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Highlights on the Golden Mushroom *Cantharellus cibarius* and unique Shaggy ink cap Mushroom *Coprinus comatus* and Smoky Bracket Mushroom *Bjerkandera adusta* Ecology and Biological Activities

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Review Article

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Abstract

Mushrooms are generous source of nutritional and medicinal compounds, and medicinal uses of the mushrooms still need to be worked out for their biological activities. This review aims to put golden mushroom *Cantharellus* and shaggy ink cap mushroom *Coprinus* and smoky bracket mushroom *Bjerkandera* under light spot through describing their morphology and ecology especially of the most common species, *Cantharellus cibarius*; *Coprinus comatus* and *Bjerkandera adusta*. Moreover discussing important secondary metabolites and biological activities exerted by ever one. *Cantharellus cibarius*; *Coprinus comatus* and *Bjerkandera adusta* are able to produce many novel and potent secondary metabolites that exerted different bioactivities especially as antimicrobial, antitumor, anti-inflammation activities and others. Further studies and investigations are fortified in order to find more about these interesting mushrooms.

Keywords: Medicinal Mushrooms; *Cantharellus cibarius*; *Coprinus comatus*; *Bjerkandera adusta*; Biological Activities

Introduction

Mushrooms have been consumed since earliest history, for centuries, the Chinese culture has treasured mushrooms as a health food, an elixir of life, hey have been part of the human culture for thousands of years and have considerable interest in the most important civilizations in history because of their sensory characteristics; they have been recognized for their attractive culinary attributes. Nowadays, mushrooms are popular valuable foods because they are low in calories, carbohydrates, fat, and sodium: also, they are cholesterol-free besides [1,2].

Mushrooms have been considered as ingredient of gourmet cuisine across the globe, and have been valued by humankind as a cooking wonder. More than 2,000 species of mushrooms exist in nature, but around 25 are widely accepted as food and few are commercially cultivated. Mushrooms are considered as a delicacy with high nutritional and functional value, and they are also accepted as nutraceutical foods; they are of considerable interest because of their organoleptic merit, medicinal properties, and economic significance [3]. However, there is not an easy distinction between edible and medical mushrooms because many of the common edible species have therapeutic properties and several used

for medical purposes are also edible [4]. Mushrooms could be an alternative source of new antimicrobial compounds, mainly secondary metabolites, such as terpenes, steroids, anthraquinones, benzoic acid derivatives, and quinolones, but also of some primary metabolites like oxalic acid, peptides, and proteins. A large variety of mushrooms have been utilized traditionally in many different cultures for the maintenance of health, as well as in the prevention and treatment of diseases through their immunomodulatory and antineoplastic properties. In the last decade, the interest for pharmaceutical potential of mushrooms has been increased rapidly, and it has been suggested that many mushrooms are like mini-pharmaceutical factories producing compounds with miraculous biological properties [5,6].

All together with a long history as food source, mushrooms are important for their healing capacities and properties in traditional medicine [7-15]. It has reported beneficial effects for health and treatment of some diseases. Many nutraceutical properties are described in mushrooms, such as prevention or treatment of Parkinson, Alzheimer, hypertension, and high risk of stroke. They are also utilized to reduce the possibility of cancer invasion and metastasis due to antitumoral attributes. Mushrooms act as antibacterial, immune system enhancer and cholesterol lowering agents; additionally, they are important sources of bioactive compounds. Mushrooms provide important nutrients, including selenium, potassium, ribolavin, niacin, vitamin D, proteins. As a result of these properties, some mushroom extracts are used to promote human health and are found as dietary supplements [16-34].

