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Nutraceutical Potential of Mushroom: Review

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Abstract: The nutraceutical potential of mushrooms is gaining gradual recognition and mushroom as such is becoming a crucial part of the diet. Mushrooms have various health benefits to offer and this article concentrates on the nutritional compositions and potential health benefits of mushrooms. The presence of bioactive compounds in edible mushroom helps to enhance their nutraceutical value. Mushrooms have versatile health benefits due to the presence of vitamins, minerals and antioxidants. Various mushroom products are gaining popularity because of their immense health benefits and eco-friendly packaging techniques. Patents filed for innovation in mushroom products and processes gives an assurance for the future of mushroom industries.

Keywords: Mushrooms, nutraceutical potential, bioactive compounds, health benefits, antioxidants, packaging.

I. INTRODUCTION

A. Origin & History

Mushrooms are macrofungi that have distinct fruiting bodies that are large enough to be seen with the naked eye and harvested by hand. Since the start of time, mushrooms have been used by humans. The usage of mushrooms as food and traditional medicines is probably as old as the human history, as evidenced by the fact that in the Bible the desert truffle (Terfezia arenaria) was described as "bread from the sky" and "manna from the Israelites" (Pegler, 2002). For nearly 300 million years, mushrooms have been a component of the fungal variety, with petrified wood going back 300 million years. Furthermore, they are a highly specialised group of fungus capable of degrading and converting a wide range of inedible plant material into valuable compounds (Teka and Chaithanya, 2019). An scientist studying the teeth of a prehistoric lady unearthed in a cave in northern Spain discovered the first indication of mushroom eating around 19,000 years ago. Plant pollen and mushroom spores were found on the plaque, indicating that they were consumed even in the stone period (Richard, 2015).

There is a scarcity of well-organized material on the history of mushroom farming. The use of mushrooms as natural foods may be dated back to the Chou Dynasty in ancient China (900 B. C.). Even yet, there is relatively little information known on the origins and early growth of mushroom farming (Liu, 1958). "Put a cooked bran on logs," stated Tang Ying-chuan of the Tang Dynasty. "Then cover it with straw and the Wood Ear (Auricularia auricula-judae) would grow." It implies that the first edible fungus to be cultivated is the Auricularia species (Chang, 1977). Then there's the A. bisporus (white button mushroom), which was farmed in vast limestone quarries in Paris in the 1600s by composting horse dung and straw. The mushroom mycelium was then put into the compost, where it thrived, and the procedure is still used today. Industry has progressed to large-scale production of edible mushrooms all over the world in the last 50–100 years. Every year, around 10,000,000 tonnes of mushrooms are produced, with Agaricus mushrooms accounting for 40%, Oyster mushrooms for 25%, and Shiitake mushrooms accounting for 10% of total global output. Asia is now the dominating region in the worldwide mushroom production industry, with China being the world's largest mushroom producer.

II. CHARACTERIZATION OF MUSHROOMS

Mushrooms are classified as members of the Kingdom Fungi, Phylum Basidiomycota, and Subphylum Agaricomycotina, respectively. The term "mushroom" is a catch-all term encompassing all 38,000 species that morphologically resemble Agaricus bisporus, the white button mushroom. Other particular names for species that deviate from this conventional shape include "bolete," "puffball," "stinkhorn," and "morel." Mushrooms and fungus in general are chlorophyll-deficient creatures that may be divided into three types: saprophytic, parasitic, and symbiotic (Hay, 1887). Some mushrooms are recognised for their nutritional and medicinal qualities in addition to their use as food. Other deadly mushroom species, commonly referred to as "toadstool," cause fatal incidents every year, primarily owing to misidentification because they closely resemble edible mushrooms. Poisonous mushrooms such as Amanita sp. and others may lead to fatal necrosis of the liver. Often known as the death cap, Amanita phalloids intoxicate people and dogs with a category of toxins called toxic cyclopeptides. A single gramme is sufficient to kill people, and even less dosages will kill canines (Brown et al. 2017) Summit.

