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The effect of some agro– industrial wastes on yield, nutritional characteristics and antioxidant activities of *Hericium erinaceus* isolates

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ABSTRACT

Four isolates of *Hericium erinaceus* cultivated in different growing media were investigated for their mycelial growth, yield, biological efficiency (BE), macro and micro element content, total phenolic content and antioxidant activity. In the study, oak sawdust (OS) was used as a base substrate, and cottonseed hulls (CSH) and olive press cake (OPC) were added at the ratios of 9:1, 8:2 and 7:3 to prepare the growing media. The control medium was prepared using OS and wheat bran (WB) at the rate of 8:2. The spawn run-period was shorter in all *H. erinaceus* isolates growing in the OS:WB (control) medium. The yield and BE (%) of *H. erinaceus isolates* ranged between 76.7 and 152.9 g/kg and 22.3–44.4%, respectively, depending on the growing medium used. The highest yield and BE% for all *H. erinaceus* isolates, except He-Trabzon, was obtained on 7OS:3CSH medium. The nutritional composition of *H. erinaceus* isolates varied with the growing medium, but there was no direct relationship between the macro- and micro-element content of the growing media and the nutrient content of the fruitbodies. The antioxidant activity and phenolic content of *H. erinaceus* isolates grown on different growing media ranged between 1.76 and 4.92 µmol TE/g fw and 0.318–0.663 mg GAE/g fw, respectively. The antioxidant activity and phenolic content of He- Ankara, He-Denizli and He-Trabzon were not affected by the growing media, whereas the addition of OPC to the oak sawdust substrate had a noticeable effect on the phenolic content and antioxidant activity of the fruitbodies of HE-İzmit. According to the results, cotton seed hulls and olive pess cake can be recommended as alternative additive materials to wheat bran to increase the yield of *H. erinaceus*. Finally, the use of olive press cake as substrate incrases the phenolic content of *H. erinaceus* mushrooms.

1. Introduction

Mushrooms have been collected and consumed by people for centuries. They are a healthy food, low in calories, and high in degradable proteins, iron, zinc, chitin, fibre, vitamins and minerals (Manzi et al., 2001; Vetter, 2007; Reis et al., 2012). Beyond their nutritional characteristics, mushrooms have been reported to posses medicinal properties (Roncero-Ramos and Delgado-Andrade, 2017; Muszynska et al., 2018).

Hericium erinaceus is a species belonging to the class *Agaricomycetes*, the order *Russulales* and the family *Hericiaceae*. It is popularly known as lion's mane, monkey's head, hedgehog fungus, pom pom mushroom and yamabushitake. *H. erinaceus* is an edible mushroom with an excellent flavour and nutritional value (Imtiaj et al., 2008; Friedman, 2015). Moreover, the medicinal properties of *H. erinaceus* have been well known for hundreds of years in traditional Chinese and Japanese medicine (Wang et al., 2014). Also today, the extract of *H. erinaceus* is reported to exhibit antimicrobial, anticancer (Gue et al., 2006), antitumor (Park et al., 2002), and blood lipid-lowering (Keun et al., 2003) properties and is used in the prevention and treatment of some cancers such as those of the oesophagus, stomach, and skin (Mizuno, 1999). *H. erinaceus* is rarely recorded in Europe (Boddy et al., 2011). The *H. erinaceus* mushroom was first cultivated in the 1960s, and today it is widely produced in many countries as both an edible and a medicinal mushroom.

Turkey has a large edible mushroom potential and is becoming an important exporter of wild mushrooms. One of the mushroom species that grows in Turkey naturally is *H. erinaceus*. Wild samples of *H. erinaceus* have been collected in Sinop (Afyon et al., 2004), the Black Sea Region of Turkey (Afyon et al., 2005) and Istanbul (Akata, 2017), but

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Table 1
Macro and micro element content of different growing media used in the study.

