Ganoderma lucidum

Subjects: Mycology

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Ganoderma lucidum has a long history of medicinal uses in the Far East countries of more than 2000 years due to its healing properties. Recently, *G*. *lucidum* has come under scientific scrutiny to evaluate its content of bioactive components that affect human physiology and has been exploited for potent components in the pharmacology, nutraceuticals, and cosmetics industries. For instance, evidence is accumulating on the potential of this mushroom species as a promising antiviral medicine for treating many viral diseases, such as dengue virus, enterovirus 71, and recently coronavirus disease of 2019 (COVID-19). Still, more research studies on the biotherapeutic components of *G*. *lucidum* are needed to ensure the safety and efficiency of *G*. *lucidum* and promote the development of commercial functional foods.

Ganoderma lucidum | prebiotics | functional food | therapeutic properties

1. Introduction

1.1. What Does History Say about *Ganoderma lucidum*?

“Lingzhi is a miraculous king of herbs”—Chinese people (221–206 BC).

Historically, the Romans considered mushrooms in general as the food of their gods and only served them for great feasts, while the Greeks and the Vikings believed that eating mushrooms gave them strength and enthusiasm before the war. America’s indigenous people have often used mushrooms in age-old rituals (e.g., magical hallucinogens) to cross the body and mental barrier [1]. Considered as one of the main folk medicinal mushrooms, *G*. *lucidum* was used for many centuries and reported under several names in China (Lingzhi), Japan (Reishi), and Korea (Mannentake). According to bimillennial beliefs, *G*. *lucidum* can promote health and longevity, but it was also considered a combination of spiritual force and a source of immortality [2][3][4]. Moreover, the Japanese people have regarded this mushroom as a “10,000-year” mushroom [5][6][7].

Several researchers have pointed out the long history of traditional medicinal uses of mushrooms, especially *G*. *lucidum*, mostly in Far East countries, dating back more than 4000 years [7][8][9][10][11][12][13][14]. This type of mushroom has therapeutic characteristics with medical claims that can be attributed to a well-respected pharmacopeia from the Qin dynasty (221–206 BC) called *Shen Nong Ben Cao Jing,* or *The Divine Farmer’s Materia Medica* [13][15]. The ethnomedicinal uses of *G*. *lucidum* had reflections on culture, such as the artworks beginning in the Yuan Dynasty (1280–1368 AD) [7][13]. This was not limited to artworks, but the use of *G*. *lucidum* images extended to furniture, carvings, paintings, and even women’s accessories [2].

For a long time, *G*. *lucidum* has been used as a traditional medicine for treating neurasthenia, debility of prolonged illness, insomnia, anorexia, dizziness, chronic hepatitis, hypercholesterolemia, mushroom poisoning, coronary heart disease, hypertension, prevention of acute mountain sickness, “deficiency fatigue”, carcinoma, and bronchial cough in the elderly [16][17]. Studies on medicinal mushrooms began in Western science more than 30 years ago. These studies have continued until the present via a series of exciting discoveries related to the biological activities of *Ganoderma lucidum*, including antitumor and anti-inflammatory effects, as well as cytotoxicity to hepatoma cells [18][19].

1.2. *Ganoderma lucidum* through the Glasses of Botanists, Taxonomists, Economists, and Scientometric Analysis

1.2.1. Through Botanists’ Glasses

Morphologically, *lucidum* is a word derived from the Latin word *lucidus,* which means “shiny” or “brilliant”, and describes the varnished look of the mushroom’s surface. Overall, *G*. *lucidum* is a large, dark mushroom distinctively characterized by a glossy surface (including a red-varnished and kidney-shaped cap) and a woody texture (see **Figure 1**). The fresh mushroom is soft, corklike, flat, lacks gills on its underside, and releases its spores via fine pores. The pore color on its underside depends on the age of the mushroom, and maybe white or brown [6][20]. Chen [21] described the nature of *G*. *lucidum*’s growth on the bases and stumps of a wide variety of deciduous trees, such as oak, maple, elm, willow, sweetgum, magnolia, and locust, and less frequently found on coniferous trees (e.g., larix, ptea, pinus) in Europe, Asia, and North and South America, especially in temperate rather than subtropical regions.