The most common edible mushroom species that are cultivated on a commercial scale are mentioned below:

Table I: Characterization of Mushrooms

Species	Binomial Classification	Common Names	Characteristics
A.bisporus	Class: Agaricomycetes Order: Agaricales Family: Agaricaceae Genus: Agaricus	common mushroom, white mushroom, button mushroom, cultivated mushroom, table mushroom, champignon mushroom, Swiss brown mushroom, Roman brown mushroom, Italian brown mushroom, Cremini/crimini mushroom, chestnut mushroom, baby bella, portobello mushroom, portabella mushroom, portobella mushroom.	Pileus or cap: pale grey-brown in colour, hemispherical,5–10 centimetres in diameter Gills: narrow, crowded, dark brown with a whitish edge. Stipe: cylindrical, 6 cm tall, 1–2 cm wide and bears a thick and narrow ring Flesh: white, firm. Spores: dark brown, oval, approx. 4.5–5.5 µm × 5–7.5 µm, usually two-spored
P.ostreatus	Class: Agaricomycetes Order: Agaricales Family: Pleurotaceae Genus: Pleurotus	oyster mushroom oyster fungus	Cap: oyster-shaped, span 2-30 cm, white-grey/tan-dark brown, margin often lobed or wavy Flesh: white, firm, varies in thickness Gills: white-cream, descend on the stalk if present Stipe: short, thick, off-centred, lateral attachment to wood. Spores: white to lilac-grey
L.edodes	Class: Agaricomycetes Order: Agaricales Family: Omphalotaceae Genus: Lentinula	Shiitake mushroom, sawtooth oak mushroom, black forest mushroom, black mushroom, golden oak mushroom, oakwood mushroom.	Caps: 10-20 cm in diameters, attached to thin stems, light to dark brown, wide umbrella shape with curled rim Flesh: cream coloured, firm, chewy, spongy Gills: white, tightly arranged, not attached to stem, often thin veil covering present Stalk: ivory-light brown, smooth, tough, fibrous

A.auricula-judae	Class: Agaricomycetes Order: Auriculariales Family: Auriculariaceae Genus: Auricularia	wood ear black wood ear (Alternatively, black fungus, jelly ear, tree ear	Body: 3-12 cm, reminiscent of a floppy ear, sometimes cup shaped Outer surface: reddish-tan-brown with a purplish hint, often covered in tiny, downy hairs of a grey colour Inner surface: lighter grey-brown in colour, smooth, sometimes wrinkled, may have veins Stalk: very short, attached to substrate laterally
V.volvacea	Class: Agaricomycetes Order: Agaricales Family: Pluteaceae Genus: Volvariella	paddy straw mushroom straw mushroom	Young: cap is encased in thin skin, dark brown with cream coloured hue near edges and stem, short stalk, oval or egg-like shape Mature: stem is 4-14 cm, protective skin separated from cap allows it to expand to convex, broad shape, sometimes appears flat, 5-12 cm diameter, cap lightens to grey/light brown Gills: white-pink coloured depending on maturity, not attached to stem
F.velutipes	Class: Agaricomycetes Order: Agaricales Family: Physalacriaceae Genus: Flammulina	enoki mushroom, golden needle mushroom, seafood mushroom, lily mushroom, winter mushroom, velvet foot, velvet shank velvet stem	Cap: 1-7 cm, convex – flat, moist and sticky when fresh; bald; dark-orange-brown to yellowish-brown Gills: crowded, broadly or narrowly attached to stem; whitish to pale yellow Stem: 2-11 cm long; 3-10 mm thick; equal or larger towards base; tough; pale to yellowish brown or orange brown when young; becoming covered with a dark, rusty brown to blackish velvety coating as it matures Flesh: Whitish to yellowish; thin
T.fuciformis	Class: Tremellomycetes Order: Tremellales Family: Tremellaceae Genus: Tremella	snow fungus, snow ear, silver ear fungus white jelly mushroom	Body: gelatinous, watery white, 7.5 cm across Frond: thin, erect, seaweed-like, branched, crisped at edges Hyphae: clamped, dense, gelatinous matrix, haustorial cells produce filaments that attach and penetrate the hyphae Basidia: tremelloid, 10-13 µm × 6.5–10 µm, sometimes stalked Basidiospores: ellipsoid, smooth, 5–8 µm × 4–6 µm, and germinate by hyphal tube or by yeast cells.

