Chemical composition and nutritional value of the most widely appreciated cultivated mushrooms: an inter-species comparative study

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Abstract

Herein, it was reported and compared the chemical composition and nutritional value of the most consumed species as fresh cultivated mushrooms: *Agaricus bisporus* (White and Brown mushrooms), *Pleurotus ostreatus* (Oyster mushroom), *Pleurotus eryngii* (King oyster mushroom), *Lentinula edodes* (Shiitake) and *Flammulina velutipes* (Golden needle mushroom). Shiitake revealed the highest levels of macronutrients, unless proteins, as also the highest sugars, tocopherols and PUFA levels, and the lowest SFA content. White and brown mushrooms showed similar macronutrients composition, as also similar values of total sugars, MUFA, PUFA and total tocopherols. Oyster and king oyster mushrooms gave the highest MUFA contents with similar contents in PUFA, MUFA and SFA in both samples. They also revealed similar moisture, ash, carbohydrates and energy values. This study contributes to the elaboration of nutritional databases of the most consumed fungi species worldwide, allowing comparison between them. Moreover it was reported that cultivated and the wild samples of the same species have different chemical composition, including sugars, fatty acids and tocopherols profiles.

Keywords: Worldwide cultivated mushrooms; Nutritional value; Sugars; Fatty acids; Tocopherols

1. Introduction

Mushrooms have a great nutritional value since they are quite rich in protein, with an important content of essential amino acids and fiber, and poor in fat. Edible mushrooms also provide a nutritionally significant content of vitamins (B1, B2, B12, C, D and E) (Heleno et al., 2010; Mattila et al., 2001). Edible mushrooms could be a source of many different nutraceuticals such as unsatured fatty acids, phenolic compounds, tocopherols, ascorbic acid and carotenoids. Thus, they might be used directly in diet and promote health, taking advantage of the additive and synergistic effects of all the bioactive compounds present (Barros et al., 2007; Barros et al., 2008a; Barros et al., 2008b; Ferreira et al., 2009; Pereira et al., 2012; Vaz et al., 2010).

More than 3000 mushrooms are said to be "the main edible species", of which only 100 are cultivated commercially, and only ten of those on an industrial scale. Their global economic value is nevertheless now staggering, and a prime reason for the rise in consumption is the above mentioned combination of their value as a food as well as their medicinal and nutraceutical values (Chang and Miles, 2004). Production of mushrooms continuously increases over time, being China the biggest producer (more than 1.5 million metric tons in 2007) (Aida et al., 2009).

The most cultivated mushroom worldwide is *Agaricus bisporus*, followed by *Lentinula edodes*, *Pleurotus* spp. and *Flammulina velutipes* (Aida et al., 2009; Chang and Miles, 2004). These species require shorter growth time when compared to other edible mushrooms, they demand few environmental controls, and they can be cultivated in a simple and cheap way (Bonatti et al., 2004).

Our research group has an extensive work in the chemical characterization of wild mushroom species. Nevertheless, it is also urgent to know the nutritional value of cultivated species, mostly of the highly appreciated ones. There are a few studies on

nutritional value of those species from different origins such as Brazil (Bonnati et al., 2004), Canada (Pedneault et al., 2007), Finland (Mattila et al., 2002), Italy (Manzi et al., 1999; Manzi et al., 2001; Manzi et al., 2004), Japan (Wang et al., 2001), Netherlands (Braaksma and Schaap, 1996), Taiwan (Tsai et al., 2007; Tsai et al., 2009), Turkey (Çağlarirmak, 2007).

Herein, it was intended to provide far information about the nutritional value and chemical composition of the most popular edible mushrooms and main cultivated species marketed in Portugal as also all over the world as fresh mushrooms: *Agaricus bisporus* (White and Brown mushrooms), *Pleurotus ostreatus* (Oyster mushroom), *Pleurotus eryngii* (King oyster mushroom), *Lentinula edodes* (Shiitake) and *Flammulina velutipes* (Golden needle mushroom).

2. Material and Methods

2.1. Mushroom species

The mushrooms species were obtained in local supermarkets (Bragança, Northeast Portugal), where they were stored at 4 ºC, in March and April 2011. Information about the studied species is provided in **Table 1**. Three fruiting bodies per species were sampled. All the samples were lyophilised (FreeZone 4.5 model 7750031, Labconco, Kansas, USA), reduced to a fine dried powder (20 mesh), mixed to obtain homogenate samples and stored in a desiccator, protected from light, until further analyses.

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, sugars (D(-)-fructose, D(-)-mannitol, D(+)-raffinosepentahydrate, and D(+)-trehalose) and tocopherols (α-, β-, γ-, and δ-isoforms) standards. Racemic tocol, 50 mg/ml, was purchased from Matreya (PA, USA). All other chemicals and solvents were of analytical grade and purchased from common sources. Water was treated in a Milli-Q water purification system (TGI Pure Water Systems, USA).

