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Nutritional value, bioactive compounds and antioxidant properties of three edible mushrooms from Poland

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ABSTRACT

Mushrooms contain a multitude of biomolecules with nutritional and/or biological activity. Among the bioactive molecules, phenolic compounds and tocopherols are the most responsible for their antioxidant activity. In the present work, *Boletus edulis*, *Lentinus edodes* and *Xerocomus badius*, three edible mushroom species originated from Poland, were analyzed for their chemical composition and antioxidant activity. Carbohydrates were the most abundant macronutrients, followed by proteins and ash. Fructose, mannitol and trehalose were the prevalent sugars, but glucose was only found in *B. edulis*. Polyunsaturated fatty acids predominated over mono and saturated fatty acids. Palmitic, oleic and linoleic acids were abundant in the three samples. α- and β- Tocopherols were quantified in all the samples, but γ-tocopherol was only identified in *X. badius*. Oxalic and fumaric acids were quantified in the three samples; quinic acid was only present in *L. edodes*, and malic and citric acids were only found in *X. badius*. *p*-Hydroxybenzoic, protocatechuic and cinnamic acids were quantified in all the species, while *p*-coumaric acid was only found in *B. edulis*. This species and *X. badius* revealed the highest antioxidant properties, being *B. edulis* more effective in radicals scavenging activity and reducing power, and *X. badius* in lipid peroxidation inhibition, which is related with the highest amounts in phenolic compounds and tocopherols, respectively.

1. Introduction

Over the last decades, the consumption of mushrooms has significantly increased due to the scientific evidence of their ability to help the organism in the combat and prevention of several diseases (Ferreira, Barros, & Abreu, 2009; Kalac, 2012). Fruiting bodies of mushrooms are consumed as a delicacy for their texture and flavour, but also for their nutritional properties

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that makes them even more attractable (Lindequist, Niedermeyer, & Julich, 2005; Kalac, 2012). Mushrooms are also described as an excellent choice to include in low caloric diets since they have high amounts of dietary fibre, minerals, vitamins, water, protein, carbohydrates, and low content in lipids (Mattila et al., 2001; Heleno, Barros, Sousa, Martins, & Ferreira, 2009; Kalac, 2012). Furthermore, mushrooms contain a huge variety of bioactive compounds, and proved to be effective mainly as antioxidants, anticancer and antimicrobial agents (Barros, Ferreira, & Baptista, 2008; Ferreira, Vaz, Vasconcelos, & Martins, 2010; Alves et al., 2012). Among the bioactive molecules, phenolic acids have attracted special attention since they are reported as strong antioxidants and the main responsible for the antioxidant properties of mushrooms (Ferreira et al., 2009; Palacios et al., 2011).

Lentinus edodes (Berk.) Pegler and *Boletus edulis* Bull. are two of the most consumed and popular mushrooms worldwide; being *L. edodes* the second most cultivated mushroom (Chang & Miles, 2004) and *B. edulis* considered as the tastiest one among the Boletus genus (Jaworska & Bernas, 2009). Several authors described these two mushroom species as being rich in nutrients and bioactive molecules, such as phenolic acids and tocopherols, that are related with their antioxidant activity (Cheung, Cheung, & Ooi, 2003; Cheung & Cheung, 2005; Heleno et al., 2011; Özyürek, Bener, Güçlü, & Apak, 2014). *Xerocomus badius* is one of the most consumed mushroom in Poland.

In the present work, the chemical composition of the mentioned mushroom species (*L. edodes*, *B. edulis* and *X. badius*), originated from Poland, was evaluated. Furthermore, the chemical compounds found in each sample were related with their antioxidant properties, measured as free radical scavenging activity, reducing power and lipid peroxidation inhibition.

2. Materials and methods

2.1. Samples

Commercial samples of *B. edulis* Bull., *L. edodes* (Berk.) Pegler and *X. badius* (Fr.) E.-J.Gilbert, three edible dried mushrooms, were obtained in a local market in Poland, in November 2012. The specimens were kept at −20 °C until further analysis.

