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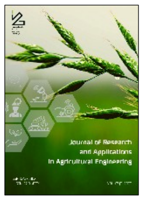

Nutritional and health-promoting value of selected tree-fungi found in Polish forests: a review

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Mushrooms have been an important part of the human diet for thousands of years. In many cultures, they are not only a source of food but also a raw material with medicinal potential. Their unique structure and chemical composition make them an interesting subject of research in the fields of nutrition, food technology, and medicine. Currently, there is a growing interest in mushrooms as functional foods that can contribute to health improvement and support the body in fighting diseases. A possible hazard linked to eating tree-growing fungi is the accumulation of heavy metals in their fruiting bodies, as these organisms have a strong ability to bioaccumulate such elements. For this reason, it is essential to avoid collecting fungi from polluted areas and to respect recommended safety limits for single servings. Despite certain restrictions—especially concerning vulnerable groups such as children—fungi can still be considered a functional food with health-promoting properties. While in vitro studies on tree fungi have revealed a rich diversity of biologically active metabolites, translation of these findings to in vivo or clinical efficacy remains limited to a few well-studied examples. The aim of this study was to assess the current state of knowledge on the chemical composition and biological potential of selected Polish species of wood-inhabiting mushrooms (Laetiporus sulphureus, Pleurotus pulmonarius, Pseudohydnum gelatinosum, Sparassis crispa, Armillaria, and Tricholomopsis rutilans in the context of their nutritional and therapeutic applications.

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1. Introduction

Mushrooms remain relatively little-known organisms. They are valued for their high content of protein, dietary fiber, vitamins, and minerals. At the same time, they are low in calories, which makes them an attractive dietary component for people who care about their health and body weight [1, 2]. Special attention is given to their content of bioactive compounds such as polysaccharides, terpenes, and phenols, which exhibit antioxidant, anti-inflammatory, and immunomodulatory properties. Thanks to these characteristics, mushrooms — including tree fungi — are not only a valuable source of nutrients but may also play a significant role in preventing and supporting the treatment of lifestyle diseases such as obesity, diabetes, and cancer [3].

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This paper evaluates the nutritional and health-promoting properties of selected species of tree-growing mushrooms, including: *Laetiporus sulphureus* (Bull.) Murrill, *Pleurotus pulmonarius* (Fr.) Quél., *Pseudohydnum gelatinosum* (Scop.) P. Karst., *Sparassis crispa* (Wulfen) Fr., *Armillaria ostoyae* (Romagn.) Herink, and *Tricholomopsis rutilans* (Schaeff.) Singer). The selected mushroom species belong to the Basidiomycota, they are saprotrophs, and some are also parasites of trees. A literature search was conducted in the Web of Science (WoS) database, which was selected because it is considered one of the most comprehensive and most frequently used databases for archiving literature employed in reviews and bibliometric analyses. The search was performed using the following keywords: "tree fungi," "nutritional value," "mineral composition," and "bioactive compounds," covering publications from 2002 to 2025.

2. Characteristics of Selected Tree Fungi

Laetiporus sulphureus (Fig. 1) belongs to the family *Laetiporaceae.*

Fig. 1. Laetiporus sulphureus, Żołędowo Forest District 24/09/2024 [source: own work]

It is a dangerous pathogenic fungus that causes the death of infected trees. *L. sulphureus* is a cosmopolitan species that attacks both healthy and weakened older deciduous trees. It rarely colonizes coniferous trees [4]. It is characterized by intensely coloured, shelf-like fruiting bodies with a soft consistency when fresh. The hymenophore is sulfur-yellow or orange-yellow, gradually fading over time to ochre or cream shades. Colour variability may be influenced by environmental factors such as sunlight exposure, air humidity, and the type of substrate [5]. Microscopically, this species produces smooth, ellipsoidal to oval spores measuring 5–7 × 3.5–5 μm, with a white spore print. The hyphae form a dimitic system consisting of both generative and binding hyphae; clamp connections are absent in the generative hyphae [6]. The hymenial trama is composed of thin-walled, hyaline hyphae measuring 4–7 μm in width. The chemical composition of *L. sulphureus* fruiting bodies is variable and depends on the age of the fruiting body, habitat conditions, and the host tree species. Studies have shown that the content of organic acids (including tartaric and malic acid), lipids, and phenolic compounds changes during the maturation of the fungus. An increase in oleic acid content and a decrease in linoleic acid content have been observed with fruiting body aging [7, 8]. Factors such as the mineral composition of the substrate, environmental pollution levels, sunlight, and humidity significantly influence the metabolic profile of this species, determining its potential nutritional value and biological activity [7]. It is both a parasite and a saprotroph, leading to the development of brown rot in wood. In Poland, it commonly occurs from May to September. Only young fruiting bodies of this species are edible, and they must be properly prepared — by rinsing, boiling, and discarding the water. Only after this treatment can the mushrooms be further processed (e.g., fried).

