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Fomes fomentarius and *Polyporus squamosus* Models of Marvel Medicinal Mushrooms

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Abstract

The medicinal uses of the mushroom still need to be worked out for their biological activities. The purpose of this review was to investigate the biological activities of extracts prepared from fruiting bodies of *Fomes fomentarius* and *Polyporus squamosus* and demonstrates that these medicinal mushrooms, similar to plants, have a great potential for the production of useful bioactive metabolites and that they are a prolific resource for drugs.

Keywords

Medicinal mushrooms; *Fomes fomentarius*; *Polyporus squamosus;* Biological activities

Introduction

Mushrooms that have existed for centuries have spread all over the world. Mushrooms were originally defined as macro fungi with a distinctive fruiting body. While mushrooms differ as poisonous and non-poisonous, it is possible to classify them as edible and non-edible mushrooms. Recently, many researches have been conducted on the benefits and importance of many species of mushrooms [1-5].

Medicinal mushrooms are widely used as food and herb medicine in China, Japan and other Asian countries. Medicinal mushrooms are a source of polysaccharide with anti-inflammatory and immune system stimulanting properties and have antioxidant, anti-inflammatory and anti diabetic effect [4,6]. A lot of research has been done on medically edible fungi. In addition, non-edible mushrooms have been found to be of medical importance in recent years. Today, it is important to investigate alternative drugs and natural therapeutics for cancer treatment [3,6].

Mushrooms need to produce antibacterial and antifungal compounds to survive in their natural environment. Antimicrobial compounds could be isolated from many mushroom species and some proved to be of benefit for humans. Edible mushrooms are our important food source. With its easily digestible and nutritious feature, it is widely used in today's tables. Because of their taste and flavour, the edible mushrooms are consumed as meals in addition to their consumption. Mushrooms are a rich source of protein, lipids, amino acids, glycogen, vitamins and minerals [7-9].

Medicinal mushrooms accumulate a wide variety of bioactive compounds including terpenoids, steroids, phenols, nucleotides and their derivatives glycoprotein's and polysaccharides that display a broad range of biological activities. These different bioactive compounds have been extracted from the fruiting body, mycelia and culture medium of various medicinal mushrooms [4,10]. Edible mushrooms, which demonstrate medicinal or functional properties include species of *Lentinula*, *Hericium*, *Grifola*, *Flammulina*, *Pleurotus* and *Tremella* while others known only for their medicinal properties, viz. *Ganoderma lucidum* [6,11,12], *Trametes versicolor* [13], and *Fomes fomentarius*, are decidedly non-edible because of their coarse texture and bitter taste [14].

In this review, it was aimed to give basic information on the identification, morphological and ecological characteristics, nutritional value and medicinal properties of *Fomes* mushrooms and *Polyporus squamosus* mushrooms.

Fomes mushrooms

Fomes mushrooms have been used for centuries for medicinal purposes. In recent years, the active compounds of *Fomes* fungus have been studied extensively and most of their biological activities have been studied. *Fomes* species, which often cause decay and destruction of wood, often cause white decay on trees [1-2].

Fomes fomentarius

Fomes fomentarius is a basidiomycete white-rot fungus belonging to the polyporaceae

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family. It has been used as a traditional medicine for centuries in treating various diseases such as gastroenteric disorder, hepatocirrhosis, oral ulcer, inflammation, and various cancers. *Fomes fomentarius* woody fruiting body is often shaped like a horse's hoof, hence one of its common names, hoof fungus. *Fomes fomentarius* also goes by the names Tinder Conk, Tinder Fungus, Tinder Polypore and Ice Man Fungus. It grows wild throughout northern North America and parts of Eurasia, as well as in the cooler areas of Africa. *Fomes fomentarius* looks quite different than most familiar mushrooms. It has no stem or stipe, nor does it have gills, but instead a flat lower surface covered with pores, which are the openings of densely-packed, spore-producing tubes. The fruiting body is perennial, adding a new layer of tubes every year, and so the flesh is tough and woody [15]. *Fomes fomentarius* can be cultivated on a wide variety of agricultural substrates/by-products and wastes for the production of feed, enzymes and medicinal compounds, or for waste degradation and detoxification [16]. *Fomes fomentarius* (Polyporales, Agaricomycetes, Basidiomycota) is economically and ecologically important not only as a source of medicinal and neutraceutical products but also in nutrient cycling in forest ecosystems as decomposers of dead wood [17].