H.tessellatus / H.marmoreus	Class: Agaricomycetes Order: Agaricales Family: Lyophyllaceae Genus: Hypsizygus	beech mushroom, also known as Bunapi-shimeji (white) and Buna-shimeji, respectively (brown).	Cap: 4–8 cm; broadly convex with a slightly inrolled margin; dry; bald; whitish to buff or light tan; generally, "tessellated" with watery spots when fresh and young. Gills: closed; attached to the stem; short-gills frequent; whitish; not bruising. Stem: 3–8 cm long, 1–2 cm thick; equal or slightly club-shaped; dry; bald or silky; whitish to very pale tan. Flesh: Firm; white; unchanging when sliced. Spores: white to light brownish-yellow
S.rugosoannulata	Class: Agaricomycetes Order: Agaricales Family: Strophariaceae Genus: Stropharia	wine cap mushroom, burgundy mushroom, garden giant mushroom, king stropharia, godzilla mushroom	Cap: reddish-brown, convex-flattening, 30cm across Gills: pale grey to dark purple-brown Flesh: white, firm Stalk: tall, bears wrinkled ring, 20cm high
C.aererita	Class: Agaricomycetes Order: Agaricales Family: Strophariaceae Genus: Cyclocybe	pioppino, velvet pioppini, poplar or black poplar mushroom, chestnut mushroom	Body: medium sized, reddish-brown to light brown, more ochre towards centre, whiter around border Cap: convex-flat, 3-10cm diameter Foot: white, fibrous, generally curved, membranous ring present on top, tobacco coloured, numeral whitish radial plates are attached Spores: light, elliptic, 8-11 by 5-7 µm
H.erinaceus	Class: Agaricomycetes Order: Russulales Family: Hericiaceae Genus: Hericium	lion's mane, Monkey head, bearded tooth, satyr's beard, bearded hedgehog, pom pom mushroom bearded tooth fungus	Body: large, irregular bulbous tubercules, 5-40 cm in diameter, dominated by crowded, hanging, spore-producing, spines (1-4cm), white-cream to yellow-brown Hyphae: monomitic, amyloid, thin-thick walled, 3-15 µm wide Basidia: 25-40 µm long, 5-7 µm wide, contains 4 spores each and basal clamp Basidiospores: white, smooth – finely roughened surface, amyloid, 5-7 µm long, 4-5 µm wide, subglobose to short ellipsoid shaped,
P.indusiatus	Class: Agaricomycetes Order: Phallales Family: Phallaceae Genus: Phallus	bamboo mushrooms, bamboo pith, long net stinkhorn, crinoline stinkhorn veiled lady mushroom.	Immature: enclosed in an egg-shaped to roughly spherical peridium Mature: develops during night, requires 10-15 hrs, emerges from peridium, 25 cm tall, girded with net-like structure (indusium) Cap: conical-bell shaped, 1,5-4 cm wide, layer of greenish-brown foul-smelling slime present usually removed by insects leaving pale off-white bare cap, small hole present on top Stalk: 7-25 cm long, 1.5-3 cm thick, hollow, white, sometimes curved, spongy, ruptured peridium remains as loose volva at the base Spores: thin-walled, smooth, elliptical/slightly curved, hyaline, 2-3 by 1-1.5 µm in size
Source: Journal of Mycology			

III. MUSHROOM AS A FOOD INGREDIENT

A. Protein

Mushrooms are mostly composed of proteins and carbs. The protein content in mushrooms is determined by a range of parameters, including the type of mushrooms, their stage of growth, the sampled part, the number of nitrogen available and their location. In comparison to meat, milk, egg and fish, the overall protein amount can be high [about 21-50 percent] (Ukwuru et al., 2018).

B. Carbohydrate

The amount of carbohydrates in mushrooms is represented by the majority of the fruiting bodies, which account for around 50 to 65 percent on a dry weight basis. Free sugar makes up around 11% of the total sugar content. Nutritional study of two edible wild mushrooms from northeast India (S. commune and L. edodes) revealed that L. edodes contained 64.4 percent carbohydrate content while S. commune contained 68 percent. Carbohydrate content was 49.20 percent, 28.38 percent, 32.08 percent, 34.88 percent, and 34.36 percent in species like C. indica, A. bisporus, P. florida, R. delica, and L. decastes, respectively. Wild mushrooms were shown to be an excellent source of carbohydrates in a research, with carbohydrate content ranging from 33.23 percent in A. auricula to 50.2 percent in L. tuberregium. The carbohydrate content of M. rhodocus was found to be the greatest in comparison to the other examined mushrooms in a proximate study of four wild mushrooms (Ukwuru et al., 2018).

C. Fat

The fat content of different mushroom species ranges from 1.1 to 8.3 percent by dry weight, with a moderate level of 4.0 percent. In general, the raw fat of mushrooms contains free fatty acids, monoglycerides, diglycerides, triglycerides, sterols, sterol esters, and phospholipids, among other lipid components. Saponifiable lipids make up a greater percentage of farmed mushrooms than non-saponifiable lipids. Saponifiable lipids in Auricularia auricula range from 78.1 percent to 58.8 percent in Volvariella volvacea. V. volvacea has a low proportion of saponifiable lipid, owing to the presence of particularly high levels of provitamin D2 and ergosterol (Ukwuru et al., 2018).

