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Edible Mushrooms: A Green Biotechnology and Great Nutritional Value for Improving Human Health

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Abstract

In recent years, great emergence of environmental issues such as "green biotechnology" or "white biotechnology" (in EUR) is developed. Green biotechnology can be regarded as application of microorganisms or their metabolites in food, medicine, and pharmaceutical fields. Edible mushroom is an ideal food due to the fairly high content of proteins include amino acids which are essential to human health and nutrition. Mushroom fungus is easily digested, free of cholesterol, and provides a source of dietary fiber. Fungal proteins compete successfully with animal protein foods and are healthy alternative to meat. Many studies have found that some species of mushrooms are having therapeutic properties such as antioxidant, antimicrobial, anticancer, cholesterol lowering and immuno-stimulatory effects. Consumption of mushroom-rich foods is associated with a reduced risk of cardiovascular diseases, and certain types of cancer. Mushrooms have nutraceutical properties such as prevention or treatment of Parkinson, Alzheimer, hypertension, and high risk of stroke. However, some of wild mushroom are considered to be poisonous and there has been some concern about the concentration of metals such as arsenic, cadmium, copper and lead in wild fungi. Consumption of wild fungi in normal quantities is, however, did not pose any significant health risk.

Keywords: Green biotechnology, Mushroom, Functional food, Nutraceutical, Human health

1. Introduction

Edible mushroom is an ideal food due to the presence of dietary fiber, fairly high content of protein (typically 20-30% dry matter as crude protein) which contains all of the essential amino acids, and it is free of cholesterol [1]. Mushroom describes a variety of gilled fungi, with or without stems, and the term is used more generally, to describe both the fleshy fruiting bodies of some Ascomycota and Basidiomycota. Consumption of mushroom has increased remarkably because of their desirable aroma, taste and high nutritional content [2]. Edibility may be defined by criteria that include absence of poisonous effects on humans [3]. Mushrooms consumed as practicing folk medicine are known as medicinal mushrooms [4]. Many studies have confirmed that some species of mushrooms are having therapeutic properties such as antioxidant, antimicrobial, anticancer, cholesterol lowering and immuno-stimulatory effects [5, 6, 7, 8, 9]. Mushrooms accumulate a variety of secondary metabolites, including phenolic compounds, terpenes and

steroids. Recently, many studies suggest that consumption of polyphenol-rich foods is associated with a reduced risk of cardiovascular diseases, stroke, and certain types of cancer in which polyphenol is linked to the antioxidant properties [5, 6]. Consumption of dietary antioxidants helps to prevent free radical damage. Antioxidants have the ability to scavenge free radicals by inhibiting the initiation step or interrupting the propagation step of oxidation of lipid and as preventive antioxidants which slow the rate of oxidation by several actions [7]. This review deals with the potential applications of mushroom as a functional food, medicinal and nutraceutical fungi, with special reference to recent advance in medicinal and industrial applications of mushroom for improving human health and promoting quality life.

2. Mushrooms

The word *mushroom* is most often applied to the fungi, *Basidiomycota* and *Agaricomycetes* that have a stem, a cap, and gills or pores on the underside of the cap. These pores or gills produce microscopic spores that help the fungus spread across the ground or its occupant surface. Forms deviating from the standard morphology usually have more specific names, such as "puffball", "stinkhorn", "morel", and gilled [10]. Mushrooms are often called "agarics" in reference to their similarity to *Agaricus* or their place Agaricales. Edible mushrooms are consumed by humans for their nutritional and medicinal value. Mushrooms consumed as folk medicine is known as medicinal mushrooms [10]. Deadly poisonous mushrooms that are frequently confused with edible mushrooms and responsible for some fatal poisonings include several species of the *Amanita* genus, in particular, *Amanita phalloides*, the death cap. Mushrooms growing in polluted locations can accumulate pollutants such as heavy metals [11].