Substrate	Ash (%)	C (%)	N (%)	C:N	P (g kg^{-1})	K (g kg^{-1})	Ca (g kg^{-1})	Mg (g kg^{-1})	Na (g kg^{-1})	Fe (mg kg^{-1})	Mn (mg kg^{-1})	Zn (mg kg^{-1})	Cu (mg kg^{-1})
OS:WB	6.4 ± 0.08^{**bc}	46.8 ± 0.04^{**bc}	0.68 ± 0.01$^{** b}$	68.8 ± 0.39$^{** c}$	0.21 ± 0.02$^{** c}$	0.32 ± 0.01$^{** a}$	2.6 ± 0.09$^{** c}$	0.11 ± 0.001$^{** b}$	0.02 ± 0.002$^{** c}$	119.4 ± 3.21$^{** e}$	53.5 ± 1.82$^{** c}$	78.8 ± 0.76$^{** a}$	8.9 ± 0.20$^{** d}$
9OS:1CSH	5.4 ± 0.12^{c}	47.3 ± 0.06^{ab}	0.57 ± 0.01^{c}	82.7 ± 0.82^{c}	0.29 ± 0.04^{b}	0.28 ± 0.01^{b}	3.1 ± 0.07^{b}	0.09 ± 0.012^{c}	0.02 ± 0.003^{c}	288.1 ± 7.38^{b}	53.5 ± 0.98^{c}	61.2 ± 0.67^{b}	8.7 ± 0.43^{d}
8OS:2CHS	6.2 ± 1.19^{bc}	46.9 ± 0.60^{abc}	0.60 ± 0.02^{c}	78.3 ± 2.81^{c}	0.30 ± 0.05^{b}	0.27 ± 0.03^{b}	3.4 ± 0.30^{b}	0.10 ± 0.001^{bc}	0.03 ± 0.001^{b}	284.9 ± 8.54^{b}	56.5 ± 0.45^{b}	58.0 ± 0.89^{c}	9.5 ± 0.32^{c}
7OS:3CHS	8.6 ± 0.12^{a}	45.7 ± 0.06^{d}	0.88 ± 0.04^{a}	51.7 ± 2.53^{d}	0.40 ± 0.02^{a}	0.27 ± 0.01^{b}	3.9 ± 0.06^{a}	0.13 ± 0.008^{a}	0.04 ± 0.004^{a}	330.4 ± 3.91^{a}	63.1 ± 0.42^{a}	61.1 ± 2.49^{b}	11.8 ± 0.81^{ab}
9OS:1OPC	5.8 ± 0.15^{bc}	47.1 ± 0.07^{abc}	0.26 ± 0.02^{e}	178.8 ± 15.73^{a}	0.11 ± 0.01^{d}	0.17 ± 0.01^{d}	1.9 ± 0.07^{d}	0.04 ± 0.001^{d}	0.01 ± 0.001^{d}	133.7 ± 2.43^{e}	48.3 ± 1.52^{d}	54.8 ± 0.11^{d}	10.5 ± 0.84^{b}
8OS:2OPC	5.3 ± 0.12^{c}	47.3 ± 0.06^{a}	0.32 ± 0.01^{d}	147.1 ± 2.56^{b}	0.13 ± 0.02^{e}	0.22 ± 0.02^{c}	1.9 ± 0.08^{d}	0.04 ± 0.001^{d}	0.01 ± 0.001^{d}	151.4 ± 4.78^{d}	43.9 ± 1.82^{e}	51.6 ± 0.74^{e}	11.5 ± 0.74^{ab}
7OS:3OPC	6.5 ± 0.51^{b}	46.8 ± 0.25^{c}	0.33 ± 0.02^{d}	146.8 ± 10.57^{b}	0.14 ± 0.02^{e}	0.26 ± 0.03^{b}	1.8 ± 0.17^{d}	0.04 ± 0.002^{d}	0.01 ± 0.004^{d}	178.8 ± 5.02^{c}	35.4 ± 0.40^{f}	57.2 ± 3.40^{cd}	12.2 ± 0.79^{a}

n.s. – no significant; * – significant at $P < 0.05$; ** – significant at $P < 0.01$; *** – significant at $P < 0.001$.Mean values in the same column followed by the same letters are not significantly different by Tukey's tests.

no information is available on their nutritional content and antioxidant properties.

For their part, olive press cake and cotton seed hulls are common by-products in the Mediterranean Basin, the latter a fibrous product primarily used to feed ruminants (Hall and Akinyode, 2000). However, olive press cake has limited use because of its low digestibility and energy content (Al-Masri and Guenther, 1999) and high content of phenolic compounds (Suárez et al., 2010). *H. erinaceus* has been reported to be easily grown on different types of lignocellulosic waste, such as beech and ash tree sawdust, wheat bran (Ehlers and Schnitzler, 2000), soybean flour (Siwulski and Sobieralski, 2005), rice bran, barley bran, soybean powder, egg shell, chinese cabbage (Ko et al., 2005), and sunflower hulls (Figlas et al., 2007). In previous studies with different fungal species, the growing medium was seen to influence the functional, organoleptic, and chemical properties of mushrooms such as *Pleurotus ostreatus* and *Hericium americanum* (Oyetayo and Ariyo, 2013; Yildiz et al.,1998; Atila et al., 2017).

Although some authors have demonstrated the presence of some macro- and microelements in *H. erinaceus* (Heleno et al., 2015), there has been no report about the effect of different growing media on the macro- and micro element content. Furthermore, many polysaccarides were isolated and identified by Mori et al. (2010) and Kim et al. (2011) from the fruitbody or mycelium of *H. erinaceus*. However, little is known about the antioxidant properties and total phenolic content (Wong et al., 2009; Han et al., 2013; Heleno et al., 2015; Koutrotsios et al., 2016).

For the above reasons, the objectives of this work were: (1) to determine suitable additive materials for the cultivation of *H. erinaceus* isolates; (2) to compare the proximate composition of isolates of *H. erinaceus* grown on different media; (3) to discover the relationship between the nutritional composition and their nutrient source; (4) to investigate the influence of the growing media composition on the total phenolic content and antioxidant activity of four isolates of *H. erinaceus*.

2. Materials and methods

2.1. Materials

H. erinaceus isolates collected from different areas of Turkey (Ankara, Denizli, Trabzon, İzmit) for a breeding project by a mushroom spawn company (Agroma Co. Ltd., Denizli, Turkey). Pure cultures of *H. erinaceus* isolates were supplied by the above-mentioned company and maintained on a malt extract agar (MEA) at 4 °C.

Wheat bran (WB) cottonseed hulls (CSH), and forest industry waste (oak sawdust, OS) were obtained from local markets in Izmir (Turkey). Olive press cake (OPC) was supplied by a pomace oil factory (Helvacikoy, Izmir, Turkey).

2.2. Growing media preparation

Oak sawdust was used as a base substrate, and cottonseed hulls and olive press cake were added in the ratios of 9:1, 8:2 and 7:3 to prepare the growing media. A control medium was prepared using OS (at the rate of 80%) and WB (at the rate of 20%) on a dry weight basis of the substrates (Table 2). The respective growing media were soaked with distilled water overnight, and the excess water was drained to reach a substrate moisture level of about 70%. Then, 1 kg (wet weight) of each growing medium was packed into a polypropylene autoclavable bag and autoclaved at 121 °C for 90 min.

2.3. Mushroom cultivation

After sterilization, the growing media were inoculated with 3% grain spawn (on a wet weight basis) and incubated at 25 ± 2 °C with 80% relative humidity in the presence of light for mycelial colonization. After full colonisation, the bags were transferred to a cropping room at