Fomes fomentarius ecology and macroscopic description

Ecology: In hardwood wood bodies (especially birch and beech), it causes white rotting, living alone or with more than one species. It has a thick rigid body. Life style is parasitic and saprotrophic. Macroscopic description: Basidiocarps: 5-45 cm in diameter, 2-25 cm in height and is shaped like a horse nail (Figure 1). Each year, there are different gray colored concentric zones with different thicknesses stacked on top of each other, gray-gray brown. When it is young, there is a white circular ring on the edge. The outer part is hard and woody. Trama: Hard, cinnamon brown, mature when poured in the form of lighter powder. The smell of fruit while fresh. Hymenium: Porous, round, 2-3 cm in mm, tubes 2-5 (8) mm long and gray brown. Spores: 5.5-6 × 18.5-19 µ, elliptic-cylindrical, flat, hyaline [17].

Fomes fomentarius benefits and uses

Fomes fomentarius have significant effects such as antioxidant enzyme activity, enzymatic activity, antimicrobial activity, antifungal activity, Anti-inflammatory effect, antioxidant activity, cytotoxicity, Antitumor, Antiviral activity, Antibacterial activity, DNA protective activity and Antioxidant. These activities are exhibited by extracts or isolated compounds from *Fomes fomentarius* fermentation broth, mycelia and fruiting bodies [8,16]. As a result of its perceived health benefits, *Fomes fomentarius* has gained wide popularity as an effective medicine and has become one of the valuable mushrooms [18-22].

Fomes fomentarius mushroom modulates the immune system, inhibits tumour growth, has anti-inflammatory, anti-nociceptive activities and hypoglycaemic, lowers blood lipid concentrations and prevents high blood pressure [23-27]. Recent advances in chemical technology have allowed the isolation and purification of some of the relevant compounds, especially polysaccharides, which possess strong immune modulation and anti-cancer activities [28]. Khadhri et al. [29] reported that crude ethanol extracts prepared from basidomes of *Fomes fomentarius* and *Phellinus torulosus* have higher total phenolic content and antioxidant activity per the DPPH and metal-chelating activity assays (Figure 1).

Figure 1: *Fomes fomentarius* (Photographs taken by **Paul W. Thomas**, Locality: Pitlochry, Scotland UK)

Polyporus squamosus

Mushrooms gain an importance due to their nutritional value as they are rich in proteins, essential amino acids as well as fibers, however they are being poor in fats. The edible mushrooms are considered vital sources of many vitamins including vitamin B1, B2, B12, C, D, and E. They also possess a great importance due to their valuable bioactive compounds such as phenolic compounds, unsaturated fatty acids, carotenoids and terpenoids. Thus, mushrooms have been used in many nutritional and pharmaceutical products [4].

Polyporus squamosus (Huds.) Fr which is also known as dryad's saddle and pheasant's back mushroom is an edible, basidiomycete bracket fungus mushroom that is distributed in Asia, Europe, Australia and North America [30] where it causes a white rot in both living and dead hardwood trees. It gains its name 'dryad's saddle' from creatures in Greek mythology known as dryads who could ride on this mushroom, while the name 'pheasant's back' refers to the pattern of colors found on the bracket and that matches that of a pheasant's back [31,32].

The fruiting bodies of *Polyporus squamosus* occur on living and dead hardwood trees during spring and autumn. Young fruiting bodies are soft, but toughen with age. Therefore, young fruiting bodies having good flavour and taste are more preferable for eating than the old ones [33]. Macroscopic description: *Polyporus squamosus* Cap is half circle or fan in shape, 8-60 cm in diameter, 12-24 cm in width and covered with brown scales, irregularly arranged in straw yellow color. Stipe is 4- 10×2-5 cm, lateral or occasionally off centre, short; the close part of stipe to the cap is yellowish, the bottom part is blackish dark brown (Figure 2). At an early stage while it is still tender, it is used as a spice. Moreover, it has been used as medicine due to its various biological activities including: diuretic, antibacterial, antifungal, nephroprotective, cytotoxic, immuno-enhancing, anti-inflammatory, hepatoprotective, antioxidative as well as hair-growing, and antimicrobial activities [30,34,35].

Bioactive compounds

The studies showed that the most abundant class of macronutrients

Figure 2: *Polyporus squamosus* (Photographs taken by **Paul W. Thomas**, Locality: Isle of Bute, Scotland, UK)

found in *Polyporus squamosus* fruiting body methanolic extract was the carbohydrates followed by proteins, ash, and finally it contained small amount of fats [36]. Considering the carbohydrate contents of *Polyporus squamosus* originating from Romania, the trehalose was found to be the most abundant compound (6.81 g per 100 g dry weight), on the other hand, the fructose was found in the least amount (0.730 g per 100 g dry weight). However, *Polyporus squamosus* fruiting bodies collected from Serbia and Portugal, trehalose was also found to be the most abundant sugar, but rhamnose was found in the least amount [30].