2.1. History

Mushrooms have been consumed since earliest history; ancient Greeks believed that mushrooms provided strength for warriors in battle, and the Romans perceived them as the “Food of the God”. For centuries, the Chinese culture has treasured mushrooms as a health food, an “elixir of life” [12, 13]. Mushrooms were introduced into the Netherlands for the first time at the beginning of the 19th century, but it was not be until after the 1900s that they were cultivated on a large-scale in the marl mines in Limburg [12]. After 1950, there are various areas in the Netherlands specialize in the cultivation of mushrooms, mainly south of the great rivers [12]. In the last 50 years, the Netherlands has grown into the largest mushroom production country within the European Union, with an annual production of 270 million kilograms [13, 14]. Food tasters were employed by Roman Emperors to ensure that mushrooms were safe to eat and to be easily preserved [15]. This century has seen an explosion of research about the positive influence mushrooms are having on our health. About 90% of what we know of the health benefits of the mushroom has emerged in the last 10 years [16].

2.2 Identification

Identifying mushrooms requires a basic understanding of their macroscopic structure. In general, identification to genus can often be accomplished in the field using a local mushroom guide. Identification to species, however, requires more effort because a mushroom develops from a button stage into a mature structure, and only the latter can provide certain characteristics needed for the identification of the species [17]. Typical mushrooms are the fruit bodies of members of the order Agaricales, whose type genus is *Agaricus* and type species is *Agaricus campestris*. However, in modern molecularly defined classifications, not all members of the order *Agaricales* produce mushroom fruit bodies, and many other gilled fungi, collectively called mushrooms, occur in other orders of the class *Agaricomycetes* [17]. Proper identification of a species is the only safe way to ensure edibility. Some mushrooms that are edible for most people can cause allergic reactions in some individuals, and old or improperly stored specimens can cause food poisoning.

2.3 Growth and cultivation of Mushrooms

Nowadays, interest to biotechnological cultivation of mushrooms is related with the growing demand of different mushroom products in food, pharmaceutical, and cosmetic industries. Mushrooms are widely appreciated all over the world for their nutritional value and medicinal properties and considered as perspective organisms to develop different healthcare biotech-product [18]. In fact, all species of mushrooms take several days to form primordial mushroom fruit bodies, though they do expand rapidly by the absorption of fluids [19]. Cultivated mushroom as well as the common field mushroom initially form a minute fruiting body, referred to as the pin stage because of their small size. Slightly expanded they are called buttons because of the relative size and shape. Once such stages are formed, the mushroom can rapidly pull in water from its mycelium and expand, mainly by inflating preformed cells that took several days to form in the primordia [20]. Not all mushrooms expand overnight; some grow very slowly and add tissue to their fruit bodies by growing from the edges of the colony or by inserting hyphae [21]. Though mushroom fruiting bodies are short-lived, the underlying mycelium can itself be long-lived and massive.

3. Nutritive value of mushroom

The mushroom has been described as “biologically distinct and nutritionally unique” [16] and the “greatest unclaimed gift of nature” [22]. Mushrooms contain several minerals and trace elements, dietary fibers, and are also producers of bioactive molecules and valuable enzymes with different therapeutic effects. [23, 24]. Mushrooms provides around 1.5 g of fiber, which is about 5-6% of the daily fiber needs of an adult. When mushrooms are cooked and lose some water, the level of fiber rises to 2.7 g per 100 g [16]. Mushrooms provides over 20% of the daily needs for 7 essential nutrients vitamins: Thiamine (B1), riboflavin (B2),

niacin (B3), pantothenic acid (B5), biotin, and Vitamin C, besides the minerals selenium, chromium, copper, as well as Phosphorus, Potassium, Sodium, and Zinc [25, 26, 10]. Vitamin B12 is present also in mushrooms; it is the same as the B12 found in beef, liver and fish [27]. The amount of B12 naturally varies from mushroom to mushroom, providing 1-5% of the recommended daily needs of B12. Mushrooms are very useful for vegetarian diets because they provide all the essential amino acids for adult requirements [24]. Demand has developed for food [33] for special use which referred to as:

1. Superfood;
2. Functional food;
3. Medicinal; or
4. Nutraceutical food

Such food category, with documented effects, includes mushrooms as natural sources of components having a positive effect on the human health [33]. Table 1, represents the nutritional value of some edible Mushrooms.

Table 1. Nutritional value of some edible Mushrooms (dry basis).

