Medicinal Properties of Mediterranean Oyster Mushrooms: Species of Genus *Pleurotus* (Higher *Basidiomycetes*)

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Abstract

The term "Mediterranean area," applied in this chapter, refers to the definition reported in Med-Checklist and particularly to all countries bordering the Mediterranean Sea plus Portugal, Bulgaria, the Crimea (Ukraine), and Jordan. The "Mediterranean oyster mushrooms" is a geographically and ecologically well-defined group of *Basidiomycetes*. The medicinal properties of some widely investigated species such as *Pleurotus ostreatus* and *P. eryngii* are recognized worldwide, while in the case of some other Mediterranean *Pleurotus* taxa, there is still a lack of knowledge. A substantial increase in knowledge about the anticancer and antibacterial properties of the group of *Pleurotus* species growing as saprophytes on dead roots of plants of family *Apiaceae* (*P. nebrodensis*, *P. eryngii* var. *elaeoselini*, *P. eryngii* var. *ferulae* in particular) has been recorded in recent years, thanks to research carried out at the University of Palermo (Italy). This chapter summarizes the latest research on medicinal oyster mushrooms growing in the Mediterranean environment.

Keywords

Mediterranean area • Medicinal mushrooms • Antibacterial activity • Oyster mushrooms • *Pleurotus*

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Contents

Abbreviations

CWE	Cold water extracts
HIV	Antihuman immunodeficiency virus
MIC	Minimum inhibitory concentrations

2.1 Introduction

The genus *Pleurotus* (Fr.) P. Kumm is one of the largest and the most diverse genus among the class *Basidiomycetes*. In a recent taxonomic assessment, the genus *Pleurotus* is included in the kingdom of *Fungi*, phylum *Basidiomycota*, subdivision *Agaricomycotina*, class *Agaricomycetes*, subclass *Agaricomycetidae*, order *Agaricales,* and family *Pleurotaceae* (Kirk et al. 2010).

Under the term "oyster mushrooms," we include basidiomata (fruit bodies) with an eccentric stalk (sometimes absent) together with a gilled hymenium, a firm flesh, and a wide cap of different color shaped like an oyster shell (Fig. 2.1a–e) (Rajarathnam and Bano 1987).

According to Zervakis and Polemis (2013), the genus comprises ca. 30 species and subspecific taxa of edible mushrooms with a worldwide distribution. Several species are widely consumed due to their high nutritional and potential medicinal value (Khan and Tania 2012). Literature data reported a large number of therapeutic values for *Pleurotus* species such as antimicrobial, antiviral, antihuman immunodeficiency virus (HIV), antineoplastic, antitumor, antimutagenic, antioxidant, antilipidemic, hyperglycemic, hypotensive, anti-inflammatory, hepatoprotective, hypocholesterolemic, immunomodulatory, and antiaging (Patel et al. 2012).

In this chapter, we want to focus the reader's attention on the medicinal properties of species of oyster mushrooms growing in the Mediterranean area. The term "Mediterranean area" refers to the definition reported in Med-Checklist (Greuter 2008) and particularly to all countries bordering the Mediterranean Sea plus Portugal, Bulgaria, the Crimea (Ukraine), and Jordan.

Fig. 2.1 Mediterranean oyster mushrooms: (**a**) *Pleurotus eryngii* var. *elaeoselini*, (**b**) *Pleurotus nebrodensis*, (**c**) *Pleurotus eryngii* var. *eryngii*, (**d**) *Pleurotus eryngii* var. *ferulae*, (**e**) *Pleurotus eryngii* var. *thapsiae*, (**f**) *Pleurotus ostreatus*

2.2 Medicinal Properties of Mediterranean Oyster Mushrooms

In the Mediterranean area, species of the genus *Pleurotus* grows as weak parasites on different broad-leaved and conifer trees or as saprotrophs on roots of herbaceous plants of the family *Apiaceae*. We analyzed literature data from the countries included in the Mediterranean area (*sensu* Greuter 2008) : East Aegean Islands, Algeria, Albania, Asiatic Turkey, Balearic Islands, Bulgaria, Corsica, Crete and Karpathos, Cyprus, Egypt, Crimea, Italy, Sinai, Tunisia, and Turkey. Some of

