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ORIGINAL ARTICLE

Total phenolics, antioxidant activities and fatty acid profiles of six *Morchella* species

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Abstract In present study, total phenolic compound, antioxidant activities and fatty acids of several *Morchella* species collected from different regions of Turkey were determined. Six species were detected, namely *Morchella dunalii* (HT562), *M. purpurascens* group (HT565, HT592, HT662, HT699), *M. deliciosa* (HT682), *M. mediterraneensis* (HT698), *M. importuna* (HT667, HT681) and *M. esculenta* (HT704). The highest phenolic content was determined in the collection numbered as HT565 (281.96 mg gallic acid equivalent (GAE)/g dry weight), followed by HT699, HT562, HT662, HT592, HT698, HT704, HT681, HT667 and HT682. Antioxidant activities were also evaluated by DPPH and FRAP assays and the maximum (0.51 and 1.04 mmol trolox equivalent (TE)/g dry weight respectively) was observed in HT565. The results for the fatty acids composition showed that assessed *Morchella* species were rich in nutritionally important unsaturated fatty acids and oleic acid, palmitoleic acid, linoleic acid, α-linolenic acid, palmitic acid, stearic acid and myristic acid were the identified compounds. Linoleic acid was the most common in samples like HT565, HT592, HT704, HT662, HT682 and HT667 and followed by oleic acid except in HT565. In HT681, HT698, HT699 and HT562, oleic acid was dominant and followed by linoleic acid. The ratios of unsaturated fatty acids to saturated fatty acids were calculated as 10.79, 4.78, 6.80, 8.09, 6.67, 4.35, 8.70, 8.64, 7.90 and 7.43 in HT562, HT565, HT592, HT662, HT667, HT681, HT682, HT698, HT699 and HT704 respectively. The sampling locations and species of Morels had influenced the bioactivities and fatty acid compositions of specimens.

Keywords *Morchella* · Morels · Polyphenols · Antioxidant activity · Fatty acids

Introduction

Edible mushrooms are considered to be an important food source because they contain high amounts of proteins, minerals, vitamins and also low amount of lipids. In addition, it is known that mushrooms have been used in the traditional-alternative medicine and pharmacy sectors in some part of world for centuries because of their medical components (Tietel and Masaphy 2018). While some of the edible mushrooms can be cultured, for others this has not been achieved yet. In terms of mushrooms consumed by collecting from nature, some countries including Turkey have a great potential. It is known that some mushroom genera and species, especially *Morchella* spp., some species of *Tricholoma* spp., *Tuber* spp. and *Boletus* spp. are collected from nature, consumed and exported among countries. The genus *Morchella* (morels) is one of the most popular mushroom genera both economically and scientifically for many years. It attracts great attention due to its magnificent taste. Therefore, there are many studies related to its components. In these studies, the medical importance has also been investigated together with its nutritional value and aromatic structure (Tietel and Masaphy 2017; Xiong et al. 2017).

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Oxidation is important for many living organisms to produce energy. However, reactive oxygen species produced as a result of oxidation, may cause several chronic diseases, such as cancer, diabetes, cirrhosis, rheumatism and arteriosclerosis (Halliwell and Gutteridge 1984). Consuming foods containing antioxidants may help the human body to reduce oxidative damage (Elmastas et al. 2007). In addition to the well-known antioxidants such as vitamins and β-carotene, it is known that phenolic compounds contribute to the protective effect and act as antibacterial, anti-inflammatory, anti-allergic, hepatoprotective, anti-thrombotic, anti-viral and anti-carcinogenic (Soobrattee et al. 2005). In this way, the use of fungal extracts as antioxidant is increasing and becoming popular (Elmastas et al. 2007). Many studies have been carried out on antioxidant activity of some edible mushrooms both in Turkey and other countries of the world (Türkoğlu et al. 2007; Gursoy et al. 2009). Further on, many studies exist on antioxidant activity of species of morels (Türkoğlu et al. 2006; Gursoy et al. 2009; Ozturk et al. 2010; Vieira et al. 2016).

Fatty acids have some important roles in metabolism as a metabolic fuel such as major metabolic storage and transport of energy. Palmitic acid (saturated, in plants, animals and microorganisms), stearic acid (saturated, in most plants (minor), animals and some fungi), myristic acid (saturated), oleic acid (monoenoic, in plants, animals, microorganisms), palmitoleic acid (monoenoic, in animals, plants and microorganisms), linoleic acid (major in plant lipids), arachidonic acid (in animal), a-pinolenic acid (in higher plants and algae), eicosapentaenoic acid and docosahexaenoic acid (in marine algae, fatty fish and fish oils) are known as common fatty acids (Rustan and Drevon 2005). Mushroom consumption is important for healthy diet due to their low lipid content. Also the fact that they contain unsaturated fatty acids, especially high content of linoleic acid, makes the fungi even healthier (Taşkın and Büyükalaca 2017). While studies on determination of fatty acids content of different mushroom species have been carried out by different researchers (Ergönül et al. 2013; Goyal et al. 2015; Woldegiorgis et al. 2016; Çayan et al. 2017; Türkekul et al. 2017; Dimitrijevic et al. 2018), few studies exist on *Morchella* species (Vieira et al. 2016; Türkekul et al. 2017; Akyuz et al. 2019).