D. Vitamins

Mushrooms are an important vitamin source. Thiamine, riboflavin, pyridoxine, pantothenic acid, nicotinic acid, nicotinamide, folic acid, and cobalamin, as well as additional vitamins including ergosterol, biotin, phytochinon, and tocopherols, are abundant in group B vitamins. According to one idea, mushrooms represent a connection between yeast and other vegetal food items in terms of thiamine concentration. When comparing the most common edible mushroom species, it is discovered that Boletus edulis has the highest vitamin B content, while Lentinula edodes has more folacine, vitamin B1 and B3, but less vitamin B12 than Agaricus bisporus and Lentinula edodes. Lentinula edodes and Boletus edulis are likewise reported to have the highest levels of vitamin D. In mushrooms, vitamins that protect the skin from pellagra are abundant [about 5mg in Agaricus bisporus] (Ukwuru et al., 2018).

E. Minerals

Minerals are abundant in mushrooms. Minerals including K, P, Na, Ca, and Mg make up roughly 56 to 70% of the total ash composition. Potassium is abundant in mushrooms, accounting for about half of the total ash content. Minerals are necessary for maintaining healthy cell function and controlling blood pressure. When compared to a banana, a large portobello mushroom is high in potassium. Except for Lentinus edodes, which has an excessive quantity of calcium, other mushrooms have roughly similar sodium and calcium contents. Copper and zinc levels are extremely high in all Pleurotus species (12.2 - 2.1 ppm). Cu aids in the absorption of oxygen and the formation of red blood cells in the body. Calcium and lead concentrations in Pleurotus species vary from 0.3 to 0.5 ppm and 1.5 to 3.2 ppm, respectively. Mushrooms also contain selenium, an antioxidant that prevents cell damage and lowers the risk of cancer and other illnesses by neutralising free radicals (Deepak and Deepika, 2016).

F. Moisture Content

Harvesting time, maturity duration, environmental variables such as humidity and temperature during development, and storage conditions all influence the moisture content of mushrooms. Moisture content ranges from 70.00 percent to 93.31 percent in all mushroom species examined (Ukwuru et al., 2018).

Table II: NUTRIENT PROFILE OF MUSHROOMS

SPECIES	PROTEIN	CARBOHYRATES	ELECTROLYTES	FATS	MINERALS	ENERGY
A.bisporus	Total:3.1g Vitamin D-0.2μg Vitamin C-2.1mg Vitamin B-6 0.104 mg	Total:3.3g Dietary fiber:1g Total Sugar:5.7g Fructose:0.03g Mannitol:5.6g Trehalose:0.16g	Potassium:318mg Sodium:3mg	Total fat:0.3g Saturated fat:01g Polyunsaturated Fat:0.2g	86 mg total Selenium:16% Phosphorus:12% Iron 0.5 mg Magnesium:9mg Zinc:0.52 mg Calcium:3mg Copper:4.33mg	93KJ (22 KCAL)
P.ostreatus	Total: 3.31g Vitamins: Folates:33 μg Niacin:4.956mg Pantothenic acid:1.294mg Pyridoxin(b-6):0.110 mg Riboflavin:0.349mg Thiamine:0.125mg Vitamin D:29 IU mg	Total:6.09g Dietary fiber:2.3g Total Sugar:4.97g Fructose:0.01g Mannitol:0.54g Trehalose:4.42g	Potassium:420mg Sodium:18mg	Total fat:0.41g	Selenium:2.6 μg Phosphorus:120mg Iron:1.33mg Maganesium:18mg Manganese:0.113mg Zinc:0.77mg Calcium:3mg Copper:0.244mg	33 (KCAL)
L.edodes	Total:2.2g Vitamin D:110g Vitamin A Vitamin C Vitamin B-6	Total:7g Dietary fiber:2.5g Total Sugar:14.03g Fructose: 0.69g Mannitol: 10.01g Trehalose: 3.38g	Potassium:304mg Sodium:9mg	Total fat:0.5g	Selenium:0.076mg Phosphorus:294mg Iron:5.5mg Magnesium:20mg Zinc:8% Calcium:23mg Copper:1.23mg	141KJ 34(KCAL)

Source: Journal of Mycology

IV. NUTRACEUTICAL VALUE

Dr. Stephen L. DeFelice, MD, created the term "nutraceutical" in 1989, with "nutra" taken from nutrition and "ceutical" derived from pharmaceutical. Nutraceuticals do not yet have a standard definition, however it may be described as a food or component of a food that has health or medical advantages, including illness prevention and therapy. Some edible mushrooms contain significant levels of bioactive substances in addition to the nutritious components. Differences in strain, substrate, cultivation, developmental stage, storage conditions, processing, and cooking techniques all impact the kind and quantities of these chemicals. Secondary metabolites (acids, alkaloids, terpenoids, lactones, polyphenols, metal chelating agents, sterols, nucleotide analogues, and vitamins), glycoproteins, and polysaccharides (-glucans) are now included to the list of bioactive compounds. Novel proteins with biological activity that can be utilised in biotechnological processes and the creation of new medicines, such as lectins, lignocellulose-degrading enzymes, proteases and protease inhibitors, hydrophobins, and ribosome-inactivating proteins, have been discovered in these mushrooms (Valverde et al., 2015).