Figure 1. Image of *Ganoderma lucidum*.

1.2.2. Through Taxonomists' Glasses

Ganoderma lucidum (Curtis) P.Karst. was first described by Curtis [22] based on material from England, and the description was sanctioned by Fries [23]. The first scientific record of *G. lucidum* from China was made by Teng [24] when he incorrectly identified a Lingzhi specimen as *G. lucidum*. Geographically, the *G. lucidum* sensu stricto (Curtis) Karst mushroom is native to Europe and some parts of China [25]. According to the Index Fungorum (2016) (http://www.indexfungorum.org, accessed on 16 February 2022), *Ganoderma lucidum* (Curt: Fr.) Karst. belongs to Basidiomycota (phylum), Polyporales (order), and Ganodermataceae (family), as classified by the taxonomist Nahata [5]:

- Kingdom: Fungi
- Division: Basidiomycota
- Class: Agaricomycetes

- Order: Polyporales
- Family: Ganodermataceae
- Genus: Ganoderma
- Species: *G*. *lucidum*

1.2.3. Through Economists' Glasses

Ganoderma-based products attract a great deal of interest in many countries within Europe and North America, although South Asia (Malaysia, Singapore, China, Japan, and Korea) are the principal producers/providers of these food products [26]. In the past, consumption of *G*. *lucidum* was restricted to the wealthy only, and therefore there was no need to expand its cultivation, and what was grown in the wild was sufficient. Recently, however, the consumption of this mushroom has increased through multiple societal groups as an effective alternative to modern medicine or alongside it, and this is what has called for the expansion of its cultivation [27][28]. With over 110,000 ton/year, China is the biggest producer and exporter of *G*. *lucidum* [29]. Therefore, *G*. *lucidum*-based products play a pivotal role in the Chinese economy as a source of foreign-exchange flow through increasing exports and as promising products at the food and medical levels.

Generally, the mushroom's ingredients possess a wide variety of biological properties, including pharmaceutical, nutraceutical, and cosmetic, as shown in **Figure 2** [8][30][31]. As such, regarding the *G*. *lucidum* mushroom, there are three types of products that are produced from it: nutraceuticals, pharmaceuticals, and cosmetics [31]. Different parts of *G*. *lucidum* are commercially available, including mycelia, spores, and fruit body [6], and are sold as many different products, including powders, dietary supplements, and herbal tea [6][13]. **Table 1** illustrates some of the commercial cosmetic products produced from *G*. *lucidum* mushrooms worldwide. Nowadays, the number of *Ganoderma*-based products well known commercially is estimated at over 100 brands [32]. The world trade market value of *G*. *lucidum* and its derivative products has reached approximately USD 4 billion [33].