2.3. 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 ºC. Total carbohydrates were calculated by difference. Energy was calculated according to the following equation: Energy (kcal) = 4 × (g protein) + 3.75 × (g carbohydrate) + 9 × (g fat).

2.4. Sugars composition

The lyophilized samples (1 g) were spiked with raffinose as internal standard (IS, 5 mg/ml) and were extracted with 40 ml of 80% aqueous ethanol at 80 ºC for 30 min. The resulting suspension was centrifuged at 15,000*g* for 10 min. The supernatant was concentrated at 60 ºC and defatted three times with 10 ml of ethyl ether, successively. After concentration at 40 ºC, the solid residues were dissolved in water to a final volume of 5 ml and filtered through 0.2 μm nylon filters for analysis by high performance liquid chromatography coupled to a refraction index detector (HPLC-RI),

as previously optimized by Heleno et al. (2009). The HPLC equipment consisted of an integrated system with a Smartline 1000 pump (Knauer, Berlin, Germany), a Smartline manager 5000 degasser, an AS-2057 auto-sampler (Jasco, Easton, MD) and a Smartline 2300 refraction index (RI) detector (Knauer). Data were analysed using Clarity 2.4 Software (DataApex). The chromatographic separation was achieved with a Eurospher 100-5 NH_2 column (4.6 × 250 mm, 5 mm, Knauer) operating at 30ºC. The mobile phase was acetonitrile/deionized water, 70:30 (v/v) at a flow rate of 1 ml/min. Sugars identification was made by comparing the relative retention times of sample peaks with standards. Quantification was made by the internal standard method and the results were expressed in g per 100 g of fresh weight (fw).

2.5. Fatty acids composition

Fatty acids (obtained after Soxhlet extraction) were methylated with 5 ml of methanol:sulphuric acid 95%:toluene 2:1:1 (v/v/v) for, at least, 12 h in a bath at 50 ºC and 160 rpm; to obtain phase separation 3 ml of deionised water were added; the fatty acids methyl esters (FAME) were recovered by shaking in a vortex with 3 ml of diethyl ether, and the upper phase was passed through a micro-column of anhydrous sodium sulphate to eliminate the water. The sample was recovered in a vial with Teflon and filtered through a 0.2 µm Whatman nylon filter. Fatty acids were determined by gas-liquid chromatography with flame ionization detection (GC-FID)/capillary column as described previously by the authors (Heleno et al., 2009). The analysis was carried out with a DANI model GC 1000 instrument (Milan, Italy) equipped with a split/splitless injector, a flame ionization detector (FID at 260 ºC) and a Macherey-Nagel column (30 m×0.32 mm ID × 0.25 µm d_f). The oven temperature program was as follows: the initial temperature of the column was 50 ºC, held for 2 min, then a 30ºC/min ramp to

125 ºC, 5ºC/min ramp to 160 ºC, 20ºC/min ramp to 180 ºC, 3ºC/min ramp to 200 ºC, 20ºC/min ramp to 220 ºC and held for 15 min. The carrier gas (hydrogen) flow-rate was 4.0 ml/min (0.61 bar), measured at 50 ºC. Split injection (1:40) was carried out at 250 ºC. 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) and expressed in relative percentage of each fatty acid (FA).

2.6. Tocopherols composition

Butylated hydroxytoluene, BHT solution in hexane (10 mg/ml; 100 µl) and IS solution in hexane (tocol; 50 µg/ml; 400 µl) were added to the sample prior to the extraction procedure. Samples (~500 mg) were homogenized with methanol (4 ml) by vortex mixing (1 min). Subsequently, hexane (4 ml) was added and again vortex mixed for 1 min. Saturated NaCl aqueous solution (2 ml) was added, the mixture was homogenized (1 min), centrifuged (5 min, 4,000*g*) and the clear upper layer was carefully transferred to a vial. The sample was re-extracted twice with *n*-hexane. The combined extracts were taken to dryness under a nitrogen stream, redissolved in 2 ml of *n*-hexane, dehydrated with anhydrous sodium sulphate and filtered through 0.2 µm nylon filters and transferred into a dark injection vial. Tocopherols content was determined following a procedure previously optimized by Barros et al. (2008). The HPLC system described above was connected to a FP-2020 fluorescence detector (Jasco, Easton, MD) programmed for excitation at 290 nm and emission at 330 nm. The column used was a normal-phase 250 mm × 4.6 mm i.d., 5 µm, Polyamide II, with a 10 mm × 4 mm i.d. guard column of the same material (YMC Waters, Dinslaken, Germany), operating at 30ºC. The mobile phase used was a mixture of n-hexane and ethyl acetate (70:30, v/v)

at a flow rate of 1 ml/min. Tocopherols identification was made by comparing the relative retention times of sample peaks with standards. Quantification was based on the fluorescence signal response, using the internal standard method, and the results were expressed in µg per 100 g of fresh weight (fw).

