy analysis, share the current situation, latest progress and main cultivation technology of shiitake mushroom breeding at home and abroad, and the topics of how to integrate shiitake mushroom industry with food will be discussed.

Part II: "The Belt and Road" Shiitake Industry Going Out Strategy Seminar

The event will focus on the macro policies and preferential measures for going out on "The Belt and Road", barriers to export of mushroom products, Shiitake strains, production technology, production equipment, talents and capital in mushroom industry. And how to realize the strategic layout of going out on "The Belt and Road", and the opportunities and challenges for mushroom industry to go out will be discussed.

Part III: How to realize the integration of domestic and foreign trade, dual circulation of domestic and international markets, and the layout of offline and online channels in the Shiitake industry

The edible mushroom industry colleagues will be invited to brainstorm on how to realize the integration of domestic and foreign trade, dual circulation of domestic and international markets, and the layout of offline and online channels in the Shiitake industry, and collide with new sparks.

Part IV: Industry Observation

The whole industry chain of shiitake mushroom will be observed.

Part IV: Professional Exhibition

Exhibition date: June 10-11, 2023

Venue: Zibo Convention and Exhibition Center Hall B, Shandong, China. (Address: No. 310 Lian Tong Road, Zhang Dian District, Zibo City, Shandong Province, China)

Comprehensive exhibition area of globalization of mushroom industry

1. "The Belt and Road, One Mushroom" going out strategy (strain, technology, equipment, talent, capital, catering culture export)
2. The new transnational business model of the edible fungus Industry going out
3. International trade and bidirectional investment promotion of edible fungi
4. Integration and integration of domestic and foreign trade, domestic and international double cycle, online and offline omni-channel layout

Exhibition Area for Industrial Innovation in the Integration of plants, animals, and fungi

1. Rural revitalization cities, counties and districts, national edible mushroom production areas and industrial bases, local business associations, and agricultural product foreign trade transformation and upgrading bases
2. Edible mushroom cultivation and production (traditional agricultural cultivation, facility cultivation, and factory cultivation)
3. Simple processing of edible mushrooms (clean vegetables, dried products, frozen products, freeze-dried products, semi-finished products, vegetarian products, etc.)
4. Edible mushroom big food (beverages, snack foods, pre-made dishes, soup seasonings, seasonings, canned food, hot pot seasoning, etc.)
5. Big health food (health food ingredients, health food)
6. Distribution channels for edible mushrooms (new retail channels such as agricultural wholesale channels,

supermarket convenience stores, chain catering, traditional e-commerce, community group buying, social e-commerce, live streaming sales, etc.)

Exhibition area for innovative and intelligent production of edible mushrooms

1. Edible mushroom strains and scientific research
2. Edible mushroom production and processing process design
3. Edible mushroom raw and auxiliary materials
4. Special equipment for edible mushroom (mixing, bottling and bagging, sterilization, inoculation, scratching, up and down rack, transmission, testing, etc.)
5. Edible mushroom production auxiliary materials (raw and auxiliary materials, mushroom frames, bottle and basket covers, bags, netting, ozone, special high-temperature wheels, trays, etc.)
6. Environmental simulation equipment (library board, refrigeration, purification, heat preservation, humidification, dehumidification, lamps, control system, winter heating equipment, etc.)
7. Packaging equipment (packaging machines, packaging materials, sealing equipment, etc.)
8. Modern food processing equipment (shredding and slicing, vacuum pre-cooling, liquid nitrogen quick-freezing, traditional quick-freezing, hot air drying, room temperature drying, freeze-drying, vacuum low-temperature frying, canning equipment, etc.)

Zibo special agricultural products exhibition area

1. Innovation and Integration of Agricultural Tourism in Zibo
2. Zibo agricultural products exhibition and sale

Booth price

1. 9 square meters (3 meters x 3 meters) standard booth: 7,000 RMB/booth, double-sided open booth plus 10% opening fee. The standard exhibition includes one table and two chairs, two spotlights, booth lintel, 220v power supply interface (non-powerful power supply).

2. Raw space booth (not including construction): 700 RMB/square meter.

CONFERENCE REGISTRATION:

No conference fee will be charged for this conference, round-trip transportation, accommodation and food expenses should be paid by yourself. Please register online: https://ty.myhuiyi.com/Pre-registration/67/qaa_en.html?ly=&qd=.

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<u>20th ISMS Congress & 26 th NAMC</u>

Abstract submissions and Delegate Registrations Now Open

20th International Congress on the Science and Cultivation of Edible and Medicinal Mushrooms

26–29th February 2024, JW Marriot Las Vegas Resort & Spa in Las Vegas, Nevada, USA

The 20th ISMS International Congress on the Science and Cultivation of Edible and Medicinal Mushrooms (ISMSC) will be a face-to-face live event held in conjunction with the 26th North American Mushroom Conference (NAMC) in Las Vegas, USA in February 2024.

The Congress will involve concurrent sessions of live oral presentations (12 min presentation with 3 mins for questions), dedicated poster sessions, as well as invited keynote presentations (25min presentation with 5 mins for questions) over a two-day period on the 26th and 27th of the joint event.

REGISTRATION INFORMATION

Conference registration entitles delegates to attend all four days of the combined NAMC and ISMSC event. The registration fee covers the book of abstracts, all scheduled meals, access to the Expo floor, and official receptions. All authors that have had their abstract submissions accepted will need to have paid their registration fee for the event by 15 December to have their abstracts published in the Congress Book of Abstracts.

PRICING

ISMS Member pricing (select member price on the registration page):

- Early bird (17/03/23 to 31/07/23) $895
- General (from 01/08/23 – 30/12/23) $995
- Late booking (from 31/12/23 – 24/02/24) $1095

Standard (non-member) Registration Fees

- Early bird (17/03/23 to 31/07/23) $1395
- General (from 01/08/23 – 30/12/23) $1495
- Late booking (from 31/12/23 – 24/02/24) $1595

As an additional incentive for ISMS members, those who are students, research institutions scientists or university personnel can also use a special promotional code to receive a further $100 discount. This code will be emailed to ISMS members in a separate email in the near future.

Note - ISMS membership is free. Visit the ISMS website membership page to become a member.

For more information and to register for the Congress, visit https://mushroomconference.org/.

ACCOMMODATION

JW Marriot Las Vegas Resort & Spa, Address: 221 North Rampart, Boulevard, Las Vegas

The cost per night is US189/night plus tax. The hotel has limited availability of double occupancy rooms so early bookings are encouraged. For more information and to book your room, click here (https://mushroomconference.org/plan-your-trip/). There are many alternative accommodation options near the conference venue but delegates will need to research and organise these themselves.

SPONSORSHIP / EXHIBITION INQUIRIES

For sponsorship and expo inquiries contact the American Mushroom Institute at info@mushroomconference.org.

PREPARATION OF ABSTRACTS

The abstract submission platform is now open and will remain open to authors until 30 September.

Abstracts can be submitted on any research related to mushrooms or the mushroom industry. The Scientific Committee will allocate submissions on similar areas of research into topic groups that will enable concurrent sessions and poster areas to function effectively at the 20th Congress.

Please note the the abstract and presentation timeline has changed slightly. Information on the preparation of abstracts, how to submit, and the new timeline, is provided here (https://isms.biz/Web/ContentAreas/Events/2024-Congress%20author%20information.aspx).

First Circular of the 12th International Medicinal Mushrooms Conference (IMMC12)

We are pleased to announce the 12th International Medicinal Mushrooms Conference. We invite scientists, students, mycologists, medical doctors, immunologists, contagious disease specialists, naturopaths, biochemists, and all those who are interested in studying and discussing the most current research on medicinal mushrooms and their properties.

BARI, AN UNEXPECTED MEETING POINT BETWEEN EAST AND WEST

Bari is a very charming city, the third-largest city in Southern Italy, in order of the population.

It's incredible the contrast between the folkloristic old town and the cozy city center, full of branded shops and polished aristocratic buildings. Bari is highly multifaceted city, and you really need to discover every single aspect to understand its true core. Known as the "Gateway to the East" due to its long tradition of trade, this capital of Apulia is rich in history: see with your own eyes in the town of Bari Vecchia and surrounding area.

Exploring the historic centre allows us to discover its most authentic character, with signs of its past scattered through the local alleyways and endless examples of age-old traditions passed from generation to generation. Then there is the famous Bari promenade, one of the most beautiful in Italy, overlooking the clear sea and the unique charm of Bari.

Today, this dynamic city, nestled in the heart of the countryside punctuated by white dry-stone walls, is an important university hub.

But it still holds dear the memory of its seafaring exploits of the Middle Ages, as well as its precious monuments and striking churches.

The history of Bari is fascinating and turbulent. The ancient settlement dates back to the Bronze Age, passing from rule by the Peucetians to the Goths, before being fought over by the Byzantines and Lombards. Repeatedly ransacked and destroyed, medieval Bari was conquered by the Saracens and became a small independent Muslim state. It was then taken over by the Franks, before returning to the hands of the Romans, who made it the major Italian political, military and commercial centre of the Eastern Roman Empire. In 1087, with the arrival of the relics of

St Nicholas of Myra, commonly known as Santa Clause, Bari became a thriving religious centre uniting the East and West.

Norman rule in Apulia ensured a long period of prosperity for Bari, though it was still subject to conflict. Rebuilt by the Swabians, it experienced a new peak of splendour, until it declined again under the Angevins, torn apart by struggles between local squires and foreign bankers.

After going to the Aragonese and then the Dukes of Milan in 1464, it was restored to its former glory by Isabella of Aragon in 1500. In 1558, it fell into Spanish hands, experiencing numerous bloody rebellions, and in 1657 it was hit hard by plague. It then passed from Austrian to Bourbon rule, being renewed under French rule in the early 1800s with the construction of the new city.

After being returned to the Bourbons in 1815, it joined the Kingdom of Italy in 1860. This tumultuous history of dominations has left Bari with a unique artistic heritage for all to admire.

Bari is not only art, history, and ancient culture. In fact, a great social life awaits you.

WARNINGS

Bari is a relatively safe city for foreigners. Even though there are some areas to avoid (the main ones are the Libertà, Japigia, San Paolo, and Madonnelle neighborhoods), tourists should not face safety problems other than petty crime, the kind of crime you find in many cities. Use common sense and apply all usual safety precautions.

AVERAGES FOR BARI IN SEPTEMBER

This month is known as a warm month. The average maximum daytime temperature in Bari in September lies at 26.2°C (79.16°F). The average minimum temperature goes down to around 17.1°C (62.78°F) (often the minimum temperature is noted at night). Rainfall during September is moderate with an average of 66mm (2.6 inches). There are generally around 8 rainy days.

DATE AND VENUE

The conference will take place in Bari, Italy, 24-27 September 2024 at the **The Nicolaus Hotel Bari - HO Collection**. The conference will be organized in parallel sessions and poster exhibitions. The official language of the conference is English.

THEME OF THE CONFERENCE:

MEDICINAL MUSHROOMS: THE BET FOR THE FUTURE OF HUMANITY

ORGANIZED BY:

University of Bari, Department of Soil, Plant, and Food Sciences (Di.S.S.P.A.) Italian Society for Medicinal Mushrooms (SIFM)

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- Secretariat: Dr. Gaetano Balenzano, Dr Raimondo Pardi, Dr Anna Scaringella
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SCIENTIFIC PROGRAM OF CONFERENCE WILL INCLUDE:

- Keynote speeches
- Plenary lectures of invited speakers

Different symposia dedicated to:

- Biodiversity, taxonomy and ecology of medicinal mushrooms;
- Medicinal mushrooms culture collections, cultivation technology and circular economy;
- Biochemistry, biotechnology and pharmacology of medicinal mushrooms;
- Use of medicinal mushrooms in animal husbandry and veterinary medicine;
- Medicinal mushrooms in human pre-clinical and clinical studies;
- Legislation, certification and safety of mushroom-based supplements;
- Medicinal mushrooms as a source of novel functional food and health benefits; Ethnomycology and the therapeutic potential of psychedelic mushrooms

CALL FOR PAPERS

We would be pleased to receive contributions from interested authors that follow the conference themes. Abstracts should focus on current issues relevant to progress in research and/or to industry and should be scientific and/or of technical content.

