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REGULAR ARTICLE

A Comparative fatty acid compositional analysis of different wild species of mushrooms from Turkey

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ABSTRACT

Mushrooms have been recognized as important food items due to their high nutritional and medicinal value. The present work quantifies and compares the fatty acids composition among eleven mushroom species (*Auricularia auricular-judae*, *Collybia dryophila*, *Flammulina velutipes*, *Helvella lacunose*, *Polyporus squamosus*, *Rhizopogon roseolus*, *Russula albonigra*, *Russula delica*, *Sparassis crispa*, *Suillus collinitus and Volvariella gloiocephala*) harvested from Turkey. The lipid contents of the mushrooms varied from 0.13% (*Auricularia auricula-judae*) to 2.90% (*Sparassis crispa*). A total of 14 fatty acids were identified and quantified by gas chromatography in the selected mushrooms species with linoleic (13.17 to 79.41%), oleic (0.71 to 55.07%) and palmitic (8.95 to 30.84%) acids as the major components in the tested mushrooms species. The amount of total saturated fatty acids (SFAs), total monounsaturated FAs (MUFAs) and total polyunsaturated FAs (PUFAs) ranged from 13.97 to 59.44%, 0.94 to 55.44% and 13.54 to 79.93%, respectively. Moreover, the mushrooms tested can be explored as a rich dietary source of essential fatty acids (13.34-79.76%) for human nutrition.

Keywords: Essential fatty acids; Gas chromatography; Monounsaturated fatty acids; Mushroom lipids; Polyunsaturates; Wild mushrooms

INTRODUCTION

It is now evident by clinical and epidemiological studies that incidence of several of the civilization diseases such as diabetes, cardiovascular diseases, cancer, aging, obesity and inflammation is strongly linked with the dietary habits (Barros et al., 2008). As a dietary component, mushrooms have high nutritional and medicinal value (Heleno et al., 2012; Kalac et al., 2009). Out of the approximate 3,000 mushroom species which are regarded as edible, 100 species have potential for commercial uses but only 10 species have an industrial scale production. Nutritionally, mushrooms are rich in moisture, minerals, proteins, fibers, and vitamins as well as contain considerable levels of phenolic compounds and essential fatty acids. Interestingly, mushrooms are considered as a low caloric food due to their low fat content (Heleno et al., 2009; Ouzouni et al., 2009).

A number of medicinal benefits have been ascribed to consumption of mushrooms including the treatment of chronic and degenerative diseases, obesity and cardiovascular disorders (Kavishree et al., 2009; Ribeiro et al., 2008). Likewise, a wide spectrum of biological activities of mushroom species/taxa such as anti-tumor, anti-microbial and anti-oxidant has been investigated (Mau et al., 2002; Wasser and Weis, 1999; Barros et al., 2007; Lindequist et al., 2005).

Turkey is rich in the diversity of mushrooms as well as medicinal and aromatic plants. In a recent research, 2158 mushrooms were recorded in Turkey (Sesli and Denchev, 2008). Some mushrooms species are traditionally used to treat various ailments such as infectious diseases (Ozyurek et al., 2014; Akyuz et al., 2010). Some scientific studies are reported in the literature on the biological activities and phytochemicals profile of mushrooms grown in Turkey (Gursoy et al., 2009; Sarikurkcu et al., 2008; Gursoy et al., 2010). To the best of our knowledge rather few studies on the fatty acids composition of the mushroom species are found in the literature. In the present work, we planned

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to conduct a detailed study on the fatty acids profiles of locally harvested and commonly consumed eleven species of mushrooms namely *Auricularia auricular-judae, Collybia dryophila, Flammulina velutipes, Helvella lacunose, Polyporus squamosus, Rhizopogon roseolus, Russula albonigra, Russula delica, Sparassis crispa, Suillus collinitus, Volvariella gloicephala.*

MATERIALS AND METHODS

Sample of mushrooms

Mushrooms species were collected at full maturity from different regions of Turkey and were authenticated based on their microscopic and macroscopic characteristics by M. Halil Solak, Program of Fungi, Ula Ali Kocman at Vocational School, Mugla University, Mugla, Turkey. They were stored at Mugla University Ula Ali Kocman Vocational School Herbarium Laboratory. The details for the selected mushroom samples along with harvest regions are given in Table 1. The fruiting bodies of mushroom samples were cut into small parts and then hot air-dried in an oven for 48 h at 40°C before analysis.