The target points of this research are to determine bioactivity levels and fatty acid compositions of some morel species. The originality of this work comes from the validation of the species by using the molecular analyses based on DNA sequences. Generally, in *Morchella* genus, morphotaxonomic identification is not sufficient and may be sometimes misleading, except some well-known species, for the phenotype of the fungus may be affected by environmental factors.

Materials and methods

Material

Samples of different species of *Morchella*, collected from different regions of Turkey, were used in this study (Table 1). They were dried at 40 °C in food dehydrator (Kangye, KYS 329) until moisture levels were below 10%. Samples (Voucher numbers HT562, HT565, HT592, HT662, HT667, HT681, HT682, HT698, HT699 and HT704) were kept at Department of Horticulture, Cukurova University (Adana, Turkey).

Molecular analyses

Genomic DNA was isolated from dried samples using Eurx GeneMatrix DNA isolation kit and CTAB buffer with slight modifications (Doğan et al. 2018). PCR amplification was performed by using ITS5 and ITS4 primers for Internal Transcribed Spacer (ITS) rDNA gene region (White et al. 1990). PCR conditions were set as follows: 94 °C for 5 min, followed by 30 cycles 30 s at 94 °C, 45 s at 52 °C, 60 s at 72 °C and final extension 5 min at 72 °C. ITS rDNA region amplified in PCR was verified by electrophoresis on 1.5% agarose gel. DNA sequence analyses of successful amplifications were made by using BigDye Terminator v3.1 Sequencing Kit, using again ITS5-ITS4 primers. ABI 3730XL Sanger sequencer (Applied Biosystems, Foster City, CA, US) was used for running of sequencing reactions. Raw sequence chromatograms were edited and aligned using Sequencher version 5.4.5 (Gene Codes, Ann Arbor, MI, USA).

Extraction of bioactive compounds

One gram of dried *Morchella* specimen was diluted with 40 ml of 80% methanol solution and then the mixture was vortexed for 10 s. The sample was put into an ultrasonic water bath (J.P. Selecta Ultrasons HD, Barcelona) running at room temperature (25 °C) for 20 min. The mixture was then centrifuged (Hettich Zentrifugen, Germany) at 3500 rpm for 15 min. The supernatant was collected and stored at 4 °C until spectrophotometric analyses which were conducted in two days (Bennett et al. 2011). All analyses were performed in triplicate.

Analysis of total polyphenol

The amounts of total phenolic were determined according to Li et al. (2015) with some modifications: 0.5 ml of each extract was mixed with 0.5 ml Folin-Ciocalteu reagent and the obtained solution was reacted with 3 ml of 10%

Table 1 Identification of the collections

CN	Species	Location	Ecology
HT562	*Morchella dunalii*	Çanakkale	*Pinus brutia*
HT565	*Morchella purpurascens* group	Çanakkale	*Pinus brutia*
HT592	*Morchella purpurascens* group	Çanakkale	*Pinus brutia*
HT662	*Morchella purpurascens* group	İzmir	*Pinus pinea*
HT667	*Morchella importuna*	Adana	*Pinus brutia*, *Arbutus* spp.
HT681	*Morchella importuna*	Balıkesir	Vegetable garden
HT682	*Morchella deliciosa*	Isparta	*Juniperus* spp., *Abies* spp.
HT698	*Morchella mediterraneensis*	Adana	*Pinus brutia*, *Pinus nigra*, *Abies* spp.
HT699	*Morchella purpurascens* group	Edirne	–
HT704	*Morchella esculenta*	Osmaniye	*Pinus brutia*, *Quercus* spp.

CN Collection number

Na_2CO_3. The volume was brought to 50 ml with distilled water. The absorbances were read at 760 nm by using a spectrophotometer (Shimadzu, UV 1800, Japan) after keeping the samples in dark for 30 min and the results were expressed as mg gallic acid equivalent (GAE) per gram of dry matter.

Quantification of antioxidant activity by DPPH method

The antioxidant activity of the extracts was evaluated by 2,2-diphenyl-1-picrylhydrazyl (DPPH) assay (Aghraz et al. 2018) which was an indicator of hydrogen donating ability. For this, 0.1 ml sample was added to 2 ml of DPPH solution (0.025 g/L) and the mixture was incubated in dark place for half an hour. The absorbances were recorded at 519 nm and the findings were indicated as mmol 6-hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid (trolox) equivalent (TE) per gram of dried *Morchella*.

Quantification of antioxidant activity by FRAP method

The ferric reducing antioxidant power (FRAP) of samples was evaluated by the procedure described by Benzie and Strain (1996). Firstly, the FRAP reagent, which contained one volume of 10 mM 2,4,6-tris(2-pyridyl)-*s*-triazine (TPTZ) in 40 mM HCl, one volume of 20 mM $FeCl_3$ and ten volumes of 0.1 M acetate buffer (pH = 3.6), was prepared. Then, 0.3 ml aliquot and 2 ml FRAP reagent were transferred into a plastic tube and the volume was brought to 10 ml with distilled water. The solution was left at 25 °C for 10 min. The absorbances were measured at 593 nm against a special blank that included one volume of FRAP reagent and four volumes of distilled water. The results were expressed in common with DPPH method.