2.7. Statistical analysis

For each one of the mushroom species three samples were used and all the assays were carried out in triplicate. The results are expressed as mean values and standard deviation (SD). The results were analysed using one-way analysis of variance (ANOVA) followed by Tukey's HSD Test with $\alpha = 0.05$. This analysis was carried out using SPSS v. 18.0 program.

3. Results and discussion

The results of the nutritional value obtained for the studied edible mushrooms are shown in **Table 2**. Moisture ranges between 79.78 g/100 g in shiitake and 91.64 g/100 g in brown mushroom. Mushrooms contain a high moisture percentage depending on the mushroom species and other parameters related to harvest, growth, culinary and storage conditions (Guillamón et al., 2010). White, brown and king oyster mushrooms gave the highest levels of protein, without significant statistical differences (1.04-1.10 g/100 g). Mushrooms are reported to be a good source of protein, and some investigators have even contended that the amino acid compositions of mushrooms are comparable to animal proteins (Longvah and Deosthale, 1998; Mattila et al., 2001). Leucine, valine, glutamine, glutamic and aspartic acids are the most abundant amino acids in mushrooms, which were analysed by different techniques such as ionic exchange chromatography coupled to an amino acids analyser (Longvah and Deosthale, 1998),

reaction with ninhydrin using an amino acids analyser (Mattila et al., 2002; Ouzouni et al., 2009), gas chromatography coupled to mass spectrometry (GC-MS) (Léon-Guzmán et al., 1997), high performance liquid chromatography (HPLC) with UV-vis detection (Ribeiro et al., 2008) and HPLC-fluorescence (Mdachi et al., 2004).

Shiitake revealed the highest ash (1.36 g/100 g) and fat (0.35 g/100 g) contents; brown mushroom gave the lowest fat levels (≤ 0.14 g/100 g). In general, mushrooms are low-calorie foods since they provide low amounts of fat (León-Guzmán et al., 1997). The main constituents in the ash are potassium and, depending on the mushroom, phosphorus (Mattila et al., 2001) or magnesium (Manzi et al., 1999), in addition to calcium, copper, iron and zinc (Guillamón et al., 2010).

Carbohydrates, calculated discounting protein, ash and fat levels, were the most abundant macronutrients and the highest levels were also found in shiitake (17.62 g/100 g). Furthermore, this species gave highest energetic contribution (72.79 kcal/100 g). Carbohydrates content includes also fiber such as the structural polysaccharides β-glucans, chitin, hemicelluloses and pectic substances (Kalač, 2009). Although, an extraordinarily high or appreciable level of total fiber was reported for *Agrocybe aegerita*, *A. bisporus*, *P. seryngii* and *P. ostreatus* (Manzi et al., 2001; Manzi et al., 2004), herein it was *Lentinula edodes* (shiitake) that gave the highest carbohydrates levels, as mentioned above. Probably its higher carbohydrates content is due to a higher level of non-fiber carbohydrates such as sugars (**Table 3**, where shiitake gave the highest sugars concentrations).

White and brown mushrooms presented similar amounts of macronutrients (**Table 2**) but with lower proteins and fat contents, and higher carbohydrates values than samples of *Agaricus bisporus* from Italy (Manzi et al., 2001) and Taiwan (Tsai et al., 2007; comparing results expressed in fresh weight calculated taking into account the dry

matter). Moisture (91-92 g/100 g), ash (~0.9-1 g/100 g) and energy (~29-31 kcal/100 g) values were similar in all those samples.

Both *Pleurotus* species (oyster and king oyster mushrooms) gave similar nutritional composition, unless proteins and fat levels, with the last one revealing higher concentrations. Oyster mushroom presented lower proteins, fat, ash and energy contents, but higher moisture and carbohydrates levels than the wild corresponding species from Croatia (Beluhan and Ranogajec, 2011) and Brazil, this one cultivated in rice or banana straws substrates (Bonnati et al., 2004). Çağlarirmak (2007) reported similar ash content (0.63 g/100 g), but higher moisture (91.34 g/110 g) and protein (0.92 g/100 g) levels in samples from Turkey, while Manzi et al. (1999) described similar moisture (85-95 g/100 g) and ash (0.5-1.2 g/100 g) contents, and higher protein levels (1.2-4.9 g/100 g) in samples from Italy. Afterwards, the same authors reported different nutritional composition in the same species (Manzi et al., 2004). Considering king oyster mushroom, these authors obtained, in a first study, higher moisture (91.69 and 91.45 g/100 g) and proteins (1.88 and 1.97 g/100 g) contents, but lower ash values (0.76 and 0.90 g/100 g) (Manzi et al., 1999). Latter, they reported lower moisture (86.6 g/100 g) and fat (0.8 g/100 g) levels, but higher proteins (2.2. g/100 g), ash (1.2 g/100 g) and carbohydrates (9.6 g/100 g) contents (Manzi et al., 2004).