V. HEALTH BENEFITS

Mushrooms are a low-calorie meal that are high in nutrients. It is high in health-promoting vitamins, minerals, and antioxidants, and is considered an essential element of any diet. Mushrooms cultivated under UV light, for example, are a rich source of Vitamin D, which is vital for bone and immunological health. The fungus is also high in potassium, which has been shown to reduce the harmful effects of salt on the body. Potassium is also recognised for decreasing blood vessel tension, which can aid in the reduction of blood pressure. They have an anti-inflammatory action that effectively strengthens the immune system by activating the immune system's microphages, increasing the immune system's capacity to combat foreign bodies and therefore lowering susceptibility to sickness. Many studies have also shown that mushrooms, when coupled with exercise and other lifestyle modifications, can help people lose weight. Mushroom antioxidants are also thought to reduce the risk of hypertension and a variety of other metabolic diseases (WebMD, 2020).

VI. MEDICINAL VALUE

Mushrooms contain over 100 therapeutic properties. Antioxidant, anticancer, antidiabetic, antiallergic, immunomodulating, cardiovascular protector, anticholesterolemic, antiviral, antibacterial, antiparasitic, antifungal, detoxification, and hepatoprotective effects, as well as protection against tumour development and inflammatory processes, are just a few of the medicinal uses. Polysaccharides are extremely important in modern medicine; -glucan is a well-known polysaccharide that is a flexible metabolite with a wide range of biological activities (Valverde et al., 2015).

VII. CULTIVATION OF MUSHROOMS

Compost preparation, spawning, spawn running, casing, fruiting, and harvesting are the processes that make up the mushroom production process in general. Compost is a substrate for button mushrooms that is made mostly from plant wastes and can include salts, cereal-straw, sugarcane bagasse, urea, super phosphate, water, and other ingredients. A sterile procedure known as spawning is necessary for mushroom cultivation. Under sterile circumstances, spawn can be made from fruiting culture or stocks of chosen mushroom strains. The spawn should be of excellent flavour, texture and size, as well as have the potential for a great yield and prolonged shelf life. The compost is then placed into polythene bags (about 90x90 cm, 150 gauge thick, capable of 20-25 kg per bag) or racks (typically wooden trays for 20-30 kg) or rails, either coated in paper or polythene, after the spawning process. After the whole spawn has been completed, the compost beds should include a layer of soil (casing) of about 3-4 cm and be thick enough to promote fruit. The materials used in the case should be porous, retain high water and have a pH range of 7-7.5. Under favourable environmental conditions, such as temperature (originally around 23 20 °C for about a week and later 16 20 °C), moisture (2-3 light water sprays for the moisture layer per day) humidity (above 85%), proper ventilation and CO_2 concentration, the fruit body initially appears as pin heads and begins to grow and develop gradually into the button stage (about 0.08-0.15 percent). When the caps have a diameter of 2.5 - 4 cm and are closed, twisted and harvested during the buttoning. After approximately three weeks of casing, the first crop emerges. Post harvest management is the cultivation stage immediately following harvest and includes chilling, cleaning, sorting and packaging (Chakravarthy, 2004).

VIII. STORAGE OF MUSHROOMS

Mushroom storage is a crucial step in keeping mushrooms fresh for as long as possible. Because mushrooms have a high water content, they can rapidly get soggy and mouldy, thus they are usually kept in the refrigerator to absorb any extra moisture. To avoid spoiling, it's vital to remember not to wash the mushrooms before storing them, and to dry the mushrooms as well. Based on the period of storage, mushrooms may be divided into two categories: short-term and long-term storage. Cooling and refrigeration are used in short-term storage. Chill storage (4-7°C) keeps mushrooms fresh for days or weeks, whereas frozen storage (below -18°C) and deep storage keep mushrooms fresh for months or years. The time it takes for a mushroom to cool down is determined by its size and kind. For excellent grade frozen mushrooms, a brief blanching period is necessary. Although vacuum cooling is a rapid and consistent procedure for evaporating water from inner cell walls and inter hydral spaces to release latent heat, it has the disadvantage of causing the mushrooms to lose fresh weight. A stack of mushrooms is pushed through a forced draught of humidified air during Ice bank chilling to decrease weight loss during traditional vacuum cooling. Long-term storage necessitates steeping preservation, which is easy, cost-effective, and effective in extending shelf life. To enhance the colour and texture of mushrooms before drying, this process involves blanching them in brine solution and using chemicals such potassium meta bisulphate and citric acid. Mushrooms may be canned and stored for up to a year. Cleaning, blanching, filling, sterilisation, chilling, labelling, and packing are some of the important procedures that must be completed as soon as possible after the harvest to ensure excellent quality mushrooms. The cans must be kept in a cold, dry location at all times.