Extraction of fatty acids and determination

Dried mushrooms (10 g) were extracted in 100 mL petroleum benzene for 2 h in Soxhlet apparatus (AOAC 1990). Fatty acid analysis was done using a GC (Gas Chromatography)/FID (Flame Ionization Detector) (Agilent, 7820A) equipped with a SGE column (100 m × 0.32 mm, ID 0.25 μm). As for the GC condition, the oven temperature was held at 140 °C for 5 min, and then increased to 200 °C at a rate of 4 °C min^{-1} and to 220 °C at a rate of 1 °C min^{-1}. FAME mix standard including 37 components was used for fatty acids identification and quantification.

Statistical evaluation

Spectrophotometric findings were assessed using an analysis of variance (ANOVA, one way) technique. Duncan test at a confidence interval of 95% was applied to the data and SPSS program version 18.0 was used for this purpose. Also, Pearson's correlation analysis was performed in order to observe relationship between total phenolic and antioxidant activities at both $p < 0.05$ and $p < 0.01$.

Results and discussion

Molecular characterization

In this study, six species were diagnosed morphologically by using the current literature (Kuo et al. 2012; Richard et al. 2015; Loizides et al. 2016; Taşkın et al. 2016) and molecularly based on ITS gene region; these are *M. deliciosa*, *M. dunalii*, *M. esculenta*, *M. importuna*, *M. mediterraneensis*, and a member of *M. purpurascens* group. The ITS primers designed by White et al. (1990) has allowed identification of many ITS sequences belonging to different fungal species. The ITS gene region has been widely used in studies among species within a genus or

among intraspecific populations (Kılıçoğlu and Özkoç 2008). *M. esculenta* is the member of the/Esculenta (yellow morels) clade; the remaining species reside in the/Elata (black morels) clade. These species have showed similarity at the rate of 99% with sequences submitted to GenBank database by different researchers. GenBank is a well-known platform which is available online in order to test sequenced data. Our collections in the *M. purpurascens* group seem to be close to *M. purpurascens*, *M. larentiana* and *M. eosphera*. For accurate identification in related group, multilocus analyses such as LSU rDNA (28 rDNA), *RPB1*, *RPB2* and translastion elongation factor 1-α (*EF1-α*) gene regions and morphotaxonomic investigation are necessary. Although some researchers have provided information to facilitate the morphological and microscopic diagnosis of *Morchella* species, molecular verification has been performed with a single gene region due to the reflection of changing environment and climatic conditions on the fruitbody morphology, which itself may lead to misleading identification.

Total polyphenol and antioxidant activities

Figure 1 demonstrates the total phenolic content of the studied morels. The minimum and maximum levels were observed in HT682 (*M. deliciosa*) and HT565 (*M. purpurascens* group) collected from Isparta and Çanakkale locations of Turkey respectively having different forest types. The levels of phenolic compounds were in range of 135.80 and 281.96 mg GAE/g dry weight. There were no statistically significant differences ($p > 0.05$) between *M. importuna* (HT667) and *M. deliciosa* (HT682). *M. dunalii* (HT562; 223.76 mg GAE/g dry weight) and *M. purpurascens* group (HT699; 227.37 mg GAE/g dry weight) obtained from locations in Çanakkale and Edirne regions had approximately same amounts of bioactive compounds ($p > 0.05$).

The antioxidant powers of species by both DPPH and FRAP methods are shown in Fig. 2 and it could be inferred from the related figure that FRAP values were always higher compared to DPPH. The results of DPPH technique were below 50% of ferric reducing potential in all samples, which implies that the nature and profile of antioxidant molecules are not the same, because some antioxidative substances can donate hydrogen, however the others have reduction capacity. Further on, there was generally the same variation in the findings of total polyphenol and antioxidant activities. In fact, the highest antioxidant behaviour (0.51 and 1.04 mmol TE/g dry weight by DPPH and FRAP, respectively) was belonged to HT565 (*M. purpurascens* group) collected from Çanakkale location of Turkey. This is due to the contributions of antioxidant character to phenolic compounds. Thus, Table 2 depicts the linear correlation results of total phenolic, DPPH and FRAP data and findings are currently in line with related claim. There are strong and positive relationships between all tested aspects ($p < 0.01$). On the contrary, HT682 (*M. deliciosa*) (0.27 mmol TE/g dry weight for DPPH and 0.61 mmol TE/g dry weight for FRAP assays) and HT704 (*M. esculenta*) (0.28 mmol TE/g dry weight for DPPH and 0.57 mmol TE/g dry weight for FRAP assays) had the weakest antioxidant potential.

M. esculenta is one of the most popular morel species investigated in terms of its bioactivity. A very recent study carried out by Akyuz et al. (2019) revealed that *M. esculenta* has higher polyphenols than several mushroom species, e.g. *Pleurotus ostreatus, Pleurotus sajor-caju*, *Pleurotus eryngii, Pleurotus floridanus, Agaricus bisporus* and *Terfezia boudieri*. In this study, *M. esculenta* (HT704) had 159.41 mg GAE/g dry weight phenolic concentration and 0.57 mmol TE/g dry weight antioxidant activity (FRAP), which was higher than the report of Yıldız et al. (2015) (25.01 mg GAE/g dry weight; 216.25 µmol TE/g dry weight) and ranked at the end of the list. Gursoy et al.