Your abstracts should clearly define the objectives of the presentation or the topics covered, key conclusions reached, and potential benefits for scientific developments and industry. Abstracts should not be more than 500 words but not less than 300.

Abstracts should be sent to IMMC12 (abstract@immc12.com) before the 15th of February 2024. Text documents must be in Word or PDF format and written according to the template included in the conference web site.

IMPORTANT DATES AND DEADLINES

February 2023	Opening of the conference website
30 April 2023	Distribution of first circular
30 May 2023	Opening of registration
15 February 2024	Distribution of second circular
30 May 2024	Abstract submission deadline
15 June 2024	Notification to authors of abstract acceptance
30 June 2024	Early bird registration deadline

15 July 2024	Full paper submission deadline
31 July 2024	Closing date for registrations and accommodation
23 August 2024	Distribution of final scientific program
23 September 2024	Registration desk opens
24-27 September 2024	IMMC12-2024

For more information visit www.immc12.com

IMMC12 International Medicinal Mushrooms Conference

SPONSORSHIP OPPORTUNITIES AND EXHIBITION TABLE REQUEST FORM

There are a number of sponsorship opportunities for this IMMC9 conference, where scientists from all over the world will meet in an atmosphere of excellence to discuss the most recent advances in medicinal mushroom researches.

Name of Organization / Country / Company	
Primary Contact Person: *Name*: *Mobile phone*: *E-mail*:	
Secondary Contact Person: *Name*: *Mobile phon*	
I need an Exhibit Table:	☐ YES ☐ NO
I would like to contribute as:	☐ Platinum Sponsor ☐ Gold Sponsor ☐ Silver Sponsor ☐ Bronze Sponsor ☐ Patron Sponsor ☐ Other

PLATINUM (€ 30,000)

- Three complimentary conference registrations for the entire three days
- VIP seating at all conference keynote plenary sessions
- Most prominently displayed name on banner and sponsorship boards at all functions
- Company logo and web link on IMMC9 conference website
- Full page color ad in Conference Program and Exhibitor Guide
- Sponsorship acknowledgment in all conference printed materials
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- Exhibit table

GOLD (€ 15,000)

- Two complimentary conference registration for the entire three days
- VIP seating at all conference keynote plenary sessions
- Very prominently displayed name on banner and sponsorship boards at all functions Company logo and web

link on conference website

- ½ page color ad in Conference Program and Exhibitor Guide
- Sponsorship acknowledgment in all conference printed materials
- Company promotional literature included in registration packet
- Exhibit table

SILVER (€ 10,000)

- One complimentary conference registration for the entire three days
- VIP seating at one of the conference's keynote plenary sessions
- Prominently displayed name on banner and sponsorship boards at all functions
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- Sponsorship acknowledgment in Conference Program and all conference printed materials
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- Exhibit table

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- Company logo on conference website
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- Exhibit table

PATRON (€ 1,000)

- Name displayed on banner and sponsorship boards at all functions
- Sponsorship acknowledgment in Conference Program and all conference printed materials

Additional Sponsorship Opportunities

Listed below are the other unique sponsorship opportunities including conference events, meals, interest sessions, and some specialty items. We are also happy to explore customizing a sponsorship that meets your budget and program requirements, and compliments theconference.

Welcome Reception Sponsor	**€ 3,000**
Congress Dinner	**€ 15,000**
Conference Welcome Bag Sponsor	**€ 7,500**
Lunch Sponsor (one day)	**€ 7,500**
Coffee break standard Sponsor	**€ 2,500**
Coffee break superior Sponsor	**€ 3,500**
Scholarship Sponsor (multiple available)	**€ 1,000 each**

For more information on sponsorships, please contact secretary@immc12.com

We would like to extend our deep appreciation to all our partners and sponsors who will help make the IMMC12 Conference possible.

FULL PAPERS

Excellent papers of the IMMC12 will be published in the International Journal of Medicinal Mushrooms (IJMM). Please send the full paper according to journal format of the IJMM before **15 July 2024** if the IMMC12 secretary informs you of your abstract acceptance.

If you have any academic question, please send e-mail to secretary@immc12.com

Registration form is available starting **30 of May 2023** on the conference website www.immc12.com

Please print your registration form and send it to secretary@immc12.com

E-Poster

IN SUBSTITUTION OF THE TRADITIONAL POSTER SESSION (NOR PAPER POSTER NEITHER MOUNTING AREA WILL BE PROVIDED BY THE IMMC12 ORGANIZATION), IMMC12 ORGANIZE THE ELECTRONIC POSTER SESSION, OR E-POSTER SESSION.

GUIDELINES FOR PRESENTERS

ARE AVAILABLE AT HTTPS://WWW.IMMC12.COM/POSTER.HTML

PAYMENT INFORMATION

Payment can be made only by bank transfer

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BENEFICIARY	Comitato Organizzatore Convegno IMMC12-2024 Bari
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Research progress

Potentiation of Antitumor Activity by Antibody Drugs and Mushroom-Derived β-Glucans in Natural Killer Cell-Mediated Tumoricidal Activities against Non-Hodgkin's B-Cell Lymphoma

Yoshiyuki Adachi, Fumiyasu Momose, Hiromi Momose, Rui Tada, Naohito Ohno

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Abstract: β-glucans are polysaccharides that activate innate immunity. We herein investigated whether P-glucans promote the immunological effects of antibody drugs against malignant tumor cells using human peripheral blood mononuclear cells (PBMCs). Rituximab bound to CD20-specific lymphoma and exhibited cytotoxic activity in the presence of human mononuclear cells, but not neutrophils. The addition of *Sparassis crispa* (cauliflower mushroom)-derived β-glucan (SCG) and granulocyte macrophage colony-stimulating factor (GM-CSF) to co-cultures of PBMCs and Raji lymphoma cells further promoted antibody-dependent cell-mediated cytotoxicity (ADCC). The GM-CSF treatment increased β-glucan receptor expression on adherent cells in PBMCs. A co-stimulation with GM-CSF and SCG of PBMCs induced an increase in the number of spreading cells and the activation of natural killer (NK) cells. The enhancement in ADCC was abolished by the removal of NK cells, indicating that SCG and GM-CSF increased ADCC against lymphoma by activating β-glucan receptor-expressing cells in PBMCs and enhancing NK cell activity. The synergistic mechanisms of action of mushroom-derived β-glucans and biopharmaceuticals, including recombinant cytokines and antibodies, in the treatment of malignant tumor cells provide important insights into the clinical efficacy of β-glucans from mushrooms.

Keywords: (1-3)-B-D-glucan, antibody-dependent cellular cytotoxicity, granulocyte-macrophage colony-stimulating factor, natural killer cell, medicinal mushrooms

Volume 25, Issue 3, 2023, pp. 1-19；DOI: 10.1615/IntJMedMushrooms.2022047219

Study of anti-fatigue activity of polysaccharide from fruiting bodies of *Armillaria gallica*

Huihui Sun, Fang Shu, Yue Guan, Fange Kong, Shuyan Liu, Yang Liu, Lanzhou Li

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Abstract: Fatigue is a common physiological response that is closely related to energy metabolism. Polysaccharides, as excellent dietary supplements, have been proven to have a variety of pharmacological activities. In this study, A 23.007 kDa polysaccharide from *Armillaria gallica* (AGP) was purified and performed structural characterization, including analysis of homogeneity, molecular weight and monosaccharide composition. Methylation analysis is used to analyze the glycosidic bond composition of AGP. The mouse model of acute fatigue was used to evaluate the anti-fatigue effect of AGP. AGP-treatment improved exercise endurance in mice and reduced fatigue symptoms caused by acute exercise. AGP regulated the levels of adenosine triphosphate, lactic acid, blood urea nitrogen and lactate dehydrogenase, muscle glycogen and liver glycogen of acute fatigue mice. AGP affected the composition of intestinal microbiota, the changes of some intestinal microorganisms are correlated with fatigue and oxidative stress indicators. Meanwhile, AGP reduced oxidative stress levels, increased antioxidant enzyme activity and regulated the AMP-dependent protein kinase/nuclear factor erythroid 2-related factor 2 signaling pathway. AGP exerted an anti-fatigue effect through modulation of oxidative stress, which is related to intestinal microbiota.

Keywords: Fungi polysaccharide; Intestinal microbiota; Oxidative stress

International Journal of Biological Macromolecules, Volume 241, 30 June 2023. https://doi.org/10.1016/j.ijbiomac.2023.124611

Structural characterization of polysaccharides after fermentation from *Ganoderma lucidum* and its antioxidant activity in HepG2 cells induced by H_2O_2

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Abstract: In this study, *Lactiplantibacillus plantarum* ATCC14917 was used to ferment *Ganoderma lucidum* spore powder. Two polysaccharides were purified from unfermented (GLP) and fermented (FGLP) *Ganoderma lucidum* spore powder. The chemical structure and antioxidant activity of the polysaccharides were studied. Finally, the effect of GLP and FGLP on the oxidative stress regulation pathway in HepG2 cells was explored. The results showed that the main structural characteristics of *Ganoderma lucidum* polysaccharides remained unchanged during the fermentation. However, the average molecular weight (M_w) of *Ganoderma lucidum* polysaccharides decreased from 1.12×10^5 Da to 0.89×10^5 Da. Besides this, the contents of mannose, galactose, and glucuronic acid increased, while the contents of xylose and glucose were decreased. In addition, the content of uronic acid was raised, and the apparent structure was changed from smooth and hard to porous and loose. In antioxidant studies, intracellular ROS and MDA contents in the oxidative stress model were decreased, and *T*-AOC content was increased under GLP and FGLP intervention. In the investigation of the regulation pathway, Nrf-1 gene expression was up-regulated, and Keap1 gene expression was down-regulated under GLP and FGLP intervention. The antioxidant genes NQO1 and NO-1 expressions were increased to activate the activities of antioxidant enzymes CAT, SOD and GSH-PA to resist oxidative stress. Compared with GLP, FGLP has a stronger regulatory role in this pathway, thus showing more potent antioxidant activity. This experiment is beneficial to the further utilization of *Ganoderma lucidum* spore powder.

Keywords: *Ganoderma lucidum,* Polysaccharide, Structure, Antioxidant activity

Food Chemistry: X, Volume 18, 30 June 2023, https://doi.org/10.1016/j.fochx.2023.100682

The Lingzhi or Reishi Medicinal Mushroom *Ganoderma lucidum* (Agaricomycetes) Can Combat Cytokine Storm and Other COVID-19 Related Pathologies: A Review

Adekunle Babajide Rowaiye[1], Akwoba Joseph Ogugua[2], Doofan Bur[1], Timipanipiri Wood[1], Zainab Labbo[1], Chimaobi Chukwu[1], Femi Johnson Afolabi[1], Ezinne Janefrances Nwonu[1], Tarimoboere Agbalalah[3]

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Abstract: Coronavirus disease 2019 (COVID-19) caused by SARS-CoV-2 is characterized by acute respiratory distress syndrome (ARDS) facilitated by cytokine storm and other risk factors that increase susceptibility and complications leading to death. Emerging as a major global public health challenge, the disease has claimed more than 6 million lives and caused catastrophic global economic disruptions. However, there are concerns about the safety as well as the efficacy of drugs and vaccines presently used to control the pandemic, therefore necessitating intense global search for safe natural products that can effectively and safely combat it. This work reviews studies on lingzhi or reishi medicinal mushroom, *Ganoderma lucidum* and its properties that may potentially combat SARS-CoV-2 infection and the co-morbidities. Available evidence suggests that medicinal properties of the *Ganoderma* mushroom can combat the complications of SARS-CoV-2 infection and the co-morbidities that can aggravate the severity of the disease. Preclinical and clinical evaluation to establish dose, efficacy, and potential toxicity and possible use in the management of COVID-19 is recommended.