Cantharellus cibarius

Cantharellus cibarius Fr. (Basidiomycota), commonly known as Chanterelle, is one of the most valued and currently most often collected species of edible mushrooms in Europe, Asia, Africa, and the northern USA. *Cantharellus cibarius* belonging to; Basidiomycota; Class: Agaricomycetes; Order: Cantharellales; Family: Cantharellaceae. Yellow to orange-yellow or orange mushrooms found in hardwood forests, featuring a broadly curved, flat, or shallowly depressed cap, a central and fleshy stem, and false gills on the underside of the cap. *Cantharellus cibarius* mushrooms are also known for their fruity, apricot-like odor, best detected when you have several of them together in your collection bag or basket. In western North America, there appears to be less diversity among the *cibarius*-like species; so far, anyway, only four species have been delineated with contemporary species concepts [34], and from Buyck B, et al. [35,36]. Spore print color white, creamy, yellow, pinkish, and deep pinkish. Color of False Gills, the whitish young false gills of *Cantharellus* sp. develops pink shades as the spores mature. The color of the false gills can be difficult to assess, and even more difficult to photograph (Figures 1 & 2) [37].

Figure 1: *Cantharellus cibarius,* (Photo was taken by: Scott T. Bates. Locality: USA, Arizona, White Mountains, Hannagan Meadow.

Figure 2: *Cantharellus cibarius*, (Photo was taken by Gerhard Koller (Gerhard).

Cantharellus cibarius Biological Activities

One of the most commonly consumed mushrooms is *Cantharellus cibarius*, also known as golden girolle or chanterelles. Polysaccharide is one of the important active ingredients of *Cantharellus cibarius* [38]. Therefore, the investigation of the pro-health properties of crude polysaccharides from this genus and species was performed by many researchers. The obtained results indicate that the polysaccharide fraction from *Cantharellus cibarius* inhibits the activity of both COX-1 and COX-2. Crude polysaccharides extracted from *Cantharellus cibarius* were found to inhibit the proliferation of colon cancer cells with the simultaneous absence of toxicity towards normal cells. The presented activities indicate for the first time that this edible mushroom possesses interesting chemo-preventive potential, especially against colon cancer [39,40].

Antibacterial and cytotoxic activities of cyclohexane, dichloromethane, methanol, and aqueous extracts of *Cantharellus cibarius* were studied by Kolundzic M, et al. [40]. Broth microdilution assay was performed against 10 bacterial strains (*Staphylococcus aureus, S. epidermidis, Micrococcus luteus, Bacillus subtilis, Enterococcus feacalis, Escherichia coli, Klebsiella pneumoniae, Pseudomonas aeruginosa, Salmonella abony*), with stress on *Helicobacter pylori*. Methanol extract was the most active against *Helicobacter pylori* strains with minimal inhibitory concentration values. All extracts were active against antibiotic resistant *Helicobacter pylori*. Chemical analysis of *Cantharellus cibarius* methanolic crude extract has shown the presence of linoleic, *cis*-vaccenic, and oleic acids, sterols, *β*-glucans, and polyphenolic compounds [41]. The medicinal and health benefits, observed in wild *C. cibarius* mushroom, seem an additional reason for its traditional use as a popular delicacy food [42].

The methanolic extract of the wild edible mushroom *Cantharellus cibarius* Fr. (chanterelle) was studied by Kozarski M, et al. [42], and analyzed for *in vitro* antioxidative, cytotoxic, antihypertensive and antibacterial activities. Various primary and secondary metabolites were found. Phenols were the major antioxidant components found in the extract, followed by flavonoids, whose content was approximately 86% of the total phenol content. Antioxidant activity, measured by four different methods, was high for inhibition of lipid peroxidation and chelating ability. The antioxidant activity of the *C. cibarius* methanol extract was achieved through chelating iron compared to hydrogen atom and/or electron transfer. The extract showed good selectivity in cytotoxicity on human cervix adenocarcinoma HeLa, breast carcinoma MDA-MB-453 and human myelogenous leukemia K562, compared to normal control human fetal lung fibroblasts MRC-5 and human lung bronchial epithelial cells BEAS-2B.