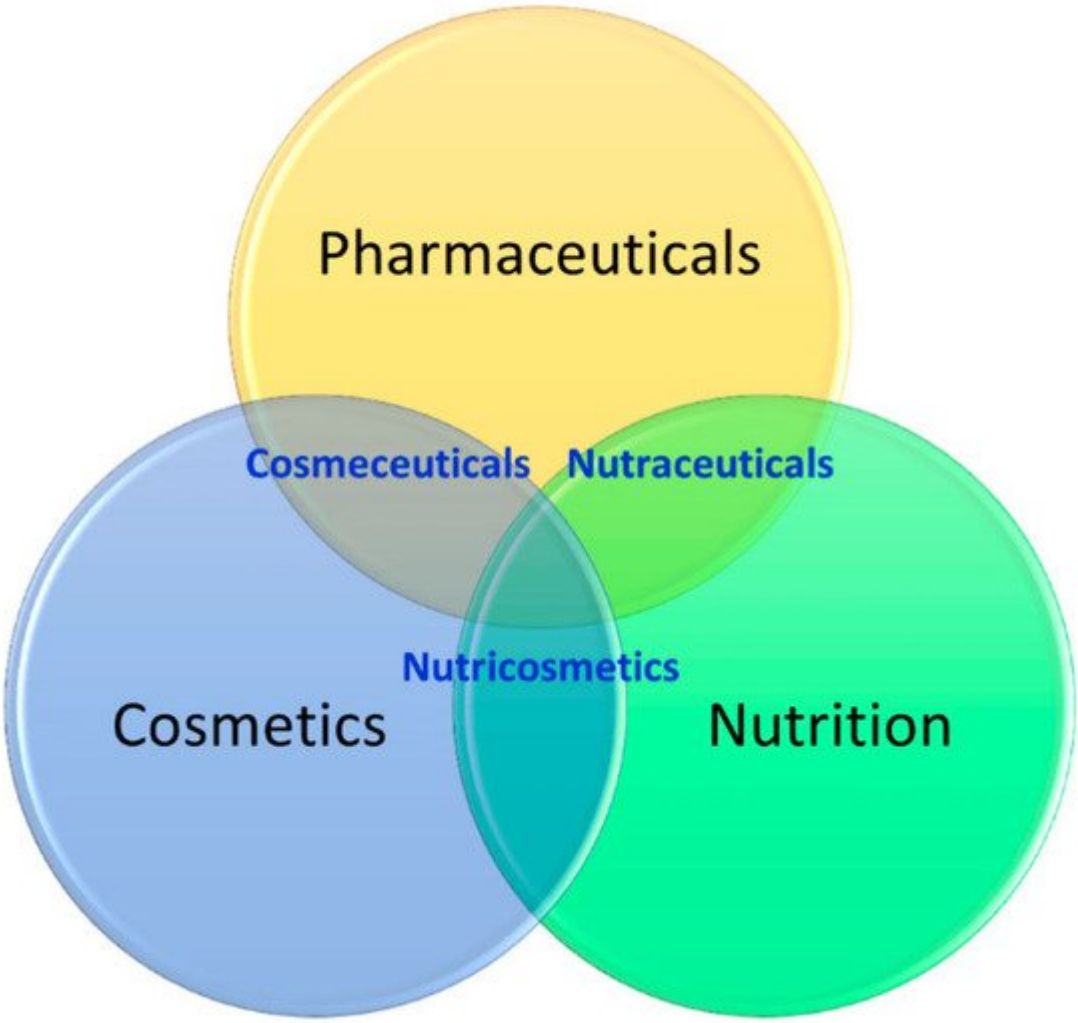

Figure 2. Wide-scale applications of mushrooms including *Ganoderma lucidum*; i.e., pharmaceuticals, nutraceuticals, and cosmetics. Source: Reprinted from Wu et al. [31]. Licensed under CC BY 4.0.

Table 1. Some of the cosmetic products are produced commercially from the *G. lucidum* mushroom worldwide *.

Commercial Product Name/Producing Country	Uses
CV Skinlabs Body Repair Lotion, USA	Wound healing and anti-inflammatory
Dr. Andrew Weil for Origins Mega-Mushroom Skin Relief Face Mask, USA	Anti-inflammatory properties
Moon Juice Spirit Dust, USA	Immune system
Estée Lauder Re-Nutriv Sun Supreme Rescue Serum sun care product, USA	Triple-action repair technology to enhance the skin's own natural defenses against the visible effects of sun exposure and sun-stressed skin
Four Sigma Foods Instant Reishi Herbal Mushroom Tea, UK	Immunity boost

Commercial Product Name/Producing Country	Uses
Kat Burki Form Control Marine Collagen Gel, UK	Boosting collagen, improving elasticity, and providing hydration
Tela Beauty Organics Encore Styling Cream, UK	Providing hair with sun protection and preventing color fading
Menard Embellir Refresh Massage, France	Skin antiaging
Yves Saint Laurent Temps Majeur Elixir De Nuit, France	Antiaging
Pureology NanoWorks Shineluxe, France	Antiaging and antifading
Hankook Sansim Firming Cream (Tan Ryuk SANG), Korea	Making skin tight and vitalized
La Bella Figura Gentle Enzyme Cleanser, Italy	Antioxidants and vitamin D
DXNGanozhi Moisturizing Micro Emulsion, Malaysia	Hydrating and nourishing the skin
Guangzhou Bocaly Bio-Tec. *Ganoderma* Cell-Repairing Antiaging Face Mask, China	Antiwrinkle, firming, lightening, moisturizer, and nourishing, pigmentation corrector; pore cleaning and whitening
Nanjing Zhongke Pharmaceuticals Ganoderma Face Cream Set (day/night cream and eye gel set), China	Immunity boost and antifatigue
Shenzhen Hai Li Xuan Technology HailiCare Skin Whitening Cream, China	Removing freckles and whitening
Menard Embellir Night Cream, Japan	Eliminating toxins and helping repair skin damage associated with overexposure to UV radiation and free radicals
MAVEX Rejuvenating Treatment, Hong Kong	Antioxidant action and deep cellular renewal; fight degenerative processes and the negative action of free radicals

