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Edible Mushroom Cultivated in Polluted Soils and its Potential Risks on Human Health: A short communication

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Abstract

Edible mushrooms are considered an important source for human nutrition nowadays because of their high contents of bioactive compounds (e.g., vitamins, proteins, terpenoids, phenolic compounds, lipids, and polysaccharides). These active ingredients are also a crucial source for many industries particularly in the pharmaceutical and therapeutic fields as well as functional foods. This manuscript focuses on what we called mushrooms and their nutritional importance as well as the therapeutic applications of edible mushrooms. The possible risks of edible mushrooms for human health were also discussed; especially for those grown on polluted soils, representing a serious potential threat for human health. The harvested edible mushrooms obtained from such polluted areas may have highcontents of potentially toxic elements and other contaminants, which can threaten the human health causing several diseases.The sustainable solutions for producing safe edible mushrooms for human nutrition under different growth conditions are of interest global issue due to edible mushrooms being established as one of the most important sources of human foods.

Keywords: Anticancer, Steroids, Ergosterol, Anti-inflammatory, Active ingredients, Heavy metals, Soil

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1. Mushrooms and their nutritional profiles

Mushrooms are eukaryotic organisms, which are classified as the kingdom of fungi and for the above-ground fruiting body (myco-carp, carpophore) of higher fungi (Fig. 1). The main functions of mushrooms in soils may represent in transformation of organic and inorganic, rock and mineral through the bio-weathering and cycling of elements in soil, as well as the myco-genic forming and interactions with clays and metals (Ronda et al. 2022). The current commercial production of edible mushrooms is around 34 million metric tons, with a 30-fold increase over the last three decades. The annual consumption of mushrooms also increased to be 4.7 kg per capita compared to about 1.0 kg in 1997 (Koutrotsios et al.

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2022). Edible mushrooms are macro-fungi that have been widely consumed by humans and used in the medicine because of their delicious taste and diverse physiological activities (Table 1). Edible mushrooms have also distinguished nutritional and functional components including proteins, dietary fiber, minerals, vitamins, polysaccharides, glycoproteins, phenolic compounds, ergosterols, unsaturated fatty acids, tocopherols, and lectins (Cardwell et al. 2018; Qing et al. 2021). Mushrooms are well-known for their richness of health-beneficial bioactive metabolites. Mushrooms have been characterized as potent functional food due to its high contents of primary metabolites (i.e., oxalic acid, proteins, and peptides) and secondary metabolites including quinolones, steroids, terpenes, and anthraquinones. The nutritional profiles of mushrooms are significant due to their abundant dietary fiber and low-fat contents. It is reported that, mushrooms are rich sources of proteins (up to 37.4%), vitamins (C, D, E, B_1, B_2, & B_{12}), and minerals (K and P). Bioactive nutraceutical compounds present in mushrooms may include ergosterols, tocopherols, glycoproteins, unsaturated fatty acids, lectins, and phenolics (Saini et al. 2021).

Fig. 1. Some photos of edible mushrooms including champignon mushroom (as dried mushroom in photo 1), and oyster mushrooms (as dried in photo 2), where photos no 3 and 4 belong oyster mushroom. These photos were taken by Jenny in Nano-Food Lab, Debrecen Uni., Hungary

TABLE 1. Main information about the edible mushrooms and their properties

Item	More details	Reference
Definition of edible mushrooms		
	Edible mushrooms are a type of macro-fungi, which already have been widely used in food and medicine due to their delicious taste and diverse physiological activities	Qing et al. (2021)
	Mushroom is a general term used mainly for the fruiting body of macro-fungi (Ascomycota and Basidiomycota) and represents only a short reproductive stage in their life cycle	Thatoi and Singdevsachan (2014)
Nutritional value of edible mushrooms		
	Mushrooms have a distinguished nutritional value, which supplies humans with fiber proteins, polysaccharides, minerals, vitamins, glycoproteins, unsaturated fatty acids, phenolic compounds, tocopherols, ergosterols, and lectins	Cardwell et al. (2018)
Historical background of mushrooms		
	Mushrooms have been consumed since the beginning of history (500 BC in India, called Charaka Samhita); mushrooms consumed to provide the warriors with strength in battles in ancient Greeks. Mushrooms are called by the Romans as the "*Food of the Gods*"	Thatoi and Singdevsachan (2014); Valverde et al. (2015)
The edible and medicinal mushrooms		
	There are over 2300 species considered to be edible and medicinal mushrooms known worldwide, where about 20 species are cultivated commercially with only 4 to 5 subjects to industrial production	Gurbuz (2019); Jacinto-Azevedo et al. (2021)
Importance of edible mushrooms for human health		
	Sterols (Ergosterol and ergosterol peroxide)	Saini et al. (2021)
	Mushrooms have the ability to promote human health because they are rich in poly-saccharides, poly-phenols, terpenoids, vitamins, and sterols, which are already known for the anticancer, anti-inflammatory, antioxidant, or antidiabetic activity	Maity et al. (2021); El-Maradny et al. (2021); Papoutsis et al. (2020); Nowak et al. (2022)
	High content of biologically active compounds High protein and phenolic contents	Jacinto-Azevedo et al. (2021)
	Biologically active polysaccharide in edible mushrooms	Maity et al. (2021)
Possible risks of edible mushrooms for human health		
	Radioactive pollution of edible mushrooms (in China)	Ernst et al. (2022)
	Accumulated heavy metals and radioisotopes in mushrooms (in Poland)	Ronda et al. (2022)
	High contents of heavy metals in edible mushrooms (in Iran)	Dowlati et al. (2021)
	Health risk of potentially toxic elements in edible mushrooms (in Iran)	Karami et al. (2021)
	High contents of potentially toxic elements (in some African countries)	Gwenzi et al. (2021)
	Metal risks of mushrooms to human health (in Turkey)	Keskin et al. (2021)
	Radionuclide risk in edible mushrooms (in China)	Wang et al. (2021)
	Risk of accumulation of metals in mushrooms (in Mediterranean regions)	Sarikurkcu et al. (2020)