Keywords: COVID-19, SARS-CoV-2, infection, *Ganoderma lucidum*, medicinal mushrooms

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Ganoderma lucidum ethanol extract promotes weight loss and improves depressive-like behaviors in male and female Swiss mice

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Abstract: Metabolic and mood-related disturbances can increase the risks of developing adverse mental health problems. The medicinal mushroom, *Ganoderma lucidum,* is utilized in indigenous medicine to improve quality of life, promote health, and boost vitality. This study investigated the effects of *Ganoderma lucidum* ethanol extract (EEGL) on feeding behavioral parameters, depressive-like symptoms, and motor activity in Swiss mice. We hypothesized that EEGL would have beneficial effect on metabolic and behavioral outcomes in a dose-related manner. The mushroom was

identified and authenticated via techniques of molecular biology. Forty Swiss mice (n = 10/group) of either sex were given distilled water (10 mL/kg) and graded doses of EEGL (100, 200, and 400 mg/kg) orally for 30 days, during which feed and water intake, body weight, neurobehavioral, and safety data were documented. The animals experienced a significant decrease in body weight gain and feed intake while water intake increased in a dose-dependent manner. Furthermore, EEGL significantly diminished immobility time in forced swim test (FST) and tail suspension test (TST). At the 100 and 200 mg/kg, EEGL did not cause significant alteration in motor activity in the open field test (OFT). Meanwhile, an increase in motor activity in male mice without remarkable difference in female mice was observed at the highest dose (400 mg/kg). Eighty percent of mice treated with 400 mg/kg survived till day 30. These findings suggest that EEGL at 100 and 200 mg/kg reduces the amount of weight gained and elicits antidepressant-like effects. Thus, EEGL might be useful for the management of obesity and depressive-like symptoms.

Physiology & Behavior*, *Volume 265*, 1 June 2023, *https://doi.org/10.1016/j.physbeh.2023.114155

Therapeutic values and nutraceutical properties of shiitake mushroom (*Lentinula edodes*): A review

Author links open overlay panelIshtiaq Ahmad [1], Maryum Arif [2], Mimi Xu [1], Jianyou Zhang [1], Yuting Ding [1], Fei Lyu [1]

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Abstract:

Background

Mushrooms are generally regarded as useful products with multiple applications in the food and health industry. Shiitake (*Lentinula edodes*) is one of the most cultured and consumed mushrooms around the world. With more complexity in medical science and phenomenon like antibiotic resistance, have led to the search for alternatives for disease treatment and prevention. Shiitake mushroom is nutritionally rich and contains numerous minerals (Potassium, Manganese, Magnesium, Iron, and Phosphorus) and vitamins (pro-vitamin D_2, vitamin B_1, B_2, B_6, B_{12}, and niacin) which make it a potential source of nutrition. Shiitake mushrooms contain essential macro and micronutrients as well as many bioactive compounds, including polysaccharides, antioxidants, dietary fiber, and ergosterol. Bioactive compounds can be helpful for maintaining the good health of the users and preventing them from diseases. Shiitake mushroom contains phenolics, polysaccharides, sterols, that play role in bodily functions resulting in improved health of the individuals.

Scope and approach

The review has focused to uncover the therapeutic potential of *L. edodes* and description of several nutraceutical properties of the shiitake mushroom that can be helpful in preventing and treating diseases. The properties like antimicrobial, antiviral, anticancer, anti-obesity, antidiabetic, antioxidant, etc. are discussed in this review with more focus on the latest update in this context.

Key findings and conclusions

It has been observed that the shiitake mushroom is one of the useful foods that can confer multiple beneficial effects on the user. Because of presence of many bioactive compounds, it can simultaneously act as an antimicrobial, antiviral, anticancer/antitumor, antidiabetic, antihyperlipidemic, anticholesterol, antioxidative, antiaging, hepatoprotective, and

immunomodulatory agent. Nevertheless, the factors like mushroom strain, growth conditions, substrate, extraction method and temperature also influence the outcomes of the studies. Moreover, the results in non-human subjects, such as animals, have shown positive outcomes but further research is required because of varying results. Importantly, the evidence of beneficial effects of Shiitake in humans is scarce and clinical studies are required.

Trends in Food Science & Technology, Volume 134, April 2023, Pages 123-135, https://doi.org/10.1016/j.tifs.2023.03.007

A brief review on the medicinal uses of *Cordyceps militaris*

Shweta, Salik Abdullah, Komal, Abhinandan Kumar

M-Pharm (Pharmaceutical Chemistry), Department of Pharmaceutical Sciences and Technology, Birla Institute of Technology, Ranchi, India

Abstract:

Introduction

Cordyceps, a popular Chinese medication, is made by drying caterpillar-borne Cordyceps fungus. The parasite needs an insect host or larvae host to survive. To strengthen those who were lacking in vitality, it was administered in tonic form. The biological effects of Cordyceps species are well documented. Its medicinal properties are because of the chemical constituents present in the mushroom namely cordycepin, cordymin, polysaccharides, glycoprotein, ergosterol, and other extracts.

Materials and methods

Some of the biological activities of *C. militaris* are anti-cancer, anti-oxidant, anti-inflammatory, anti-aging, immunomodulatory, antimicrobials, immunosuppressive, hypolipidemic, hypoglycemic, neuroprotective, and fertility enhancer. Because of their bioactive compounds, edible fungus like *C. militaris* is a multifunctional food supplement. Many mushroom species can be grown on domestic refuse, popularizing the mushroom industry in sustainable economies worldwide.

Conclusion

C. militaris extract can improve health when added to the diet. Further, the complexity of clinical investigations and the challenges of developing therapies using mushroom extracts are both exacerbated by the abundance of bioactive chemicals present in mushrooms. Cordycepin has the most therapeutic potential of all the bioactive compounds described in the studies. Recent studies indicate that cordycepin may be effective against COVID-19's SARS-CoV-2 strain. Therefore, this review lays the groundwork for clinical use and examines the research program for the near future.

Keywords: *Cordyceps militaris,* Infection, Cordycepin, Mechanism, Pharmacological effect

Pharmacological Research - Modern Chinese Medicine, Volume 7, June 2023, https://doi.org/10.1016/j.prmcm.2023.100228

Reed-mushroom-fertilizer ecological agriculture in wetlands: Harvesting reed to cultivate mushroom and returning waste substrates to restore saline-alkaline marshes

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Key Laboratory of Wetland Ecology and Environment, Northeast Institute of Geography and Agroecology, Chinese Academy of Sciences, Changchun 130102, China

Abstract: Construction of wetland ecological agriculture is recommended to perform ecological function and produce considerable economic value. A mode of wetland ecological agriculture was established on inland saline-alkaline marshes in Northeast of China here. This study used reed as substrate to cultivate *Pleurotus citrinopileatus* and return the waste substrate (SMS) to ameliorate the saline-alkalized soil. The biological efficiency of mushroom was 69.01 %, and the contents of sugar, crude protein, crude fat, and amino acids were 30.82 %, 23.07 %, 1.58 %, and 19.48 %, respectively in *P. citrinopileatus*. The cultivated mushrooms had higher contents of Ca, Fe, Zn and Cu, with lower levels of harmful heavy metals. When compared with initial substrates, the SMS remained 93.42 % fiber, 87.08 % carbon, 97.72 % nitrogen, 51.35 % phosphorus, and more Ca contents. Compared with the control, SMS application decreased the soil pH and electro-conductivity by 12.33 % and 30.75 %, and increased total nitrogen and organic matter by 34.98 % and 46.55 %, respectively. In addition to the soil improvements, the above- and belowground biomasses of reed were increased by 172.92 % and 59.64 %, respectively. The study indicated that reed could be used as mushrooms substrates, subsequently applied SMS to ameliorate the saline-alkaline soil. Our wetland ecological agriculture mode of "reed-mushroom-fertilizer" is available and effective for saline-alkaline wetland functioning and economic development.

Keywords: Ecological restoration, Fiber, Mushroom cultivation, Nutrient cycling, Reed, Spend mushroom substrate

Science of The Total Environment, Volume 878, 20 June 2023, https://doi.org/10.1016/j.scitotenv.2023.162987

Exploring the Bioactive Mycocompounds (Fungal Compounds) of Selected Medicinal Mushrooms and Their Potentials against HPV Infection and Associated Cancer in Humans

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Abstract: Medicinal mushrooms have been used as a medicinal tool for many centuries and ,nowadays, are used in the prevention and therapy of various diseases, including as an adjunct to cancer treatment It is estimated that 14-16% of global cancer cases are caused by infectious events; one well-known infectious agent that leads to cancer is the human papillomavirus (HPV).HPV is responsible for more than 99.7% of cervical cancer cases and also may play a role in vaginal, vulvar, penile, anal, rectal, and oropharyngeal carcinogenesis. *Coriolus versicolor*, a basidiomycetes dass mushroom, consists of glycoproteins called polysaccharide-K (PSK) and polysaccharopeptide(PSP), which are mainly responsible for

its effectiveness in the fight against a variety of cancers. Its beneficial effect lies in its ability to arrest different phases of the cell cycle , immunomodulation or induction of apoptosis. *Coriolus versicolor* extract can reduces BCL-2 expression or increases the expression of p53 tumour suppressor genes in breast tumour cell lines. Inhibition of proliferation was also demonstrated with HeLa cells , while cervical cytology abnormalities improved in patients who locally applied *Coriolus versicolor* -based vaginal gel. *Coriolus versicolor* extract itself, and also its combination with another medicinal mushroom, *Ganodrnma lucidum*, leads to improved HPV clearance in HPV cervical or oral-positive patients. Medicinal mushrooms can also increase the effectiveness of vaccination. This review considers the use of medicinal mushrooms as a suitable adjunct to the treatment of many cancers or precanceroses, including those caused by the HPV virus.

Keywords: HPV; cervical dysplasia; medicinal mushrooms

Life 2023, 13, 244. https://doi.org/10.3390/life13010244

The effect of six dried and UV-C-irradiated mushrooms powder on lipid oxidation and vitamin D contents of fish meat

Author links open overlay panelShuhei Kido [1], Etsuo Chosa [2], Ryusuke Tanaka [1]

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Abstract: The effect of dried and UV-C-irradiated mushroom powder on lipid oxidation and vitamin D content in fish meat was investigated. To this end, *Flammulina velutipes*, *Grifola frondosa*, *Hypsizygus marmoreus*, *Lentinula edodes*, *Pleurotus eryngii*, *Pleurotus ostreatus* were dried by hot air and irradiated by UV-C and evaluated the effect of these treatments on the components. In general, the ergothioneine content did not change substantially, the total phenolic compound content decreased by hot-air drying, and the ergocalciferol content increased by UV-C irradiation. To the evaluate effect of mushroom powder on lipid oxidation and vitamin D content in fish meat, 5% of the hot air dried and UV-C-irradiated mushroom powder was added to fish meat and oxidized. Consequently, all six mushrooms prevented lipid oxidation, and ergocalciferol content in each mushroom powder remained between 58.2% and 69.7%. Overall, *P. eryngii*, *L. edodes*, and *P. ostreatus* strongly prevented the generation of lipid peroxide and aldehyde.