Mushroom species	Protein %	Fat %	Ash %	Carbohydrates %	Energy kcal/kg
Agaricus bisporus	14.1	2.2	9.7	74.0	325
Lentinus edodes	4.5	1.73	6.7	87.1	772
Pleurotus ostreatus	7.0	1.4	5.7	85.9	416
Pleurotus eryngii	11.0	1.5	6.2	81.4	421
Pleurotus sajor-caju	37.4	1.0	6.3	55.3	-
Flammulina velutipes	3.87	2.89	7.2	85.99	426
Hypsizigus marmoreus	21.0	5.62	8.26	65.6	-

*Carneiro *et al*. 2013 [28]; Kalac 2013 [29]; Phan *et al*. 2012 [30]; Reis *et al*. 2012 [31]; Prasad *et al*. 2012 [32].

3.1 *Mushroom as superfoods*

Yet there is no formal definition of the term “superfood”. Such a definition of superfood might have the following characteristics [16, 22, 24, 34]:

• Minimally processed without nutrient enriching and have a high nutrient density.
• Have nutritional benefits not found in other common foods eaten in similar meals.
• Have at least 20% of the daily needs of three or more essential nutrients in a normal serve.
• Provide essential nutrients without increasing the consumption of salt, saturated fat or other compounds linked to poor health.
• Provide bioactive compounds such as antioxidants.
• Have research linking the food to a potential reduced risk of long-term disease.
• Be easily available and affordable.

Judging against these characteristics, it is indisputable that the mushroom is quite an exceptional food [34]. Mushrooms have the following benefits:

• A popular and frequently consumed fresh produce item.

• Provides nutrients in amounts not usually found in vegetables.

• Provides good nutrition without adding fat, cholesterol or sodium to the meal.

• Has an antioxidant capacity similar to, or better than, common vegetables.

• Provides bioactive compounds that appear to improve immune function and potentially lower the risk of common diseases like heart disease and cancer.

There is no doubt that the mushroom is a food that punches nutritionally well above its weight.

The mushroom has all the attributes of a superfood – nutrient-rich, flavour-rich, low joule, high in bioactive compounds, positive immune effect, widely consumed, easy-to-buy and affordable.

3.2 *Mushrooms as functional foods*

Mushrooms contain many bioactive components and have a beneficial effect on human health and well-being and should to be classified as a functional food. Many bioactive substances, derived from mushrooms, have found their use not only as a pharmaceutical but as a novel class of dietary supplement or nutraceuticals [33, 35, 36] that fall very well into the concept of functional food due to:

● Health-promoting properties of mushrooms have been shown in many studies. Effectiveness of functional food must, however, be confirmed by health claims [33]. New regulations in health claims for food can help to increase the acceptability of functional products by consumers.

● Mushroom as a functional food products should not be consumed in unlimited amounts because they may contain excessive amounts of active substances or minor toxic amounts causing potential interactions. Mushrooms may be consumed directly, or as purified fungal extracts and fungal preparations [33].

● Edible mushrooms are considered to be potential prebiotics which recognized as food components that are not digestible in the alimentary tract but have the capacity of stimulating the growth and activity of beneficial bacteria in the large intestine. This function is served by the carbohydrates contained in mushrooms, primarily chitin, hemicellulose, β- and α-glucans, mannans, xylanes and galactans [37].

3.3 *Medicinal Mushroom*

Medicinal mushrooms are mushrooms or their extracts that could be used for treatment of diseases. Mushrooms-extracted substances have been shown to possess potent antitumor activities in both pre-clinical models and clinical trials, reduce blood pressure, blood cholesterol, blood sugar level, and prevent platelet aggregation [32, 35]. The safety criteria of mushroom compounds have been exhaustively studied with little evidence of toxicity. Generally *Ganoderma* species are described as beneficial to all viscera and

non-toxic [35]. Extensive studies have confirmed the role of medicinal mushrooms for improving and promoting human health as discussed below:

3.3.1 Enhancing the immune function

Many reports have demonstrated the effectiveness of mushroom on immune function. Mushroom extracts given to mice decrease inflammation, up-regulate the immune response, enhance the action of natural killer cells, and increase the anti-cancer immune response [34, 38, 39]. Mushrooms exhibited immunomodulatory action, as they boost the immune system by the activation of dendritic cells, NK cells, T-cells, macrophages, and production of cytokines and have curative actions against a lot of degenerative diseases without having any side effects; unlike that involves in usage of synthetic drugs [22]. Numerous bioactive polysaccharides or polysaccharide-protein complexes from medicinal mushrooms appear to have immunotherapeutic properties by destruction of tumor cells and are used extensively and successfully in clinical trials for treatment of various cancers and other diseases [24]. Fungal immunomodulatory proteins are a new family of bioactive proteins isolated from mushrooms, which have shown a potential application as adjuvants for tumor immunotherapy mainly due to their activity in suppressing tumor invasion and metastasis [40]. A total of 126 medicinal functions are thought to be produced by selected mushrooms [41].