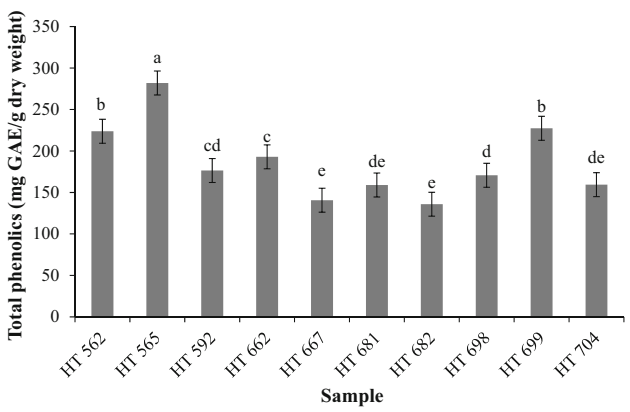


Fig. 1 Amounts of total phenolics in dried *Morchella* samples

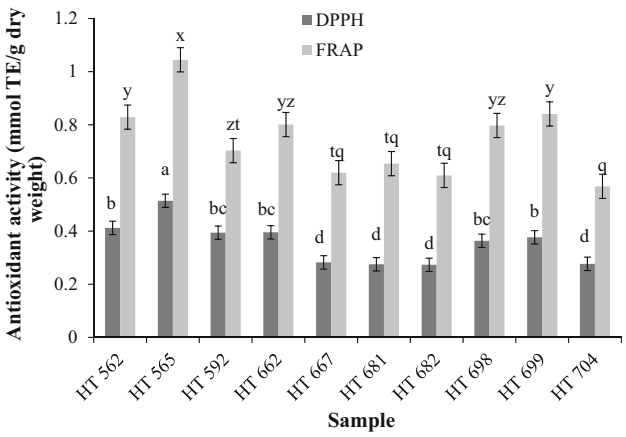


Fig. 2 Antioxidant activities of mushrooms by different assays

Table 2 The results of Pearson's correlation

	Total polyphenol	DPPH	FRAP
Total polyphenol	1	0.90**	0.92**
DPPH		1	0.93**
FRAP			1

**Correlation is significant at the 0.01 level (2-tailed)

(2009) investigated the total phenolic and antioxidant activities of seven *Morchella* species such as *M. rotunda, M. crassipes, M. esculenta, M. deliciosa, M. elata, M. conica* and *M. angusticeps* which were collected from Muğla province. They reported that *M. esculenta* contained the maximal amount of bioactive compounds after *M. conica*. Also, DPPH results showed that the antioxidant potential of *M. conica* was followed by *M. crassipes* and *M. esculenta*. The DPPH radical scavenging activity of our *M. esculenta* was found to be 0.28 mmol TE/g dry weight and as such in total phenolic, it is placed between *M. importuna* (HT667) and *M. mediterraneensis* (HT698).

Differences in sampling locations may affect polyphenol levels and antioxidative properties. Vieira et al. (2016) assessed bioactivity of wild *M. conica* from Portugal and Serbia and declared that Portuguese mushrooms were more active with respect to Folin–Ciocalteu, ferricyanide/prussian blue and DPPH assays. Similarly, *M. purpurascens* group from İzmir (HT662) and *M. importuna* from Adana (HT667) gave lower results than samples collected from Çanakkale (HT565) and Balıkesir (HT681), respectively. Lalotra et al. (2018) collected *M. deliciosa* from Jamnu and Kasmir regions of India and emphasized the phenols concentration as 11,500 mg GAE/kg dry weight which was excessively greater than *M. deliciosa* supplied from Isparta (HT682). However, species identification in morels, not supported by molecular techniques based on DNA sequencing will always be questionable in the species-based comparisons. For example, new systematic information on morels suggests that the former *M. elata* may be *M. importuna*. Similarly, we do not still know the real name of the old *M. conica*. On the other hand, there could be variations in the levels of phenolic compounds among several *Morchella* species. For instance, Ozturk et al. (2010) determined the phenolic content of *M. conica* as 20.64 mg GAE/g dry weight (in ethanolic extract) and this value was notably below *M. dunali*, *M. purpurascens, M. importuna, M. deliciosa, M. mediterraneensis* and *M. esculenta* which were analysed in our research. In this case however, the solvents used were not the same.

Fatty acid profiles

Fatty acid compositions of different morel species are presented in Table 3. As shown in the same table, linoleic acid was found to be the most abundant fatty acid in the collection numbered HT565 (*M. purpurascens* group) (69.61), HT592 (*M. purpurascens* group) (69.17), HT704 (*M. esculenta*) (67.57), HT662 (*M. purpurascens* group) (58.18), HT682 (*M. deliciosa*) (52.09) and HT667 (*M. importuna*) (50.82) and it was followed by oleic acid except HT565. For the rest collection numbered HT681 (*M. importuna*) (64.54), HT698 (*M. mediterraneensis*) (63.29), HT699 (*M. purpurascens* group) (63.14) and HT562 (*M. dunalii*) (56.17), oleic acid was dominant and followed by linoleic acid in the same collections. The ratio of unsaturated fatty acids (UFAs) to saturated fatty acids (SFAs) was calculated as 10.79 in the collection numbered HT562, 4.78 in HT565, 6.80 in HT592, 8.09 in HT662, 6.67 in HT667, 4.35 in HT681, 8.70 in HT682, 8.64 in HT698, 7.90 in HT699 and 7.43 in HT704. The UFAs/SFAs ratio should be higher than 1.6 (WHO 2003) and the related value of all samples were above the recommendation. Kostić et al. (2017) calculated the UFAs/SFAs ratio between 0.80 and 3.70 and Oroian et al. (2020) observed as 0.712 in pollens.