Food Chemistry, Volume 398, 1 January 2023, *https://doi.org/10.1016/j.foodchem.2022.133917*

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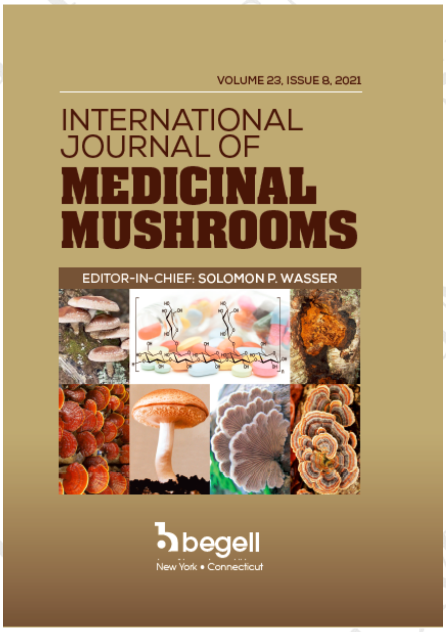

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Aims and Scope

The rapid growth of interest in medicinal mushrooms research is matched by the large number of disparate groups that currently publish in a wide range of publications. The *International Journal of Medicinal Mushrooms* is the one source of information that will draw together all aspects of this exciting and expanding field - a source that will keep you up to date with the latest issues and practice. The *International Journal of Medicinal Mushrooms* publishes original research articles and critical reviews on a broad range of subjects pertaining to medicinal mushrooms, including systematics, nomenclature, taxonomy, morphology, medicinal value, biotechnology, and much more. Papers on new techniques that might promote experimental progress in the aforementioned field are also welcomed. In addition to full-length reports of original research, the journal publishes short communications and interesting case reports, together with literature reviews. Letters to the editor on topics of interest to readers are also published.

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2023, Vol. 25, Issue no.7

Points and Reviews

Mycochemicals in Wild and Cultivated Mushrooms: Nutrition and Health

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Orgainal Published on Phytochem Rev (2022) 21:339–383

Abstract: The mushrooms have contributed to the development of active ingredients of fundamental importance in the field of pharmaceutical chemistry as well as of important tools in human and animal health, nutrition, and functional food. This review considers studies on the beneficial effects of medicinal mushrooms on the nutrition and health of humans and farm animals. An overview of the chemical structure and composition of mycochemicals is presented in this review with particular reference to phenolic compounds, triterpenoids and sterols, fatty acids and lipids, polysaccharides, proteins, peptides, and lectins. The nutritional value and chemical composition of wild and cultivated mushrooms in Italy is also the subject of this review which also deals with mushrooms as nutraceuticals and the use of mushrooms in functional foods. The nutraceutical benefits of UV irradiation of cultivated species of basidiomycetes to generate high amounts of vitamin D2 is also high- lighted and the ability of the muhsrooms to inhibit glycation is analyzed. Finally, attention is paid to studies on bioactivities of some Italian wild and cultivated mushrooms with particular reference to species belonging to the genus *Pleurotus*. The review highlights the potential of medicinal mushrooms in the production of mycochemicals that represent a source of drugs, nutraceutical, and functional food.

Graphic abstract

Sample	Molecular Weight (kDa)	Monosaccharide Composition (%)[a]						
		Glc	Rham	Gal	Xyl	Ara	Man	Fru
PEPS-A	—	94.8	—[b]	—	—	—	5.2	—
PEPS-B	—	60.8	—	—	—	—	3.0	36.2
PEPS-A1	68	100	—	—	—	—	—	—
PEPS-A2	43	100	—	—	—	—	—	—

[a]Individual components were identified by comparison with standard sugars.
[b]Not detected.

Keywords: Fungal diversity, Cultivation, Mycochemicals, Chemical structures, Nutrition

Abbreviations

AGLs	Acidic glycosphingolipids
BEPF	*Boletus edulis* Polysaccharides
BRMs	Biological response modifiers
CBAEP	Cibacron blue affinity-purified protein
COSY	Correlation spectroscopy
FAB-MS	Fast atom bombardment
FAME	Fatty acid methyl esters
FIP	Immunomodulatory proteins
FT-IR	Fourier-transformed infrared spectroscopy
GC	Gas chromatography
GLC–MS	Gas-liquid chromatography–mass spectrometry
GLS	Glycosphingolipids
GSH	Glutathione peroxidase
HBA	Hydroxybenzoic acid
HCA	Hydroxycinnamic acid
HIV	Human immunodeficiency viruses
HMBC	Heteronuclear multiple bond coherence
HMG-CoA	β-Hydroxy β-methylglutaryl-CoA
HMQC	Heteronuclear multiple quantum coherence
HPLC–MS	Liquid chromatography–mass spectrometry
HS-ITEX	Head Space ‘‘In Tube Extraction’’
GC-MS	Technique and gas chromatography
IEC	Ion-exchange chromatography
iNKT	Invariant natural killer cell
LCB	Long-chain base
LDG-M	*Lactarius deliciosus* Polysaccharides

MHS-SPME	Multiple headspace-solid phase microextraction
MIC	Minimum inhibitory concentration
MM	Medicinal mushrooms
MUFA	Monounsatured fatty acid
NMR	Nuclear magnetic resonance
NOESY	Nuclear overhauser effect spectroscopy
OMW	Olive mill wastewaters
PELPS	*Pleurotus eryngii* var. *elaeoselini* polysaccharides
PEPE	*Pleurotus eryngii* Purified polysaccharides
PSK	Polysaccharide K
PSP	Polysaccharide peptide
PUFA	Polyunsaturated fatty acid
ROESY	Rotating-frame nuclear overhauser effect correlation spectroscopy
RVP	*Russula virescens* Polysaccharide
SEC	Size-exclusion chromatograpy
SFA	Saturated fatty acid
SPG	Schizophyllan
TLC	Thin layer chromatography
TOCSY	Total correlation spectroscopy
TPC	Total phenolic content
VOC	Volatile organic compounds

Continued from previous issue:

Nutritional value of mushrooms

The consumption of mushrooms as food has ancient origins. There is evidence of their inclusion in the diet, in fact, already in the civilizations of the Greeks and Romans, who considered them ''the food of the Gods'' (Valverde et al. 2015).

The enormous alimentary potential of mushrooms lies not only in their rich aroma and flavor, which make them an authentic delicacy but also in their high nutritional value so that they are considered functional foods (Barros et al. 2008; Tsai et al. 2009; Wani et al. 2010; Wang et al. 2014c; Kumar 2015; Correˆa et al. 2016; Rathore et al. 2017; Reis et al. 2017; Antunes et al., 2020). The fungal fruiting body is composed mostly of water, so the caloric intake provided by it is very low (about 350–400 kcal kg-1; Kalacˇ 2012). Dry matter (DM) represents only 5–15%, with variable contents of carbohydrates and proteins, but also fibers and minerals, depending on the fungal species (Barros et al. 2008; Wani et al. 2010; Reis et al. 2012; Cheung 2013; Kalogeropoulos et al. 2013; Wang et al. 2014c; Heleno et al. 2015).

Of all the species of mushrooms cultivated or available in Italy, those belonging to the genus *Pleurotus* are among the most appreciated for their high nutritional value. Studies have shown that the content of *P. eryngii* carbohydrates, the main components of the fungal fruiting body, is very high (75.4%), even comparable to that of wheat grains and oat bran (Venturella et al. 2015; Carrasco-Gonza´lez et al. 2017). *C. aegerita* has an even higher content, around 84% (Petrovic´ et al. 2015), in the wild *L. deliciosus* is 66.61 g/100 g dw, while that of *C. comatus*, *M. procera* and *B. edulis* is significantly lower (58.4%, 54.70% and 46.95%, respectively) (Tsai et al. 2007; Ayaz et al. 2011; Xu et al. 2019). Lower is also the carbohydrate content of *A. bisporus* (51.05%; Atila et al. 2017). Particular is the case of the wild mushrooms *R. cyanoxantha* and *R. virescens*, which, although belonging to the same genus, may show significantly different, and in any case rather low, carbohydrate contents (9.56 and 24.40%, respectively) (Srikram and Supapvanich 2016). Most of the fungal carbohydrates are not digestible and include dietary fiber, cell wall polysaccharides as chitin, ß-glucans and mannans, and oligosaccharides. Mushroom dietary fiber is composed by insoluble fiber: mostly chitin and ß-glucans, but also other structural polysaccharides such as hemicelluloses. Soluble fiber (mainly pectines) is generally less than 10% DM. *Pleurotus* genus has a high content of crude fiber (10.2%), as well as *C. comatus* (12.5%), and ß-glucans (25.9%); in particular, the highest amount of ß-glucans is found in *P. ostreatus* (up to 50%) (Tsai et al. 2007; Correˆa et al. 2016; Carrasco-Gonzalez et al. 2017; Bulam et al. 2019). This makes this genus one of the main and most interesting sources of ß-glucans, including pleuran, currently commercialized as a natural immunostimulant (Imunoglukan P4H®) due to its bioactivity (Carrasco-Gonza´lez et al. 2017; Reis et al. 2017; Golak-Siwulska et al. 2018; Bulam et al. 2019). On the contrary, the chitin level is significantly higher in *A. bisporus* than in *P. ostreatus* (Atila et al. 2017). Of the total free sugars, the most abundant is mannitol (80% ca, enough to be called ''the mushroom sugar''), except in *C. aegerita* and *C. comatus*, where the dominant sugar is trehalose (12.49 g/100 g dw and 169.14 mg/g dw, respectively) (Tsai et al. 2007; Wani et al. 2010; Petrovic´ et al. 2015; Atila et al. 2017).

Another important component of the fungal dry matter (19–35% DM) are proteins, which confer mushrooms a nutritional value comparable to some foods such as meat, eggs and, milk products (Barros et al. 2008; Kalacˇ 2009; Wani et al. 2010; Wang et al. 2014c; Khatun et al. 2015; Correˆa et al. 2016; Rathore et al. 2017). In fact, not only these are highly digestible proteins (e.g. the digestibility of *Pleurotus* proteins is even higher than plants, that is 90%, hence only slightly below the meat and comparable with casein and eggs), but they also include all the essential amino acids usually found in animal proteins: tryptophan, isoleucine, valine, phenylalanine, leucine, threonine, lysine, histidine, methionine. There are, also, non- essential amino acids such as arginine, glutamic acid, aspartic acid, tyrosine, serine, aspargine, and many others (Tsai et al. 2009; Wani et al. 2010; C¸ agˇlarirmak 2011; Erjavec et al. 2012; Kakon et al. 2012; Kalacˇ 2012; Kivrak et al. 2014; Wang et al. 2014c; Kumar 2015; Correˆa et al. 2016; Atila et al. 2017). Excellent protein content was found by Srikram and Supapvanich (2016) in *R. cyanoxantha* (49.20%, while it was 29.50% in *R. virescens*), by Ayaz et al. (2011) in *B. edulis* (32.50 g/100 g dw) and a good one by Xu et al. (2019) in *L. deliciosus* (17.19 g/100 g dw), rather low (4.22%), instead, in *M. procera*. Recent studies have shown as *P. ostreatus* (protein content 23%) meets the nutritional requirements for all essential amino acids, or even doubles or triples for some of them (Correˆa et al. 2016; Carrasco-Gonza´lez et al. 2017; Bulam et al. 2019), and that *A. bisporus* has significant amounts of numerous essential and non- essential amino acids, with an overall protein content of 29.14% (Kakon et al. 2012; Atila et al. 2017). Also relevant is the fact that mushrooms are the major food source of ergothioneine, especially *B. edulis*, and some species also of glutathione (mainly *C. aegerita* among the national mushrooms, followed by *B. edulis* and *P. ostreatus*), amino acid compounds that are important antioxidants (Kalaras et al. 2017). Interesting is also the content of c-aminobutyric acid (GABA), a hypotensive agent, in *C. comatus*, as well as in *B. edulis* (Tsai et al. 2007). Therefore, mushrooms are a viable dietary alternative for vegetarians and vegans and also an ideal component of healthy food especially for child development.