The golden chanterelle edible mushroom, *Cantharellus cibarius*, has medicinal value. Given that this species has good radical scavenging activity and strong antioxidant potential and bactericidal effects beside that anti-inflammatory activity. Nasiry D, et al. [43] reported that, Significant wound-healing activity in each wound model was observed in the *Cantharellus cibarius* extract-treated and Madecassol-treated groups compared with the nontreated and vehicle-treated groups. Histological assessment showed complete repair of the epidermal layer, increased collagen production, and a remarkable degree of neovascularization and epithelization in the extract group, which were significantly different from those in the other groups. Therefore, *Cantharellus cibarius* methanolic crude extract showed significant wound-healing and anti-inflammatory effects, which could be the scientific rationale for the medicinal use of the golden chanterelle mushroom in treating wounds [44].

Coprinus comatus Shaggy ink cap Mushroom

Mushrooms have been used for centuries not only as food but also in traditional medicine as a source of components with pro-health activity. One of them is *Coprinus comatus* also called shaggy mane, shaggy ink cap, chicken drumstick mushroom, or lawyer's wig. In Asian countries, *Coprinus comatus* is approved as edible mushroom and often cultivated for consumption, whereas in many other countries, although it is widespread, it is unrecognized and not used. Various studies show many of the biological activities by *Coprinus comatus*, such as antioxidant, anticancer, antiandrogenic, hepatoprotective, acetylcholinesterase inhibitory, antiinflammatory, antidiabetic, antiobesity, antibacterial, antifungal, antinematode, and antiviral [45-48].

Figure 3: *Coprinus comatus,* Photo was taken by: Vera S. Evenson. Locality: USA, Colorado, Aspen; Hosted by: http://mycoportal.org).

Figure 4: *Coprinus comatus,* Photo was taken by: Vera S. Evenson. Locality: USA, Colorado, Aspen; Hosted by: http://mycoportal.org).

Coprinus comatus belonging to Basidiomycota, Class; Agaricomycetes, Order; Agaricales, Family; Agaricaceae. *Coprinus comatus mushroom* appear in troops or lines or rings, this mushroom is well known and relatively easily recognized. Its unique features include its shape and stature, and the fact that the gills "deliquesce," turning themselves into black ink as they mature. DNA studies over the last

decade make it clear that *Coprinus comatus* is closely related to species of *Agaricus* and *Lepiota*. The genus *Coprinus*, which once held all such mushrooms, now holds only *Coprinus comatus* and a few similar mushrooms, and it turns out that the presence of a ring on the stem and a string-like strand of fibers inside the stem's hollow cavity (Figure 3&4) turn out to be better predictors of the genus *Coprinus* than deliquescing gills. *Coprinus comatus* growing as saprobic, alone or in clusters, lines, or fairy rings on lawns, wood chips, or hard-packed ground; summer and fall; widely distributed in North America. Cap: 3-15cm; oval to rounded-cylindrical when young, expanding to bell-shaped with a lifting margin; in age turning to black "ink"; dry; whitish with a brownish center; with large, shaggy scales; margin lined at maturity. Gills: Free from the stem; white, becoming pinkish, then black turning to black "ink"; very crowded. Stem: 5-20cm long; 1-2cm thick; frequently tapering to apex; smooth; white; easily separable from cap; hollow, with a string-like strand of fibers hanging inside. Body flesh white throughout and soft. Odor and taste not distinctive. Spore color Black. Microscopic Features: Spores 9-13x7-9µ; elliptical; smooth; with a central to slightly eccentric pore. Basidia 4-spored; surrounded by brachybasidia. Pleurocystidia absent. Cheilocystidia variously shaped; up to 60 x 40µ. Pileipellis cutis-like. Veil elements cylindric; 7-30µ wide [49-52].

Coprinus comatus Biological Activities and Therapeutic Food

Coprinus comatus, an edible and medicinal mushroom, not only tastes delicious, but also has various pharmacological activities [51]. Recently, it has been reported that researchers have extracted more and more active ingredients, including polysaccharides, comatin, active protein complexes, and phenols from fruit bodies, mycelium, or fermentation liquor of *Coprinus comatus* and studied their corresponding functions. Cao H, et al. [51], summarizes not only the hypoglycemic effect of *Coprinus comatus*, but also other functions, such as antioxidant activity, alcohol liver protection, cancer inhibition, antiandrogenic function, anti-inflammatory effect, treatment of leukemia, and so on, which will provide scientific basis for the deep processing and comprehensive utilization of *Coprinus comatus*.