Shiitake samples from Italy (Manzi et al., 1999) and Turkey (Çağlarirmak, 2007) were also studied and presented higher moisture (>90 g/100 g) and proteins (>1.18 g/100 g) contents, and lower ash values (<0.95 g/100 g) than the sample herein studied (**Table 2**).

Golden needle mushroom from Croatia gave higher moisture (88.05 g/100 g), proteins (3.34 g/100 g) and fat (0.77 g/100 g) contents, lower carbohydrates (5.09 g/100 g) and

energy (34.4 kcal/100 g) levels, and similar ash content (0.88 g/100 g) (Beluhan and Ranogajec, 2011) than the sample from Portugal (**Table 2**).

It is known that the growth compost can influence the chemical composition and, as a consequence, the nutritional value of the cultivated mushrooms (Manzi et al., 1999). Mushroom quality is also influenced by other parameters such as the stage of development and pre and post-harvest conditions. All these interfering factors justify the variability in composition data published by different authors working with even the same species of mushroom (Manzi et al., 1999), in addition to the intraspecific genetic variability of samples from different geographic origins and producers.

Mannitol and trehalose were abundant sugars in the studied cultivated edible mushrooms (**Table 3**). The first one predominated in *Agaricus bisporus* (white and brown mushrooms) and shiitake, while the other predominated in *Pleurotus* species (oyster and king oyster mushrooms). Sucrose was found only in king oyster and golden needle mushrooms and in very low amounts (0.03 and 0.09 g/100 g, respectively). Curiously, fructose was the most abundant sugar in golden needle mushroom (4.60 g/100 g). In previous studies (Grangeia et al., 2011; Pereira et al., 2012), our research group reported the presence of fructose only in mycorrhizal wild species. This monosaccharide as also sucrose was not detected in the wild saprotrophic species *Flammulina velutipes* (golden needle mushroom) studied by us. The observed differences in sugars composition might be related to the fact that the sample herein studied was cultivated, while the other one was a wild sample. This gains strength if we consider the results reported for a wild sample from Croatia that gave lower total sugars content (3.60 g/100 g, calculated taking into account the dry matter; Beluhan and Ranogajec, 2011) and a different individual sugars composition: glucose (1.44 g/100 g),

mannitol (0.94 g/100 g), mannose (0.86 g/100 g) and trehalose (0.35 g/100 g). In the studied cultivated sample, neither glucose nor mannose were detected (**Figure 1A**).

Among the analysed fresh cultivated mushrooms, shiitake revealed the highest total sugars content (14.08 g/100 g), with the highest levels of mannitol (10.01 g/100 g). The total sugars concentration found in *Agaricus bisporus* species (white and brown mushrooms) was similar and higher than the values found in samples from Taiwan (1.75-3.13 g/100 g, results expressed in fresh weight calculated taking into account the dry matter; Tsai et al., 2007). Nevertheless, those authors reported the presence of other sugars besides mannitol (also the most abundant one), trehalose and fructose, such as sucrose, glucose, lactose, myo-inositol and ribose. In the studied cultivated samples those sugars were not detected as can be observed in **Figure 1B**. Considering oyster mushroom, total sugars were similar to the reported for a wild sample from Croatia (4.41 g/100 g, calculated taking into account the dry matter; Beluhan and Ranogajec, 2011), that showed different individual sugars composition: glucose (1.75 g/100 g), mannose (1.30 g/100 g), mannitol (1.15 g/100 g) and trehalose (0.21 g/100 g). Tsai et al. (2009) reported the presence of myo-inositol, trehalose, mannitol, arabitol and glucose in samples from Taiwan. In the studied cultivated sample we did not find glucose, mannose, myo-inositol or arabitol (**Figure 1C**).

The absence of other nutrients (for instance vitamin D2) in cultivated mushroom species in comparison to the wild ones was already reported (Mattila et al., 2001). The absence of vitamin D2 could be due to cultivation in dark, as it occurs for button mushroom.

The results of the main fatty acids found in the studied cultivated mushrooms, as also their saturated fatty acids (SFA), monounsaturated fatty acids (MUFA) and polyunsaturated fatty acids (PUFA) percentages are shown in **Table 3**. Up to twenty-six fatty acids were detected in most of the samples (data not shown). The major fatty acid

found was by far linoleic acid (C18:2n6c), contributing to the prevalence of PUFA. Oleic acid (C18:1n9c) was the most abundant MUFA in all the samples, while palmitic acid (C16:0) was the major SFA. Shiitake gave the highest levels of PUFA (82.0%) and the lowest levels of SFA (15.1%); *Pleurotus* species (oyster and king oyster mushrooms) gave a similar fatty acids composition and the highest levels of MUFA (13-14%) without significant statistical differences. The same profile (C18:2>>C18:1>C16:0, **Table 3**, **Figure 2**) was described for cultivated samples of *Pleurotus ostreatus* (oyster mushroom) from Canada (Pedneault et al., 2007). Nevertheless, in wild samples of *P. ostreatus* and *A. bisporus* from Turkey, stearic acid (C18:0) predominated over palmitic acid (C16:0) (Yilmaz et al., 2006).

