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RESEARCH ON BIOCONVERSION OF LIGNOCELLULOSIC WASTE FOR THE CULTIVATION OF BIOCOMPOUNDS PRODUCING MACROMYCETES

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Abstract

Macromycetes are a topic of great interest for researchers around the globe and in our country, mushrooms being well-known for their nutritional, gourmet and medicinal values. In line with current ecological trends, a sustainable solution for environmental protection is to produce mushrooms by bioconversion of some lignocellulosic waste/by-products of agro-forestry origin and therefore to examine the qualitative and quantitative impacts of multiple substrate recipes upon mushroom production. Assiduous research has improved the biotechnologies for the production and propagation of mycelium used for seeding spawn, in parallel with obtaining and characterization of extracts rich in bioactive compounds from both mycelium and fruiting bodies of edible and medicinal species of macromycetes. This review proposes a current presentation of the knowledge at the intersection of these research directions, focusing on their applications, targeting the species of the genus Pleurotus.

Key words*: biocompounds , bioconversion, macromycetes, mycelia, Pleurotus spp.*

INTRODUCTION

A future-oriented bioeconomy, based on renewable resources for replacing petroleum materials and chemicals, can fulfill important environmental, social and economic requirements for a sustainable development of modern society. Many innovative products and materials derived from renewable sources have already been developed in the context of the green economy concept. A sustainable waste management strategy might be successfully implemented by cultivating the well-known group of oyster mushrooms for the bioconversion of agro-industrial wastes achieved by myco-remediation in an economically efficient manner (El-Ramady et al., 2022). Lignocellulosic matter, found in agricultural, industrial and forest residuals accounts for more than half of all vegetal biomass produced on the planet and is used in biotechnological applications including cosmetics, medicines, foods and feeds, biofuels, biopesticides, biofertilizers and a variety of other products. This scientific overview is focused on the recovery of lignocellulosic residues from different industries for the generation of nutritious and suitable substrates for the cultivation of edible and/ or medicinal macromycetes.

Edible mushrooms have been a component of human civilization from the ancient period. They've made a significant contribution to mankind's history due to their organoleptic and appealing culinary traits, edible species gaining enormous popularity. Mushrooms are trendy these days due to their multiple nutritional and health benefits (Fulgoni and Agarwal, 2021). Mushroom industrial cultivation, as a notable biotechnological process, displays a worldwide expanded and economically valuable industry that generate protein rich foods by fungal bioconversion of cellulosic materials. *Pleurotus* species are the second most widely cultivated edible mushroom in the world after *Agaricus* spp. Many edible species of macromycetes with significant therapeutic, biotechnological, gourmet and environmental applications are present in this genus (Comandini and Rinaldi, 2020; Melanouri et al., 2022). In recent years, the worldwide production of *P. ostreatus* was estimated to be more than 4.1 million tons, being cultivated on a variety of lignocellulosic based substrates (Hřebečková et al., 2020).

Unlike some other species, *Pleurotus* spp. (oyster mushrooms) are the simplest, fastest and least expensive to cultivate, with more than 100% biological efficiency, which combined with its distinct flavor, aroma and excellent drying and preservation qualities, secures its status as a delicacy. The cultivation of *Pleurotus* mushrooms for the recovery and reuse of lignocellulosic biomass provides an opportunity to use renewable energy sources in the production of protein-rich aliments that might ensure food security for people in underdeveloped countries. Mushrooms cultivation is one of the most economically effective methods for the bioconversion of lignocellulosic wastes (Cohen et al., 2002; Sanchez et al., 2002).