2. Edible mushrooms and their common species

More than 70,000 types of mushrooms are recognized; yet only 2300 types are considered as edible mushrooms such as Portobello mushrooms (*Agaricusbisporus*), straw mushrooms (*Volvariellavolvacea*), oyster mushrooms (*Pleurotusostreatus*), and shiitakes (*Lentinus edodes*) (Chaurasia et al. 2019; Dowlati et al. 2021). The most cultivated edible mushrooms are *Agaricusbisporus*, *Lentinus edodes* and *Pleurotus* spp. and China is considered the largest producer of Mushrooms in the world (Jacinto-Azevedo et al. 2021). A list of edible mushroom species is presented in Table 2.

TABLE 2. Selected list of some edible mushroom species as reported by some literatures

Mushroom species name	Common English name	Family
Agaricus arvensis Schaeff.	Horse Mushroom	Agaricaceae
Agaricusbitorquis(Quél.) Sacc.	Pavement Mushroom	*Agaricaceae*
Agaricusbisporus(J.E. Lange) Imbach, white	White Cultivated Mushroom	Agaricaceae
Agaricusbisporus (J.E. Lange) Imbach, brown	Brown Cultivated Mushroom	Agaricaceae
*Agaricussylvaticus*Schaeff.	Blushing Wood Mushroom	Agaricaceae
Agrocybecylindracea (Brig.) Fayod	Poplar mushroom	Strophariaceae
Amanita vaginata(Bull.) Lam.	Grisette	Amanitaceae
Armillaria mellea(Vahl) P. Kumm.	Honey Fungus	Physalacriaceae
Auricularia auricula-judae (Fr.) Quél	Black wood ear	Auriculariaceae
Cantharellus cibarius Fr.	Chanterelle	Cantharellaceae
Clavariadelphuspistillaris(L.) Donk	Giant Club	Clavariadelphaceae
Clitocybenebularis(Batsch) P. Kumm.	Clouded Funnel	Tricholomataceae
Clitopilusprunulus(Scop.) P. Kumm.	The Miller	Entolomataceae
Hygrophorusmarzuolus(Fr.) Bres.	March mushroom	Hygrophoraceae
Hygrophorusrussula(Schaeff. ex Fr.) Kauffman	PinkmottleWoodwax	Hygrophoraceae
Lactariussanguifluus(Poulet) Fr	Bloody Milkcap	Russulaceae
Lactariusvolemus(Fr.) Fr.	Fishy Milkca	Russulaceae
Lentinus edodes (Berk.) Pegler	Shiitake	Marasmiaceae
Lentinus tigrinus(Bull.) Fr	Tiger Sawgill	Hygrophoraceae
Lepista nuda (Bull.) Cooke	Wood Blewit	Tricholomataceae
*Lycoperdonmolle*Pers.	Soft Puffball	Lycoperdaceae
Lyophyllumdecastes (Fr.) Singer	Clustered Domecap	Tricholomataceae
Pleurotuscitrinopileatus Singer	Golden oyster mushroom	Pleurotaceae
Pleurotusostreatus (Jacq. ex Fr.) P. Kumm	Oyster mushroom	Pleurotaceae
Polyporussquamosus(Huds.) Fr.	Dryad's Saddle	Hygrophoraceae
Macrolepiota mastoidea (Fr.) Singer	Slender Parasol	Agaricaceae
Russulaalbonigra (Krombh.) Fr.	Menthol Brittlegill	Russulaceae
Russuladelica Fr.	Milk White Brittlegill	Russulaceae
*Russulaviscida*Kudř na	Viscid Brittlegill	Russulaceae
Suillusbellinii (Inzenga) Kuntze	Champagne Bolete	Suillaceae
Suillusbovinus(L.) Roussel	Bovine Bolete	Suillaceae
Suillus luteus (L.) Roussel	Slippery Jack	Suillaceae
Tricholomaterreum (Schaeff.: Fr.) Kumm	Grey Knight	Tricholomataceae
Volvariellavolvacea (Bull.) Singer	Straw mushroom	Pluteaceae
Xerocomussubtomentosus(L.) Fr.	Homotypic synonym	Boletaceae