Pleurotus pulmonarius (Fig. 2) is classified under the family *Pleurotaceae.*

Fig. 2. *Pleurotus pulmonarius*, Żołędowo Forest District, 20.10.2024 [source: own work]

It grows on both living and weakened deciduous trees as well as on dead wood. This species is a parasite and saprotroph that causes white rot in wood. It can be found in Poland from June to October and is relatively widespread.

The fruiting bodies of this mushroom are commonly used in cooking — for pickling or as an addition to meat dishes and sauces. Due to its sweet flavor, it is particularly recommended for vegetarians as a standalone dish. The fruiting bodies are fan-shaped or semicircular, with a smooth, glossy cap surface ranging in colour from light cream to light ochre or gray-brown, depending on age and sunlight exposure. The hymenophore consists of densely arranged gills, initially white, which gradually turn yellowish while retaining a delicate, creamy colouration. Microscopically, this species is characterized by elliptical, smooth, hyaline spores measuring 7–12 × 3–5 μm. The hyphae form a monomitic system composed exclusively of generative hyphae, with clamp connections present. The gill trama is soft, thin-walled, hyaline, and non-amyloid, which is typical of the genus *Pleurotus* [9, 10]. The chemical composition of *P. pulmonarius* fruiting bodies shows considerable variability depending on the substrate, growth conditions, and developmental stage of the fruiting body. The fruiting bodies are rich in proteins, polysaccharides, organic acids, and phenolic compounds with antioxidant properties. The content of lipids and amino acids varies according to the type of substrate [11]. Environmental factors such as humidity, temperature, substrate chemistry, and sunlight significantly influence the metabolite profile and biological activity of the mushroom, determining its health-promoting potential and nutritional value [9, 10].

However, it is important to note that the lung oyster mushroom is considered rare in Poland and is listed on the Polish Red List of Plants and Fungi. Therefore, it should be harvested responsibly, leaving some fruiting bodies behind to allow for reproduction and population maintenance.

Pseudohydnum gelatinosum (Fig. 3) belongs to the family *Exidiaceae*.

Fig. 3. *Pseudohydnum gelatinosum*, Żołędowo Forest District, 10.11.2024 [source: own work]

Its spiny hymenophore is made up of small white spines 2–3 mm in length, closely packed together. The spores are nearly spherical, smooth, and hyaline (~5–8.5 × 3.5–6.5 μm). The fungal structure is monomitic, with clamp connections and basidia featuring long, septate sterigmata. Although detailed data on the influence of habitat conditions on chemical composition are limited, it is known that the habitat (type of wood, degree of decomposition, humidity) affects morphological characteristics and likely also the bioactive and chemical profile of this species. This jelly fungus grows in mixed and coniferous forests, usually on the northern side of dead and decaying spruce and pine logs. It is a saprotroph and commonly occurs in Poland from summer to autumn. It is an edible species, typically used in salads after blanching.

Sparassis crispa (Fig. 4) is an edible mushroom belonging to the *Sparassidaceae* family [5].

Fig. 4. *Sparassis crispa*, Żołędowo Forest District, 08.10.2024 [source: own work]

Its fruiting bodies can reach 40 cm wide by 20 cm high, and a single specimen can weigh up to 6 kg. The fruiting bodies are creamy white when young, gradually turning yellow-ochre or yellow-brown with age. The hymenophore is located on the inner surfaces of the folded lobes ("flabellae") and is usually smooth, with slight surface undulations [12]. Microscopically, the spores are smooth, hyaline, and broadly ellipsoidal to oval, measuring approximately 5–7 × 4–5 μm, while the hyphae possess clamp connections. The hyphal system in the fruiting body is monomitic (composed only of generative hyphae) [12].