Mushrooms are rich in high-quality protein, have a large amount of dietary fibers and contain numerous vitamins and minerals. The presence of secondary metabolites isolated from both mushroom fruiting bodies and mycelia is responsible for the multidirectional health promoting and therapeutic applications. The biologically active compounds found in oyster mushrooms include polysaccharides, peptides, proteins, terpenes, fatty acid esters, polyphenols etc. This biocompounds exhibit anti-diabetic, anti-neoplastic, antioxidative, immuno-stimulatory and a plenty of other human health-enchasing properties (Alam et al., 2009; Jayakumar et al., 2011; Wasser, 2014, Chilanti et al., 2022). This review summarizes the current state of knowledge regarding the recovery of lignocellulosic waste of agro-forestry origin through the cultivation of edible and/or medicinal macromycetes of the genus *Pleurotus*, an overall picture of the *in vitro* mycelium manipulation biotechnology and the production of fruiting bodies, the current level of industrialization of the entire process of obtaining the spawn and its fruiting potential in the substrate, all of that proceeding in parallel with an increased attention to the main biologically active compounds.

LIGNOCELLULOSIC BIOMASS

Because billions of tons of lignocellulosic biomasses are collected worldwide each year, researchers are increasingly interested in its recovery, being extremely essential to capitalize on the bioconversion and valorisation of these materials as efficiently and productively as possible. Improper waste disposal can have negative environmental, health and socio-economic consequences. In recent years, there has been a serious interest in converting these resources into value-added goods. Nevertheless, the potential of these materials is restrained due to the complex and rigid structure of lignocellulosic waste, which necessitates advanced depolymerisation of the three main components: lignin, cellulose and hemicellulose to break them down into victual units. These polymers are associated with each other in a hetero-matrix of varying proportions and different composition depending on the type, species and the source of the biomass (Chandra et al., 2007; Carere et al., 2008). Lignocellulose is the main constituent of both woody and non-woody plants such as grass or weeds and is a substantial source of renewable organic matter, making them a valuable source for biotechnological substrates (Table 1).

Table 1. Composition of grain straws (source: Tian et al., 2018)

Lignocellulosic biomass	% dry matter		
	Cellulose	Hemi cellulose	Total lignin
Wheat straw	30	22	17
Rice straw	31	22	13
Corn stover	38	26	17
Barley straw	34	22	14
Rye straw	31	22	25
Oat straw	39	27	18

Lignin is the most abundant natural organic polymer found in plant cell walls; an hetero polymorphic network of phenyl propane units (p-coumaril, coniferyl and synaptic alcohol) which limits the action of enzymes in the hydrolysis of lignocellulosic raw materials. Lignin is the most challenging polymer to process in the lignocellulosic biomasses preventing the enzymatic and microbiological hydrolysis of the biomass due to its tight interaction with cellulose microfibers. Chang and Holtzapple (2000) revealed that reducing lignin improves biomass digestibility. Because lignin is hydrophobic, it prevents water from penetrating the cell walls, therefore protecting cellulose and hemicellulose (Mokhothu and John, 2015), being resistant to chemical and enzymatic degradation and responsible for the preservation of lignocellulosic biomass against bacterial activity (Mussatto and Teixeira, 2010; Isikgor and Becer, 2015). Because of its challenging structural breakdown, lignin is very difficult to be depolymerized by enzymatic hydrolysis, which further impedes the decomposition and utilization of cellulose and hemicellulose. The most significant constraint to the large-scale industrial implementation of biological conversion is lignocellulose's low degradation efficiency. Because lignocellulose is very resistant to decomposition directly by microorganisms, a pretreatment is required to breakdown the structure of lignocellulose matter and subsequently depolymerize lignin (Bhatia et al., 2020), fortunately the cultivation of macromycetes does not require such treatments due to the very efficient enzymatic system of mycelia.