3.3.2 Cancer prevention

Mushroom has been linked to cancer prevention. Mushrooms contain compounds that kill breast cancer cells and suppress the enzymes aromatase and 5-alpha-reductase [42, 43], both thought to promote breast cancer and prostate cancer cell proliferation, respectively. The β-glucans are well known for their biological activity, specifically related to the immune system. Hence, activating and reinforcing the host immune system seem to be the best strategy for inhibiting the growth of cancer cells [44]. In China, studies on women revealed that those eating only 10 g or more of mushrooms each day reduced their risk of breast cancer by over 60% [45]. The most common mushroom consumed was the button mushroom, which was found also to reduce prostate tumor size and tumor proliferation, and increased tumor cell death, in mice [43]. Many bioactive compounds in mushroom show anti-cancer properties include β-glucans, polysaccharides, and bio-active proteins such as lectins [46, 47]. The glucans stimulate the phagocyte system (e.g., macrophages and monocytes) that consume foreign cells.

3.3.3 Cardiovascular disorders

Cardiovascular disorders (CVD) are the leading cause of death and disease burden globally, an estimated 17.3 million people died from CVDs in 2008 [48]. The prevalence of chronic illnesses is rising continuously, first and foremost due to population ageing. The CVDs such as stroke, diabetes mellitus and atrial fibrillation are strongly associated with age [49, 50]. Preventable cardio-metabolic risk factors are responsible for more than 60% of worldwide deaths from CVDs, diabetes mellitus, and chronic kidney disease [51]. Prehypertension, haemorrhagic- and ischemic stroke included smoking, alcohol use, and

physical inactivity are major risk factors for CVDs [51]. Mushroom bioactive substances are proved and promising in controlling CVD and Alzheimer's diseases, which remain a grave threat to both the developed and the developing countries. Based mainly on *in vitro, ex vivo,* cell line and animal studies, pharmaceutical role of mushrooms for treating Alzheimer's disease and cardiovascular diseases are recently discussed [51].

3.4 *Nutraceutical Mushrooms*

The term "*Mushroom Nutraceuticals*" has been coined by Chang and Buswell [52]. Mushroom nutraceuticals are traditional preparations which were used in ancient times in the form of extracts, health tonics, concentrates, fermented beverages, tinctures, teas, soups, herbal formula, powders and arid healthful food dishes [53]. Concentrations of bioactive compounds are affected by differences in strain age, substrate, cultivation, storage conditions, processing, and cooking practices. Bioactive compounds found in mushrooms can be divided into proteins, polysaccharides, (mainly β-glucans), and phenolic compounds.

3.4.1 Proteins

Bioactive proteins are an important part of functional components in mushrooms and also have great value for their pharmaceutical potential. Mushrooms produce a large number of proteins and peptides with interesting biological activities such as lectins, fungal immunomodulatory proteins, antimicrobial proteins, ribonucleases, and laccases [54]. Fungal immunomodulatory proteins are a new family of bioactive proteins isolated from mushrooms, which have shown a potential application as adjuvants for tumor immunotherapy mainly due to their activity in suppressing tumor invasion and metastasis [55]. Lectins are non-immune proteins or glycoproteins binding specifically to cell surface carbohydrates, and are proved to possess immunomodulatory properties, antitumoral, antiviral, antibacterial, and antifungal activities [24].

3.4.2 Carbohydrates

Polysaccharides are potent mushroom derived substances with antitumor and immunomodulating properties. Polysaccharides content in mushrooms, first of all β-glucans, are connected with their anti-cancer properties. The anticancer activity of β-glucans is found mainly in the β-(1→3) and (1→6) forms [22, 46]. In clinical trials, β-glucans linked with proteins showed strong antioxidant and antitumour activity than free β-glucans [56]. Natural products with fungal β-glucans have been consumed for thousands of years due to: 1) The β-glucans are not synthesized by humans and they are not recognized by human immune systems as self-molecules; as a result they induce both innate and adaptive immune responses; 2) Fungal β-glucans protect also the human immune system from pathogenic microbes and harmful effects of environmental toxins and carcinogens that impaired immune systems; 3) Fungal β-glucans protect from infectious diseases and cancer and aid patients recovery from chemotherapy and radiotherapy [57].