Pleurotus species are widely cultivated for food use and/or their medicinal properties. Literature data are mostly available for the most common species such as *P. ostreatus* and *P. eryngii*, while little or nothing is known about the potential therapeutic properties of some taxa (i.e., *P. opuntiae*). The medicinal value of *Pleurotus* taxa is still under-investigated in most of the Mediterranean countries.

2.2.1 *Pleurotus cornucopiae* (Paulet) Rolland

P. cornucopiae is one of the potential mushrooms that contain antioxidants or increase antioxidant enzyme activity. In particular, *P. cornucopiae* possesses antigenotoxic and bio-antimutagenic activities when tested on *Salmonella typhimurium* and *Escherichia coli* (Filipic et al. 2002). In addition, Hagiwara et al. (2005) have reported D-mannitol content and antihypertensive activity in *P. cornucopiae*.

2.2.2 *Pleurotus eryngii* (DC.) Quél. var. *eryngii*

The protein eryngeolysin, isolated from *P. eryngii* basidiomata, exhibited cytotoxicity against leukemia cells and inhibited the stimulated mitogenic response of murine splenocytes (Ngai and Ng 2006). Sano et al. (2002) have reported antiallergic activity of *P. eryngii* extract.

The antifungal peptide eryngin is active against *Fusarium oxysporum* Schltdl. and *Cercospora arachidicola* Hori (sub: *Mycosphaerella arachidicola* W. A. Jenkins), while the hemolysin designated as eryngeolysin shows antimicrobial activity against *Bacillus* spp. (Gregori et al. 2007).

Extracts of *P. eryngii* var. *eryngii* were tested for their in vitro growth inhibitory activity against *Staphylococcus aureus*, *S. epidermidis*, *Pseudomonas aeruginosa*, and *Escherichia coli*. The extracts were able to inhibit all tested microorganisms (Schillaci et al. 2013).

2.2.3 *Pleurotus eryngii* (DC.) Quél. var. *elaeoselini* Venturella, Zervakis, & La Rocca

Schillaci et al. (2013) recently reported the antibacterial activity of extracts obtained from this taxon. The extracts were tested in vitro against a group of bacteria of medical relevance. The extracts of *P. eryngii* var. *elaeoselini* inhibited the tested microorganisms with activity expressed as minimum inhibitory concentrations (MIC) in the amount of 0.05 MIC (% v.v.) for *P. aeruginosa* and *S. epidermidis* and 0.1 MIC (% v.v.) for *S. aureus* and *E. coli*.

2.2.4 *Pleurotus eryngii* (DC.) Quél. var. *ferulae* (Lanzi) Sacc

The methyl alcohol extracts of basidiomata of *P. eryngii* var. *ferulae* cultivated on various agro-wastes in Turkey show an antimicrobial activity against some bacteria, yeasts, and dermatophytes (Akyuz and Kirbag 2009).

Cold water extracts (CWE) from basidomata of *P. eryngii* var. *ferulae*, collected in Sicily (southern Italy), was tested in vitro on human colon cancer cells. The results demonstrated that the extracts are able to inhibit cell migration and to affect homotypic and heterotypic cell-cell adhesion (Fontana et al. 2014).

The growth inhibitory activity of extracts of *P. eryngii* var. *ferulae* was tested in vitro against *S. aureus*, *S. epidermidis*, *P. aeruginosa*, and *E. coli*. The extracts were able to inhibit all tested microorganisms (Schillaci et al. 2013).

2.2.5 *Pleurotus nebrodensis* (Inzenga) Quél

Venturella et al. (2016) have recently clarified the proper taxonomic identity of this taxon in comparison to Asian populations.

