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Review

Functional foods based on extracts or compounds derived from mushrooms

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ABSTRACT

Background: Due to an aging population and illnesses related to current lifestyles, health-related concerns are becoming increasingly more important. Moreover, today's society is more aware of the potential side effects of medicines and is looking for innovative therapeutic alternatives. Hence, the use of natural compounds in the prevention of various diseases and health maintenance has been studied. Among the natural products studied are mushrooms, which are well known for their nutritional value and health-promoting properties. These have been considered as both functional foods and a source of nutraceuticals.

Scope and approach: The present review is aimed at collecting and critically examining current data on the bioactive properties of mushrooms as well as their classification as functional foods and source of nutraceuticals. It also intended to describe the state of the art regarding mushroom formulations currently available on the market, and to highlight what could be done to improve this market in order to make a variety of quality and duly-certified products that promote human well-being available.

Key findings and conclusions: Mushrooms are natural matrices of excellence. Their bioactivity has been proved and therefore, their incorporation in foods has been studied. However, these new food products have not yet gone to market and most of the mushrooms and their compounds are mainly consumed in their natural form or in dietary supplements. Despite interest in such products having grown over the years, in Western countries, mushroom products are not as common as in Asia and legislation needs to be implemented to permit an increase in their consumption.

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1. Introduction

1.1. Functional foods and nutraceuticals

Today's numerous/diverse media channel outlets disclose a wide range of information and generally emphasise the

nutrition:health relationship by underlining the need to adopt healthy eating habits. International health organizations recommend 1) limiting energy intake from total fats and 2) shifting fat consumption from saturated to unsaturated fat, while eliminating *trans*-fatty acids. Diets should be rich in fruits, vegetables, legumes, grains and nuts while the intake of free sugars and salt should be limited. By adopting this advice and avoiding sedentary behaviour, it is possible to attain energy balance and a healthy weight as well as to reduce the risk of some diseases (WHO, 2004). The primary role of diet is to provide nutrients essential for metabolic needs but it also prevents malnutrition, promotes satiety and well-being and provides health benefits at physiological levels while ensuring

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optimal health and preventing disease (Alkerwi, 2014).

Given the strong evidence linking diet quality to life quality and due to advances in food science and technology, new food concepts have been developed, including “functional foods” and “nutraceuticals”. Although sometimes confused, these terms include related but different concepts. Succinctly, functional foods are conventional or everyday foods consumed as part of the normal daily diet. They should be composed of naturally occurring components (possibly in unnatural concentrations or present in foods which would not normally supply them). Functional foods exert positive effects on target function(s) beyond their nutritive value, enhancing the well-being and quality of life, and/or reducing the risk of disease (El Sohaimy, 2012). Nutraceuticals were first described by DeFelice in 1989 and the definition remains until today. These are defined as “a food (or part of a food) that provides medical or health benefits, including the prevention and treatment of a disease” (El Sohaimy, 2012). Therefore, the role of functional foods is mainly related to reducing the risk of disease rather than preventing it, while nutraceuticals are usually consumed to promote well-being, through the prevention and/or treatment of diseases and/or disorders (El Sohaimy, 2012;; Ghosh, Bagchi, & Konishi, 2014). Nutraceuticals may be a food extract, a single natural compound or nutrient and not necessarily a complete food (e.g., resveratrol, curcumin, vitamin E) which may be included in pharmaceutical form (pills, tablets, etc.) as dietary supplements and as part of a specific diet (Gupta, Chauhan, Mehla, Sood, & Nair, 2010; Sikora, Scapagnini, & Barbagallo, 2010; Silk & Smoliga, 2014).

Sometimes this concept is also misused to describe another food concept – the “food supplement”. Food supplements have essentially a feed function, taking the form of medicines (pills or capsules). Once they take the form of medicines and are not consumed as traditional food in the daily diet, they cannot be regarded as functional foods. However, given that from a legal point of view, they are not considered as treating or preventing diseases, they are still governed by food laws (Howlett, 2008). Of note is the fact that functional foods, as conventional foods consumed daily according to a regular food pattern, are not pills, capsules, or have any form of food supplement (EU, 2010). Nutraceuticals, while exerting a pharmacological function, should not be confused with medicines, which are administered in precise doses, under medical supervision, to treat or prevent a specific disease (Howlett, 2008).