One more advantage of mushrooms as nutrients is their low crude fat content (2–6% of DM), making them suitable for a low-calorie diet. Among the species of the genus *Pleurotus*, the lowest lipid levels are found in *P. nebrodensis* (Inzenga) Que´l. (1.6%), while the highest in *P. eryngii* and *P. ostreatus* (3.5% and 3.4%, respectively) (Venturella et al. 2015; Carrasco-Gonza´lez et al. 2017; Sande et al. 2019). The crude fat content of *C. comatus* is 3.11% (Tsai et al. 2007), while lower are that of *B. edulis* and *M. procera* (2.85% and 2.40%, respectively) (Ayaz et al. 2011), whereas *L. deliciosus* show a slightly higher content (4.82 g /100 g dw) (Xu et al. 2019). A higher fat content was found in *R. virescens* (12.54%) and *R. cyanoxantha* (7.87%) (Srikram and Supapvanich 2016). Generally, in mushrooms, the unsaturated fatty acid prevail over the saturated ones. In *Pleurotus* spp., for example, monounsaturated fatty acids prevails over others, accounting for up to about 70% of the total, and their content is considerably higher than other species such as *A. bisporus* (Correˆa et al. 2016). In this species, the essential polyunsaturated linoleic acid is the most abundant, 5-folds more than in *P. ostreatus*, followed by palmitic, stearic, oleic acids, and others (Atila et al. 2017; Sande et al. 2019). As reported by Reis et al. (2012), however, the total content of monounsaturated fatty acids is higher in *P. eryngii* and *P. ostreatus*; in the latter, the oleic acid seems to be the prevailing monounsaturated fatty acid while linoleic acid is the major polyunsaturated one, whereas palmitic acid is the most abundant among the saturated ones (Correˆa et al. 2016). Also in *C. aegerita* linoleic acid is the most abundant (78.4%), followed by palmitic, oleic and, stearic acids (Petrovic´ et al. 2015). In *L. deliciosus*, on the other hand, the prevalent fatty acid is palmitic, followed by stearic, oleic, and linoleic acid (Xu et al. 2019). Thus, mushrooms can play an important role in nutrition as a source of essential fatty acids for humans as linoleic and linolenic.

The content of primary vitamins such as riboflavin, niacin, thiamine, tocopherol, vitamin of D complex, and folates is noteworthy (La Guardia et al. 2005). Mushroom is, thus, the only non-animal-based food containing vitamin D. As regards niacin, a significantly high content (5.9 mg/kg) was found in *P. eryngii* var. *eryngii* (DC.) Que´l., hence sufficient to satisfy 55–82% of the recommended dietary allowance (RDA) of nicotinic acid, and higher than that of other mushroom species such as *P. ostreatus* (4.95 mg), *A. bisporus* (3.8 mg) and *Boletus* spp. (0.8 mg); the riboflavin content (0.2 mg/kg) is similar for all these species, while the values of biotin are higher for *P. eryngii* (7.45 lg) (Venturella et al. 2015; Atila et al. 2017). A high vitamin B12 and riboflavin content has been reported for *P. nebrodensis* (La Guardia et al. 2005; Venturella et al. 2015). *B. edulis* is the mushroom species with significant ascorbic acid content (4.11 g/kg dw) as found by Ayaz et al. (2011). If compared with vegetables, mushrooms have riboflavin content significantly higher. The bioavailability of folates is good, content in ergosterol (a precursor of vitamin D2) is high. For this reason, mushrooms are particularly suitable for those who need to take ergocalciferol from foods of non-animal origin, such as vegetarians and vegans. Also of note is the vitamin C content in *Pleurotus* spp. (Kalacˇ 2009, 2012; C¸ agˇlarirmak 2011; Feeney et al. 2014; Kumar 2015; Atila et al. 2017; Rathore et al. 2017; Papoutsis et al. 2020). Compared with vegetables, mushrooms have a higher or similar content of micro- and macro-elements, mostly K and P, followed by Ca, Mg, and Fe (La Guardia et al. 2005; Wani et al. 2010; Ayaz et al. 2011; Kakon et al. 2012; Kalacˇ 2012; Wang et al. 2014c; Correˆa et al. 2016; Atila et al. 2017; Carrasco-Gonza´lez et al. 2017). Particularly interesting is the iron content of *P. ostreatus*, which overcomes that of pork and beef liver (23.3 and 4.9 mg Fe/100 g) (Carrasco-Gonza´lez et al. 2017). Thanks to the lower Na content that characterizes them, mushrooms are recommended for the prevention of hypertension and particularly for the diet of whose suffer from this medical condition (Vetter 2003; Kalacˇ 2012; Rathore et al. 2017).

No less important is the characteristic and excellent aroma of edible mushrooms, which, together with the texture of their flesh, makes them a valid and delicious substitute for meat and an ideal enrichment for many dishes. Mushrooms are appreciated for their umami or savory flavor, deriving from non-volatile (taste) and volatile (smell) components, such as terpenes, aldehydes, lactones, free amino acids, aromatic alcohols, 50-nucleotides, soluble sugars, ketones, octanes, and octenes (Kalacˇ 2009, 2012; Tsai et al. 2009; Feeney et al. 2014; Wang et al. 2014c; Atila et al. 2017; Rathore et al. 2017).

Also in *Tuber* species, there is interesting nutrient composition, which changes qualitatively and quantitatively at various stages of maturation. Basically, their composition reflects that of the most commonly described fungi, with the exception of two characteristics: the absence of mannitol and the presence of melanins. As reported by Harki et al. (2005) and Lee et al. (2020), *T. melanosporum* and *T. magnatum*, two common species in Italy and among the most appreciated among truffles, are rich in proteins, K and P, sulfur amino acids and unsaturated fatty acids such as oleic and linoleic acid (more than 60% of total FA content). More specifically, the mature (stage VI) ascocarps of *T. melanosporum* contain 30.6% carbohydrates (lower than many species of basidiomycetes), 29.7% proteins, and 5.4% lipids, of which linoleic acid prevails (55.9%), followed by oleic and palmitic acid.

According to Patel et al. (2017) and Wang and Marcone (2011), truffles are reached in free (particularly the sulfur-containing cysteine and methionine) and essential amino acids (methionine, phenylalanine, valine, serine, isoleucine, and threonine), metals (Fe, Ca, K, P, Cu, Zn, and Mn), contain rhamnose, ergosterol (especially in *T. melanosporum*, 1.90 mg/ g DM), as well as being rich in melanins (up to 15% dry weight). Also important are their volatile organic compounds such as aldehydes, alcohols, ketones, and organic acids (ascorbic acid), responsible for their typical umami and aroma.

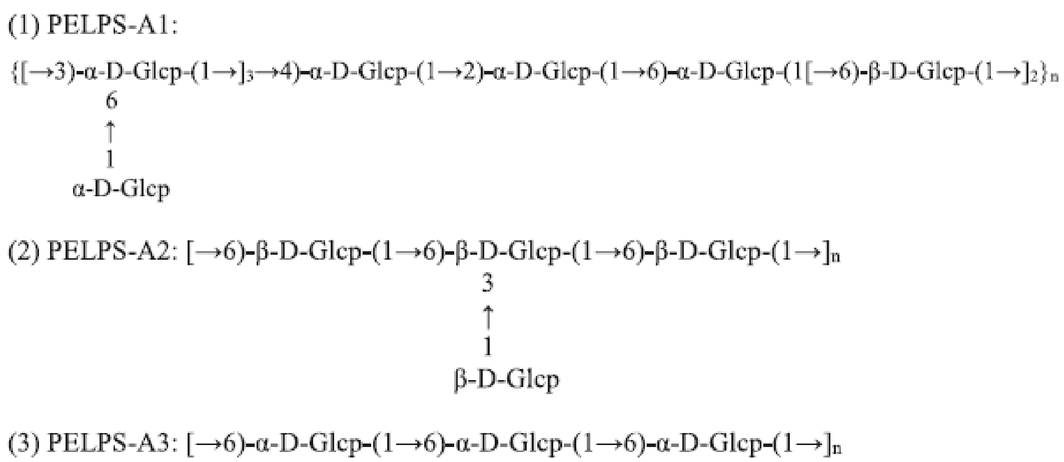
Chemical composition of Italian wild mushrooms

The consumption pattern from Europe shows a greater preference for wild mushrooms than for cultivated ones (Peintner et al. 2013). In Italy, gathering wild mushrooms is a common practice due to the favorable geographic conditions where the Alps, the Apennine mountains and the forests of southern Italy are ideal grounds for the growth of the most popular mushrooms. The knowledge of edible species is necessary since non-edible ones may have toxic effects. The peak season for mushroom gathering in most areas of Italy is from April to early November, with variations from region to region. Weather conditions are key factors for an abundant mushroom season, which requires a perfect combination of sun, rain, humidity, and warmth.

With the aim of evaluating the chemical composition of mushrooms widely consumed in Italy, different species have been examined to determine their proximate composition.

Pseudomonas eryngii var. *eryngii* the 'cardoncello' mushroom, is a highly prized and widely distributed edible mushroom throughout Italy. Protein acidic extracts of Mediterranean culinary-medicinal Oyster mushrooms *P. eryngii* var. *eryngii*, *P. eryngii* var. *ferulae* (Lanzi) Sacc., *P. eryngii* var. *elaeoselini* Venturella, Zervakis & La Rocca and *P. nebrodensis* were tested for their in vitro growth inhibitory activity against *Staphylococcus aureus* ATCC 25,923, *Staphylococcus epidermidis* RP 62A, *Pseudomonas aeruginosa* ATCC 15,442 and *Escherichia coli* ATCC 10,536. All the *Pleurotus* species analyzed inhibited the tested microorganisms in varying degrees (Schillaci et al. 2013).

From the basidiomata of the edible mushroom *P. eryngii* var. *elaeoselini* three water-soluble glucans (PELPS-A1, PELPS-A2 and PELPS-A3) were obtained from the hot water extract by chromatography on DEAE-cellulose 32 and Sephadex G-100 column. Acid hydrolysis, periodate oxidation and NMR experiments (^{1}H-, ^{13}C-NMR, DQF-COSY, TOCSY, ROESY, HMQC and HMBC) were useful in providing information for their structural elucidation. Based on the data obtained, the structures of the repeating unit of the three isolated polysaccharides were established as follows:



PELPS-A1 is a new polysaccharide, isolated and identified for the first time from *P. eryngii* var. *elaeoselini*. The crude extract of *P. eryngii* var. *elaeoselini* was tested for the antioxidant activity by DPPH and hydroxyl radical scavenging assays showing an SC50 of 1.4 mg/mL and SC50 of 5.7 mg/mL, respectively. In vitro, antioxidant tests showed that the three isolated polysaccharides exhibited moderate and similar hydroxyl radical scavenging activity (Cateni et al. 2020).

Costa et al. (2015) developed a headspace-solid- phase microextraction (HS-SPME) method coupled with GC–MS and GC-FID to evaluate the volatile profiles of ten wild mushroom species including *C. aegerita* and *L. deliciosus* collected in south Italy. The mushroom *C. aegerita* showed consistent amounts of ethanol (34%), isopropyl acetate (10%) and isopentanol (30%), while *L. deliciosus* presented not only an abundant fraction of 3-octanone but also consistent amounts of terpenoids, such as limonene (5%), linalool (8%), and dihydrocitronellol (4%).