* Sources: Wu et al. [31], Taofiq et al. [34], Hapuarachchi et al. [35], www.vegamebeljepara.com, www.dazzlinggroup.com, www.dxnmalaysia.com, and www.vegamebeljepara.com (accessed on 16 February 2022) Adapted from Wu et al. [31]. Licensed under CC BY 4.0. Adapted with permission from Taofiq et al. [34]. 2022, Elsevier.

1.2.4. Scientometric Analysis

During the last decade, the *G*. *lucidum* mushroom has attracted multiple research fields, including biochemistry, genetics and molecular biology, agricultural and biological sciences, pharmacology, toxicology, pharmaceutics, and medicine. **Figure 3** illustrates the increasing interest in multidisciplinary utilization of *G*. *lucidum* based on the number of research articles in the past 10 years.

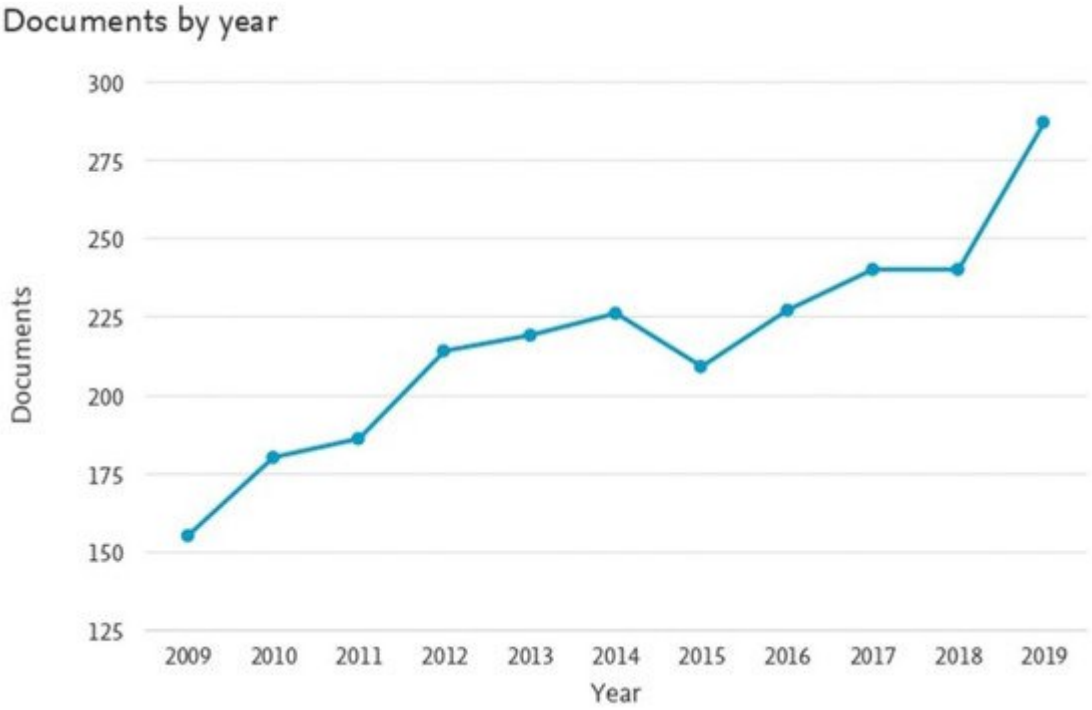

Figure 3. A scientometric analysis of increasing interest in *Ganoderma lucidum* over the last 10 years. Reprinted with permission from Scopus. 2020, Elsevier.