Shitake and brown mushroom presented the highest content of tocopherols (~11 µg/100 g), the first species with the highest levels of α- (0.92 µg/100 g) and δ- (4.36 µg/100 g) isoforms, and the second species with the highest γ-tocopherol levels (7.63 µg/100 g). β-tocopherol was found only in white, brown and king oyster mushrooms, the latter with the highest concentration (2.16 µg/100 g). *Agaricus* species and *Pleurotus* species revealed, between them, similar total tocopherols contents, but with different levels of the individual isoforms (**Table 3**). A quite different profile was obtained for cultivated *Agaricus bisporus* (white or brown mushrooms) and *Flammulina velutipes* (golden needle mushroom) and the corresponding wild samples also studied by us (Barros et al., 2008a; Pereira et al., 2012). β-tocopherol was the major isoform found in the wild sample of *Flammulina velutipes* (Pereira et al., 2012), and γ-tocopherol was not detected. Otherwise, in the cultivated sample β- and δ-tocopherols were not found, being γ-tocopherol the major isoform (**Table 3; Figure 3**).

Overall, the rich nutritional composition of the studied fresh cultivated mushrooms (high contents in protein and carbohydrates, low contents in fat with the precious contribution of unsaturated fatty acids) makes them excellent foods that can be used in low caloric diets. This study contributes to the elaboration of nutritional databases of the most consumed worldwide, allowing comparison between them. Shiitake (*Lentinula edodes*) revealed the highest levels of macronutrients, unless proteins, as also the highest sugars, tocopherols and PUFA levels, and the lowest SFA content. *Agaricus bisporus* (both white and brown mushrooms) showed similar macronutrients composition, as also similar values of total sugars, MUFA, PUFA and total tocopherols. *Pleurotus* species gave the highest MUFA contents with similar contents in PUFA, MUFA and SFA in both samples (oyster and king oyster mushrooms). They also revealed similar moisture, ash, carbohydrates and energy values. Moreover it was demonstrated that cultivated and the wild samples of the same species have different chemical composition, including sugars, fatty acids and tocopherols profiles.

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Table 1. Information about the studied edible mushrooms from Portugal.

Scientific name (Species)	Photo	English name/Local name	Packing date	Main uses
Agaricus bisporus (J.E.Lange) Imbach		White mushroom/Champignon	23-03-2011	Soups, gravies, stir-fries or in salads.
Agaricus bisporus (J.E. Lange) Imbach		Brown mushroom/ Portobello	24-03-2011	Soups, gravies, stir-fries or in salads.
Pleurotus ostreatus (Jacq. ex Fr.) P.Kumm.		Oyster mushroom/ Repolga	21-03-2011	Soups, in stir-fry recipes with soy sauce or eaten stuffed.
Pleurotus eryngii (DC.) Quél.		King oyster mushroom/ Eryngii	06-04-2011	Vegetarian dishes (consumed fresh). Served sautéed, grilled, braised, stewed, or boiled.
Lentinula edodes (Berk.)Pegler		Shiitake/Shiitake	06-04-2011	Soups, sauces and salads. Can be prepared in a similar way to the meat.
Flammulina velutipes (Curtis) Singer		Golden needle mushroom/ Enoki	06-04-2011	Soups and salads.

Table 2. Nutritional value of the studied edible mushrooms (mean ± SD).

	White mushroom	Brown mushroom	Oyster mushroom	King oyster mushroom	Shiitake	Golden needle mushroom
Moisture (g/100 g fw)	91.27± 0.45 ba	91.64 ± 0.99 a	89.17 ± 2.12 ba	89.00 ± 1.39 ba	79.78 ± 1.31 c	87.87 ± 1.33 b
Ash (g/100 g fw)	0.85 ± 0.17 cb	0.95 ± 0.02 b	0.62 ± 0.08 d	0.68 ± 0.06 dc	1.36 ± 0.05 a	0.88 ± 0.13 b
Proteins (g/100 g fw)	1.23 ± 0.02 a	1.29 ± 0.04 a	0.76 ± 0.06 b	1.21 ± 0.02 a	0.89 ± 0.09 b	0.47 ± 0.00 c
Fat (g/100 g fw)	0.19 ± 0.03 cb	0.14 ± 0.02 d	0.15 ± 0.02 dc	0.16 ± 0.03 dcb	0.35 ± 0.02 a	0.21 ± 0.04 b
Carbohydrates (g/100 g fw)	6.46 ± 0.57 c	5.98 ± 1.03 c	9.30 ± 2.08 cb	8.95 ± 1.04 cb	17.62 ± 1.29 a	10.57 ± 1.26 b
Energy(kcal/100 g fw)	30.86 ± 1.98 cb	28.85 ± 3.71 c	39.27 ± 7.76 cb	39.84 ± 3.74 cb	72.79 ± 4.98 a	43.41 ± 4.49 b

In each row, different letters mean significant differences between species (p<0.05).