Polysaccharides from *Trametes versicolor* inhibits growth of infection yeast, such as *Candida albicans* [35]. Bioactive compounds and polysaccharides from the medicinal mushroom, *Hericium erinaceum*, show strong antimicrobial activity against a broad range of infectious agents [58].

3.4.3 Phenolic compounds

Phenolic compounds are secondary metabolites possessing an aromatic ring with one or more hydroxyl groups. The main characteristic of these groups of compounds is related to its antioxidant activity because they act as reducing agents, free radical scavengers, singlet oxygen quenchers, or metal ion chelators [24]. Phenolic compounds in mushrooms show a powerful antioxidant capacity; they can scavenge free radicals, reactive oxygen species, and show a wide range of physiological properties such as antiallergenic, antiatherogenic, anti-inflammatory, antimicrobial, and vasodilator effects. Moreover, phenolic compounds provide protection against several degenerative disorders, including brain dysfunction, cancer, and cardiovascular diseases [24]. In a comparison of 30 common vegetables, using three different analytical methods, mushrooms were placed in the top five for antioxidant capacity [33, 34, 59]. Studies on some mushroom species have shown to be a good source of antioxidants and phytoconstituents such as alkaloids, cardiac glycosides, saponins, flavonoids, terpens, steroids, tannins, and phenols [60, 61].

3.4.3 Lipids

Polyunsaturated fatty acids are mostly contained in edible mushrooms; thus, they may contribute to the reduction of serum cholesterol. It has been reported that a diet rich in sterols is important in the prevention of cardiovascular diseases [23]. The major sterol produced by edible mushrooms is ergosterol, which shows a great antioxidant properties. One antioxidant in particular, *ergothioneine*, is high in red blood cells, bone marrow and semen. It seems that *ergothioneine* protects the haemoglobin in red blood cells, and protects monocytes against oxidation [33, 34]. The red blood cells deliver *ergothioneine* to other cells where it can protect them against oxidative stress [33].

6. Safety of Mushrooms

Mushrooms are extensively used in cooking, in many cuisines (notably Chinese, Korean, European, Japanese and Indian). Mushrooms are known as the "meat" of the vegetable world [62]. The mushroom *Agaricus bisporus* contains carcinogens called hydrazines. These carcinogens are, however, destroyed by moderate heat when cooking. Types of edible mushrooms are represented in Fig. 1 [63].

Separating edible from poisonous species of mushrooms requires careful attention to detail. There is no single trait by which toxic or edible mushrooms can be identified. Additionally, even edible mushrooms may produce allergic reactions in susceptible individuals, from a mild asthmatic response to severe anaphylactic shock [64]. So, careful attention should be taken when wild type edible mushrooms are used and to avoid mistaken identity as well Fig. 2 [63].

Fig.1. Types of edible mushroom: A, Morel - *Morchella spp.*; the white mushroom; B, *Agaricus bisporus*, one of the most widely cultivated and popular mushrooms in the world; C, the gold-yellowish or brilliant orange color mushroom, chanterelles; and D, Oyster mushrooms [63].

Fig.2. Types of poisonous mushrooms: (*left image*), *Amanita phalloides* (death cap) accounts for the majority of fatal mushroom poisonings worldwide; (*middle image*) *Jack-O-Lantern*; and (*right image*) false Morel [63].

7. Toxic Mushrooms

A number of species of mushrooms is poisonous, and consuming some of them could be fatal. Mushroom poisoning refers to harmful effects due to ingestion of toxic substances present in a mushroom. Symptoms can vary from slight gastrointestinal discomfort to some death cases. The toxins present are secondary metabolites produced in specific biochemical pathways in the fungal cells. Although there are only a small number of deadly species, several others can cause particularly severe symptoms [65]. Mushroom poisoning is usually the result of ingestion of wild mushrooms after misidentification of a toxic mushroom as an edible species [63, 66]. The most common reason for this mistake is close resemblance in terms of colour and general morphology Fig. 3. The consequences of a misidentification about whether a mushroom is edible can be severe, sometimes fetal or even resulting in death. A majority of mushroom poisoning cases are:

● Poisoning due to mistaken identity or toxic look-alikes poisonous mushrooms that resemble edible ones [63]. Although usually not fatal, *Omphalotus* ssp., and Jack-o-lantern mushrooms, are cause of sometimes significant toxicity [66]. They are sometimes mistaken for chanterelles (Fig. 3). Both are bright-orange and fruit at the same time of year. Some types of mushrooms that are recorded with death case reports are represent in Fig. 4 [67].