Cellulose is a polymer formed of ß-D-glucopyranose linked by -1,4 glycosidic bonds, the main component of the plant cell walls that provides structural support, also being found in bacteria and fungi. In nature, the degree of polymerization of cellulose chains ranges from 10 to 15 thousand units of glucopyranose. Cellulose molecules are consistently organized into microfibers, which are then grouped into cellulose fibers. The structure of cellulose is mostly determined by the existence of covalent and hydrogen bonds along with the Van der Waals forces. Hydrogen binding in a cellulose microfibril determines the linearity of the chain, but the inter-dependence of hydrogen bonds induce the structure (crystalline) or disturbance (amorphous) of the cellulosic structure. Cellulose is primarily used in the manufacture of paperboard and paper. Smaller amounts are transformed into a broad range of derivative products, including cellophane and rayon. As a sustainable energy source, cellulose from crop residues is being converted into biogas and ethanol. Because of its advantageous properties including its biocompatibility, hydrophilicity and reactive hydroxyl groups, cellulose is a versatile resource for derivate materials such as films, composites, fibers, fuels and chemicals (Baig, 2020).

Hemicelluloses are a mixture of polysaccharides and vegetable gums found in plant cell walls along with cellulose and lignin. Hemicellulose are firmly connected to cellulose microfibrils and lignin, composing a complex network of covalent linkages that provide structural support (Speight and Radovanovic, 2020). Hemicelluloses are made up of a variety of sugars including: xylose, arabinose, glucose, mannose, galactose and rhamnose. The proportion of the compounds is different depending on the type of the source, which is mostly xylan in hardwood and glucomannan in softwood. Hemicelluloses have a random, amorphous structure, with lower breakdown resistance. They are easily hydrolysed by diluted acids or bases, as well as a wide variety of hemicellulase enzymes. Because of their structural diversity, hemicelluloses can be used as thickeners, emulsifiers, stabilizers and binders in a wide range of industries including foods, cosmetic, pharmaceutical and agricultural (Spiridon and Popa, 2008). The amorphous nature of hemicellulose, as well as its low degree of polymerization and pretreatment processes, make it ideal for usage in a variety of industrial applications such as hydrogels, drug carriers and cosmetics (Ashokkumar et al., 2022).

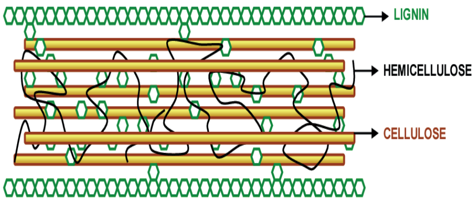

Figure. 1 Lignocellulose structure showing cellulose, hemicellulose and lignin fractions (source: Mussatto and Teixeira, 2010)

Fungi's ability to efficiently degrade lignocellulose (Figure 1) containing materials is due to their highly efficient enzymatic system. The hydrolytic system, which includes cellulase and hemicellulase that are accountable for polysaccharide breakdown, together with the ligninolytic enzymes are responsible for the transformation and degradation of the lignocellulosic biomass. The bioconversion of residues is based on the mechanism characteristic of basidiomycetes to produce enzymes called ligninases: phenol oxidases (laccase) or hem-peroxidases (mangan peroxidases and lignin peroxidases) and thus can solve the complex problem of high-cost degradation of cellulose, hemicellulose and lignin (Adebayo and Carrera, 2015; Gutiérrez-

Soto et al., 2015). The ligninolytic enzymes referenced above have applications in food processing, cosmetics, biosynthesis of fine chemicals and the production of biofuels (Kumar and Chandra, 2020).