Table 3. Composition in sugars, fatty acids and tocopherols of the studied edible mushrooms (mean ± SD).

	White mushroom	Brown mushroom	Oyster mushroom	King oyster mushroom	Shiitake	Golden needle mushroom
Frutose	0.03 ± 0.00 c	0.04 ± 0.00 c	0.01 ± 0.00 c	0.03 ± 0.00 c	0.69 ± 0.09 b	4.60 ± 0.34 a
Mannitol	5.60 ± 0.19 b	4.01 ± 0.20 c	0.54 ± 0.04 d	0.60 ± 0.00 d	10.01 ± 1.30 a	0.97 ± 0.11 d
Sucrose	nd	nd	nd	0.03 ± 0.00 b	nd	0.09 ± 0.00 a
Trehalose	0.16 ± 0.02 e	0.22 ± 0.03 e	4.42 ± 0.03 b	8.01 ± 0.19 a	3.38 ± 0.37 c	2.63 ± 0.22 d
Total Sugars (g/100 g fw)	5.79 ± 0.21 c	4.27 ± 0.20 c	4.97 ± 0.02 c	8.67 ± 0.19 b	14.08 ± 1.76 a	8.29 ± 0.68 b
C16:0	11.9 ± 0.3 b	11.1 ± 0.1 c	11.2 ± 0.2 cb	12.8 ± 0.8 a	10.3 ± 0.2 d	11.0 ± 0.2 dc
C18:0	3.1 ± 0.0 a	3.0 ± 0.2 a	1.6 ± 0.2 c	1.7 ± 0.3 cb	1.6 ± 0.1 c	2.0 ± 0.1 b
C18:1n9c	1.1 ± 0.6 d	1.2 ± 0.4 d	12.3 ± 0.3 a	12.3 ± 0.6 a	2.3 ± 0.3 c	5.7 ± 0.1 b
C18:2n6c	77.7 ± 0.7 b	79.4 ± 0.2 ba	68.9 ± 0.8 c	68.8 ± 2.1c	81.1 ± 0.4 a	45.4 ± 0.1 d
C18:3n3c	0.1 ± 0.0 c	0.1 ± 0.0 c	0.1 ± 0.0 c	0.3 ± 0.0 b	0.1 ± 0.0 c	28.8 ± 0.1 a
Total SFA (% of total FA)	20.3 ± 0.1 a	18.4 ± 0.6 b	17.0 ± 0.5 c	17.4 ± 1.1 cb	15.1 ± 0.1 d	18.5 ± 0.2 b
Total MUFA (% of total FA)	1.4 ± 0.6 d	1.8 ± 0.4 d	13.6 ± 0.3 a	13.1 ± 1.0 a	2.9 ± 0.3 c	7.2 ± 0.1 b
Total PUFA (% of total FA)	78.3 ± 0.7 b	79.8 ± 0.2 b	69.4 ± 0.7 d	69.4 ± 2.1 d	82.0 ± 0.4 a	74.3 ± 0.2 c
α-Tocopherol	0.23 ± 0.02 c	0.28 ± 0.08 c	0.59 ± 0.08 b	0.25 ± 0.01 c	0.92 ± 0.04 a	0.19 ± 0.02 c
β-Tocopherol	0.85 ± 0.02 b	0.71 ± 0.11 c	nd	2.16 ± 0.02 a	nd	nd
γ-Tocopherol	1.51 ± 0.14 c	7.63 ± 6.32 a	1.49 ± 0.00 c	1.83 ± 0.21 c	5.55 ± 0.60 b	1.62 ± 0.02 c
δ-Tocopherol	2.60 ± 0.20 b	2.54 ± 0.10 b	1.64 ± 0.22 c	0.62 ± 0.03 d	4.36 ± 0.54 a	nd
Total tocopherols (μg/100 g fw)	5.19 ± 0.03 ba	11.16 ± 6.31 a	3.72 ± 0.29 b	4.86 ± 0.26 ba	10.83 ± 0.10 a	1.81 ± 0.02 b

nd- not detected. C16:0 (palmitic acid); C18:0 (stearic acid); C18:1n9c (oleic acid); C18:2n6c (linoleic acid); C18:3n3c (α-linolenic acid);SFA (saturated fatty acids); MUFA(monounsaturated fatty acids); PUFA (polyunsaturated fatty acids); The difference to 100% corresponds to other 21 less abundant fatty acids (data not shown).In each row, different letters mean significant differences between species (p<0.05).