The chemical composition of the fruiting bodies is very rich and diverse. Polysaccharides, including 1,3-β-glucans, can account for over 40% of the dry weight of the fruiting body [12, 13]. Additionally, bioactive compounds such as ergosterol peroxides, sparoside A, sparalide A, alkaloids, phenols, and terpenes have been identified, exhibiting antioxidant, anti-inflammatory, immunomodulatory, and anticancer properties [12, 14]. Chemical analyses have also revealed high levels of mineral elements, including potassium, phosphorus, and sodium [15, 16]. Habitat conditions, such as tree species, humidity, and the degree of wood decay, influence the content of metabolites and the biological activity of the fruiting bodies, although detailed quantitative studies of these relationships are still limited [12].

It is used in soups, for frying, and for drying. *S. crispa is* a saprotroph and parasite that attacks coniferous tree wood, typically appearing on trunks and roots of pines. Fruiting bodies are visible from July to January and often reappear in the same location for several years. Its mycelium causes brown rot in wood and emits a characteristic turpentine-like odor [17].

Armillaria ostoyae (Fig. 5) belongs to the family *Physalacriaceae.* Its fruiting bodies are hemispherical, and the caps become concave with age. This species mainly grows on the trunks and roots of coniferous trees. It is a dangerous parasite and saprotroph that causes white rot in wood.

Fig. 5. *Armillaria ostoyae*, Żołędowo Forest District 24.09.2024 [source: own work]

Fruiting bodies appear from July to November and are very common in Poland. Only the caps of this species are edible. The fruiting bodies of *A. ostoyae* usually appear in large clusters at the base of tree trunks or stumps. The cap measures 5–15 cm in diameter, ranging in colour from yellow-brown to dark brown, often covered with small scales. The gills are white or cream-coloured, turning light brown with age. The stipe is fibrous, often with a ring, and the flesh is white with a pleasant, mushroom-like odor. The spores are smooth, ellipsoidal, hyaline, measuring 8–11 × 5–7 μm, producing a white spore print. The hyphae are monomitic, with clamp connections, which are typical for the genus *Armillaria* [17].

The fruiting bodies of *A. ostoyae* contain numerous bioactive compounds with health-promoting potential [18, 19]. Methanolic extracts revealed a high content of phenols (6.12 mg GAE/g dry weight), chlorogenic acid, as well as the presence of fructose as the main carbohydrate and malic acid as the dominant organic acid [20]. Elemental analysis showed a predominance of potassium, phosphorus, and sodium, with only trace amounts of heavy metals, making the species safe for consumption under controlled environmental conditions [18].

Studies of liquid cultures have revealed the presence of secondary metabolites such as isoliquiritigenin, 7-hydroxycoumarin, and 4-(dimethylamino)-N-[7-(hydroxyamino)-7-oxoheptyl]benzamide.
These compounds exhibit potential anticancer and anti-inflammatory activities [21]. Additionally, polysaccharides isolated from the fruiting bodies (AkPS1V-1, AkPS1V-2) show strong antioxidant activity and immunostimulatory potential [20]. The chemical composition and growth of *A. ostoyae* mycelium depend on environmental conditions such as temperature, humidity, CO_2 concentration, and the host tree species. Studies have shown that increased CO_2 concentration limits rhizomorph formation in vitro, which may affect colony development and fruiting body structures [21]. Moreover, the genetic diversity of populations in pine forests in Poland suggests adaptive differences resulting from local habitat conditions [22].

Due to the presence of phenolic compounds, polysaccharides, and secondary metabolites, *A. ostoyae* is considered a species with pharmacological and nutraceutical potential. At the same time, because of its ability to bioaccumulate heavy metals, it is recommended to avoid harvesting fruiting bodies from industrially contaminated areas [18].

Tricholomopsis rutilans (Fig. 6) belongs to the family *Tricholomataceae.* Its rounded caps are mounted on a central stipe and can reach up to 15 cm in diameter.

Fig. 6. *Tricholomopsis rutilans*, Żołędowo Forest District 10.11.2024 [source: own work]

This species is a saprotroph that decomposes roots and trunks of both coniferous and deciduous trees. Fruiting bodies can be found from July to December. It is edible after boiling. Due to its attractive appearance, it is also used for culinary decoration. It is a common species in Poland. Microscopically, the spores are smooth, hyaline, and ellipsoidal or slightly broadly ellipsoidal, with approximate dimensions of 5–7 × 3.5–5.5 μm. The hyphae possess clamp connections [23].