Source of references: Koutrotsios et al. (2022); Nowak et al. (2022); Ronda et al. (2022); Wang et al. (2022); Cateni et al. (2021); Qing et al. (2021); Mleczek et al. (2021); Keskin et al. (2021a, b); Zhang et al. (2021); Isik (2020); Sarikurkcu et al. (2020); Gurbuz (2019);
English name from this website: https://www.gbif.org/species/180070116/ accessed on 14.11.2021

3. Therapeutic applications of edible mushrooms

Mushrooms are filamentous fungi of high pharmacological and medicinal benefits. For example, edible mushrooms can protect people from a large number of diseases such as anti-cancerous, antiviral, antibacterial, antioxidant, and hypo-cholesterolemic, which are valuable for human health. This is associated with the presence of different health-promoting components such as polyphenols, vitamins, polysaccharides, terpenoids, and sterols, which are already known for their antioxidant, anti-inflammatory, or antidiabetic activity (Roncero-Ramos and Delgado-Andrade 2017; Chaturvedi et al. 2018; Papoutsis et al. 2020; Maity et al. 2021). There are many therapeutic applications of edible mushroom, which may include

(1) mushrooms as anti-cancerous agents, (2) anti-diabetic property of mushrooms, (3) mushrooms against cardiovascular diseases, (4) the role of mushrooms on immunity, (5) anti-asthmatic properties of mushrooms, (6) hepatoprotective activity of mushrooms, (7) anti-viral properties of mushrooms, (8) mushroom activity against neuro-degenerative diseases, (9) anti-mutagenic activity of mushrooms, (10) anti-ageing property of mushrooms, (11) and anti-obesity activity of mushrooms (Chaturvedi et al. 2018).

4. Edible mushrooms and potential risks for human health

It is well known that soils have many fundamental functions, which represent in buffering, filtering, storage and transformation of received pollutants as an open, dynamic and complex system. Anthropogenic activities have a rapid impact on soils and their functions through atmospheric depositions, which may involve in the geochemical, geological, and biological processes in the lithosphere (Kokkoris et al. 2019). The pollution of soils has impacts on the consumed plant foods, which will threaten human health particularly under long-term consumption. Cultivation of edible mushrooms in polluted soil represents a real threat to human health. Therefore, periodic monitoring of contaminants in soil is a must to avoid the potential risks that may arise when feeding on mushrooms containing high levels of contaminants in their tissues. Also, there is a need to offer a broad overview of the nutritional value of these edible mushrooms (Mleczek et al. 2021).The benefits of mushrooms for human health have been reported by several researchers as mentioned before. In many places all over the world, mushrooms may threaten human health when they are growing in polluted soils. Therefore, understanding the occurrence, fate, and behaviour of pollutants like potentially toxic elements in soil-growing mushrooms-human nexus is crucial for mitigating and assessing their risks to human health (Gwenzi et al. 2021). Recently, enormous literatures from several countries have been published on the risks of edible mushrooms containing toxic pollutants for human health as reported in Poland (Siwulski et al. 2020; Mleczek et al. 2021; Ronda et al. 2022), China (Wang et al. 2021; Ernst et al. 2022), Iran (Dowlati et al. 2021; Karami et al. 2021), Turkey (Keskin et al. 2021a, b), and Spain (Melgar and García 2021). Generally, pollutants may contain organic toxicants, potentially toxic elements (heavy metals), radioactive pollutants or radioisotopes or radionuclides (Dowlati et al. 2021; Gwenzi et al. 2021; Karami et al. 2021; Wang et al. 2021; Ernst et al. 2022; Ronda et al. 2022). Further studies, which take these variables into account, will need to be undertaken. However, more research on consumption of mushrooms cultivated in pollutant soils needs to be undertaken before the association between pollutants and edible mushrooms is more clearly understood.

This is a call by Egyptian Journal of Soil Science (EJSS) for submitting articles including original articles, reviews, minireviews, and short communications about the topic. EJSS has a great handling the polluted soils and their impacts on cultivated plants through publishing many articles, which issued several articles in the last decade such as Hashim et al. (2017), Mester et al. (2018), El-Shony et al. (2019), Bassouny et al. (2020), El-Ramady et al. (2020a, b), and Abdel-Rahman et al. (2021).

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