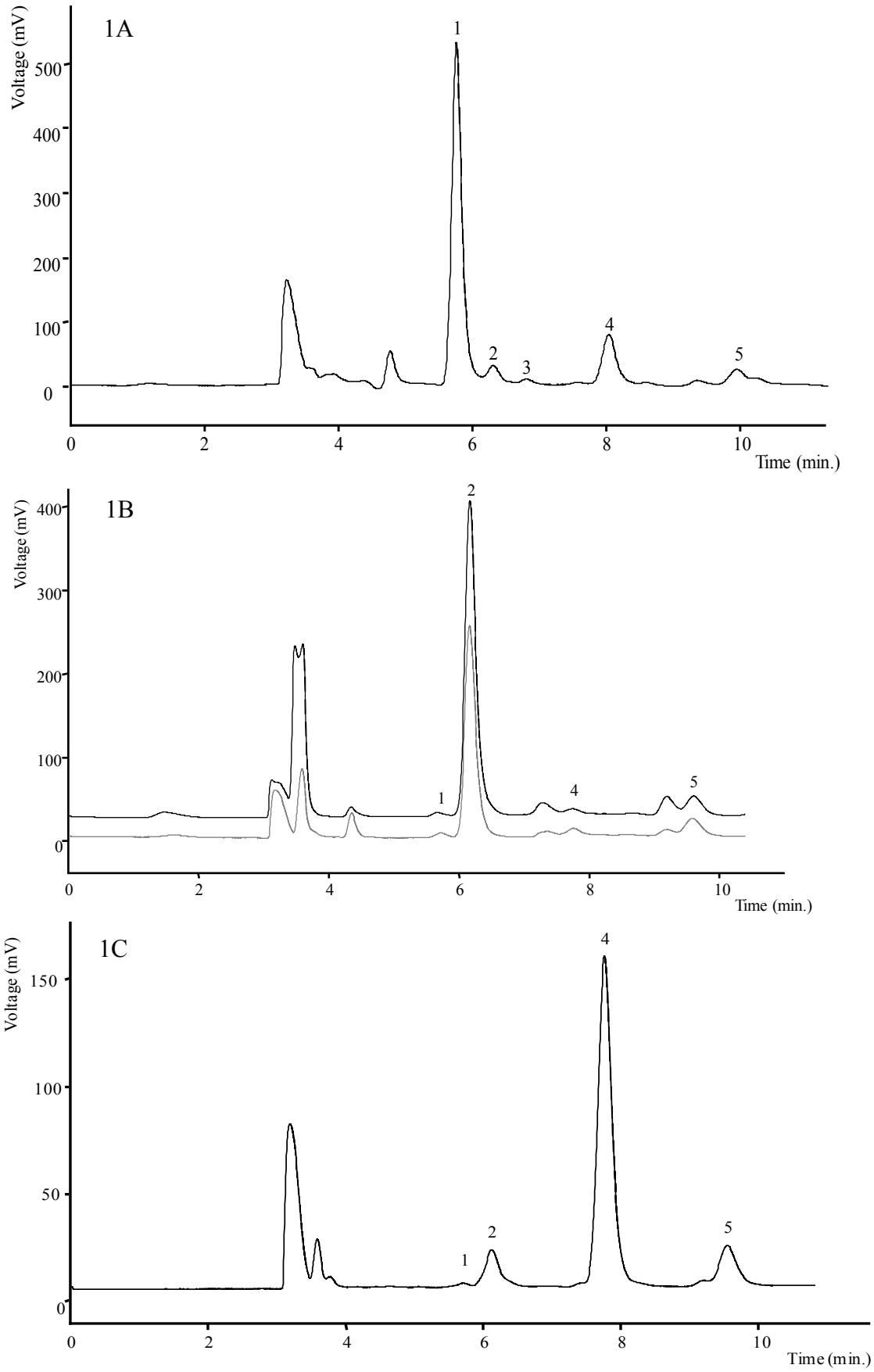

Figure 1. Individual chromatograms of golden needle mushroom (1A), white (—) and brown (—) mushrooms (1B) and oyster mushroom (1C). 1- Fructose; 2- Mannitol; 3- Sucrose; 4- Trehalose; 5- Raffinose (IS).