Radiation preservation makes use of gamma rays, which helps to reduce contamination and extend the shelf life of mushrooms. Irradiation should always be done after harvesting since it provides the best results in terms of reducing water loss, colour, flavour, texture, and quality. Before harvesting, irradiation retards the development of the cap, stalk, gills, and spores. Cobalt 60 is the most often utilised gamma ray (Rai and Arumuganathan, 2008).

IX. MUSHROOM PRODUCTS

Because consumers are becoming more aware of the health and environmental advantages of fungus, the mushroom product category is thriving across sectors, from packaging to food and drinks. Mushroom-infused coffees are an example, and it was created in response to a growing need for a healthier alternative to caffeine. Many strong herbs, such as cognitive-boosting Lion's Mane, anti-inflammatory Chaga, mineral-rich Chanterelle, and others, are mixed with the coffee powder, making it healthier. Mushroom products also have significant implications for environmentally friendly and sustainable packaging, and several firms are experimenting with this (Nedelcheva, 2020).

Some of the products available in the market are mentioned here:

Table III: Mushroom Products

Mushroom products	Description
Mushroom coffee	It is a combination of organic coffee and professionally chosen fungi.
Mushroom seasonings	The multipurpose seasoning comprises kosher salt, black pepper, red pepper, mustard seed and mushroom powder, that altogether creates, which comes together to create an “umami” flavour often described as “fifth taste”.
Mushroom-infused hot chocolate	Including organic cacao powder, organic cinnamon powder, cocoa milk powder as well as reishi, chaga and maitake mushrooms.
Liquid creamer	Infused with functional mushroom varieties including Lion's Mane, Cordyceps and Chaga.
Mushroom snacks	Mushroom based jerky, snack bars and chips in different flavours.
Immunity boosters	Chaga mushrooms are used in these products packed with powerful antioxidants, which are known to reduce inflammation, lower high blood sugar, and combat abnormal cell growth.
Protein powder	The powders are packed with proteins, which has been sourced from peas, pumpkin seeds, hemp, coconuts, chia, pumpkin and contains 1,000mg of mushroom extras.
Hydrating serum	It is packed with pure aloe vera, snow mushroom, olive oil, coconut fatty acids, white tea, shea butter, mimosa bark, tamarind and four types of hyaluronic acid.
Face masks	The benefits of medicinal mushrooms for stress reduction, sleep, and detoxification are discussed, as well as how to cleanse pores, smooth fine lines, and reduce redness.
Packaging	100% compostable packages made from natural ingredients like mushroom and hemp.
Source: Trend Hunter	

Table IV: Some Companies involved with Mushroom Production

Companies	Location	Products
Agro Dutch Inductries Ltd.	Chandigarh, Punjab, India	Canned Mushrooms. Whole Mushroom. Buttons Mushrooms. Thick Slices - Mushrooms. Sliced Mushrooms
Weikfields Foods Pvt. Ltd.	Pune, Maharashtra, India	Mushroom Pickles, Mushroom Pasta, Mushroom Pasta sauce, Mushroom Jelly
BioFungi GmbH	Augsburg, Bavaria, Germany	Mushroom powder and mushroom granules
California Mushroom Farms Inc.	Ventura, California, USA	Pickles, Peppers, Relishes, Organic Mushrooms
Monaghan Mushrooms	Tyholland, Ireland	Meat alternative, Mushroom Powder, Immunity boosters
Highline Mushrooms	Langley City, BC, Canada	Stuffed Portabella Mushrooms
Scelta Mushrooms BV	Venlo, Netherlands	Frozen Mushrooms
Monterey Mushrooms Inc.	Watsonville, California, United States	Packaged fresh mushrooms – packed in cans, jars, frozen sauces
Banken Champignons B.V.	Wijchen, Gelderland, Netherlands	Fresh mushrooms include rare wild and farmed species, as well as ordinary white and chestnut mushrooms.
Bonduelle	Villeneuve-d'Ascq, France	Canned mushrooms, Frozen mushrooms, Fresh mushrooms