● Mushrooms may be rendered poisonous by insecticides or herbicides sprayed on lawns or reserves. In addition, mushrooms are sometimes contaminated by concentrating pollutants, such as heavy metals or radioactive material [68].

● Rotten mushrooms may cause food poisoning. Mushrooms that are mushy, bad-smelling, or moldy (even of a choice edible species) may be toxic due to bacterial decay or mold. In addition, excessive consumption of mushrooms may lead to indigestion, which may be diagnosed as mushroom poisoning.

Symptoms of mushroom poisoning may vary from gastric upset to life-threatening organ failure resulting in death. Serious symptoms do not always occur immediately after eating, often not until the toxin attacks the kidney or liver, some days or weeks later [65].

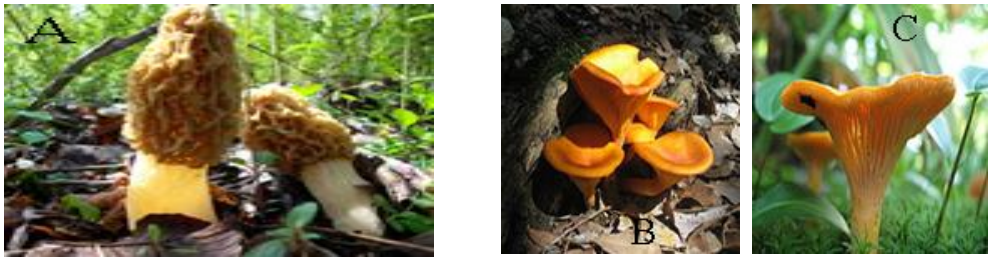

Fig. 3. Types for mistaken-identity of Mushrooms: (*Image* A), False *Morels* (at *left*) and Edible *Morels* (at *right*) [63]; (*Image* B); a poisonous mushroom (*Jack-O-Lantern*) which sometimes mistaken with a *Chanterelle* sp. (Image C) [66].

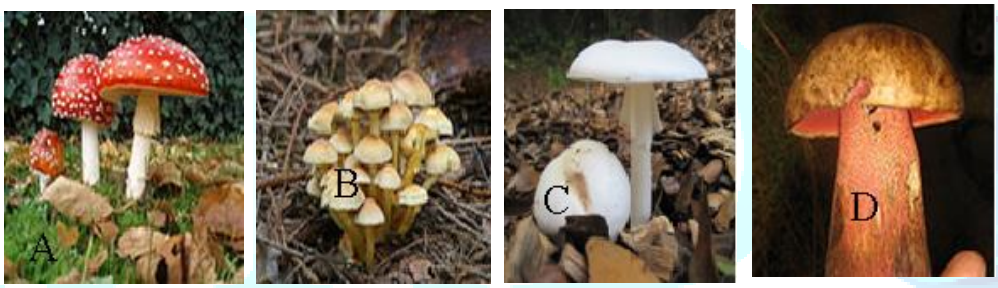

Fig. 4. Types of Mushroom where death cases have been reported: (A) *Amanita muscaria*; (B) *Hypholoma fasciculare*; (C) Destroying angels: genus *Amanita*; and (D) *Boletus pulcherrimus* [67].

8. Novel Mushroom Biotech Products

Biotech products of *Hericium erinaceus* mushrooms have been extensively used in treating Alzheimer diseases. *Hericenones* from the fruit bodies, and *erinancines* from the mycelium of this mushroom have induced the expression of neurotrophic factors such as nerve growth factor in astrocytes [69]. Healthy food developed from biotechnologically cultivated mycelia of medicinal edible mushrooms and *Tremella spp*. in combination with other natural substances (e.g., medicinal plants, algae) possesses antioxidant and immune-stimulating activity and blood glucose and lipid controlling effects [70]. *Hericium erinaceus* can be mistaken for other species of *Hericium*, all popular edibles [58, 70]. Since some mushroom products are able to decrease high glucose and lipid levels in blood they are recommended as neuro-and vasotonics, hepatoprotective and thrombolytic agents [71, 72]. There are certain commercial mushroom dietary supplements (nutraceuticals) which are produced and consumed around the world [32]. A list of such Biotech products is represented in Table 2.