Regarding the chemical composition and nutritional properties, studies have shown that fatty acids dominate in the fruiting bodies of *T. rutilans.* In one study from Turkey, oleic acid (~39.04%) and linoleic acid (~37.09%) were the most abundant fatty acids. Additionally, various minerals were detected, with sodium (Na) and magnesium (Mg) being the most abundant among the analysed elements [24].

In terms of polysaccharides, experimental antioxidant activities, and β-glucan content, the species has also been studied—for example, a quantitative study revealed the presence of β-1,3/β-1,6 glucans in *T. rutilans* [25].

3. Nutritional Value of Tree Fungi

The energy value of edible mushrooms is generally low, which makes them suitable for low-calorie diets. Geological diversity of the area, type of ecosystem, and the developmental stage of the fruiting body contribute to significant variations in the chemical composition of mushrooms, even within the same species [26, 27].

Carbohydrates are one of the main nutrients in mushrooms, accounting for approximately 40–70% of their dry matter [26]. According to Muszyńska et al., [28], carbohydrates make up an average of up to 6% of the fruiting body mass. The most abundant carbohydrates include glycogen, mannitol, and sorbitol. In the fruiting bodies of Basidiomycota, free forms of glucose, galactose, mannose, and fructose are present. The predominant disaccharide is trehalose.

Mushrooms are a rich source of dietary fiber due to their cell walls, which are composed of chitin, hemicellulose, and mannans. It is estimated that 100 g of fresh mushrooms can provide between 10% and 40% of the recommended daily intake of dietary fiber [26]. Compared to conventional sources of dietary fiber such as cereals, legumes, fruits, and vegetables, mushrooms remain underutilized [29].

Proteins in edible mushrooms are characterized by a favourable amino acid profile and high digestibility, reaching up to 90%, depending on the species [30, 31, 32, 33]. Dried mushroom fruiting bodies may contain up to 25% digestible protein. Some edible mushrooms contain more protein than vegetables, fruits, or grains [32]. Certain Basidiomycota species also contain biogenic amines such as adenine, trimethylamine, choline, betaine, and guanine, which are essential for human growth and development [8]. In addition to proteins, nitrogenous compounds in mushrooms include free amino acids, amines, and nucleic acids [25].

Lipids account for 2–6% of the dry mass of mushrooms [27]. Primarily in the form of fatty acids, which regulate intracellular signalling pathways and the expression of bioactive lipid mediators in the human body [34, 35]. Despite their low total fat content, mushrooms can contain up to 37 different types of fatty acids [15]. Fruiting bodies have a relatively low fat content, about 70% of which consists of unsaturated fatty acids [9]. Thirty-one types of saturated fatty acids were identified in *Trametes versicolor* (L.) Lloyd [4]. Forty-one percent of the fat fraction consisted of saturated fatty acids, with hexadecanoic acid (23%) and octadecanoic acid (11%) being dominant [36].

Among the unsaturated fatty acids, oleic acid was most prevalent (21%), comprising 35% of the total fat fraction. Polyunsaturated fatty acids made up 24% of the fat content, with linoleic acid being the most abundant (19%).

Edible mushroom fruiting bodies contain significant amounts of B vitamins such as pyridoxine, niacin, riboflavin, and thiamine. In dry matter, their levels are approximately: 1.8–5.1 mg (pyridoxine), 31–65 mg (niacin), and 0.30–0.64 mg (thiamine). This means that the riboflavin content in mushrooms exceeds that found in vegetables [7]. According to Assemie and Abaya [37], mushrooms are also a source of vitamins such as tocopherol, β-carotene, and ascorbic acid. Some fruiting bodies also contain lycopene — a carotenoid pigment.

Mushrooms contain significant amounts of ergosterol, which strengthens cell membranes, modulates their fluidity, and supports intracellular transport. Under UV radiation, ergosterol in the fungal cell wall converts into vitamin D2. Although vitamin D2 levels in mushrooms can decrease during storage and cooking, they still retain over 10 μg/100 g of fresh weight during their shelf life. This level is higher than that found in most other foods containing vitamin D and is comparable to the daily requirement of 15 μg for adults [38].

