Trends in Food Science & Technology 50 (2016) 103–117

Contents lists available at ScienceDirect

Trends in Food Science & Technology

journal homepage: http://www.journals.elsevier.com/trends-in-food-science-and-technology

Review

Biotechnological, nutritional and therapeutic uses of *Pleurotus* spp. (Oyster mushroom) related with its chemical composition: A review on the past decade findings

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ARTICLE INFO

Article history:
Received 5 January 2016
Received in revised form
19 January 2016
Accepted 22 January 2016
Available online 2 February 2016

Keywords:
β-glucan
Functional foods
Mushrooms
Natural products
Submerged cultures

ABSTRACT

Background: The particular characteristics of growth and development of mushrooms in nature result in the accumulation of a variety of secondary metabolites, several of them with biological activities. The genus *Pleurotus* is a cosmopolitan group of mushrooms with high nutritional value and therapeutic properties, besides a wide array of biotechnological and environmental applications.
Scope and approach: The present report aims to provide a critical review on aspects related to chemical compounds isolated from the genus *Pleurotus* with possible biotechnological, nutritional and therapeutic uses. Investigations on the genus have immensely accelerated during the last ten years, so that only reports published after 2005 have been considered.
Key findings and conclusions: The most important *Pleurotus* species cultivated in large scale are *Pleurotus ostreatus* and *Pleurotus pulmonarius*. However, more than 200 species have already been investigated to various degrees. Both basidiomata and mycelia of *Pleurotus* are a great renewable and easily accessible source of functional foods/nutraceuticals and pharmaceuticals with antioxidant, antimicrobial, anti-inflammatory, antitumor and immunomodulatory effects. A series of compounds have already been precisely defined including several polysaccharides, phenolics, terpenes and sterols. However, intensification of structure determination is highly desirable and demands considerable efforts. Further studies including clinical trials need to be carried out to ascertain the safety of these compounds as adequate alternatives to conventional drugs. Not less important is to extend the search for novel bioactives to less explored *Pleurotus* species.

1. Introduction

Mushrooms have been regarded as gourmet cuisine across the globe since antiquity for their unique taste and subtle flavor. They are considered as sources of important nutrients including dietary fiber, minerals, and vitamins, in particular, vitamin D (Ren, Perera, & Hemar, 2012). More than 2000 species of mushrooms exist in nature, but only around 25 are widely accepted as food and few are commercially cultivated (Valverde, Hernández-Pérez, & Paredes-López, 2015). Recently, they have become increasingly attractive as functional foods due to their potential beneficial effects on human health. Hence, food industry is especially interested in both cultivated and wild edible mushrooms. The most extensively cultivated mushroom worldwide is *Agaricus bisporus* (J. E. Lange) Emil J. Imbach., followed by *Lentinula edodes* (Berk.) Pegler and *Pleurotus ostreatus* (Jacq. ex Fr.) P. Kumm. Mushrooms production is continuously increasing. The commercial production in 2012 hit 7,959,979 tonnes of mushrooms, with China accounting for most of the production (5,150,000 tonnes), while 1,869,091 tonnes were harvested in Europe (Grujić, Potočnik, Duduk & Vujčić, 2015). Due to the increase in population and consumption, the world demand for mushrooms is projected to grow 15% a year (Kamarudzaman, Chay, Amir, & Talib, 2015).

The genus *Pleurotus* (Fries) Kummer (Basidiomycota, Agaricales)

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http://dx.doi.org/10.1016/j.tifs.2016.01.012
0924-2244/

was defined by Paul Kummer in 1871. It is a cosmopolitan group of mushrooms with high nutritional value and therapeutic properties, besides a wide array of biotechnological and environmental applications (Knop, Yarden, & Hadar, 2015). Usually regarded as oyster mushrooms, these edible basidiomycetes are among the most popular worldwide, as much as they achieved the third position in the production of edible mushrooms, behind the species of the genus *Agaricus* and *Lentinula* (Fernandes, Barros, Martins, Herbert, & Ferreira, 2015). The most important *Pleurotus* species cultivated in large scale are *P. ostreatus* and *Pleurotus pulmonarius* (Fr.) Quél (Bazanella et al., 2013). *P. pulmonarius* has been often marketed by spawn manufacturers and cultivators under the incorrect name "*Pleurotus sajor-caju*". The real *P. sajor-caju* (Fr.) Singer is in fact a separate species of mushroom, which was returned to the genus *Lentinus* by Pegler (1975), and is correctly named *Lentinus sajor-caju* (Fr.) Fries (Buchanan, 1993).

Since the first report of hypotensive activity of the *Pleurotus* mushroom in a mouse model in 1986, many researchers have demonstrated their medicinal potentialities and classified them as 'mushroom nutraceuticals'; that were posteriorly added to the group of functional foods (Patel, Naraian, & Singh, 2012). In the last decade, the number of patents and scientific articles regarding the genus *Pleurotus* has exponentially increased, with an increment of more than 2-fold in the total of scientific research/review articles in the last 5 years (Fig. 1).