1.3. Why Should Mushrooms, including *Ganoderma lucidum*, Be Considered Functional Foods?

1.3.1. How to Define Functional Food?

In the early 1980s, the idiom “functional food” first appeared in Japan. Functional food is a broad term that includes several concepts [36]; for example, the definition of functional food provided by the Food and Agriculture Organization (FAO) states that “the functional food is the source that provides the human body with the necessary quantities of nutrients, i.e., proteins, carbohydrates, fats, vitamins, minerals, and others to keep it healthy. In addition, functional food can be cooked or prepared using ‘artificial intelligence technology’ [37]. In addition, the European Food Safety Authority (EFSA) defined functional food as “a food, which beneficially affects one or more target functions in the body, beyond adequate nutritional effects, in a way that is relevant to either an improved state of health and well-being and/or reduction of risk of disease” [38]. As described by the Functional Food Center (FFC) in the United States, functional foods are “real or processed foods that contain known or unknown biologically active compounds that, efficient, in defined and non-toxic quantities, recorded health benefit or provide a scientifically validated using unique biomarkers for the prevention, treatment or control of chronic disease or its symbiotic diseases” [39]. According to the definition of the Institute of Food Technologists (IFT), functional foods are

those with ingredients that have health benefits in addition to basic nutrition, which is similar to the definition published by the International Life Sciences Institute (ILSI) [40][41].

Comprehensively, functional food can be defined as “a whole ingredient or a part of food that is used as food. It is part of a standard diet and is consumed on a regular basis, in normal quantities. It has proven health benefits that reduce the risk of specific chronic diseases or beneficially affect target functions beyond its basic nutritional functions” [42][43].

1.3.2. What Do the Definitions of Functional Foods Conclude?

The use of the term “ingredient” means that functional food is not only conventional food but also could be a part of other food or food ingredients. In addition, the above-mentioned definitions of functional foods allow for adaptation to cultural differences, including widely differing “standards” among cultures and countries. Moreover, the use of the term “health benefits” is not restrictive. It refers to physiological, psychological, and biological advantages [43][44].

1.3.3. Functional Foods and Their Relation with Gut Health

Among the important health effects of foods including the functional ones are those associated with gut health, a major determinant of an individual’s overall health. Several diseases are related in this context; e.g., gluten-therapy-resistant celiac, Crohn’s disease, ulcerative colitis, and irritable bowel syndrome. These adverse effects are caused by overgrowth and imbalance of intestinal bacteria linked to an individual’s food system [45]. The question that comes to mind is, what are the roles of the human gut in the body? These can be summarized as follows [45]:

- It converts food to nutrients;
- The human gut, via epithelial cell walls, assists in the absorption process of nutrients into the blood;
- The human gut inhibits toxic and strange particles from entering the bloodstream.

Consequently, and directly, any gut malfunction has adverse effects on human health. In this regard, functional foods, including pre- and probiotics, have become increasingly important due to their positive role in human gut health.

1.3.4. *Ganoderma lucidum* as a Functional Food: How?

Historically, mushrooms, including *Ganoderma lucidum*, were traditionally consumed due to their nutritional and culinary values, and for their medical benefits when used in folk medicine. This historical heritage has recently been translated through molecular research to explore the present bioactive components and unlock mushrooms’ nutrition and therapeutic values [46][47]. Among these health benefits, mushrooms could help prevent diseases; e.g., hypertension, diabetes, hypercholesterolemia, and cancer, as mentioned in many reports. Hence, mushrooms can

be considered a curative food [8][48]. Mushrooms are still untapped sources of bioactive substances such as glycoproteins, polysaccharides, mainly β-glucans, and secondary metabolites; i.e., nucleotide analogs, metal-chelating agents, terpenoids, polyphenols, alkaloids, lactones, and sterols. These biologically active components possess several therapeutic implications, such as antiviral, anticancer, hepatoprotective, immunopotentiating, and hypocholesterolemic agents [47][48][49][50][51].