In their natural environment, mushrooms absorb nutrients effectively from the substrate. A key quality feature is their high content of minerals and trace elements — often higher than in grains or garden plants. In particular, mushrooms are a valuable source of phosphorus, potassium, calcium, and magnesium [39]. Fruiting bodies also contain iron, zinc, copper, manganese, molybdenum, and selenium. Conversely, their sodium content is low, which makes them suitable for people with high blood pressure.

In addition to essential minerals, mushrooms can also absorb heavy metals from the substrate via their mycelium. However, they have a limited ability to eliminate these elements. The content of heavy metals in fruiting bodies depends on factors such as the contamination level of the substrate and anthropogenic influences in the area [20]. Mushrooms growing near roads have been found to contain elevated levels of lead, while those collected near industrial facilities showed higher mercury content [40, 41].

4. Biologically Active Compounds in Tree Fungi

In recent years, there has been a growing interest in large-fruiting fungi, particularly regarding their nutraceutical properties. Research has confirmed that certain species of tree fungi are rich sources of compounds with health-promoting effects [42, 43]. A wide variety of compounds with diverse structures and multifaceted actions on the human body have been identified [19, 44]. However, while *in vitro* studies frequently demonstrate bioactivity, only a fraction of these effects have been validated in *in vivo* or clinical settings.

Phenolic compounds represent a large and diverse group of secondary metabolites with well-established *in vitro* antioxidant activity, including radical scavenging and metal ion chelation (Fe^{2+}, Cu^{2+}). These mechanisms have been documented in numerous mushroom species, including *Ganoderma lucidum* (Curtis) P. Karst., *Inonotus obliquus* (Fr.) Pilát, and *Fomes fomentarius* (L.) Fr. Due to their broad pharmacological effects, phenolic compounds are used to support the treatment of various diseases. Based on their structure, they are categorized into flavonoids and phenolic acids [16]. Fruiting bodies of both wild and cultivated mushrooms are rich in phenolic compounds, primarily quercetin and catechin, as well as p-coumaric, caffeic, and gallic acids. Other notable compounds include homogentisic, ferulic, and phydroxybenzoic acids [45]. *In vivo* studies in rodents indicate that phenolic-rich extracts can reduce oxidative stress markers and lipid peroxidation [e.g., reduction of malondialdehyde (MDA) and increased superoxide dismutase (SOD) activity]. However, clinical evidence confirming direct antioxidant or disease-preventing effects of phenolic compounds from mushrooms remains limited. While small human trials have shown mild improvements in antioxidant capacity (e.g., plasma ORAC values), these studies often suffer from low participant numbers and lack of blinding. Therefore, the broad pharmacological claims—such as anti-aging or anti-cancer efficacy—remain largely extrapolations from *in vitro* experiments rather than confirmed therapeutic outcomes.

Indole compounds in mushrooms include non-hallucinogenic substances such as L-tryptophan, 5-hydroxytryptophan, serotonin, melatonin, and tryptamine. These compounds function as neurotransmitters or their precursors and exhibit anti-cancer, antioxidant, and anti-aging properties. They may be particularly important for their potential role in preventing depression and neurodegenerative diseases such as Parkinson's and Alzheimer's [36]. Non-hallucinogenic indoles such as L-tryptophan, 5-hydroxytryptophan, serotonin, and melatonin have been detected in several wood-decaying fungi. *In vitro* data demonstrate their antioxidant and anti-proliferative activities, while *in vivo* studies suggest possible neuroprotective effects through modulation of serotonergic pathways. Nonetheless, *clinical trials* directly examining mushroom-derived indole compounds are lacking. Existing evidence on antidepressant or neuroprotective benefits stems mainly from studies using *synthetic* or *plant-derived* analogues. Thus, the suggestion that indole metabolites from tree fungi prevent neurodegenerative disorders such as Parkinson's or Alzheimer's disease remains hypothetical and not supported by direct human data.

Sterols are steroid-based chemical compounds commonly found in living organisms. They are classified into three groups: zoosterols (animal origin), phytosterols (plant origin), and mycosterols (produced by fungi). Formerly referred to as sterines, they are polycyclic hydroaromatic alcohols occurring in free or bound forms [16]. Particularly rich in sterols are *P. pulmonarius* [46].