When regarding previous studies, very few reports have been found on the fatty acids profile in *Morchella* genus. Vieira et al. (2016) determined four fatty acids in *M. conica* collected from Portugal and Serbia comparatively. *M. esculenta* collected from Turkey were studied by Akyuz et al. (2019). In a study carried out by Türkekul et al. (2017), the fatty acid compositions of *M. elata* collected from Turkey was investigated together with *Lactarius volemus*, *Cantharellus cibarius* and *Tricholoma terreum* in dried mushroom samples. In these three studies, identification of species was performed only by morphotaxonomic methods. The results of these three researches were compared with ours in Table 4. While the results are consistent, only linoleic acid value detected by Türkekul et al. (2017) in *M. elata* appears to be lower than other ones.

Considering researches performed on the fatty acid compositions of different mushroom species, Ergönül et al. (2013) determined fatty acid profiles of six edible mushrooms; *Boletus reticulatus* (BR), *Flammulina velutipes* var. *velutipes* (FV), *Lactarius salmonicolor* (LS), *P. ostreatus* (PO), *Polyporus squamosus* (PS), and *Russula anthracina* (RA) in dried specimens. C18:2 *trans*-linoleic acid (0.09%), C18:3 linolenic acid (0.27%) and C16:0 palmitic acid (17.21%) were found to be higher in *P. squamosus* (C18:2 *trans*-linoleic acid in PO:0.06%, LS:0.03%, FV:0.05%, RA:0.03%, BR:0.02%; C18:3 linoleic acid in PO:0.03%, FV:0.01%, RA:0.01%; C16:0 palmitic acid in PO:12.40%, LS:7.76%, FV:14.56%, RA:9.16%,

Table 3 Fatty acid compositions of *Morchella* species (%, in dry weight)

Fatty acid	HT562	HT565	HT592	HT662	HT667	HT681	HT682	HT698	HT699	HT704
Oleic acid	56.17 ± 0.56	10.30 ± 0.10	16.69 ± 0.17	29.34 ± 0.29	34.57 ± 0.35	64.54 ± 0.65	36.15 ± 0.36	63.29 ± 0.63	63.14 ± 0.63	19.13 ± 0.19
Palmitoleic acid	0.77 ± 0.02	1.44 ± 0.03	0.45 ± 0.05	0.53 ± 0.01	0.59 ± 0.03	1.16 ± 0.01	0.56 ± 0.05	0.79 ± 0.09	0.77 ± 0.04	0.57 ± 0.01
Linoleic acid	33.37 ± 0.33	69.61 ± 0.70	69.17 ± 0.69	58.18 ± 0.58	50.82 ± 0.51	14.70 ± 0.15	52.09 ± 0.52	24.68 ± 0.25	23.98 ± 0.24	67.57 ± 0.68
α-Linolenic acid	0.30 ± 0.05	0.53 ± 0.01	ND	ND	0.14 ± 0.01	0.10 ± 0.01	ND	ND	ND	ND
Palmitic acid	6.68 ± 0.07	12.86 ± 0.13	10.01 ± 0.10	8.31 ± 0.08	9.68 ± 0.1	12.83 ± 0.13	7.83 ± 0.08	7.56 ± 0.08	7.41 ± 0.07	9.48 ± 0.09
Stearic acid	0.93 ± 0.01	2.22 ± 0.02	2.63 ± 0.03	2.59 ± 0.03	2.90 ± 0.03	4.78 ± 0.05	2.23 ± 0.02	2.68 ± 0.03	3.54 ± 0.04	2.14 ± 0.02
Myristic acid	0.79 ± 0.01	2.06 ± 0.02	0.05 ± 0.01	0.06 ± 0.01	0.33 ± 0.02	0.89 ± 0.01	0.15 ± 0.01	0.03 ± 0.01	0.18 ± 0.02	0.12 ± 0.01
Total MUFAs	56.94 ± 0.57	11.74 ± 0.12	17.14 ± 0.17	29.87 ± 0.30	35.16 ± 0.35	65.70 ± 0.66	36.71 ± 0.37	64.08 ± 0.64	63.91 ± 0.64	19.70 ± 0.20
Total PUFAs	33.67 ± 0.34	70.14 ± 0.70	69.17 ± 0.69	58.18 ± 0.58	50.96 ± 0.51	14.80 ± 0.15	52.09 ± 0.52	24.68 ± 0.25	23.98 ± 0.24	67.57 ± 0.68
Total SFAs	8.40 ± 0.08	17.14 ± 0.17	12.69 ± 0.13	10.96 ± 0.11	12.91 ± 0.13	18.50 ± 0.19	10.21 ± 0.1	10.27 ± 0.10	11.13 ± 0.11	11.74 ± 0.12