Souce: Fortune Business Insights

Table V: Mushroom Production Worldwide (tonnes)

Countries	2016-2017	2017-2018	2018-2019
China, Mainland	7,952,059	8,346,761	8,741,463
Japan	459,500	463,000	468,500
USA	425,642.5	419,705	400,005
Netherlands	300,000	300,000	300,000
Poland	285,852.5	245,758.5	281,280
Spain	153,527.5	162,634	168,205
India	88,845	117,845	158,000

Source: FAOSTAT

Table VI: Some recent representative Patents on Mushrooms

Title	Patent Number	Inventors	Published
Method and apparatus for vitamin D enhancement in mushrooms	US 2016-0205981 A1	William F. Chalupa Gary M. Schroeder	Jul 21, 2016
Quality control of agricultural products based on gene expression	US 2016-0376667 A1	Monique Francisca Van Wordragen Rudolf Aart De Maagd Jurriaan Johannes Mes Peter Albert Balk	Dec 29, 2016
Hybrid mushroom strain J11500 and descendants thereof	US 2015-0216128 A1	Richard W. Kerrigan Mark P. Wach Michelle E. Schultz	Apr 18, 2017
Ergothioneine-containing preparation, method of production, and usage of mushroom extracellular ferment liquor	US 2018-0163238 A1	Wenxia Jiang Ping Yang Qi Liu Weiya Zhang Tao Zhou Baoliang Mei Zizhen Zhou Miao Li Dalong Zhang	Jun 14, 2018
Agroindustrial process with minimal environmental impact	US 2018-0255716 A1	Gian Paolo Rolli	Sep 13, 2018
Flag mushroom cup nozzle assembly and method	US 2019-0143345 A1	Benjamin D. Hasday Evan Hartranft	May 16, 2019
Arrangement and method for the cultivation of horticultural products	US 2019-0208717 A1	Martinus Leonardus Hendrikus Maria Christiaens	Jul 11, 2019
Method for preparing high productivity mushroom β-glucan and products thereof	US 2019-0249211 A1	Shiu-Nan Chen	Aug 15, 2019
Chaga mushroom chew composition	US 2019-0343167 A1	Dale Paul Carey	Nov 14, 2019
Mushroom line J14756-s3 and methods and uses thereof	US 2020-0084993 A1	Richard Kerrigan Mark Wach Michelle Schultz Mark G. Loftus Michael A. Kessler William P. Swanik Anne Rodier Anica Amini Sylvie Delbecque Richard Rucklidge	Mar 19, 2020
Mushroom based compositions for conferring flavour to liquids	US 2020-0305479 A1	Marilyn Weigensberg Aharon Bar-Tur Oren Kessler Harold Kruger Arturo Geifman Tal Leizer	Oct 1, 2020
Extruded ready to consume food product	US 2020-0390142 A1	Marilyn Weigensberg Aharon Bar-Tur Oren Kessler Harold Kruger Arturo Geifman Tal Leizer	Dec 17, 2020
Source: USPTO			

X. CONCLUSION

Mushroom is becoming an important part of diet for its nutritional value and various health benefits. Research was conducted on mushrooms and some new proteins were found having biological activities that can be used in several biotechnological processes. Mushrooms are in high demand these days due to their low calorie, carbohydrate, fat, salt, and cholesterol content. Mushrooms also include essential bioactive components such as minerals such as selenium, potassium, riboflavin, niacin, and vitamin D, as well as proteins, fibre, and antioxidants such as glutathione and ergothioneine. These have a significant impact on the nutraceutical potential of mushrooms. The various developments and innovations in products and processes related to mushrooms are contributing to the growth of the mushroom markets.

REFERENCES

[1] Biesalski, H. K. (2001). Nutraceuticals: link between nutrition and medicine. In: Nutraceuticals in Health and Disease Prevention, K. Kramer, P. P. Hoppe, and L. Packer (Eds.), 1–26.

[2] Brown, D. L., Wettere, A. J. V. and Cullen, J. M. (2017). Chapter 8 - Hepatobiliary System and Exocrine Pancreas. In: Pathologic Basis of Veterinary Disease, Zachary J.F. (Ed.). Mosby, 6:412-470.e1, ISBN 9780323357753.

[3] Chakravarthy, A. (2004). Mushroom (White Button) cultivation. In: Selected Agricultural Technologies - A Compendium, R. Parshad (Ed.). Indian Council of Agricultural Research. 70-73.