Edible mushrooms are a rich source of ergosterol (provitamin D2), with contents ranging from 300 to 700 mg per 100 g dry matter. Under solar radiation, ergosterol converts to ergocalciferol. Studies have shown that gills have the greatest potential for D2 synthesis during exposure to UV light, even though caps naturally contain more ergocalciferol. This is likely because the gills, being younger parts of the fruiting body, tend to contain more sterols, including ergosterol, than the more mature caps and stems [47]. Several *in vitro* studies have confirmed ergosterol's antioxidant and membrane-stabilizing properties, and *in vivo* supplementation with UV-treated mushrooms has been shown to increase serum 25(OH)D_2 levels in humans. Clinical trials indicate that mushroom-derived vitamin D_2 can improve vitamin D status comparably to synthetic D_2, but its biological potency is slightly lower than that of D_3. Beyond vitamin D activity, claims of ergosterol's anti-cancer or cholesterol-lowering effects remain insufficiently validated. Most evidence derives from cell culture assays without corroborating *in vivo* or clinical data.

Benzoquinones are pigmented compounds derived from p-benzoquinone, found mainly in fungi. Their colours range from violet to brown, and less frequently orange. They are described as cytotoxic and antibiotic in action. Due to their diverse biological properties, benzoquinones are studied for potential use in antibacterial, anticancer, and cardiovascular therapies [48]. However, these effects are often non-selective, and *in vivo* toxicity studies indicate potential hepatotoxicity and genotoxicity at higher doses. No clinical studies have been conducted to confirm their therapeutic safety or efficacy in humans. Consequently, while benzoquinones are chemically interesting as lead compounds, their direct pharmacological use remains unsubstantiated. Benzoquinones, including emodin-like pigments found in some polypores, show *in vitro* cytotoxic and antibacterial properties. However, these effects are often non-selective, and *in vivo* toxicity studies indicate potential hepatotoxicity and genotoxicity at higher doses. No clinical studies have been conducted to confirm their therapeutic safety or efficacy in humans. Consequently, while benzoquinones are chemically interesting as lead compounds, their direct pharmacological use remains unsubstantiated.

Terpenoids are derivatives of terpenes, composed of isoprene units and containing additional heteroatoms. They are synthesized via the mevalonic acid pathway and are one of the most numerous groups of fungal secondary metabolites. They include monoterpenoids, diterpenoids, triterpenoids, sesquiterpenoids, and squalene derivatives.

Diterpenoids such as pleuromutilin have been successfully developed into semisynthetic antibiotics (e.g., retapamulin, lefamulin), with proven *in vivo* and clinical efficacy against Gram-positive pathogens. This represents one of the few examples where a fungal metabolite from tree fungi has translated into approved clinical use. [49].

Triterpenoids, on the other hand, exhibit antiviral activity (e.g., against herpes), inhibit cholesterol synthesis, reduce platelet aggregation, and lower blood pressure—factors that reduce cardiovascular disease risk. The most commonly studied triterpenoids are those derived from *G. lucidum*, widely used in traditional Chinese medicine. Over 150 different triterpenoids have been isolated from this mushroom, including ganoderic acid, ganodermadionic acid, and ganodermadiol. These compounds inhibit tumor growth and invasiveness [2, 33]. Nevertheless, systematic reviews of human trials reveal inconsistent clinical results, often due to small sample sizes, non-standardized extracts, and poor bioavailability. No triterpenoid from tree fungi has yet been registered as a pharmaceutical agent.

Sesquiterpenoids are the largest group of terpenoids found in fungi. They exhibit both anticancer and antibiotic properties. *Armillaria mellea* (Vahl) P. Kumm is a tree fungus in which significant amounts of sesquiterpenoids have been identified. Compounds such as armillarins and melleolides, detected in *A. ostoyae*, belong to the protoilludane derivative group [9]. Sesquiterpenoids, such as melleolides from *Armillaria* spp., display strong *in vitro* cytotoxicity but have limited *in vivo* data due to poor solubility and potential toxicity. Thus, their anticancer potential remains theoretical.