ND Not determined, *MUFAs* monounsaturated fatty acids, *PUFAs* polyunsaturated fatty acids, *SFAs* saturated fatty acids

Table 4 Comparison of fatty acid contents with other studies carried out *Morchella* genus (%, in dry weight)

Fatty acid	This study	Vieira et al. (Serbia)	Vieira et al. (Portugal)	Türkekul et al. (Turkey)	Akyüz et al. (Turkey)
Oleic acid	10.30–64.54	21.00	19.00	77.57	8.31
Palmitoleic acid	0.45–1.44	ND	ND	ND	3.49
Linoleic acid	14.70–69.61	63.00	67.00	7.24	71.41
α-Linolenic acid	0.00–0.53	ND	ND	ND	0.45
Palmitic acid	6.68–12.86	11.00	10.00	12.73	12.54
Stearic acid	0.93–4.78	2.40	1.50	ND	2.51
Myristic acid	0.03–2.06	ND	ND	ND	ND
Total MUFAs	11.74–65.70	22.00	20.00	77.83	ND
Total PUFAs	14.80–70.14	64.00	67.00	8.36	ND
Total SFAs	8.40–18.50	14.00	14.00	12.48	ND
UFAs/SFAs	4.35–10.79	6.14	6.21	6.90	ND

ND Not determined, *MUFAs* monounsaturated fatty acids, *PUFAs* polyunsaturated fatty acids, *SFAs* saturated fatty acids, *UFAs* unsaturated fatty acids

BR:11.26%). C18:1 *trans*-oleic acid (0.12%), C16:1 palmitoleic acid (0.75%) and C14:1 myristoleic acid (0.11%) were recorded as higher in *B. reticulatus* (C18:1 *trans*-oleic acid in PS:0.07%, PO:0.05%, LS:0.05%, FV:0.06%, RA:0.04%; C16:1 palmitoleic acid in PS:0.65%, PO:0.46%, LS:0.22%, FV:0.70%, RA:0.64%; C14:1 myristoleic acid in PS:0.06%, PO:0.03%, LS:0.03%, FV:0.04%, RA:0.01%) and C14:0 myristic acid (0.66%) and C18:2 *cis*-linoleic acid (65.29%) were dominant in *P. ostreatus* (C18:2 *cis*-linoleic acid in PS:38.91%, LS:59.44%, FV:40.87%, RA:22.39%, BR:36.60%; C14:0 myristic acid in PS:0.58%, LS:0.16%, FV:0.50%, RA:0.15%, BR:0.37%). *R. anthracina* was the first in the list of C18:1 *cis*-oleic acid (52.11%) and C18:0 stearic acid (12.96%) (C18:1 *cis*-oleic acid in PS:33.02%, PO:10.36%, LS:18.98%, FV:16.37%, BR:37.61%; C18:0 stearic acid in PS:3.28%, PO:3.71%, LS:7.27%, FV:3.56%, BR:5.84). SFA, MUFA (monounsaturated fatty acids) and PUFA (polyunsaturated fatty acids) were found to be higher in *P. squamosus* (25.19%), *R. anthracina* (53.30%) and *P. ostreatus* (66.48%), respectively. Fatty acid composition of eleven species within Boletaceae and Russulaceae families was determined by Dimitrijevic et al. (2018) using gas chromatography (GC) and gas chromatography–mass spectrometry (GC–MS). Twenty-six fatty acids were determined. *Cis*-linoleic (19.5–72%), *cis*-oleic (0.11–64%), palmitic (5.9–22%) and stearic acids (0.81–57%) were identified as major among twenty-six fatty acids detected. Woldegiorgis et al. (2016) investigated fatty acid composition of six wild mushroom species (*Agaricus campestris*, *Laetiporus sulphureus*, *Termitomyces clypeatus*, *T. microcarpus*, *T. letestui* and *Termitomyces* sp.) collected from Ethiopia and three cultivated (*P. ostreatus*, *Lentinula edodes*, *A. bisporus*) edible mushroom species by gas chromatography with flame ionization detection. The dominant fatty acids were linoleic acid (C18:2) (1044.5–2759.4 mg/100 g), oleic acid (C18:1n9c) (43.8–1558.8 mg/100 g), palmitic acid (C16:0) (189.9–1081.5 mg/100 g) and stearic acid (C18:0) (13.5–374.1 mg/100 g) on dry basis respectively. The amount of unsaturated fatty acids were detected higher than saturated ones. In a comparative study carried out by Çayan et al. (2017), the fatty acid profiles of *Armillaria tabescens*, *Leucopaxillus gentianeus*, *P. eryngii* and *Suillus granulatus* collected from Turkey were figured out using GC-FID and GC-M and fifteen fatty acids were detected. The most abundant fatty acid was linoleic acid in *L. gentianeus*, *P. eryngii*, and *S. granulatus* (40.92–68.24%). In *A. tabescens*, it was oleic acid (35.92%). Palmitic and stearic acids were also detected at higher concentrations. The percentages of total saturated, monounsaturated and polyunsaturated fatty acids recorded as 16.71–31.90%, 12.04–40.41%, 27.64–68.24%, respectively and quantity of unsaturated fatty acid was high. The ranges among different mushrooms species examined in these studies were almost similar with ours except stearic acid detected by Dimitrijevic et al. (2018). The ranges obtained from the studies carried out by Ergönül et al. (2013), Çayan et al. (2017) and Dimitrijevic et al. (2018) were 0.11–64%, 19.5–72%, 5.9–22%, 0.81–57%, 0.06–1.30% and 0.16%–4.49% for oleic, linoleic, palmitic, stearic, myristic and palmitoleic acids, respectively.