In vitro antitumor effects of CWE from basidiomata of *P. nebrodensis*, collected in Sicily (southern Italy) and tested on human colon cancer cells, underline that they can be considered as possible sources for new alternative therapeutic agents for cancer treatment (Fontana et al. 2014).

Schillaci et al. (2013) recently evaluated the antibacterial activity of *P. nebrodensis*. The extracts were tested in vitro against a group of bacteria of medical relevance. The extracts of *P. nebrodensis* inhibited the tested microorganisms with activity expressed as MIC (minimum inhibitory concentrations) in the amount of 0.05 MIC (% v.v.) for *P. aeruginosa*, ≤0.025 MIC (% v.v.) for *S. epidermidis*, and 0.1 MIC (% v.v.) for *S. aureus* and *E. coli*.

2.2.6 *Pleurotus ostreatus* (Jacq.) P. Kumm

P. ostreatus represents one of the most popular mushroom species in the Mediterranean area. Pleuran is an insoluble polysaccharide [β-(1,3/1,6)-D-glucan] isolated from the oyster mushroom (Karácsonyi and Kuniak 1994) and one of the most famous bioactive polysaccharides from the mushroom origin (El Enshasy et al. 2013).

P. ostreatus contains lovastatin, a naturally occurring compound and the hypolipidemic agent used for lowering cholesterol and prevention of cardiovascular diseases (Gunde-Cimerman 1999; Wasser and Weis 1999). A high production of lovastatin was detected from strains of *P. ostreatus* collected in Turkey (Atli and Yamac 2012).

The immunostimulatory effect of B-glucans from *P. ostreatus* was also demonstrated in daily intake in individuals debilitated by extreme conditions such as

prolonged wars and subsequent famine in Bosnia and Herzegovina (western Balkan) (Redzic et al. 2010).

In Egypt the production of *P. ostreatus* by submerged fermentation, using glucose as a medium, has been positively tested by Daba et al. (2008): These authors demonstrated the potential of oyster mushrooms as fungal protein and as a source of medicinal compounds.

In a study of the action of cyclophosphamide and extract of the mycelium of *P. ostreatus* in vivo on mice bearing melanoma, Meerovich et al. (2005) demonstrated that the mushroom mycelium extract combined with the chemotherapeutic agent cyclophosphamide decreased the degree of leukopenia. Water-soluble proteins and/or polypeptides in the water extract of *P. ostreatus* exhibited significant cytotoxicity by inducing apoptosis of human carcinoma cells (Gu and Sivam 2006). The α-glucans from *P. ostreatus* induced apoptosis of colon cancer cells in vitro (Lavi et al. 2006), lectin inhibited growth of sarcoma and hepatoma in mice (Wang et al. 2000), the *P. ostreatus* DNA stimulated natural mouse killer cytotoxic activity in vitro (Shlyakhovenko et al. 2006), and anti-HIV activity was also demonstrated (Wang and Ng 2000).

Various extracts of *P. ostreatus* possess antimicrobial activities against Gram-positive (*Bacillus subtilis*), Gram-negative (*Escherichia coli*, *Pseudomonas aeruginosa, Vibrio cholerae*), *Salmonella typhi*, bacteria, black mold (*Aspergillus niger* Tiegh.), and *F. oxysporum* (Gregori et al. 2007).

2.2.7 *Pleurotus pulmonarius* (Fr.) Quél

Jose et al. (2002) have demonstrated the therapeutic potential of methanol extract of *P. pulmonarius* as an antitumor and anti-inflammatory agent. The hot water extracts of *P. pulmonarius* demonstrate inhibitory activity against human immunodeficiency virus (HIV) (Wang et al. 2007) (Table 2.1).

2.3 Conclusions

The importance of a Mediterranean diet and its benefits on human health mainly refer to its anti-inflammatory effects (Djuric 2011). The Mediterranean diet ensures lower risk for cardiovascular disease, for several forms of cancer, and for Alzheimer's disease (Scarmeas et al. 2006). Fruits and vegetables are a key part of an overall healthy life (Slavin and Lloyd 2012).