Polysaccharides are the best-known group of biologically active compounds in fungi. Their anti-cancer mechanisms are not yet fully understood, but they are known to activate immune cells. They stimulate lymphocyte and macrophage proliferation and support the synthesis of cytokines such as interleukins, interferons, and immunoglobulins. Their activities include anti-cancer, immunostimulatory, and antioxidant effects. In Asian countries, polysaccharides isolated from tree fungi are already marketed as anti-cancer drugs [50, 51]. Extensive *in vitro* research demonstrates their immunomodulatory and anti-tumor effects via activation of macrophages, T-cells, and cytokine synthesis (IL-2, IFN-γ). *In vivo* studies in rodents have confirmed that β-glucans from *G. lucidum*, *Lentinula edodes* (Berk.) Pegler, and *T. versicolor* can inhibit tumor growth and enhance immune responses. Clinically, polysaccharide-protein complexes (PSP and PSK) from *T. versicolor* are among the few fungal metabolites with verified human data. In randomized controlled trials in Japan and China, PSP/PSK used as adjuncts to chemotherapy improved immune markers, reduced chemotherapy-induced immunosuppression, and slightly extended survival in gastric and colorectal cancer patients. These effects are well-documented and reproducible, though not curative. Conversely, many polysaccharide fractions isolated from other fungi lack clinical confirmation. Claims of direct anti-cancer activity or life extension effects based solely on *in vitro* assays should therefore be treated with caution.

These biologically active polysaccharides are found not only in fruiting bodies but also in cultivated mycelium and sclerotia. Their properties and chemical structures vary greatly. Many are glucans with different glycosidic linkages; some are protein-bound or heteroglycans. The anti-cancer activity is most likely associated with fungal cell wall components, including chitin, cellulose, (1→3, 1→6)-β-glucans, (1→3)-α-glucans, and polysaccharide-protein complexes. Notably, chitin itself does not exhibit anti-cancer properties. Based on structure, polysaccharides are classified as homoglycans or heteroglycans, with heteroglycans being the largest group of anti-cancer compounds [50, 51]. Among wood-dwelling fungi, species of the genus *Pleurotus* are distinguished by numerous health-promoting properties, especially their anticancer effects [46].

Trametes versicolor (commonly known as turkey tail) is a tree fungus widespread throughout Poland, known to contain polysaccharide-protein complexes (PSP). These polysaccharidopeptides exhibit strong immunomodulatory properties and are non-toxic even at high doses and with prolonged use. Consequently, this mushroom is widely used in Chinese and Japanese medicine, especially as supportive therapy in cancer treatment, including chemotherapy.

PSP is a 100 kDa complex composed of a polypeptide chain rich in aspartic and glutamic acids, containing more than 20 amino acids and six sugars: glucose, arabinose, galactose, rhamnose, mannose, and xylose. The polysaccharide structure of PSP is branched, with main glycosidic bonds including β1→4, β1→3, and α1→4. Glucose is the principal monosaccharide, permanently bound to the protein backbone [38].

5. Summary

Tree fungi are common species found throughout Poland. They can be a valuable addition to the diet due to their content of easily digestible amino acids, minerals, vitamins, and fibre. They are also an important source of biologically active compounds that have applications in preventing and treating lifestyle diseases, particularly cancers and heart diseases. The active compounds present in the fruiting bodies of tree fungi help lower blood sugar and cholesterol levels. They also exhibit anti-inflammatory, antibacterial, antiviral, and antioxidant properties. However, a potential risk associated with the consumption of tree fungi is the presence of heavy metals in their fruiting bodies, due to their high bioaccumulation capacity. Therefore, it is crucial not to collect fungi from contaminated areas and to adhere to acceptable limits for their single consumption. With some limitations, particularly for specific population groups (especially children), fungi can be recommended as functional and health-promoting food.

While *in vitro* studies on tree fungi have revealed a rich diversity of biologically active metabolites, translation of these findings to *in vivo* or clinical efficacy remains limited to a few well-studied examples—most notably pleuromutilin antibiotics and PSP/PSK polysaccharide complexes. Most reported antioxidant, anti-aging, or anti-cancer activities of phenolics, indoles, triterpenoids, and sesquiterpenoids lack robust *in vivo* or human validation. Many effects are likely overstated due to reliance on high-concentration cell culture experiments that do not reflect physiological conditions. Future research should focus on standardized extraction, pharmacokinetic studies, and large-scale randomized clinical trials to clarify which of these fungal metabolites truly possess therapeutic potential.

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