C. aegerita, commonly known as Pioppino, an edible wild species of the Campania Region (southern Italy), was screened for its bio-chemical composition, nutritional values, and antioxidant effect. GC–MS analysis showed that the most abundant unsaturated acid in Pioppino was linoleic acid (C18:2; 0.618 g kg $^{-1}$), while palmitic acid (C16:0; 0.107 g kg $^{-1}$) was the major of saturated fatty acids.

The alcoholic extracts of three different samples of Pioppino were analyzed by liquid chromatography- high resolution mass spectrometry (LC-HRMS) in full scan mode (Landi et al. 2017a). Pioppino was mainly constituted of disaccharides, hexitol derivatives and malic acid. Other metabolites as saccharopine, agaritine, pentosylhexitol, ergothioneine, c-glutaminyl-4-hydroxybenzene, pentosyl xanthosine, homogentisic acid, malic acid, pentos-2-ulose, fumaric acid, veratric acid, *p*-cumaric acid, *o*-cumaric acid, δ-tocopherol and, γ-tocopherol were identified by comparison of their relative retention times and MS/ MS spectra with those of reference pure compounds.

Wild mushrooms [*Fistulina hepatica* (Schaeff.) With., *Infundibulicybe geotropa* (Bull.) Harmaja, *Laetiporus sulphureus* (Bull.) Murrill, *Macrolepiota procera* var. *procera* (Scop.) Singer and *Suillus granulatus* (L.) Roussel] collected in different forests of Sicily (southern Italy) were analyzed for the content of protein, fat, carbohydrate and, vitamins showing their importance from a nutritional point of view (Palazzolo et al. 2012).

A lectin was isolated from the wild mushroom *B. edulis* (porcini mushroom) collected in Italy. This protein is a dimer and each monomer folds as a b- trefoil domain. Its X-ray structure, the interaction with galactose, lactose, N-acetylgalactosamine, Galb1- 3GalNAc and, T-antigen disaccharide were studied together with its antiproliferative properties on human cancer cells (Bovi et al. 2013).

B. edulis is a culinary mushroom highly appreciated for its aroma, but fresh mushrooms are very perishable products with a limited shelf life of 1 to 3 days at room temperature. Thus, dehydration is one of the significant preservation methods used for the storage of mushrooms. The composition of volatile compounds of dried porcini mushroom during commercial shelf- life (up to 12 months) at the storage temperature of 20 °C and under stressed conditions at 37 °C was investigated using two mass spectrometry (MS)-based techniques.

66 volatile compounds were identified, 36 of which reported for the first time. Alcohols, aldehydes, ketones, and monoterpenes diminish during the storage while carboxylic acids, pyrazines, lactones and, amine increase. The storage temperature influences the final quality of the dried porcini (Aprea et al. 2015).

The mycochemical studies regarding truffles are mainly focused on the complex mixture of volatile organic compounds (VOCs) released from their ascomata that in addition to their biological value determine their economic value.

T. magnatum grows in some regions in Italy (Tuscany, Piedmont, Marche and, Umbria) and its volatile organic compounds were analyzed by PTR- TOF–MS experiments comparing samples from different regions of Italy and different seasons (Vita et al. 2015). The chemical composition of the aroma has led to the identification of 111 compounds divided into six different chemical classes as follows: hydrocarbons, aromatic hydrocarbons, phenols, sulfur compounds, terpenes, and other compounds. The VOCs profiles vary within the different seasonal and geographical productions.

A further study of the VOCs generated by *T. magnatum* fruiting bodies from different regions of Italy with different environmental conditions was reported by Vita et al. (2018). The white truffle's aroma is frequently correlated to sulfur-containing volatiles which can be used to trace the origin of truffle fruiting bodies. Dimethyl sulfide, dimethyl disulfide, bis (methylthio) methane were detected in all samples, dimethyl trisulfide in some samples while S-allylthiopropionate and 3-methylthio-propionaldehyde were found for the first time in the aroma. Aldehydes [e.g. (4*Z*)-decenal, (2*E*)-butenal, 4-methylpent-2-enal, 2-methylpent-2-enal], alcohols [e.g. 1-octen-3-ol, dodecanol, (4*Z*)-decen-1-ol], ketones [e.g. 3-octanone, 2-octanone, 6-methyl-5-hepten-2-one, 2-decanone, 2-undecanone], terpenes [e.g. limonene, α- and β- pinene, α-terpinene, eucalyptol, camphor], hydrocarbons and esters [e.g. (2*E*)-hexenyl-acetate, ethyl lactate, 3,5,5-trimethylhexyl-acetate, isobutyl pentanoate, 3-acetoxyoctane] were also detected.

Besides, since the quality of the fruiting bodies of *T. magnatum* varies significantly based on of the origin area due to the differences in environmental growth conditions, a proteomic analysis was reported for samples collected in different areas of Italy (Vita et al. 2017).

As concerns the black truffle *T. melanosporum* Vitt. the volatile organic compounds from samples collected in middle Italy and the variation induced by the storage temperature was reported (Bellesia et al. 1988). The major volatile compounds of *T. melanosporum* are butan-2,3-dione, 2- and 3-methylbutanal, 2- and 3-methylbutanol. The two aldehydes (2- and 3-methylbutanal) and two alcohols (2- and 3-methylbutanol) play an important role, while sulfur compounds are present at trace levels. On storage, all these compounds are lost, but at 0 °C, an increase of the 2- and 3-methyl butanal and of 2- and 3-methyl butanol occurs.

In many cases, *T. borchii* is illegally used as a substitute of the more appreciated *T. magnatum*. The composition of the volatile organic fraction of *T. borchii* was analyzed by gas–solid extraction and purge and trap injection in GC–MS, together with the variations during storage (Bellesia et al. 2001). In fresh samples the aroma mainly consists of a mixture of alcohols, the most important one is 1-octen-3-ol together with aldehydes and 2- and 3-methylthiophenes as sulfur compounds. Also for *T. borchii* the best preservation conditions seem to be at 0 °C, while comparing *T. borchii* with *T. magnatum*, the absence in the volatile fraction of dimethyldisulfide, dimethyltrisulfide and 2,4-dithiapentane seems to be the distinguishing feature.

D'Auria et al. (2012) reported a further study on volatile organic compounds of samples of *T. borchii* and *T. asafoetida* Lesp., collected in woodlands of the Basilicata region (southern Italy). Solid-phase microextraction-gas chromatography–mass spectrometry analysis of the samples showed the presence of 2-methyl-1,3-butadiene as the significant component in both truffles. In *T. borchii* 3-methylbutanal, 3-methyl-1-butanol and tetradecane were present in low amounts.

Besides, a lectin named TBFL-1 was isolated and identified from *T. borchii*. The fruiting body that is able selectively to bind the exopolysaccharides produced by ascoma-associated *Rhizobium* spp. TBFL-1 is a 11.9-KDa phase-specific protein, it is a nonglycosylated polypeptide chain localized on the hyphal cell wall and is the main soluble protein in the fruiting body aqueous extract. Studies of the related gene *tbf-1* demonstrated the presence of an N-terminal signal peptide of 12 amino acids (Cerigini et al. 2008).

Chemical composition of Italian cultivated mushrooms

A study conducted on different mushroom strains cultivated in an Italian farm (Italmiko, Senise-Potenza, Italy) was carried out by solid-state 13C CPMAS NMR (Pizzoferrato et al. 2000). This technique can investigate the chemical composition in the solid-state of a food sample. This property was useful to study mushrooms of different species [*P. ostreatus*, *P. eryngii*, *Pleurotus pulmonarius* (Fr.) Que´l. And *L. edodes*] to obtain the quantitative evaluation of the protein/polysaccharide ratio. The value of the protein/ polysaccharide ratio has been correlated with the results obtained by chemical analysis and a good correlation (R2 = 0.93; R2 = 0.81) has been obtained. As concerns *P. ostreatus* the resonances are quite similar and only slight changes in the relative intensity can be observed. The *P. eryngii* samples analyzed show a similar pattern with a high content of polysaccharides and a low amount of proteins.

P. ostreatus, *P. eryngii* and *C. aegerita* were investigated for their β-1–3-glucan synthase activity and its induction by olive mill wastewaters (OMW) (Reverberi et al. 2004). In the control medium, although with different degrees, all fungal strains displayed β-1,3-glucan synthase activity. When the isolates grew on OMW an increase of about 12-fold was observed for *P. ostreatus*, while no differences were reported for *P. eryngii* and *C. aegerita*.

Two different polysaccharides (PEPS-A1 and PEPS-A2) were isolated from the cultivated edible mushroom, *P. eryngii* C-

142-c strain. The chemical structures of the repeating unit of PEPS-A1 and PEPS- A2 were established based on acid hydrolysis, methylation analysis, and NMR experiments as follows:

(1) PEPS-A1 (α-glucan):

$$[\rightarrow 6) - \alpha - D - Glcp - (1 \rightarrow 6) - \alpha - D - Glcp - (1 \rightarrow 6) - \alpha - D - Glcp - (1 \rightarrow]_n$$

(2) PEPS-A2 (β-glucan):

$$[\rightarrow 6) - \beta - D - Glcp - (1 \rightarrow 6) - \beta - D - Glcp - (1 \rightarrow 6) - \beta - D - Glcp - (1 \rightarrow]_n$$

The antioxidant activity of PEPS-A1 and PEPS-A2 was evaluated by hydroxyl radical scavenging activity test showing SC50 values of 400 µg/mL and 122 µg/mL, respectively. Both polysaccharides affected cell viability after 48 and 72 h of treatment, inducing the death of 50% of HT-29 cells between 0.25 and 1µg/mL and 0.5 and 1 µg/mL, respectively for PEPS-A1 and PEPS-A2 (Cateni et al. 2018).

Punelli et al. (2009) reported the molecular char- acterization and enzymatic activity of laccases in *P. eryngii* and *P. eryngii* var. *ferulae*. Using a PCR- based approach, four putative laccase genes (*lac1*, *lac2*, *lac3* and *lac5*-like gene) have been isolated and identified in both *P. eryngii* and *P. eryngii* var. *ferulae*. Multiple headspace-solid phase microextraction (MHS-SPME) followed by gas chromatography/ mass spectrometry (GC–MS) and flame ionization detection (GC-FID) was applied to the identification and quantification of volatiles from the mushroom *A. bisporus* (Costa et al. 2013). 1-Octen-3-ol, 3-octanone, 3-octanol, 1-octen-3-one and benzaldehyde are key compounds of mushroom samples analyzed. Quanti- tative differences among the samples were observed, in particular for 1-octen-3-ol when fresh mushrooms were differently pre-treated (0.75 and 3.30 μg^{-1}, in chopped and homogenized samples, respectively). It seems that from 1-octen-3-ol breakdown other 8-car- bon compounds are formed: 3-octanone (3.34 vs. 2.01μg^{-1}) and 3-octanol (0.19 vs. 0.07μg^{-1}) were found in high amount in chopped samples, balancing the reduced presence of 1-octen-3-ol.

Agaricus bisporus is the most cultivated mushroom in Italy. Samples of the cultivated species *A. bisporus* in Sicily (South Italy) were analyzed by the head- space-solid-phase microextraction (HS-SPME) method coupled with GC–MS and GC-FID to evaluate compositional changes occurring during storage (Costa et al. 2015). 51 compounds were identified, with high amounts of C8 compounds such as 3-octanone, 3-octanol and (2*E*)-octenol. Besides, compounds with the aromatic ring were determined at significative amounts, such as benzaldehyde and benzyl alcohol. In Italy, *A. bisporus*, when purchased in the supermarkets, is found in refrigerated counters. So, 10-day-old mushrooms, kept in the refrigerator were analyzed. After 10 days of storage, a reduction of about 3.5% of the volatile fraction was observed. Ethanol, (2*E*)-octenol and phenylacetaldehyde were not detected in the stored mushrooms. As concerns compounds with aromatic ring a drastic decrease was observed. The amount of terpenoids was constant, while a reduction of C8 compounds, 3-octanol and (2*E*)-octenol was observed.