Mushrooms have a unique nutrient profile, and they are biologically distinct from the plant- and animal-derived foods (Feeney et al. 2014). Europe is the largest market for cultivated mushrooms, accounting for more than 35% of the global market. On the contrary, the industry of medicinal mushrooms is less developed than in Eastern countries. Most of the companies that have headquarters in the Mediterranean countries and which sell food supplements based on medicinal mushrooms are directly dependent on foreign companies, and most of the fungi are cultivated

Table 2.1 *Pleurotus* Mediterranean taxa and corresponding medicinal properties

Taxa	Active compounds	Medicinal properties	References
Pleurotus cornucopiae	β-Glucans	Antioxidant; antigenotoxic; bio-antimutagenic; antihypertensive	Filipic et al. (2002) and Hagiwara et al. (2005)
Pleurotus eryngii var. *eryngii*	Eryngeolysin, β-Glucans, Eryngin	Anticancer (leukemia); antiallergic; antimicrobial; antibacterial	Gregori et al. (2007), Ngai and Ng (2006), Sano et al. (2002), and Schillaci et al. (2013)
Pleurotus eryngii var. *elaeoselini*	β-Glucans	Antibacterial	Schillaci et al. (2013)
Pleurotus eryngii var. *ferulae*	β-Glucans	Antimicrobial; anticancer	Akyuz and Kirbag (2009), Fontana et al. (2014), and Schillaci et al. (2013)
Pleurotus nebrodensis	β-Glucans	Antimicrobial; anticancer	Fontana et al. (2014), Schillaci et al. (2013), and Venturella et al. (2016)
Pleurotus ostreatus	Pleuran, Lovastatin, α-Glucans	Hypolipidemic; prevention of cardiovascular diseases; immunostimulatory; anticancer (melanoma, sarcoma, hepatoma); antimicrobial; antibacterial; antifungal	Atli and Yamac (2012), Daba et al. (2008), El Enshasy et al. (2013), Gregori et al. (2007), Gu and Sivam (2006), Gunde-Cimerman (1999), Karácsonyi and Kuniak (1994), Lavi et al. (2006), Meerovich et al. (2005), Redzic et al. 2010, Shlyakhovenko et al. (2006), Wang et al. (2000), Wasser and Weis (1999), and Wang and Ng (2000)
Pleurotus pulmonarius	β-Glucans	Anticancer; anti-inflammatory; anti-HIV	Jose et al. (2002) and Wang et al. (2007)

abroad, while the extracts they buy are mainly sourced from China. This induces considerable confusion for the consumers that buy food supplements only apparently labeled in Europe. In addition, the certification of fungal extracts is often not responsive to the standards established by the European Community.

There is an increasing request by the pharmaceutical companies of Mediterranean countries to the research laboratories in the Universities to activate scientific cooperation in order to identify new fungal extracts and stimulate entrepreneurs to start large-scale cultivation of edible and medicinal mushrooms to allow those companies a greater autonomy from the market of Eastern countries.

For the above reasons, the recent preliminary in vivo experiments (still in progress) based on *Pleurotus* species and carried out at the University of Palermo (Italy) on humans, pets, and livestock are very encouraging.

In particular, attention is paid on some new varieties of *P. eryngii* (i.e., *P. eryngii* var. *elaeoselini* and *P. eryngii* var. *thapsiae* Venturella, Zervakis, & Saitta) and on *P. nebrodensis*, creating the conditions for the production of a new line of mushroom-based supplements.

The specificity of the *Pleurotus* species growing in the Mediterranean area, compared to the same wild edible species of oyster mushrooms growing in Asiatic countries, lies mainly in their high nutritional value (La Guardia et al. 2005). For this reason, the possibility of combining quality food and medicinal value is the true challenge for the near future for a better enhancement of the Mediterranean oyster mushrooms.

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