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Reactive oxygen species and antioxidant properties from mushrooms

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ABSTRACT

Preventive medicine and food industry have shown an increased interest in the development of natural antioxidants, since those most commonly used synthetic antioxidants may have restricted use in food. This could explain why there is currently much research on the antioxidant properties from natural products such as mushrooms. Many mushrooms have been reported to possess antioxidant properties, which enable them to neutralize free radicals. The oxygen molecule is a free radical, which lead to the generation of the reactive oxygen species and can damage the cells. Cell damage caused by free radicals appears to be a major contributor to aging and degenerative diseases. Mushrooms antioxidant components are found in fruit bodies, mycelium and culture both, which include polysaccharides, tocopherols, phenolics, carotenoids, ergosterol and ascorbic acid among others. Fruit bodies or mycelium can be manipulated to produce active compounds in a relatively short period of time, which represent a significant advantage in antioxidant compounds extraction from mushrooms. Antioxidant compounds may be extracted to be used as functional additives or mushrooms can be incorporated into our food regime, representing an alternative source of food to prevent damage caused by oxidation in the human body.

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1. Introduction

1.1. Mushroom

The term mushroom may come from the Latin word *mucus* (slime) [1]. According to Chang and Miles [2] "mushroom is a macro

Abbreviations: ROS, reactive oxygen species; DPPH•, 1,1-diphenyl-2-picrylhydrazyl; TEAC, Trolox equivalent antioxidant capacity; ABTS•+, 2,2′-azino-bis-(3-ethylbenzothiazoline-6-sulphonate) radical cation; NBT, nitroblue tetrazolium.

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fungus with a distinctive fruit body, which can be either epigeous (grow above the earth) or hypogeous (grow underground; i.e. truffles) and large enough to be seen with naked eye to be picked by hand". These organisms are a very large and diversified group of macrofungi (i.e. higher fungi) belonging to basidiomycetes and ascomycetes that can be edible or non-edible. The fungal spores for these two groups of macrofungi are located in a special structure called basidium (for basidiomycetes) or ascus (for ascomycetes). Mushrooms grow mostly above the earth and some of them have an umbrella-shaped fruiting body, where spores are produced (in lamellae, structures on the underside of the pileus or cap). Two phases of growth are distinguishable in these organisms; the reproductive phase (fruit bodies) and the vegetative phase (mycelia or mycelial growth). During substrate invasion, hyphae continually grow and branch to form a network of hyphae (mycelia) and a fruit body grows from underground mycelia by a process called fructification. Mycelial growth is generally coupled with increased enzyme production and respiration. Hyphae absorb digestive products, penetrating the substrate to some extent. The fungal cell wall can be formed by β-D-glucans, proteins, and chitin (Fig. 1). From the ecological point of view, mushroom can be saprotrophs, parasites and mycorrhiza. There are only few parasitic mushrooms. Most of the cultivated mushrooms are saprotrophs. Mycorrhizal mushrooms have a symbiotic relationship with some vegetation, mainly trees, having a relationship of mutual need. Saprotrophs are able to obtain nutrients from dead organic material and parasites obtain their food from living animals and plants, causing harm to the host [3]. Mushrooms have been eaten and appreciated for their exquisite flavor, economic and ecological values, and medicinal properties for many years. In general, mushrooms contain 90% water and 10% dry matter [4]. They have chemical composition which is attractive from the nutritional point of view [5]. Their nutritional value can be compared to those of eggs, milk, and meat [6]. Mushrooms contain vitamins (thiamine, riboflavin, ascorbic acid, ergosterol and niacin) as well as an abundance of essential amino acids. They also have proteins, fats, ash, and glycosides. Volatiles oils, tocopherols, phenolic compounds, flavonoids, carotenoids, folates, organic acids, etc [7,8]. The total energetic value of mushroom caps is between 250 and 350 cal/kg of fresh mushrooms [4]. Mushrooms can be considered as functional food which provides health benefits in addition to nutritional value [9]. They have been collected in several countries for hundreds of years and technological improvements have made possible their cultivation world-wide.

1.2. Reactive oxygen species and antioxidant system

Around 2.45 billions of years ago molecular oxygen was introduced in our environment by the O_2-evolving photosynthetic organisms and reactive oxygen species (ROS) has been present ever since in aerobic life [10]. The O_2 molecule is a free radical (it has two impaired electrons), which lead to the generation of the ROS and can damage the cells of all organisms. A free radical is a chemical compound that contains one or more unpaired electrons in atomic or molecular orbitals [11]. Reactive molecules such as superoxide anion ($O_2^{\bullet -}$), hydroxyl radical ($OH^{\bullet}$), hydroxyl ion (OH^-), nitric oxide ($NO^{\bullet}$) and hydrogen peroxide (H_2O_2) are free radicals and non-radical molecular forms, respectively derived from molecular oxygen. In humans, oxidation is a process that the body uses for normal energy production and immune function. This is part of the process that enables the body to transform nutrients such as carbohydrates, fats, and proteins into energy. During oxidation, ROS are produced at low levels in normal physiological conditions, which are necessary for maintaining normal cell functions, and the endogenous antioxidant defense systems of the body have the capacity to avert any harmful effects. However, ROS are extremely harmful to organisms at high concentrations. When the level of ROS exceeds the defense mechanisms, they can affect many cellular

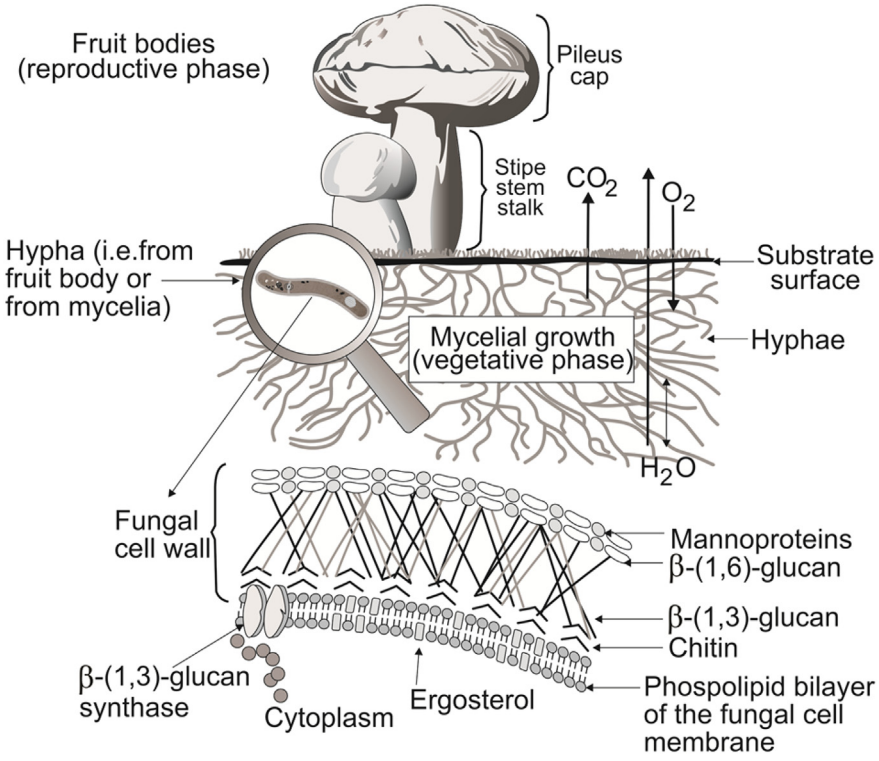

Fig. 1. Illustrative representation of fungal cell wall components and stages of mushroom growth.