The present entry critically discusses the benefits of *G*. *lucidum*, from nutritional value to medicinal impacts, and sheds light on its potential as a source of nutraceuticals and functional food. Moreover, this entry provides answers with a critical vision to many questions, such as why the bioactive compounds of *G*. *lucidum* need to be further studied in vitro and in vivo, and what secrets are still behind them. Is it important to ensure *G*. *lucidum*'s quality and safety, as well as the best method to achieve that? With the potential of *G*. *lucidum*, will the future carry researchers to the possibility of commercial widescale use of *G*. *lucidum* and its products as new functional foods and medicines?

Despite that *Ganoderma lucidum* is not edible in its raw state due to its higher content of bitter compounds, its palatability can be increased by turning it into manufactured products such as powders, supplements, and tea [52]. The nutritional value of *G*. *lucidum* will be tackled in-depth in the following section.

2. The Nutritional Profile of *Ganoderma lucidum*

"Medicines and food have a common origin"—Kaul [53].

For thousands of years, mushrooms have been valued throughout the world as food and medicine [8]. Nevertheless, mushrooms are still largely untapped resources in producing effective pharmaceutical products, nutrients, and cosmetics. Indeed, only approximately 150,224 species have been described [54] out of the estimated 2.2–3.8 million fungal species worldwide [55]. About 3000 species that belong to Macrofungi are safe for human consumption, such as edible mushrooms [56].

From the nutritionist's point of view, generally, fresh mushrooms contain both soluble and insoluble fibers; the soluble fiber is mainly β-glucanpolysaccharides and chitosans [57]. However, a question comes to mind: does *G*. *lucidum* that is grown naturally or wild differ from that grown artificially in its nutritional components? According to the research in this regard, the answer is yes, as it was found that the quantities of crude protein, carbohydrates, and crude fiber were greater in the artificially grown variety [58]. Few studies have revealed the nutritional profile of *G*. *lucidum*. Roy and others [59] reported the nutritional value and mineral composition of *G*. *lucidum*. Through an analytical view of the nutritional profile of the *G*. *lucidum* mushroom (**Table 2**), several important conclusions can be reached.

Table 2. Physicochemical properties and chemical composition of *Ganoderma lucidum* mushroom.

Constitute	Content			DRIs * (g/day)	Value in 100 g Mushroom/DRIs × 100
	Value	g/100 g Mushroom (Wet-Weight Basis)	g/100 g Mushroom (Dry-Weight Basis)		
Moisture %		47			
Total solids (TS) %			53		
pH value	5.6				
Energy (kcal)	238.98 **			Men: 2215 ***	10.79
				Women: 2025	11.80
Water-soluble proteins %		19.5	36.80	Men (total proteins) ****: 56	34.82
				Women (total proteins): 46	42.39
Total lipids %		3.00	5.66	44–77 *****	3.90–6.82
Total ash %			6.3		
Reducing sugars %		4.39	8.28		
Nonreducing sugars %		1.02	1.92		
Total sugars %		5.41	10.21	130	4.16
Crude fibers %			3.5	Men: 38	9.21
				Women: 25	14.00
Polyphenols “as gallic acid”		0.04	0.08	1 ******	7.5

Mineral	Mineral content (mg/100 g mushroom)	DRIs (mg/day)	Value in 100 g mushroom/DRIs × 100
Major minerals			
Potassium	432	4700	9.19

Constitute	Content		DRIs * (g/day)	Value in 100 g Mushroom/DRIs × 100
	Value	g/100 g Mushroom (Wet-Weight Basis)	g/100 g Mushroom (Dry-Weight Basis)	
Phosphorus	225		700	32.14
Sulfur	129		200–1500	8.60–64.50
Magnesium	7.95		Men: 400	2.00
			Women: 310	2.60
Sodium	2.82		1500	0.20
Calcium	1.88		1000	0.20
Trace minerals				
Copper	26		0.9	2889
Manganese	22		Men: 2.3	956.52
			Women: 1.8	1222.22
Iron	2.22		Men: 8	27.75
			Women: 18	12.33
Zinc	0.7		Men: 11	6.40
			Women: 8	8.75
Vitamin	Vitamin content (mg/100 g mushroom)		DRIs (mg/day)	Value in 100 g mushroom/DRIs × 100
Thiamine (B1)	3.49		Men: 1.2	290.83
			Women: 1.1	317.27
Riboflavin (B2)	17.10		Men: 1.3	1315.38
			Women: 1.1	1554.54
Niacin (B3)	61.9		Men: 16	386.87
			Women: 14	442.14
Pyridoxine (B6)	0.71		Men: 1.4	50.71
			Women: 1.2	59.16