[4] Chang, S. T. (1977). The origin and early development of straw mushroom cultivation. Econ Bot 1977, 31:374-6.

[5] Chang, S. T. and Wasser, S. P. (2012). The role of culinary-medicinal mushrooms on human welfare with a pyramid model for human health. International Journal of Medicinal Mushrooms, 14:2:95–134.

[6] Deepak, K. R., & Deepika, M. (2016). Diversity of Mushrooms and Their Metabolites of Nutraceutical and Therapeutic Significance. Journal of Mycology, 2016:18 pages, Article I 7654123.

[7] Erjavec, J., Kos, J., Ravnikar, M., Dreo, T. and Sabotič, J. (2012). Proteins of higher fungi—from forest to application. Trends in Biotechnology, 30:5:259–273.

[8] Finimundy, T. C., Gambato, G., Fontana, R. et al. (2013). Aqueous extracts of Lentinula edodes and Pleurotus sajor-caju exhibit high antioxidant capability and promising in vitro antitumor activity. Nutrition Research, 33:1:76–84.

[9] Hay, W. D. (1887). An Elementary Text-Book of British Fungi. S. Sonnenschein, Lowrey, 6–7.

[10] Li, G. S. F. and Chang, S. T. (1982). The nucleic acid content of some edible mushrooms. European Journal of Applied Microbiology and Biotechnology, 15:4, 237–240.

[11] Liu, B. (1958). The primary investigation on utilization of the fungi by ancient Chinese. Shansi Norm Coll J, 1:49-67.

[12] Moser, M. (1993). Guida alla determinazione dei funghi. Polyporales, Boletales, Agaricales, Russulales Italy: Saturnia. 565.

[13] Muller, W. H. (1979). Botany: a functional approach. (5th Edtn), Mac Milan Publishing Co. Inc., London, UK.

[14] Muray, P., Drew, W., Koibayashi, G., Thompson, J. (1990). Medical microbiology. Wolfe Medical Publications Limited, London, UK.

[15] Nedelcheva, K. (2020). 15 Innovative Mushroom Products. Trend Hunter. https://www.trendhunter.com/slideshow/mushroom-products2

[16] Nordt, S. P., Manoguerra, A., Clark, R. F. (2000). 5-Year analysis of mushroom exposures in California. West J Med, 173: 314-317.

[17] Onwuka, G. I. (2014). Food science and technology: mushroom toxins. Naphtali Prints, Lagos, Nigeria.

[18] Pegler, D. N. (2002). Useful fungi of the world: The poor man's truffles of Arabia and manna of the Israelites. Mycologist 2002; 16:8-9.

[19] Power, R. C., Salazar-García, D. C., Straus, L. G., Morales, M. R. G., Henry, A. G. (2015). Microremains from El Mirón Cave human dental calculus suggest a mixed plant–animal subsistence economy during the Magdalenian in Northern Iberia. Journal of Archaeological Science, 60:39-46, ISSN 0305-4403.

[20] Rai, R. D. and Arumuganathan, T. (2008). Post-Harvest Technology of Mushrooms. National Research Centre for Mushroom. Indian Council of Agricultural Research.

[21] Ramsbottom, J. (1954). Mushrooms & Toadstools: a study of the activities of fungi. London: Collins.

[22] Richard, G. (2015). Stone Age man ate mushrooms: Oldest evidence for fungi in the human diet discovered in 19,000-year-old tooth plaque. Mail Online, 21 April.

[23] Teka, Z., and Chaithanya K., (2019). Historical perspectives of mushroom cultivation in the world. Drug Invention Today, 13:4, 593-595.

[24] Ukwuru, M.U., Muritala, A. and Eze, L.U. (2018). Edible and Non-Edible Wild Mushrooms: Nutrition, Toxicity and Strategies for Recognition. J Clin Nutr Metab, 2:2.

[25] Valverde, M. E., Hernández-Pérez, T. and Paredes-López, O. (2015). Edible mushrooms: improving human health and promoting quality life. International journal of microbiology, 2015, 376387.

[26] WebMD. (2020). Health Benefits of Mushrooms. https://www.webmd.com/diet/health-benefits-mushrooms

[27] Yu, S., Weaver, V., Martin, K. and Cantorna, M. T. (2009). The effects of whole mushrooms during inflammation. BMC Immunology, 10:12.

[28] Zhang, L., Fan, C., Liu, S., Zang, Z. and Jiao, L. (2011). Chemical composition and antitumor activity of polysaccharide from Inonotus obliquus. Journal of Medicinal Plants Research, 5:7:1251–1260