Extensive research on cultivation techniques (Carvalho, Sales-Campos, & Andrade, 2010; Gregori, Svagelj, & Pohleven, 2007), chemical composition and nutritional profile (Atri, Sharma, Joshi, Gulati, & Gulati, 2013; Maftoun et al., 2015; Reis, Barros, Martins, & Ferreira, 2012) has been done in the last ten years, along with a comprehensive account of the biotechnological capabilities of the genus *Pleurotus* including enzyme production (Inácio, Ferreira, Araujo, Brugnari et al., 2015; Knop et al., 2015) (Fig. 2). More recently, the scientific reports referring to *Pleurotus* species have also focused on novel approaches for taxonomic issues (Maftoun et al., 2015; Menolli, Breternitz & Capelari, 2014), isolation and characterization of new functional compounds, besides the in depth-study of their medicinal properties (Khan & Tania, 2012; Patel et al., 2012; Yahaya, Rahman, & Abdullah, 2014).

In view of the above, this review aims to summarize and evaluate the past decade findings related to biotechnological, nutritional and therapeutic uses of *Pleurotus* sp. with special attention to novelties regarding their chemical composition. This includes discussion of the main isolated and identified compounds or fractions and their corresponding bioactivities.

2. Biodiversity and taxonomy

As of 2015 the Index Fungorum lists 202 species in the *Pleurotus* genus. Table 1 presents the most studied species in the past ten years, the main areas of publications regarding these mushrooms, as well as their geographical distribution worldwide.

Species delimitation within the *Pleurotus* genus has been a complex issue for decades (Menolli, Breternitz & Capelari, 2014). Years ago, Bao et al. (2004) pointed out the main causes of the taxonomic controversy involving *Pleurotus* species: initial misidentification, absence of type specimens, instability of morphological characters due to environmental changes, limited reports on physiological characteristics, and the lack of mating compatibility studies. Fortunately, in recent years the adoption of biochemical and molecular approaches has brought some clarifications for species delimitation in the genus, mainly when combined with morphology and sexual compatibility (Menolli, Breternitz & Capelari, 2014). The currently adopted methodologies of identification include isozyme electrophoresis, sequence analysis of ribosomal DNA, internal transcribed spacer region (ITS), random amplified polymorphic DNA (RAPD), amplified fragment length polymorphism (AFLP), restriction fragment length polymorphism (RFLP) and mating compatibility testing (Maftoun et al., 2015). Recently, molecular approaches made it possible to confirm the taxonomic status of some important *Pleurotus* varieties such as *Pleurotus eryngii*, *Pleurotus ferulae*, and *Pleurotus elaeoselini*. It also enabled reclassifications and the identification of new species (Zervakis et al., 2014).

In 2009, sequencing of the *P. ostreatus* genome was completed. Thanks to this accomplishment, a broad picture of the ligninolytic peroxidase gene family has been obtained. Besides, molecular techniques have also enabled progresses such as targeted gene replacement, RNAi-based gene silencing, and overexpression of genes in *P. ostreatus*. By this way, the recent information of the genomics of *P. ostreatus* secondary metabolism will allow an upgrade in the production of these compounds (Knop et al., 2015).

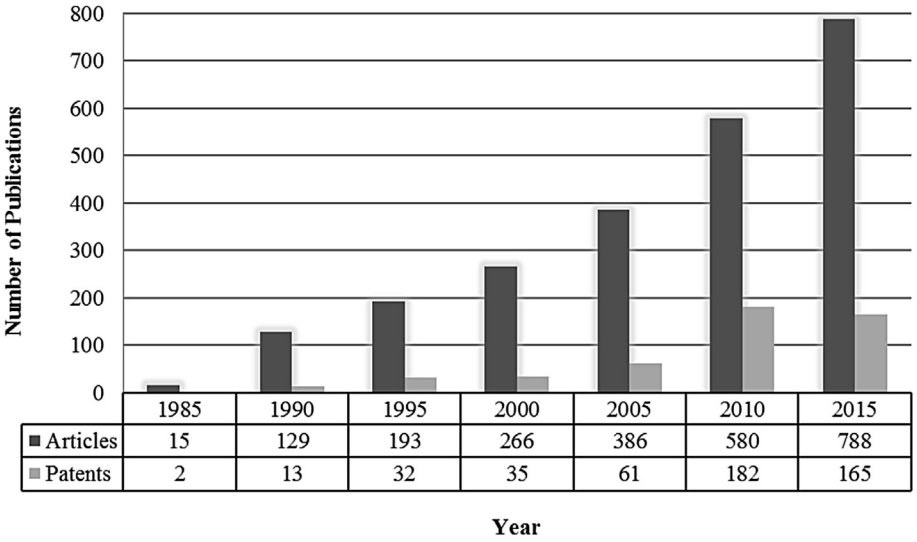

Fig. 1. Number of research articles and reviews, and patents published in the period from 1985 to 2015 regarding the *Pleurotus* genus (obtained on Web of Science, August 2015; keyword restrict to the title: *Pleurotus*).