Constitute	Content			DRIs * (g/day)	Value in 100 g Mushroom/DRIs × 100
	Value	g/100 g Mushroom (Wet-Weight Basis)	g/100 g Mushroom (Dry-Weight Basis)		
Ascorbic acid		32.2		Men: 90	35.77
				Women: 75	42.93

- *G*. *lucidum* contains a considerable amount of water-soluble proteins (19.5 g/100 g mushroom (*w*/*w*)). Moreover, 18 kinds of amino acids have been found in *G*. *lucidum*, and the most abundant amino acid was leucine, which possessed strong hypoglycemic and antioxidant activities [60][61].
- *G*. *lucidum* contains 3.5 g of dietary fiber per 100 g of mushroom (d/w).
- *G*. *lucidum* contains significant amounts of major minerals (e.g., phosphorus, sulfur) and other trace mineral contents; i.e., Cu, Mg, and Fe.
- As also mentioned in **Table 2**, *G*. *lucidum* is a highly rich source of vitamins such as riboflavin, niacin, thiamin, etc. Additionally, Ahmad [62] reported that several vitamins have been found in *G*. *lucidum*, such as vitamins B1, B2, B6, β-carotene, C, D, and E.
- Based on the nutritional profile of *G*. *lucidum*, this mushroom possesses a high nutrient potential that reflects positively on its health benefits.

Through this vision, the *G*. *lucidum* mushroom is increasingly becoming one of the natural and untapped medicine resources, which should be of interest to pharmaceutical, nutraceutical, and cosmetics manufacturers and consumers worldwide [63]. *Ganoderma lucidum* contains myriad biologically active compounds (over 400 compounds), including polysaccharides, triterpenoids, steroids, fatty acids, amino acids, nucleosides, proteins, and alkaloids [64]. Still, how do these bioactive compounds reflect their medical properties? The following section will discuss the therapeutic impacts of these bioactive compounds.

2.1. *Ganoderma lucidum* Is a Factory of Biologically Active Useful Compounds

“Mushroom of immortality & symbol of traditional Chinese medicine”—Chen et al. [65].

The biologically active molecules of *G*. *lucidum* rely on their chemical composition, with polysaccharides, peptidoglycans, and triterpenes being the three major bioactive compounds [58][62][64][65][66][67]. Additionally, this mushroom contains other constituents with distinct biological functions, such as minerals (e.g., germanium), proteins, lectins, crude fibers, phenols, enzymes, sterols, and long-chain fatty acids [6][68][69][70][71]. **Table 3** shows the major bioactive compounds and their biological effects. ***Snapshots of these bioactive compounds could be found as follows.***

Table 3. The major bioactive compounds of *G. lucidum* and their biological effects.

Bioactive Compounds	Biological Effects	References
Triterpenoids		
Ganoderic acids, lucidumol, lucialdehyde, lucidenic acids, ganodermic, ganolucidic acids, ganoderals, ganoderiols	Anticancer	Wachtel-Galor et al. [6], El Mansy [69]
Triterpenoids	Antidiabetic	Ahmad [62], Ma et al. [72]
Ganoderic acids T-Q and lucideinic acids A, D2, E2, and P	Anti-inflammatory	El Mansy [69]
Triterpenes	Antioxidant	El Mansy [69]
Ganoderic acids, ganodermin, ganoderic acid A, ganodermadiol, ganodermanondiol, lucidumol B, ganodermanontriol, ganoderic acid B, ganolucidic acid B	Antimicrobial	Cör et al. [64], Sudheer et al. [67]
Triterpenoids, ganoderic acid, ganoderiol F, ganodermanontriol	Antiviral	Bishop et al. [13], Zhang et al. [73], Zhu et al. [74]
Polysaccharides		
1→3, 1→4, and 1→6-linked β and α-D (or L)-glucans, GLP-2B	Anticancer	Wachtel-Galor et al. [6], Ferreira et al. [75]
Polysaccharides	Antidiabetic	Ahmad [62], Ma et al. [72]
Polysaccharides	Antioxidant	El Mansy [69]
Polysaccharides	Antimicrobial	Cör et al. [64]
Polysaccharides (ganopoly)	Cardiovascular problems	Chan et al. [76]
Proteins, Glycoproteins, and Peptidoglycans		
Glycopeptides and peptidoglycans	Anticancer	Wachtel-Galor et al. [6], Sudheer et al. [67], Ferreira et al. [75],
Protein Ling Zhi-8 (LZ-8), lectin, ribosome-inactivating proteins, antimicrobial proteins, glycopeptides/glycoproteins,	Immunomodulatory, anticancer, and antitumor	Wachtel-Galor et al. [6], El Mansy [69]