MUSHROOM CULTIVATION

Because of their economic importance, *Pleurotus* species have been the most dynamic group of mushrooms in terms of culture expansion and production volume reported globally over the last decade. An impressive evolution of the biotechnologies involved in the production of the spawn, the biological material needed for "seeding", was implicated among with the economical worth in the spectacular development of the *Pleurotus* cultivation. According to the current systematics, *Pleurotus* species are part of the most evolved phylum of fungi - *Basidiomycota*, order *Agaricales*, family *Pleurotaceae*, genus *Pleurotus*. The main cultivated species and varieties are: *P. ostreatus, P. pulmonarius, P. columbinus, P. florida, P. citrinopileatus, P. eryngii* and *P. sajor-caju.* These lignivorous/xylophagous macromycetes sprout in nature on dead wood waste and, along with other *Pleurotus* group members, are highly effective agents for the biological recycling of a very numerous lignocellulosic agro-forestry waste or by-products from the food, textile, paper and other industries. By cultivating them, as with other edible/therapeutic mushroom species, organic matter from lignocellulosic by-products is directly converted into human food via a sustainable biotechnological process. Since the second half of the past century, the worldwide popularity of mushrooms has grown due to the development of the cultivation technique, an increased knowledge of their therapeutic benefits supported by scientific studies and the new trends in healthy diets that have required the use of rich alternative protein sources. It is intended that mushroom cultivation would become a significant industrial activity in rural development programs, resulting in economic growth for the communities. Given the technological advances, the worldwide mushroom business is in the phase of a high-tech sector in several affluent nations of Europe, Asia and America, with extremely high levels of industrialization. Edible grown mushrooms have become a symbol of recovering protein from lignocellulosic residues. Wood decomposing fungi easily consume this biomass which is linked to their ability to breakdown lignin. *Pleurotus* species have been shown to be one of the most effective lignocellulose degrading variety of white rot fungi, numerous agro-industrial by-products being used as a suitable substrate for the cultivation of *Pleurotus* mushrooms, based on the agricultural wastes that are locally available.

Mushrooms cultivation involves two main phases: obtaining the seeding spawn and the fruiting bodies production. Performance in mushroom cultivation, as in other horticultural crops, can only be achieved with the application of a high-quality biological material - spawn (commercial mycelium) - that provides high and consistent yields of quality mushrooms. The manufacture of commercial mycelium is the first and most important component of the intensive-industrial system of mushrooms production. Spawn is the vegetative mycelium produced on a suitable medium such as wheat grains, pearl millet, rye, sorghum etc. to produce the biological “seeding" material. The nutrient substrate/type of support on which it grows, as well as the technique employed to produce it, have a major influence on the quality of the spawn, along with microclimate parameters such as temperature, O_2/CO_2 saturation, humidity and light conditions. This process involves preparing of a pure culture of mycelia from tissues or spores, commonly maintained on many agar media, followed by inoculation on sterilized grains (premixed with calcium salts) and further colonization of the grains. The quality of the spawn is vital for the efficient mushroom cultivation. The success of production and productivity is strongly dependent on the quality and biological purity of the spawn. For the production of the spawn, the most highly advanced technological model is being applied in numerous major laboratories around the world, benefiting from current, high-capacity industrial machinery as well as top mechanization of the whole mycelium production chain. Cereal grains, water and calcium salts ($CaCO_3$ and $CaSO_4$) are combined in massive double-walled stainless steel mixers. Calcium carbonate and sulphate form a thin layer at the surface of grain caryopsis or substrate, preventing clogging and material conglomeration, therefore avoiding the initiation of fermentation processes, as well as the possibility of expanding the mycelium's growth front. $CaCO_3$ is used to raise the pH (increasing alkalinity) by neutralizing acids, and $CaSO_4$ is used to supply calcium and sulfur. The mixture is sterilized, cooled and injected with pure mycelium cultures, all in the same place. The sterilized and inoculated grains are then distributed in polypropylene bags/sacks equipped with microbiological filters and placed for incubation in dedicated rooms under rigorous air sterility control. Within the upgraded technologies applied in some laboratories provided with modern equipment, some firms use "liquid" mycelium as an inoculation source for generating commercial mycelium (spawn). Submerged cultures provide an increased rate of mycelium growth into the substrate that reduce the duration of the production, hence, a reduction of time and costs, lowering the contamination risk and ensuring the biological purity. Different growing techniques and substrate types are employed for submerged cultivation of medicinal and edible species depending on the physiological and morphological properties of the mycelia and their behavior in different environmental situations.