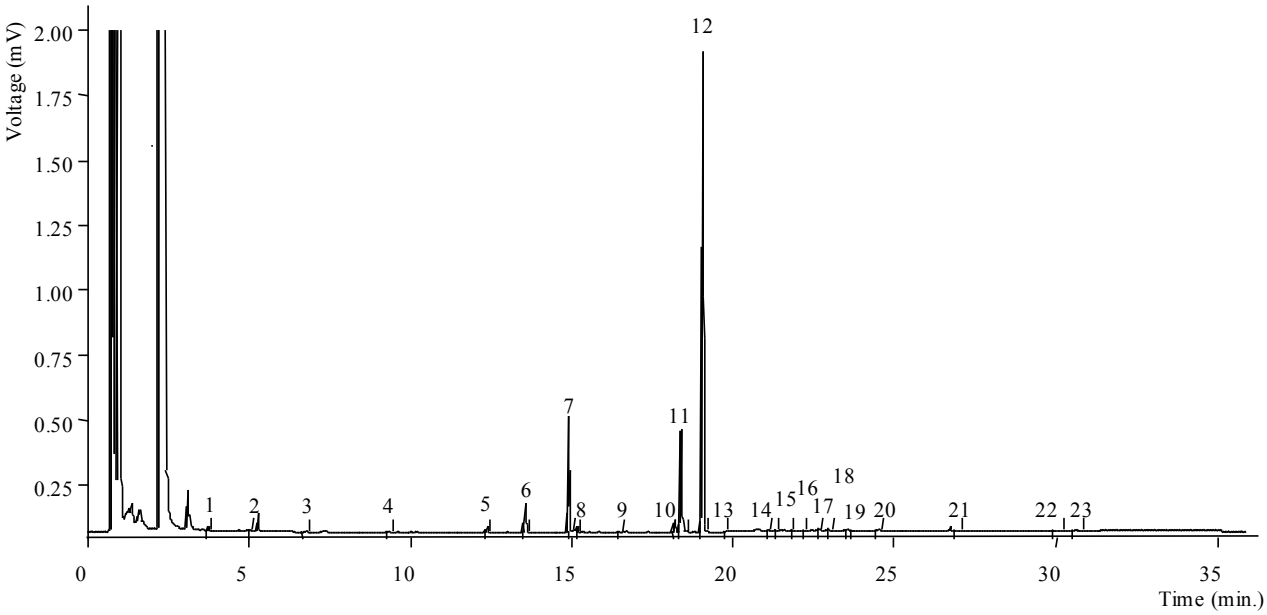

Figure 2. Fatty acid profile of oyster mushroom. 1- Caproic acid (C6:0); 2- Caprylic acid (C8:0); 3- Capric acid (C10:0); 4- Lauric acid (C12:0); 5- Myristic acid (C14:0); 6- Pentadecanoic acid (C15:0); 7- Palmitic acid (C16:0); 8- Palmitoleic acid (C16:1); 9- Heptadecanoic acid (C17:0); 10-Stearic acid (C18:0); 11- Oleic acid (C18:1n9c); 12- Linoleic acid (C18:2n6c); 13- α-Linolenic acid (C18:3n3c); 14-Arachidic acid (C20:0); 15-Eicosenoic acid (C20:1c); 16- cis-11,14-Eicosadienoic acid (C20:2c); 17- Arachidonic acid (C20:4n6); 18- cis-11, 14, 17-Eicosatrienoic acid and Heneicosanoic acid (C20:3n3+C21:0); 19- cis-5,8,11,14,17-Eicosapentaenoic acid (C20:5n3); 20- Behenic acid (C22:0); 21- Tricosanoic acid (C23:0); 22-Lignoceric acid (C24:0); 23- Nervonic acid (C24:1).

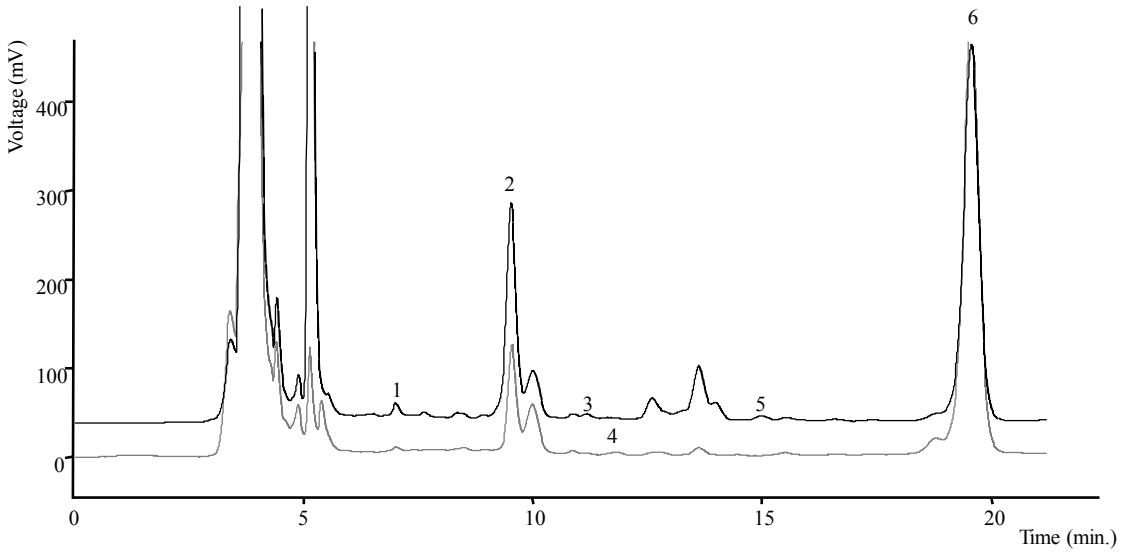

Figure 3. Tocopherols profile of commercial golden needle mushroom (—) and the corresponding wild sample (—). 1- α-Tocopherol; 2- BHT; 3- β-Tocopherol; 4- γ-Tocopherol; 5- δ-Tocopherol; 6- Tocol (IS).