Once the functional foods and nutraceuticals have properties inherent to foods and medicines, it is considered that they are located on the border between conventional foods and medicines (Smith & Charter, 2011).

For a better understanding of the concepts of functional foods and nutraceuticals, as well as the related (and sometimes misused) food supplements and medicines, Table 1 shows the main differences between them.

2. Mushrooms “as” and “in” functional foods

2.1. Bioactive properties of mushrooms that confer them the “status” of functional foods

When we think of a balanced diet and the healthiest means by which to achieve it, plants and plant products immediately come to mind as well as mushrooms. Although their use has been reported for thousands of years, it has only been in recent years that the consumption of mushrooms has increased, mainly due to the increasing awareness that a stable and balanced diet exerts a key role in normal body functioning and sustaining health. Consumed for their texture, aroma and flavour, mushrooms are an excellent choice for both their nutritional value and medicinal properties (Valverde, Hernández-Pérez, & Paredes-López, 2015). Indeed, some authors consider mushrooms as “inherent functional foods” (Smith & Charter, 2011). Their chemical composition includes several bioactive compounds which gives them the ability to exert beneficial effects at different levels. These bioactive properties include immunomodulating, antitumour, anti-hypercholesterolemia, antibacterial and antifungal, anti-inflammatory, antiviral, anti-diabetic, and cardiovascular beneficial effects (Valverde et al., 2015; Wasser, 2014). In the supplementary material, Table S1 lists the wide-range bioactive properties reported for different mushroom species.

2.1.1. Antioxidant properties of mushrooms

In the human body (as in other aerobic organisms) free radicals and other reactive species are continually being produced during normal cellular metabolism. This may occur by “accident” (e.g., the leakage of electrons from the mitochondrial electron transport chain) or with some required purposes, such as involvement in cell signalling and homeostasis processes or defence against pathogens (Ferreira, Barros, & Abreu, 2009; Halliwell & Gutteridge, 2015).

As shown in Fig. 1, free radicals have different causes and different cellular targets, namely proteins, carbohydrates, lipids and nucleic acids. For this reason, many disease conditions have been associated with oxidative stress, such as atherosclerosis, diabetes and cancer (Halliwell & Gutteridge, 2015). As is common sense, the antioxidant defences can be endogenous or acquired through the diet. Natural compounds have emerged as key candidates for obtaining antioxidant compounds, due to recognition of the inverse relationship between dietary intake of natural antioxidants and the incidence of human diseases. This has led to an increased worldwide interest in using natural antioxidants in food, cosmetics and the pharmaceutical industries (Taofiq, González-Paramás, Martins, Barreiro, & Ferreira, 2016; Valverde et al., 2015).

Mushrooms have been reported as a source of several antioxidants. These include phenolic compounds, vitamin C and E and carotenoids (Ferreira et al., 2009). Actually, many mushroom extracts have been studied for their antioxidant potential. These studies reported a direct relationship between the compounds

Table 1
General differences between functional foods, nutraceuticals, food supplements and medicines.

	Functional food	Nutraceutical	Food supplement	Medicines
Form	Food	Pill, tablet, capsule, syrup	Pill, tablet, capsule, syrup	Pill, tablet, capsule, syrup, injectable, etc.
Consumption	Consumed as part of the normal diet	Daily consumed, (usually for a period of time) once they are food constituents/extracts	Usually during a certain period of time	Controlled doses according to medical prescription and for a predetermined period of time
Purpose	Exert a health or physiological effect; Improvement of the state of health and well-being and/or reduction of the risk of disease	Promote well-being through the prevention and/or treatment of diseases and/or disorders	Typically consumed to ensure the intake of certain ingredient(s) (e.g., vitamins, minerals, amino acids); They may also help to reduce the risk of disease	Pharmacological purpose; To treat a specific disease

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