Table 2. Potential nutritional value of some important "Biotech" products of mushrooms.

Mushroom species	Active Constituents/Extracts	Activity Reported
Agaricus bisporous	Fibers, Lectins	Hypocholesterolemic, Hypoglycemic
Flammulina velutipes (Curtis) Singer	Fibers, ethanolic extracts	Antioxidant, Hypocholesterolemic, Antiallergic
Grifola frondosa (Dicks.) Gray	MD-fraction, ergosterol	Antioxidant, hypotensive, Hypoglycemic, Immunotherapy, Antiinflammatory activity
Ganoderma lucidum (Curtis) P. Karst	Ganoderan A and B, glucans, Triterpenes, ganosporeric acid A, ganopoly, the polysaccharide-containing preparation	Hypoglycemic, antioxidant and antitumor, antiviral (HIV-1), Antiallergic Anti-inflammatory antihepatotoxic, inhibit the biosynthesis of cholesterol, antioxidative and free radical scavenging effects.
Hypsizigus marmoreus	Ethanolic extracts	Antioxidant, Antiallergic
Lentinula edodes (Berk.) Pegler	Methanolic and water extracts, eritadenine, lentinan, oxalic acid, ethanolic mycelial extracts.	Antioxidant, Hypocholesterolemic, Immunotherapy, Antimicrobial, antiprotozoal

* Sushila et al., 2012 [72], Prasad *et al*. 2012 [32].

8. Future perspectives

Future use of mushroom will not be solely limited to food production; exploitation of the mushroom fungi are already expanding into the fields of nutraceutical and medicine. Both developed and developing countries cultivate and sell mushrooms [24]. However, advances in cultivation technology guarantee control of a product quality, consistency, and permit modification are required to meet market demands. Current biotechnology is likely to include the demands of the market and positive response of the consumer as well as the introduction of innovative products to the market as a result of scientific innovation [23, 24]. Developing cultivation methods means applying, adapting, and integrating mushroom cultivation with waste disposal and remediation [73]. Cultivation of edible mushroom on agricultural and industrial wastes may be a valuable process capable of converting these discharges, which are otherwise considered to be wastes, into foods and feeds. *Bioremediation* through mushroom cultivation will be a support to solve two of the world's major problems i.e. waste accumulation and production of proteinaceous food simultaneously. Thus, there is a need for further research towards the exploitation of potential of mushroom as bioremediation tool and its safety aspects for consumption as product [63]. Such biological approach based on industrial and environmental biotechnology is focusing on the development of "*clean technologies*" which emphasizes on the maximum production, reduced waste generation, treatment and conversion of waste in some useful form. Further, these clean technologies focus on the use of biological methods for the remediation of waste. Mushrooms possess enzymatic machinery for the degradation of waste/pollutants and therefore, can be applied for a wide variety of pollutants [73]. Bioremediation using

mushrooms, is becoming a key feature nowadays because it is not only a bioremediation tool but also provide mycelium or fruiting bodies as a source of protein.

Conclusion

Mushrooms, in the recent years, are distinguished as important natural resource for improving human health and promoting quality life. A wide range of studies have confirmed the important nutritional value of mushrooms. Extracts and metabolites from mushroom were found to contain components with outstanding properties for prevent or treatment of diseases. Several mushrooms have been pointed out as sources of bioactive compounds, in addition to their nutritional value. The inclusion of whole mushrooms into the diet or, recently, mushroom plus species may have efficacy as potential dietary supplements. Some formulations could be used as antioxidants to prevent oxidative stress and thus ageing. Future studies into the mechanisms of action of mushroom extracts help to further evaluation of the interesting role and properties of various mushrooms in prevention and treatment of some degenerative diseases. Novel properties and health benefits that are provided for mushrooms are still, however, need further investigations to ensure high quality and safety.

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