Bioactive Compounds	Biological Effects	References
peptidoglycans/proteoglycans, ganodermin A, ribonucleases, proteinases, metalloproteases, laccases		
Proteoglycans, proteins (LZ-8)	Antidiabetic	Ahmad [62], Ma et al. [72]
Polysaccharide–peptide complex	Antioxidant	Mehta [77]
Phenolic compounds		
Phenolic components, phenolic extracts	Antioxidant	Mehta [77]
Saponins	Anticancer and antioxidant	Lee et al. [78]
Sterols; e.g., ergosterol	Provitamin D2	Wachtel-Galor et al. [6]
Long-chain fatty acids	Antitumor	Gao et al. [79]

2.2. Polysaccharides and Peptidoglycans

Polysaccharides, such as ganoderans, represent diverse biological macromolecules with a broad range of biological properties [58]. Additionally, *G. lucidum* is a source of polysaccharides, glycopeptides, and polysaccharide crude extracts, as indicated by several studies [80]. In addition, these components of *G. lucidum* mushroom showed strong biological activities, including, for example, antioxidant, anti-tumor, and antibacterial activities due to its content of sugars, glycoproteins, and polysaccharide extracts obtained from the fruiting bodies [75][81][82][83]. Anti-inflammatory, hypoglycemic, antitumorigenic, and immunostimulating activities are among the multiple biological roles of polysaccharides extracted from *G. lucidum* [84][85][86][87][88][89]. Free radical scavenging abilities, reducing power, and chelating on ferrous ions are among the reported antioxidant properties [90][91]. Ospina et al. [92] reported that the isolated chitosan from *G. lucidum* has promising and desirable characteristics in specialized sectors such as biomedicine, pharmaceutics, and cosmetics, beyond the food industry. Regarding the peptidoglycans, *G. lucidum* contains a proteoglucan (GLPG) that has antiviral activity [93].

2.3. Triterpenes

Several triterpenes extracted from *G. lucidum* have been reported (around 100 types of triterpenes), with half of these types being novel and unique to *G. lucidum* [18]. Ganoderic and lucidenic acids are the major triterpenes produced by *G. lucidum*, while other triterpenes have been identified; e.g., ganodermic, ganoderiols, and ganoderal acids [58][94][95][96][97][98][99][100][101].

2.4. Other Bioactive Compounds

2.4.1. Germanium

The element germanium has brought some attention to *G*. *lucidum*. Germanium is one of the most prevalent elements in wild *G*. *lucidum*. With 489 µg/g, germanium occupied the fifth-highest rank among the other detected minerals in terms of concentration [102]. This element possesses significant biological activities; i.e., antimutagenic, antitumor, immune-potentiating, and antioxidant [103]. There is no rigorous proof linking germanium with the specific health benefits of *G*. *lucidum*.

2.4.2. Proteins

Some bioactive proteins purified from *G*. *lucidum* have been found to contribute to the medicinal properties of this mushroom; for example:

- LZ-8, an immunosuppressive protein [104];
- GLP, which possesses both antioxidant and hepatoprotective activities [105][106];
- Ganodermin, an antifungal protein [107].

Many other bioactive compounds have been isolated from *G*. *lucidum*, including:

- Enzymes; e.g., a metalloprotease that delays clotting time [6].

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