A successful growth of submerged cultivated mycelium can be ensured by increasing the accessibility of nutrients from the culture medium and enriching it with sources of organic nitrogen, carbon and minerals. To generate submerged mycelial biomass from most macromycetes, cultivation media including glucose, peptone, yeast extract, minerals and vitamins in various forms are frequently applied. This implicitly leads to a rise in the nutrient content of the mycelium, which has a good impact on fruiting, harvest quantity and quality. After complete colonization, the spawn is stored under refrigerated conditions, regardless of the technique used for production. The spawn is sent directly to the mushroom growers in the same container in which it was grown and obtained, transforming the technological recipient into commercial packaging, the risk of contamination during distribution preparation is reduced, the technological process is standardized and the production cost of the biological product is less expensive. Mushrooms are highly effective biological recyclers of various lignocellulosic residues from agro forestry, food, textile, paper and other industries.

Table 2. Agro-industrial wastes chemical composition (source: Sadh et al., 2018)

Agro-industrial wastes	Wastes chemical composition (% w/w)				
	Cellu lose	Hemi-cellulose	Lignin	Ash	Moisture
Sugarcane bagasse	30.2	56.7	13.4	1.9	4.8
Corn stalks	61.2	19.3	6.9	10.8	6.40
Sawdust	45.1	28.1	24.2	1.2	1.12
Barley straw	33.8	21.9	13.8	11	_
Cotton stalks	58.5	14.4	21.5	9.98	7.45
Oat straw	39.4	27.1	17.5	8	_
Sunflower stalks	42.1	29.7	13.4	11.17	_
Wheat straw	32.9	24.0	8.9	6.7	7

For the fruiting bodies production, residues (Table 2) such us cereal straws, corn cobs, cotton stems, various grasses and plants, maize or sorghum stover, sugarcane bagasse, corn husks, coffee pulp/husk, cotton and sunflower seed hulls, rice husks, sawdust and woodchips are some examples of residues and by-products that can be recovered and transformed to higher value and suitable substrate components degraded by mycelia (Pandey et al., 2000b; Webb et al., 2004; Sadh et al., 2018). Substrates for the cultivation of edible mushrooms require varied degrees of pretreatment, heat treated done by pasteurization or sterilization, to assure the exclusion of other organisms for the mycelium to grow. The substrate must be rich in essential nutrients that are accessible for the mycelium to feed on. After obtaining commercial mycelium, the technological flow proceeds with its seeding in the substrate and fructification, including the following phases of the process:

1. Raw and auxiliary materials are typically processed/ chopped into adequate sizes using a suitable machine.
2. The lignocellulosic materials are then moistened with water. This procedure can be performed out in different ways:

a) by laying the materials in compacted and irrigated layers, with the possibility of draining and recirculating the liquid flow; 24-48 hours;

b) by total immersion in a container; 24-48 hours;

3. Depending on the technological system used and the availability of steam, thermal disinfection or sterilization of lignocellulosic materials can be achieved in a variety of ways:

a) hot water treatment: sunken lignocellulose material can be brought to and maintained at 75-85°C for a few hours before cooling progressively;
b) large amounts are treated by direct steam action in thermally insulated pasteurization chambers/ tunnels equipped with ventilation and temperature monitoring systems; the steam treatment lasts 12-24 hours depending on the temperature to which the cellulose mixture is exposed (60-80°C);
c) sterilization at 121-123°C for 90-100' for experimental batches or for certain species who require substrate microbiological purity.

4. The next stage is to administer the calcium amendments: chalk (4-6%), plaster (3-5%) or in some cases whitewash (2-3%).

5. "Seeding" is performed by the combination of substrates and commercial mycelium. The average spawn inoculation rate is 2-4%.

6. The inoculated substrate is dispersed in polyethylene or polypropylene bags using modern equipment, which maximizes performance and diminishing contamination risk. Bags of various sizes and capacities can be used, with either opaque or clear foil. The bags are pierced to enable gas exchange between the substrate and the external environment and subsequently fruiting at this level. To avoid overheating of the seeded substrate during incubation, the diameter of the bags should not exceed 50 cm.