Landi et al. (2017a) reported the nutritional value, chemical composition, and anti-radical properties of cultivated *A. bisporus* (J.E. Lange) Imbach purchased in Campania (South Italy). As concerns fatty acid composition analysis the most abundant unsaturated acids in Champignon were linoleic (C18:2; 0.858 g kg^{-1}) and c-linolenic (C18:3; g kg^{-1}), which represented 67% and 19% of the total, respectively. The prevalence of polyunsaturated fatty acids (PUFA) showed linoleic acid (C18:2) as the major fatty acid, while palmitic acid (C16:0) was the major of saturated fatty acids (SFA). The tentative identification of constituents from Champignon alcoholic extract by liquid chromatography—high-resolution mass spectrometry (LC- HRMS) showed the presence of mannitol, saccharopine, trehalose, agaritine, pentosylhexitol, ergothioneine, c-glutaminyl-4-hydroxybenzene, malic acid, fumaric acid, ferulic acid, sinapic acid, and cinnamic acid.

Mycochemicals as nutraceuticals

Mushrooms are an excellent food not only from a culinary point of view, as unique sensory experiences, but also for well-being because of the many positive effects they have on the human body, helping it to maintain a good state of health and defend it against illness. This aspect is becoming increasingly important in a society more and more threatened by an unhealthy lifestyle, pollution, radiation and many other stress factors. Thereby in the last decades, the gaze on food has changed, and new concepts of it were developed. The term 'nutraceuticals' was first used by de Felice (1989) who, combining the words nutrition and pharmaceuticals, defined them as 'a food (or part of a food) that provides medical or health benefits, including the prevention and treatment of a disease'.

The term ''mushroom nutraceuticals'' refers to refined or partially refined extracts, single compounds or nutrients, or dried biomass obtained from either mushroom mycelium or fruiting body, usually included in dosed, concentrated, and purified form in different pharmaceutical formulations such as capsules, tablets, pills, etc., and consumed as a dietary supplement and has potential therapeutic applications (Reis et al. 2017). Nonetheless, being considered non- specific biologic therapies, nutraceuticals differ from pharmaceuticals in that they are not currently subject to medical prescription and their therapeutic properties are not recognised from a legal point of view. Since 2011, in fact, in EU the registration and marketing of 'botanical medicinal products' is no longer permitted and, therefore, despite their pharmacological properties, they can only be classified as food supplements, falling under EU Regulation no. 1924/2006 (Pirillo and Capatano 2014). Therefore, several aspects of their preparation and marketing remain still unresolved, such as standardization of the production chain, safety parameters, regulation, efficacy, and mechanism of action. Although the market does not have production standards, it is mainly developed in Asian countries; Western countries, on the other hand, are used to buy from the East finished products for resale or raw materials (powders and extracts not always of ascertained origin) and then make the final pipeline. In these areas, therefore, the potential for exploitation and investment is enormous. Several recent studies have demonstrated the multiple nutraceutical properties of mushrooms by the presence of numerous bioactive molecules that give them antioxidant, antimicrobial, antitumor, immunomodulating, anti-hypercholesterolemia, anti- inflammatory, antiviral, radical scavenging, hypolipidemic, antithrombotic, hepatoprotective, anti-hypercholesterolemia, hypotensive, and anti-diabetic activities, antinociceptive and cardiovascular beneficial effects (Barros et al. 2008; Carrasco-Gonza´lez et al. 2017; Gargano et al. 2017; Rathore et al. 2017; Reis et al. 2017; Ma et al. 2018; Islam et al. 2019). These bioactive compounds, contained in different quantities depending on the fungal species and growing conditions, are the most varied, including polysaccharides and especially ß-glucans, dietary fibers, phenolics, peptides, terpenes, glycoproteins, ergosterols, alcohols, unsaturated fatty acids (UFA), lectins, tocopherols, ascorbic acid, carotenoids and others (Barros et al. 2008; Rathore et al. 2017; Reis et al. 2017; Ma et al. 2018; Islam et al. 2019).

As for the genus *Pleurotus*, many species belonging to it have shown activity against various chronic diseases in various studies, thus with a wide spectrum for potential biotechnological applications. They possess numerous bioactive compounds such as polysaccharides, lipopolysaccharides, proteins, peptides, glycoproteins, nucleosides, triterpenoids, lectins, lipids, and their derivatives (Patel et al. 2012; Talkad et al. 2015; Golak-Siwulska et al. 2018). Fruiting bodies possess higher concentration of antioxidants than other commercial mushrooms (Talkad et al. 2015); the AOX properties of different kinds of *Pleurotus* extracts efficiently contrast reducing the occurrence of age-associated disorders like stroke, Parkinson's disease, atherosclerosis, diabetes, cancer, and cirrhosis (Patel et al. 2012); they help also to reduce the severity of inflammatory skin disease and regulate hyperpigmentation disorders (Taofiq et al. 2016).

Pleuran is the polysaccharide isolated from *Pleurotus* spp. A variety of properties such as immunomodulatory, antitumor, AOX, antiviral and antimicrobial, and anti-inflammatory. It was also found that by including 100 mg of Imunoglukan in the diet of elite athletes, the suppressed immune system responses induced by short-term high-intensity exercise decreased (Bobovcˇa´k et al. 2010).

Studies have remarked also on the importance of proteins isolated from *P. ostreatus* and *P. eryngii* (pleurostrin and eryngin) as an effective antifungal and antibacterial agents (Carrasco-Gonza´lez et al. 2017). Many bioactive compounds of *Pleurotus* spp. and their properties are reported in Table 6.

A. bisporus is also of increasing importance thanks to the innumerable medicinal properties of its bioactive extracts and compounds, which make it suitable against many human diseases such as coronary heart diseases, diabetes mellitus, bacterial and fungal infections, disorders of the human immune system, and cancers (O¨ ztu¨rk et al. 2011; Atila et al. 2017).

Even the Canadian Cancer Society recommends its consumption because of its beneficial effects against various diseases (Atila et al. 2017). The high dietary fiber and antioxidant content of this mushroom, including vitamins C, D, and B12, as well as folate and polyphenols have positive effects on diabetes and cardiovascular diseases (Atila et al. 2017).

Moreover, the prebiotics contained in the fruiting bodies has a positive influence on gut health. A study conducted by Hess et al. (2018) has shown that, compared to meat, the consumption of mushroom may impact laxation in healthy adults. It is demonstrated by the increase in stool weight and presence of undigested mushrooms in stool and by the different fecal microbiota composition, with a greater abundance of Bacteroidetes and lower presence of Firmicutes.

In vivo tests on mice have shown analgesic and antipyretic properties comparable to that of the common drug diclofenac (Bose et al. 2019). As reported by Ismaya et al. (2020), recently a new molecule from *A. bisporus* has been discovered; is a mannose-binding protein (Abmb) that might be employed as a drug carrier for oral administration due to its capability to permeate a dialysis bag made of fresh jejunum ex vivo, that doesn't suffer alterations in a bioconjugation with a drug model, and to its resistance to the harsh gastrointestinal tract (Ismaya et al. 2020). Some activities and compounds of *A. bisporus* are reported in Table 7.

Other mushrooms already mentioned, which can be found spontaneous or cultivated in Italy, are still less studied compared to the previous ones. This is also due to the fact that their consumption is often smaller in quantitative terms or less widespread. Some of the studies carried out to date are reported in Table 7. They reveal the enormous therapeutic potential of these mushrooms, as well as the benefits that their more frequent inclusion in the diet would bring to the individual's state of health.

As far as truffles are concerned, most of the studies carried out refer to the culinary aspect, analyzing their composition and focusing mainly on the volatile components responsible for their particular aroma and flavor.

In recent years, studies on the therapeutic potential of this type of food are increasing.

It has been seen, in fact, as *Tuber* spp. have numerous bioactive compounds, with properties ranging from anti-tumor to anti-inflammatory, antioxidant, hepatoprotective, anti-cholesterolemic, and even antidepressant. In Table 7 some bioactivities of this genus are reported.

A more recent topic concerns the nutraceutical benefits of UV irradiation of cultivated *A. bisporus* and *P. ostreatus* to generate high amounts of vitamin D2 and to maintain the ability of the fungus to inhibit glycation of a target protein (Gallotti and Lavelli 2020). Besides polysaccharides from cultivated *Rubroboletus sinicus* (W.F. Chiu) Kuan Zhao & Zhu L. Yang showed high inhibitory effects on glycation (Liping et al. 2016). A medium-molecular-weight fraction obtained by sclerotia of *Lignosus rhinocerus* (Cooke) Ryvarden contain bioactive compounds which exhibit potent anti-glycation activity and is eligible for preventing diabetic complications by Advanced Glycation End Products (AGE) (Yap et al. 2018).

Table 6 Bioactivities of *Pleurotus* spp

Activity	Bioactive compound or extract	*Pleurotus* species	Mechanisms of action	References
Anti-oxidative	Lectins	*P. ostreatus*	Activation of Toll-like receptor 6 signal pathway of dendritic cells	Ma et al. (2018)
	Polysaccharides	*Pleurotus* spp.	Improved activity after polysaccharides sulphonation,	Li and Shah (2016)
		P. ostreatus	Increase of the activity of SOD and consequent inactivation of superoxide radicals;	Islam et al. (2019)
			Increase of CAT activity by upregulating gene expression and consequent prevention of the cells from hydrogen peroxide toxicity;	Islam et al. (2019)
			Reduction of GPx activity and increase of GR, GST and APx activity	Islam et al. (2019)
		P. eryngii *P. ostreatus*	Activation of SOD, CAT and GPx and decreasing ALT in mice with CCl_4-induced liver injury;	Carrasco-González et al. (2017)
			Inhibition of lipid peroxidation on porcine brain homogenates	Carrasco-González et al. (2017)
		P. eryngii	Inhibition of cell viability in colorectal adenocarcinoma cell line (HT29)	Cateni et al. (2018)
	Phenols	*P. ostreatus*	Inhibition of the growth of HL-60 cells by inducing apoptosis	Patel et al. (2012) and Vanamu (2012)
	Flavonoids, ß-carotene, ascorbic acid	*P. ostreatus*	Inhibition of the growth of HL-60 cells by inducing apoptosis;	Patel et al. (2012) and Vanamu (2012)
			Reduction of ascorbate radicals	Islam et al. (2019)
	α-tocopherol (Vitamin E)	*P. ostreatus*	Prevention of lipid peroxidation in cell membranes	Islam et al. (2019)
	Glutathione	*Pleurotus* spp.	Prevention of GSH oxidation and assurance of the safety of its redox enzymes	Islam et al. (2019)
	Statins (lovastatin)	*P. ostreatus*	Inhibition of the plasma and hepatic lipid peroxidation and increase of the hepatic catalase activity in high-cholesterol fed rabbits	Jeon et al. (2001)