Many organic acids that plays an important role in the reduction of oxidative stress were also detected in the methanolic extract of *Polyporus squamosus* [37]. Oxalic, malic, quinic and fumaric acids were detected. Malic acid was found in the highest amount which was about 2.21 g per 100 g dry weight; however oxalic and fumaric acids were exist in considerably small amounts [36]. Lipophilic compounds, such as tocopherols and fatty acids, were also detected, both saturated and unsaturated fatty acids were found in the fruiting bodies. The high quantities of fatty acids detected were linoleic, oleic and palmitic acids. Also, polyunsaturated fatty acids, which have many health beneficial effects, were detected in high percentage (57.37%), this was followed by monounsaturated fatty acids (24.96%), and finally saturated fatty acids were detected in smaller percentage (17.68%) [36]. Tocopherols which are one of the potent natural antioxidants, are also detected. α-, β-, γ- and δ-Tocopherols were found in *Polyporus squamosus* sample. β-tocopherol was found in the highest amount which was about 114.7 µg per 100 g dry weight. Interestingly, it was reported that β-tocopherol was the main tocopherol in *Polyporus squamosus* originating from Portugal, while in the Serbian originating samples the γ-tocopherol was the major one, and these differences could be attributed to variability inherent to both samples as a consequence of growing under various environmental conditions [30]. Phenolic compounds, another bioactive compound which is involved in the antioxidative protection and is crucial in stabilizing the lipid per oxidation was also detected in the fruiting body of *Polyporus squamosus* [38]. Fernandes et al. [30] showed that *p*-hydroxybenzoic acid is the main phenolic acid found *Polyporus squamosus* of different origins, also it was mentioned that cinnamic acid which is a phenolic related compound, was also found but in small amounts [30].

Polyporus squamosus benefits and uses

The antioxidant activity for *Polyporus squamosus* was evaluated. Different assays were employed to test the antioxidant activity and trolox was employed as a reference standard. For the radical scavenging (DPPH scavenging activity) was employed, reducing power activities (ferricyanide/Prussian blue assay) was employed, while for the lipid peroxidation inhibition (TBARS, β-carotene/linoleate) were used. All assays showed positive antioxidant activities [39,40].

The antimicrobial activity of *Polyporus squamosus* extract was also evaluated against various bacteria and fungi species by the micro dilution method. The extract showed antibacterial activity towards *Enterobacter cloacae* and *Bacillus cereus,* Fernandes et al. [30] showed that *Staphylococcus aureus* exhibit the highest sensitivity to *Polyporus squamosus* extract where the minimum inhibition concentration (MIC) value was 0.20 $mgmL^{-1}$. Moreover, the bacteriostatic and the bactericidal concentration of *Polyporus squamosus* extract for *Pseudomonas aeruginosa* were also determined by the microdilution method and they were 20.4 $mg\ mL^{-1}$ and 40.8 $mg\ mL^{-1}$. [30,36-38,41].

As a conclusion *Polyporus squamosus* is an edible wild wood-decaying mushroom in Asia,Europe, Australia, North America and Black Sea Region and is important for its nutritional value and the content of bioactive compounds. The chemical analysis of the various compounds obtained from the fruiting bodies of *Polyporus squamosus* showed that it is a rich source of bioactive molecules with various potential in vitro activities. Nonetheless, further studies are required to evaluate the cyto toxicity of the extract as well as elucidate the mechanisms of action for the tested biological activities (Figure 2).

Conclusion

Current Review demonstrates that *Fomes fomentarius* and *Polyporus squamosus* mushrooms have medicinal properties possesses a number of beneficial medicinal properties such as antitumor, antioxidant, anti-inflammatory, anti-allergic, antihypertensive, Anti hyperglycemic, antimicrobial and antiviral activities. These activities have been reported for various extracts and isolated compounds, such as polysaccharides, polysaccharide-protein complexes, phenols, organic acids, lactone, steroids, triterpenoids, from mushroom fermentation broth, mycelia or fruiting bodies.

As a result of the researches, it was determined that *Fomes fomentarius* and *Polyporus squamosus* have medical potential and it can be used as a natural resource for pharmacological researches. Further researches and clinical trials have to be carried out to confirm *Fomes fomentarius* and *Polyporus squamosus* as sources of bioactive compounds responsible for antioxidant and antimicrobial and other biological agents in their extracts.

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