7. The optimum temperature for incubation is in the range of 24-26°C within the substrate and will be 3-5°C higher than the air in the room throughout the incubation due to the rapid metabolism of the developing mycelium. As a result, special care is necessary to control the temperature in the incubation room within normal ranges in order to avoid heating of the substrate (temperatures beyond 29-30°C), which would result in the demise of the *Pleurotus* spp. mycelium. Ventilation is less necessary at this stage since the mycelium is encouraged to grow by a higher CO_2 content in the air, but vigorous air quality control is required. Light is not required at this stage of development. The incubation period spans from 15 to 22 days, depending on the species and cultivated strain, as well as the microclimate factors, particularly the temperature.

8. Unlike *Pleurotus ostreatus*, where a negative shock is required for the appearance of primordia, hybrids do not require a thermal shock to promote fruiting. Bags/ sacks are placed in fruiting conditions for the appearance of primordia by either keeping them in the same spaces where the incubation and significant modification of the microclimate conditions (monozonal system) or transferring them in facilities with climate specific to the stage of fruiting-harvesting (bizonal system). The climate conditions needed during this phase vary based on the species or strain cultivated, have the following features and values on average: RH of 92-95% at the primordia appearance, 80-85% in full harvest wave and 85-90% between flushes; light with an intensity of 150-250 lux during waves, conversely 50-100 lux between waves; vigorous ventilation during waves to keep CO_2 concentration below 1200 ppm in the air. The best time to harvest *Pleurotus* mushrooms is during the carpophores development period, when the pileus is still slightly bulging or flat, before the margins twist upwards.

A balanced diet is a major concern in developed countries around the world in order to ensure and maintain the health and good functioning of the human body. A number of scientific studies have shown that a controlled diet can regulate human bodily processes, thereby contributing to the maintenance of health or homeostasis, which is required to lower the risk of many chronic diseases. Because mushrooms contain a higher concentration of celluloid substances, including dietary fiber, they are used as a low-calorie diet with a higher therapeutic value for diabetic patients.

Figure 2. *Pleurotus* mushrooms (*P. ostreatus, P. citrinopileatus, P. eryngii, P. columbinus*) - "Mushroom laboratory" - RDIVFG

Mushrooms (Figure 2) began to be used increasingly frequently as dietary supplements in the treatment of various diseases and health problems. Many of these actions and new applications have been developed over the last decades. Edible mushrooms contain high-quality protein that can be synthesized with greater biological efficiency than animal protein. They are high in fiber, minerals, vitamins and have a low crude fat content, with a high amount of polyunsaturated fatty acids relative to total fatty acid content. These qualities are important contributors to mushrooms longstanding status as healthy foods. Macronutrient content of *Pleurotus ostreatus* are shown in Table 3.

Table 3. Macronutrients of *P. ostreatus* (source: Khan et al., 2010)

Nutrients Content (g/100 g dried mushroom)	
Proteins	17-42
Carbohydrates	37-48
Lipids	0.5-5
Fibers	24-31
Minerals	4-10
Moisture	85-87%

Mushrooms are an inexhaustible source of immunomodulatory biologically active compounds with clinically established effects in the treatment of tumor, infectious and immunologic illnesses. Currently, over 270 fungus species are known for their varied qualities (antimicrobial, antioxidant, anti-inflammatory and hepatoprotective).

Mushrooms possess biocompounds (Table 4) such as glucans and protein-polysaccharide complexes with therapeutic qualities including antitumor, antioxidant, hypoglycemic, anti-inflammatory and antimicrobial (Dufosse et al., 2021; Jovanovic et al., 2021). Vitamins are present, particularly several of group B vitamins (thiamine, riboflavin, folic acid), mushrooms being the only non-animal source of ergosterol. Mushrooms are high in K and P, but low in Ca and Na, which is ideal for hyposaline diets. Potassium is an extremely vital mineral that controls arterial blood pressure and keeps cells operating properly. The zinc content of *Pleurotus* species is often the highest. Selenium is an antioxidant that contributes in the neutralization of free radicals, avoiding cell damage and decreasing the risk of cancer and other disorders. Mushrooms have the highest selenium content of any food. They also contain vital elements such as phosphorus, zinc and magnesium (Deepak and Deepika, 2016).