When the studies carried out on fatty acid profile of different mushroom species have been examined, it is clear that the contents of linoleic, oleic and palmitic acid are dominant. Similarly, in our study, these three fatty acids were dominant in different morel species. While linoleic acid and palmitic acid were observed in *M. purpurascens*

group (HT565) at high concentration, oleic acid was detected in *M. importuna* (HT681). Considering that linoleic and oleic acids are unsaturated fatty acids, it is important to have these two acids in the genus *Morchella* in terms of nutrition. Mushrooms have low fat content and therefore, they are a good diet product in terms of health. Besides, their high unsaturated fatty acid content has increased their value.

Conclusion

Indigenous morels supplied from various regions of Turkey which could be classified in functional foods group, are potential sources of bioactive compounds and fatty acids. *M. purpurascens* group from Çanakkale (HT565) appears superior in terms of polyphenols rather than same kind of samples collected from İzmir and Edirne. PUFAs are more dominant than MUFAs and SFAs in Turkish *Morchella*. It is clear that the data are variable with respect to species and even in same species; there is certain variance probably due to ecological reasons such as forest structure, soil, climate and elevation. The maturity of mushroom samples may also have an effect on findings. Further studies should be conducted in order to enlighten the contribution of fatty acids to the antioxidant behaviour and types of bioactive substances which can influence human health in a positive way.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no Conflict of interest.

References

Aghraz A, Gonçalves S, Rodríguez-Solana R, Dra LA, Di Stefano V, Dugo G, Cicero N, Larhsini M, Markouk M, Romano A (2018) Antioxidant activity and enzymes inhibitory properties of several extracts from two Moroccan Asteraceae species. S Afr J Bot 118:58–64

Akyuz M, Kireçci ADÖ, Gökçe Z, Kırbağ S, Yilmaz O (2019) Biochemical constituents and antioxidant activities of some mushrooms from Turkey: *Agaricus* spp., *Pleurotus* spp., *Morchella esculenta* and *Terfezia boudieri*. Istanbul J Pharm 49(1):1–6

Association of Official Analytical Chemists (AOAC) (1990) Official methods of analysis of the association of official analytical chemists, 15th edn. Association of Official Analytical Chemists, Washington, DC

Bennett LE, Jegasothy H, Konczak I, Frank D, Sudharmarajan S, Clingeleffer PR (2011) Total polyphenolics and anti-oxidant properties of selected dried fruits and relationships to drying conditions. J Funct Foods 3(2):115–124

Benzie IFF, Strain JJ (1996) The ferric reducing ability of plasma (FRAP) as a measure of "antioxidant power": the FRAP assay. Anal Biochem 239:70–76

Çayan F, Tel-Çayan G, Özler MA, Duru ME (2017) Comparative study of fatty acids profile of wild mushroom species from Turkey. Eurasian J Anal Chem 12(3):257–263

Dimitrijevic MV, Mitic VD, Jovanovic OP, Stankov Jovanovic VP, Nikolic JS, Petrovic GM, Stojanovic GS (2018) Comparative study of fatty acids profile in eleven wild mushrooms of Boletacea and Russulaceae families. Chem Biodivers 15(1):e1700434

Doğan HH, Bozok F, Taşkın H (2018) A new species of *Barssia* (Ascomycota, Helvellaceae) from Turkey. Turk J Bot 42(5):636–643

Elmastas M, Isildak O, Turkekul I, Temur N (2007) Determination of antioxidant activity and antioxidant compounds in wild edible mushrooms. J Food Compos Anal 20:337–345

Ergönül PG, Akata I, Kalyoncu F, Ergönül B (2013) Fatty acid compositions of six wild edible mushroom species. Sci World J. https://doi.org/10.1155/2013/163964

Goyal R, Grewal RB, Goyal RK (2015) Fatty acid composition and dietary fibre constituents of mushrooms of North India. Emirates J Food Agric 27(12):927–930

Gursoy N, Sarikurkcu C, Cengiz M, Solak MH (2009) Antioxidant activities, metal contents, total phenolics and flavonoids of seven *Morchella* species. Food Chem Toxicol 47(9):2381–2388

Halliwell B, Gutteridge JHMC (1984) Oxygen toxicity, oxygen radicals, transition metals and disease. J Biochem 219:1–14

Kılıçoğlu M, Özkoç İ (2008) Molecular developments in fungal systematic. J Fac Agric OMU 23(1):65–72 (**in Turkish**)

Kostić AŽ, Mačukanović-Jocić MP, Špirović Trifunović BD, Vukašinović IŽ, Pavlović VB, Pešić MB (2017) Fatty acids of maize pollen—quantification, nutritional and morphological evaluation. J Cereal Sci 77:180–185