Mushrooms have been reported as sources of biomolecules with various potential. *Coprinus comatus* was studied by Stojkovic D, et al. [52], *Coprinus comatus* methanolic extract was tested for its antioxidant potential (reducing power, radical scavenging activity and lipid peroxidation inhibition) and antimicrobial properties (tested against Gram positive and negative bacteria, and microfungi). Both studied samples (Cultivated and wild *Coprinus comatus*) revealed similar nutritional value and energy contribution. The cultivated *Coprinus comatus* revealed the highest content in free sugars, monounsaturated fatty acids and tocopherols, while the wild *Coprinus comatus* mushroom was richer in saturated and polyunsaturated fatty acids, organic acids and phenolic compounds. The cultivated *Coprinus comatus* also revealed the highest antioxidant potential and antimicrobial activity (with exception towards Gram negative bacteria and *Aspergillus ochraceus*). Stojkovic D, et al. [52] reported that cultivated and wild mushrooms from the same species could be excellent options as food and as sources of nutritional and bioactive compounds.

Coprinus comatus, also called chicken drumstick mushroom, is currently commercially available in China. Hot water and ethanolic extracts were prepared from cap and stipe of *C. comatus* fruit bodies and their antioxidant properties were studied by Li B, et al. [53]. Ethanolic extract from stipe showed high antioxidant activity (80.6%) at 1mg/mL. Reducing power of hot water extracts from cap was 1.653 at 10mg/mL. Extracts from cap showed better scavenging ability on DPPH (57.9% at 1mg/mL) than stipe ones. Ethanolic extracts were more effective in scavenging ability on hydroxyl radicals (57.4–61.3% at 5mg/mL) than hot water extracts. Naturally occurring antioxidant components including total phenols (3.60–20.00 mg/g), tocopherols (0.58–11.93mg/g), flavonoids (0.19–3.52mg/g) and polysaccharides (58.52–547.86mg/g) were found in *Coprinus comatus* methanolic extracts. Alkalic-extractable polysaccharides (ALPS) from *Coprinus comatus*, was studied by Zhao H, et al. [54], to explore it's *in vivo* antioxidant activities and protective effects on alcohol-induced liver injury. Alkalic-extractable polysaccharides showed strong antioxidant and anti-inflammatory abilities and low serum enzyme activities, hepatic and serum lipid levels, as well as low hepatic lipid peroxidation levels; moreover, Alkalic-extractable polysaccharides improved the alcohol metabolism system. These results may offer support for the use of Alkalic-extractable polysaccharides as a functional food or natural drug source that can prevent and treat alcohol-induced liver injury.

Stilinovic N, et al. [55], investigated the chemical and nutritional profile and antioxidative properties of cultivated *Coprinus comatus*. Nearby analysis revealed that *Coprinus comatus* is rich in carbohydrates, dietary fibres and proteins, and could also be a valuable source of phenolics. Additionally, fat content is low, consisting mainly of polyunsaturated and omega-3 fatty acids. Oral treatment with *Coprinus comatus* for 42 days improved the antioxidant capabilities and ameliorated carbon tetrachloride induced liver damage in rats, marked by decreased serum aminotransferase levels and lipid peroxidation intensity. Histological morphometric and immunohistochemical analysis confirmed antioxidative and hepatoprotective potential. These findings suggest that cultivated *Coprinus comatus* could be considered a

nutraceutical, having beneficial nutrient and therapeutic properties [55]. In order to determine the nutraceutical and pharmacological potential of Philippine wild strain of *Coprinus comatus*, the antibacterial property, phytochemical composition, and antioxidant activity were evaluated by Kalaw SP, et al. [56], both ethanol and acetone basidiocarp extracts exhibited antibacterial activity against *Staphylococcus aureus*. *Coprinus comatus* ethanol extract produced wider zone of inhibition than acetone extract. Phytochemical screening revealed the presence of alkaloids, flavonoids, saponins and terpenoids in *Coprinus comatus* mushroom.