Table 4. Nutrients Content of *Pleurotus* mushrooms (source: Golak-Siwulska et al., 2018)

Bioactive compounds	Species	References
β-glucans	*P. ostreatus*	Jedinak et al., 2010
α-glucan	*P. ostreatus*	Lavi et al., 2006; Wu et al., 2011
proteins	*P. ostreatus* *P. nebrodensis*	Wang and Ng, 2000 Lv et al., 2009
polysaccharides proteoglycans lectin	*P. ostreatus* *P. ostreatus* *P.citrinopileatus* *P. ostreatus*	Tong et al., 2009 Sarangi et al., 2006 Li et al., 2008 Wang et al., 2000
polysaccharides heteroglycan	*P. ostreatus* *P. cornucopiae* *P. ostreatus*	Shamtsyan et al., 2004 Devi et al., 2013
lovastatin ergosterol	*P. ostreatus* *P. sajor-caju* *P. ostreatus*	Alam et al., 2009 Khan et al., 2011 Dissanayake et al., 2009
D-mannitol peptides	*P. cornucopiae* *P. cornucopiae*	Hagiwara et al., 2005 Jang et al., 2011

The fruiting bodies of *Pleurotus* mushrooms contain lovastatin, which belongs to the class of statins that influence cholesterol metabolism. These chemicals reduce LDL cholesterol oxidation. They are anti-inflammatory, anti-oxidative and anticoagulant (Golak-Siwulska et al., 2018). Antioxidants are protective compounds with a wide range of structures and biological functions that serve as free radical scavengers. As a result, an antioxidant is described as a substance that can prevent or slow down the oxidation of other molecules (Bita et al., 2022). Polyphenols and structural polysaccharides such as β-glucans are among the key bioactive substances produced by macromycetes.

Basidiomycetes contain an abundance of other therapeutic and beneficial metabolites such as alkaloids, flavonoids, saponins and steroids. Because of their presence, these mushrooms are valued both for their consumption and for the industrial applications in the production of new pharmaceuticals. The discovery of the synergistic action of these compounds in the human body would allow for the full utilization of oyster mushrooms' health-promoting and medicinal potential.

CONCLUSIONS

Lignocellulose, found in agricultural, industrial and forest residuals accounts for more than half of all vegetal biomass produced on the planet and is used in biotechnological applications including cosmetics, medicines, foods and feeds, biofuels, biopesticides, biofertilizers and a variety of other products. Macromycetes have the ability to convert lignocellulosic waste materials into a wide range of products that offer multiple benefits for humans such as food, tonics, medications, feeds, fertilizers and for safeguarding and regenerating of the environment. Mycelia can secrete enzyme complexes that directly attack/degrade the lignocellulosic residues and by-products. Mushroom cultivation can not only transform these massive lignocellulosic biomass wastes into human food, but it can also produce remarkable nutraceutical products with numerous health benefits. Furthermore, mushroom production has the potential to generate equitable economic growth. Mushroom cultivation can be labour intensive and as a result the activity has the potential to create new jobs, particularly in tropical or less developed countries. Mushrooms, with their pleasant flavour, high protein content, tonic and therapeutic properties, are without a doubt one of the world's biggest emerging supplies of healthy and appetizing food for the future. A number of scientific studies have shown that a controlled diet can regulate human bodily processes, thereby contributing to the maintenance of health or homeostasis. Mushrooms began to be used increasingly frequently as dietary supplements in the treatment of various diseases and health problems.

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