Kuo M, Dewsbury DR, O'Donnell K, Carter MC, Rehner SA, Moore JD, Moncalvo JM, Canfield SA, Stephenson SL, Methven AS, Volk TJ (2012) Taxonomic revision of true morels (Morchella) in Canada and the United States. Mycologia 104(5):1159–1177

Lalotra P, Bala P, Kumar S, Sharma YP (2018) Biochemical characterization of some wild edible mushrooms from Jammu and Kashmir. Proc Natl Acad Sci India Sect B Biol Sci 88(2):539–545

Li Y, Ma D, Sun D, Wang C, Zhang J, Xie Y, Guo T (2015) Total phenolic, flavonoid content, and antioxidant activity of flour, noodles, and steamed bread made from different colored wheat grains by three milling methods. Crop J 3(4):328–334

Loizides M, Bellanger JM, Clowez P, Richard F, Moreau PA (2016) Combined phylogenetic and morphological studies of true morels (Pezizales, Ascomycota) in Cyprus reveal significant diversity, including *Morchella arbutiphila* and *M. disparilis* spp. nov. Mycol Prog 15(4):39

Oroian M, Ursachi F, Dranca F (2020) Ultrasound-assisted extraction of polyphenols from crude pollen. Antioxidants 9(4):322

Ozturk I, Sahan S, Sahin U, Ekici L (2010) Bioactivity and mineral contents of wild-grown edible *Morchella conica* in the Mediterranean Region. J Consum Prot Food Saf 5:453–457

Richard F, Bellanger JM, Clowez P, Hansen H, O'Donnell K, Urban A, Sauve M, Courtecuisse R, Moreau PA (2015) True morels (*Morchella*, Pezizales) of Europe and North America: evolutionary relationships inferred from multilocus data and a unified taxonomy. Mycologia 107(2):359–383

Rustan AC, Drevon CA (2005) Fatty acids: structures and properties. In: Encyclopedia of life sciences. Wiley: Chichester

Soobrattee MA, Neergheen VS, Luximon-Ramma A, Aruoma OI, Bahorun T (2005) Phenolics as potential antioxidant therapeutic agents: mechanism and actions. Mutat Res 579:200–213

Taşkın H, Büyükalaca S (2017) Minimally processed mushrooms. In: Yildiz F, Wiley R (eds) Minimally processed refrigerated fruits and vegetables. Food engineering series. Springer, Boston, MA. https://doi.org/10.1007/978-1-4939-7018-6_12

Taşkın H, Doğan HH, Büyükalaca S, Clowez P, Moreau PA, O'Donnell K (2016) Four new morel (Morchella) species in the Elata Subclade (sect. Distantes) from Turkey. Mycotaxon 131(2):467–482

Tietel Z, Masaphy Z (2017) Aroma-volatile profile of black morel (*Morchella importuna*) grown in Israel. J Sci Food Agric 98(1):346–353

Tietel Z, Masaphy S (2018) True morels (*Morchella*)-nutritional and phytochemical composition, health benefits and flavor: a review. Crit Rev Food Sci Nutr 58(11):1888–1901

Türkekul İ, Çetin F, Elmastaş M (2017) Fatty acid composition and antioxidant capacity of some medicinal mushrooms in Turkey. J Appl Biol Chem 60(1):35–40

Türkoğlu A, Kıvrak I, Mercan N, Duru ME, Gezer K, Türkoğlu H (2006) Antioxidant and antimicrobial activities of *Morchella conica* Pers. Afr J Biotechnol 5(11):1146–1150

Türkoğlu A, Duru ME, Mercan N, Kıvrak I, Gezer K (2007) Antioxidant and antimicrobial activities of *Laetiporus sulphureus* (Bull.) Murrill. Food Chem 101:267–273

Vieira V, Fernandes Â, Barros L, Glamočlija J, Ćirić A, Stojković D, Martins A, Soković M, Ferreira IC (2016) Wild *Morchella conica* Pers. from different origins: a comparative study of nutritional and bioactive properties. J Sci Food Agric 96:90–98

White TJ, Bruns T, Lee S, Taylor JW (1990) Amplification and direct sequencing of fungal ribosomal RNA genes for phylogenetics. In: Innis MA, Gelfand DH, Sninsky JJ, White TJ (eds) PCR protocols: a guide to methods and applications. Academic Press, New York, pp 315–322

WHO (2003) Diet, nutrition and the prevention of chronic diseases. World Health Organ Tech Rep Ser 916:1–149

Woldegiorgis AZ, Abate D, Haki GD, Ziegler GR, Harvatine KJ (2016) Fatty acid profile of wild and cultivated edible mushrooms collected from Ethiopia. J Nutr Food Sci 5(3):1–5

Xiong C, Luo Q, Huang WL, Li Q, Chen C, Chen ZQ, Yang ZR (2017) The potential neuritogenic activity of aqueous extracts from *Morchella importuna* in rat pheochromocytoma cells. Food Sci Biotechnol 26(6):1685–1692

Yıldız O, Can Z, Laghari AQ, Şahin H, Malkoç M (2015) Wild edible mushrooms as a natural source of phenolics and antioxidants. J Food Biochem 39(2):148–154

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