Table 6 continued

Activity	Bioactive compound or extract	*Pleurotus* species	Mechanisms of action	References
Immunomodulatory	Polysaccharides	*Pleurotus* spp.	Macrophage stimulation	Corrêa et al. (2016)
		P. ostreatus	In children with RRTIs, pleuran (Imunoglukan P4H®) increases immunoglobulin isotypes, slows down the decline of T-cytotoxic lymphocytes, and e increases the NK cell number	
		P. nebrodensis	PN-S evaluated in RAW264.7 macrophage; improved phagocytosis of macrophages, enhanced production of f interleukin-6 (IL-6), nitric oxide (NO), interferon gamma (INF-γ), and tumor necrosis factor-a (TNF-α) in the macrophages, with up-regulation of mRNA expressions of interleukin6 (IL-6), inducible nitric oxide synthase (iNOS), interferon gamma (INF-γ) and tumor necrosis factor-α (TNF-α)	Corrêa et al. (2016)
		P. ostreatus	Immunomodulatory activity against infectious bursal disease (IBD) in broilers;	Islam et al. (2019)
			Decrease of the toxicity of cyclophosphamide in mice	Islam et al. (2019)
	Triterpenoids (i.e. ergosterol) and steroids	*Pleurotus* spp.	Not specified	Gargano et al. (2017)
Anti-inflammatory	Polysaccharides (ß-glucans)	*P. ostreatus*	Synergistic effect with methotrexate in arthritis induced rats	Carrasco-González et al. (2017)
	Aqueous extract	*P. ostreatus*	Inhibition of DNA-binding activity of AP-1 and NF-kB in RAW264.7 cell line and suppression of the secretion of TNF and IL-6 in a mice model;	Carrasco-González et al. (2017) and Patel et al. (2012)
			Reduction of NO and TNF-a production in murine macrophage cell line RAW264.7	Carrasco-González et al. (2017)
	Pleuran	*P. eryngii*	Suppression of inflammation in delayed type (type IV hypersensitive) allergy response in mice	Patel et al. (2012); Talkad et al. (2015)
	Phenols (ethanolic extract)	*P. eryngii*	Suppression of induced dermatitis and decrease of serum level of IgE and TARC as well as expression of cytokines related with inflammation (TNF-a, INF-g, IL-4, IL-5 and IL-13) and severe skin lesions in mice	Carrasco-González et al. (2017) and Ma et al. (2018)

Table 6 continued

Activity	Bioactive compound or extract	*Pleurotus* species	Mechanisms of action	References
Antihypercholesterolemic	Statins (Lovastatin)	*P. ostreatus*	Inhibition of 3-hydroxy-3-methylglutaryl coenzyme A (HMG CoA) reductase that catalyzes the conversion of HMGCoA to mevalonic acid in the cholesterol synthesis pathway; pleiotropic actions in the cardiovascular, immune and nervous systems;	Talkad et al. (2015)
			Inhibition of the plasma and hepatic lipid peroxidation and increase of the hepatic catalase activity in high-cholesterol fed rabbits;	Jeon et al. (2001)
			Acceleration of HDL, reducetion of production of VLDL, LDL, cholesterol; reduction of cholesterol absorption and of HMG-CoA reductase activity in the liver;	Patel et al. (2012)
			Positively affect the coagulation system and fibrinolysis	Golak-Sivulska et al. (2018)
	Flavons (Chrysin)	*P. ostreatus*	Decrease in mean blood/serum levels of glucose, lipid profile parameters, and hepatic marker enzymes and a concomitant increase in enzymatic and nonenzymatic antioxidant parameters in hypercholesterolemic rats	Anandhi et al. (2013)
Anti-cancer and anti-tumor	Cold-water extract	*P. eryngii* var. *ferulae* *P. nebrodensis*	On human colon cancer cells: inhinition of viability of HCT116 cells; promotion of apoptosis; increase of *Bax*-to-*Bcl-2* messenger RNA ratio; inhibition of cell migration and effect on homotypic and heterotypic cell–cell adhesion; negative influence on protein tyrosine and phosphorilation levels of extracellular signal-regulated kinase 1/2	Fontana et al. (2014)
	Methanolic extract	*P. ostreatus*	In breast cancer: suppression of different cell lines proliferation (MCF-7, MDA-MB-231);	Chaturvedi et al. (2018)
			Induction of expression of tumor suppressor p53 and cyclin-dependent kinase inhibitor p21	Carrasco-González et al. (2017)

Table 6 continued

Activity	Bioactive compound or extract	*Pleurotus* species	Mechanisms of action	References
	Polysaccharides	*P. eryngii*	In mice with renal cancer: increase of relative thymus and spleen lymphocytes proliferation by elevated activity of NK cells and CTL in spleen; increase of serum concentration level of TNF-α and IL-2;	Chaturvedi et al. (2018)
			Inhibition of tumor growth and increased relative thymus and spleen indices	Zhang et al. (2016)
		P. ostreatus	Inhibition the development of Ehrlich Tumor (ET) and Sarcoma 180 (S-180)	Carrasco-González et al. (2017)
		P. nebrodensis	Apoptosis induction by reduction of mitochondrial membrane potential and changes in migration cell rate	Carrasco-González et al. (2017)
		P. ostreatus	Cytotoxic activity towards HeLa cell lines	Golak-Sivulska et al. (2018)
		P. citrinopileatus Singer	Cytotoxic activity to cervical cancer cells (and no to normal cells)	Golak-Sivulska et al. (2018)
		Pleurotus spp.	Thymus-dependent immune mechanism, which involves the activation of cytotoxic macrophages, monocytes, neutrophiles, natural killer cells, dendritic cells, and chemical messengers (cytokines, such as interleukins, interferons., and colonystimulating factors) which triggers the complementary and acute phase responses	Rathore et al. (2017)
	Pleuran (ß-glucan)	*P. ostreatus*	Anti-neoplastic properties against different cells, including breast cancer MCF-7, prostate cancer cells PC-3 and colorectal HT-29 cancer cells	Golak-Sivulska et al. (2018)
	Proteins	*P. ostreatus*	Therapeutic effect towards the colorectal cancer cell line SW 480 and monocytic leukaemia THP-1 by inducing their apoptosis	Golak-Sivulska et al. (2018)
	Proteins (hemolysin)	*P. nebrodensis*	Strong growth inhibition (IC50 $<$ 40 mg/mL) against five cancer cell lines (Lu-04, Bre-04, HepG2, L929 and HeLa) and apoptosis induction in L929 and HeLa cell lines	Carrasco-González et al. (2017)

Table 6 continued

Activity	Bioactive compound or extract	*Pleurotus* species	Mechanisms of action	References
	Lectins	*P. ostreatus*	Reduction of tumor burden in Sarcoma S180 (88.4%) and hepatoma H-22 (75.4%) inoculated mice and increase of the survival time	Carrasco-González et al. (2017)
	Ethanolic extract	*P. eryngii* var. *ferulae*	Inhibition of growth and proliferation of stomach (BGC 823) and melanoma (B16F10) cancer cells;	Carrasco-González et al. (2017)
			Induction of cell cycle arrest in G0/G1 of stomach and melanoma cancer cell lines;	Carrasco-González et al. (2017)
			Delay and reduction of melanoma tumor growth in a murine model	Carrasco-González et al. (2017)
	Laccase	*P. cornucopiae*	Inhibition of proliferation of the hepatoma cells HepG2, the breast cancer cells MCF-7	Wu et al. (2014)
	Monoterpenes and sesquiterpenoids (Pleurospiroketal)	*P. cornucopiae*	Cytotoxicity against cancer line	Rathore et al. (2017)
	Triterpens	*P. eryngii*	Inhibitory activity against breast cancer MCF-7 cell lines in vitro	Zhang et al. (2016)
Antihypertensive	Aqueous extract	*Pleurotus* spp.	High angiotensin l-converting enzyme (ACE) inhibition	Carrasco-González et al. (2017)
	Hot water extract D-mannitol Oligopeptides	*P. cornucopiae*	ACE inhibition in vitro and antihypertensive effect on spontaneously hypertensive rats	Carrasco-González et al. (2017)
	Not specified	*P. ostreatus*	Pressure lowering activity	Patel et al. (2012)
Antiviral, antimicrobial	Nebrodeolysin	*P. nebrodensis*	Inhibition of the viral cytopathic effect of HIV-1	Carrasco-González et al. (2017)
	Laccase	*P. ostreatus*	Antiviral effects against hepatitis C	Golak-Sivulska et al. (2018)
	Ubiquitin-like protein	*P. ostreatus*	Antiviral effects against HIV-1 viruses	Carrasco-González et al. (2017)
	Lectin	*P. citrinopileatus*	Potent effect against HIV-1 reverse transcriptase activity	Carrasco-González et al. (2017)
	Water-soluble sulfonated polysaccharides	*P. eryngii*	Inhibition in growth of pathogenic *Escherichia coli*, *Staphylococcus aureus* and *Listeria monocytogenes*	Carrasco-González et al. (2017)
	Nanoparticles synthesized through mixing queous extract with silver nitrate	*P. cornucopiae*	Remarkable antifungal effects	Carrasco-González et al. (2017)
	Nanoparticles synthesized through mixing a silver solution with aqueous extract	*P. ostreatus*	Inhibition in Gramnegative bacteria growth	Carrasco-González et al. (2017)

Table 6 continued

Activity	Bioactive compound or extract	*Pleurotus* species	Mechanisms of action	References
	Aqueous extract	*P. ostreatus*	Inhibition in replication of Herpes simplex virus type 1 in vitro	Carrasco-González et al. (2017)
	Polysaccharides	*Pleurotus* spp.	Activation of the microbial autolytic system of eight strains: seven autolyzing strains with intensity values ranging from 2.7% in *Candida* sp. to 36.1% in *Saccharomyces cerevisiae*, while autolysis was of 1.8% in one non-autolyzing strain (*Bacillus cereus*)	Corrêa et al. (2016)
	Methanolic extract	*Pleurotus* spp.	Inhibition in growth of *Bacillus megaterium*, *S. aureus*, *E. coli*, *Klebsiella pneumoniae*, *C. albicans*, *C. glabrata*, species of *Trichophyton* and *Epidermophyton*	Patel et al. (2012)
	Ether and acetone extract	*P. ostreatus*	Effective against *B. subtilis*, *E. coli* and *S. cerevisiae*	Patel et al. (2012)
	Ethanolic extract	*P. ostreatus*	Inhibition in growth of Gram positive bacteria (*Listeria innocua*, *B. cereus*, *Staphylococcus aureus*), Gram negative bacteria (*E. coli*, *Pseudomonas aeruginosa*), and yeast (*Candida albicans*, *Candida* sp.)	Vanamu (2012)
	Ribonucleases	*P. ostreatus*	Potentiality to neutralize HIV through degradation of viral genetic material	Patel et al. (2012)
	Protein (hemolysin)	*P. nebrodensis*	Anti-HIV-1 activity in CEM cell culture	Patel et al. (2012)
Hyperglycemic	Guanide	*Pleurotus* spp.	Anti-hypoglycemic effect	Patel et al. (2012)
	Polysaccharides	*P. citrinopileatus*	Elevation of the activity of glutathion peroxidase	Patel et al. (2012)
Hepatoprotective	Polysaccharopeptides	*P. ostreatus*	Alleviation of thioacetamide-induced alterations, inflammation, steatosis, necrosis and fibrosis	Patel et al. (2012)
	Hot-water extract	*P. ostreatus*	Less leakage of alkaline phosphatase, less pronounced increase in hepatic malondialdehyde concentration, less notable reduction in hepatic total protein, RNA and DNA contents; in contrast, increase in hepatic superoxide dismutase, glutathione peroxidase and glutathione reductase activities	Patel et al. (2012)

Table 6 continued

Activity	Bioactive compound or extract	*Pleurotus* species	Mechanisms of action	References
Anti-Ageing	Aqueous, methanolic, and acetonic extracts	*Pleurotus* spp.	Anti-tyrosinase, anti-hyaluronidase, anti-collagenase and anti-elastase activity	Taofiq et al. (2016)
	Mushroom powder	*P. ostreatus* and *P. eryngii*	Significant bifidogenic effect and strong lactogenic effect, respectively	Mitsou et al. (2020)
	Extracts	*P. ostreatus*	Lowered levels of malondialdehyde, a polyunsaturated lipid and an electrophilic mutagen, on administration of mushroom extract to aged rats, and subsequent reaction with deoxyadenosine and deoxyguanosine in DNA, forming a DNA adduct	Patel et al. (2012)

(To be continued)

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