2.2. Standards and reagents

Acetonitrile 99.9%, n-hexane 95% and ethyl acetate 99.8% were of HPLC grade from Fisher Scientific (Lisbon, Portugal). The fatty acids methyl ester (FAME) reference standard mixture 37 (standard 47885-U) was purchased from Sigma (St. Louis, MO, USA), as also other individual fatty acid isomers and standards of sugars (L-(+)-arabinose, D-(+)-mannitol, D-(+)-trehalose), tocopherols (α-, β-, and γ-isoforms), organic acids (malic, oxalic quinic, citric and fumaric acids), phenolic compounds (*p*-hydroxybenzoic, protocatechuic, *p*-coumaric and cinnamic acids), trolox (6-hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid). Racemic tocol, 50 mg/mL, was purchased from Matreya (PA, USA). 2,2-Diphenyl-1-picrylhydrazyl (DPPH) was obtained from Alfa Aesar (Ward Hill, MA, USA). Water was treated in a Milli-Q water purification system (TGI Pure Water Systems, Greenville, SC, USA).

2.3. Chemical composition

2.3.1. Nutritional value

The samples were analysed for chemical composition (moisture, proteins, fat, carbohydrates and ash) using the AOAC procedures (AOAC, 1995). The crude protein content (N × 4.38) of the samples was estimated by the macro-Kjeldahl method; the crude fat was determined by extracting a known weight of powdered sample with petroleum ether, using a Soxhlet apparatus; the ash content was determined by incineration at 600 ± 15 °C. Total carbohydrates were calculated by difference. Energy was calculated according to the following equation: Energy (kcal) = 4 × (g protein + g carbohydrate) + 9 × (g fat).

2.3.2. Free sugars

Free sugars were determined by a High Performance Liquid Chromatography (HPLC) system consisted of an integrated system with a pump (Knauer, Smartline system 1000, Berlin, Germany), degasser system (Smartline manager 5000) and auto-sampler (AS-2057 Jasco, Easton, MD, USA), coupled to a refraction index detector (RI detector Knauer Smartline 2300) as previously described by the authors (Heleno et al., 2009). Sugars were identified by comparing the relative retention times of sample peaks with standards. Data were analysed using Clarity 2.4 Software (DataApex, Prague, Czech Republic). The chromatographic separation was achieved with a Eurospher 100-5 NH_2 column (5 μm, 250 mm × 4.6 mm i.d., Knauer) operating at 35 °C (7971 R Grace oven). The mobile phase was acetonitrile/deionized water, 70:30 (*v*/*v*) at a flow rate of 1 mL/min. Quantification was based on the RI signal response of each standard, using the internal standard (IS, raffinose) method and by using calibration curves obtained from commercial standards of each compound. The results were expressed in g per 100 g of dry weight.

2.3.3. Fatty acids

Fatty acids were determined after a trans-esterification procedure as described previously by the authors (Heleno et al., 2009), using a gas chromatographer (DANI 1000, Contone, Switzerland) equipped with a split/splitless injector and a flame ionization detector (GC-FID at 260 °C) and a Macherey–Nagel (Düren, Germany) column (50% cyanopropyl-methyl-50% phenylmethyl-polysiloxane, 30 m × 0.32 mm i.d. × 0.25 μm d_f). The oven temperature program was as follows: the initial temperature of the column was 50 × C, held for 2 min, then a 30 °C/min ramp to 125 °C, 5 °C/min ramp to 160 °C, 20 °C/ min ramp to 180 °C, 3 °C/min ramp to 200 °C, 20 °C/min ramp to 220 °C and held for 15 min. The carrier gas (hydrogen) flow-rate was 4.0 mL/min (0.61 bar), measured at 50 °C. Split injection (1:40) was carried out at 250 °C. Fatty acid identification was made by comparing the relative retention times of FAME peaks from samples with standards. The results were recorded and processed using CSW 1.7 software (DataApex 1.7, Prague, Czech Republic). The results were expressed in relative percentage of each fatty acid.