Bjerkandera adusta

Bjerkandera adusta belonging to; Basidiomycota; Class: Agaricomycetes; Order: Polyporales; Family: Meruliaceae. This interesting polypore mushroom has a striking, dark gray to black pore surface that contrasts with its pale cap surface. It is a common decomposer of the deadwood of hardwoods, widely distributed across the continent. Ecology: Saprobic on the deadwood of hardwoods and, rarely, conifers; causing a white rot, widely distributed throughout North America. Cap: Bracket-like to shelf-like, or merely a turned-over edge above a spreading pore surface or occasionally lacking entirely; semicircular to irregular in outline; convex to flat; to about 10cm wide and 6cm deep; velvety to finely hairy, becoming bald with maturity; whitish to grayish, tan, or brownish; sometimes zoned; when mature with a brown to black margin. Pore Surface: Gray to black; sometimes bruising darker black; with 6-7 tiny, angular pores per mm; tubes to 2mm deep. Stem: Absent. Flesh: Whitish to faintly brownish; tough and corky or leathery. Odor and Taste: Odor fragrant, or not distinctive. Taste sour, or not distinctive. Spore Print: White. Microscopic Features: Spores 4-6 x 2.5-3.5µ; smooth; elliptical; inamyloid. Cystidia absent. Hyphal system monomitic; hyphae with abundant clamp connections (Figures 5 & 6) [57,58].

Figure 5: *Bjerkandera adusta*, (Photo was taken by: Renee Lebeuf. Locality: Canada, Quebec, MRC Maskinongé, Saint-Mathieu-du-Parc (Cited in: https://mycoportal.org).

Figure 6: *Bjerkandera adusta*, (Photo was taken by Dominic. Locality: United States, California, Lodi Lake Park, Lodi, San Joaquin County, California (Cited in: https://mycoportal.org).

Bjerkandera adusta Biological Activities

Many Ascomycetes and Basidiomycetes have been reported as producers of antibacterial, antifungal and insecticidal compounds, which they use to protect themselves against unwanted microorganisms and insects in their natural environments [59,60]. These bioactive compounds could therefore be isolated from edible and inedible mushrooms. Akata I, et al. [61], reported that antagonistic effects of *Bjerkandera adusta* crude extracted by methanol were found against *Fusarium inflexum*, *Fusarium heterosporium*. This was obtained by the clear zone of inhibition produced by the fungi around the tested mushroom extracts. An antifungal activity of *Bjerkandera adusta* extracts was high at the *Fusarium inflexum* than *Fusarium heterosporium.*

The antimicrobial potential of *Bjerkandera adusta* solvent extracts were evaluated on some selected bacteria. Some solvent extracts of *Bjerkandera adusta* were very effective against three Gram-negative bacteria (*Escherichia coli, Salmonella typhimurium* and *Pseudomonas aeruginosa*) and three Gram-positive bacteria (*Staphylococcus aureus, Staphylococcus epidermidis* and *Bacillus cereus*). The effectiveness of *Bjerkandera adusta* solvent extracts as antibacterial agents should be well explored with development of optimized methods for mass production of this macrofungi in controlled environments [62]. Because *Bjerkandera adusta* produces important enzymes that can degrade polycyclic aromatic hydrocarbons, such as those used in synthetic textile dyes, there has been research interest in investigating the fungus for possible use in bioremediation [63,64].

Conclusion

Basidiomycetous mushrooms represented by *Cantharellus cibarius, Coprinus comatus* and *Bjerkandera*

adusta have a rich history of use as an edible source and well-claimed medicinal properties. This review summarises a number of sources with details of nutritional content and beneficial compounds (Antimicrobial, antioxidant properties to antitumor, health-promoting sterols and others). Despite these advances, there is much we have yet to understand and these hypogeal fruiting Basidiomycetes prove to be a fruitful source of novel medicinal compounds.

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