Fatty acids analysis

Extraction of oils and fatty acid methyl esters (FAMEs) preparation

The oil extraction from powdered mushrooms samples (10 g) was carried out for 6 h using a Soxhlet extractor and petroleum ether (boiling point (65-68°C) as a solvent. After, extraction, the excess of the solvent was distilled off under reduced pressure using a rotary evaporator. The fatty acids in the oil were trans esterified into fatty acids methyl esters (FAMEs) by saponification with 0.5 N methanolic sodium hydroxide in the presence of 14% BF_3 –methanol solution (IUPAC, 1979).

High-resolution gas liquid chromatographic (HR-GLC) analysis

The GLC analysis of FAMEs was carried out on 6890 N model gas chromatograph equipped with an auto-sampler (7683) from Agilent using a HP-88 capillary column, 100 m × 0.25 mm i.d. x 0.2 μm. Helium was used as a carrier gas with a flow rate of 1 mL/min. The column temperature was adjusted at 60°C for 1 min and increased up to 190°C at the rate of 20°C/min, held for 60 min then increased again at the rate of 1°C/min to 220°C and held for 10 min at 220°C. The injection and FID temperatures were set at 250 and 280°C, respectively. The sample injection volume and split ratio were 1 μL and 40:1, respectively. FAMEs were identified by comparing their retention times with those of the pure FAMEs standards (Accu Standard Inc., New Haven, USA) and were quantified as percentages of the total fatty acids. Each reported result is given as the average value of three GLC analyses ± S.D.

Statistical analyses

The results are expressed as mean and standard deviation values (mean ± SD). Differences between means were determined by analysis of variance (ANOVA) with Tukey's honestly significant difference post hoc test with α=0.05, which were analysed with SPSS v. 14.0.

RESULTS AND DISCUSSION

Fatty acid composition including total saturated fatty acids (SFAs), monounsaturated fatty acids (MUFAs), polyunsaturated fatty acids (PUFAs), unsaturated fatty acids (UFAs), essential fatty acids (EFAs), ω-6 and ω-3 fatty acids of the studied mushrooms is presented in Table 2. A total of 14 fatty acids with carbon chain C12 to C18 were detected in mushrooms oils. Generally, linoleic (C 18:2 ω6), oleic (C 18:1 ω9) and palmitic acid (C 16:0) predominated in studied mushrooms. Stearic acid (C 18:0) was identified as a major fatty acid in one mushroom species (*R. albonigra*). Trans fatty acids were not detected in the studied mushrooms. The total fat content varied from 0.13% in *Auricularia auricula-judae* to 2.90% in *Sparassis crispa*. A similar variation for lipid contents and fatty acids distribution were observed for different mushroom species

Table 1: Class, harvest area, habitat and edibility of different mushroom species

Sample no	Species	Harvest area	Habitat	Edibility
1	*Auricularia auricula-judae* (Fr.) Quél.	Kaypak village, Osmaniye	On oaks	Edible
2	*Collybia dryophila* (Bull.) P. Kumm.	Palamutköy village, Fethiye-Muğla	*Pinus brutia* ve *Quercus* forests	Edible
3	*Flammulina velutipes* (Curtis) Singer	Kırkoluk village, Ödemiş- İzmir	Forest clearing	Edible
4	*Helvella lacunosa* Afz.: Fr.	Çamlıyayla village, Samandağ-Hatay	*Pinus brutia* forest	Inedible
5	*Polyporus squamosus* (Huds.) Fr.	Between Ula and Muğla	On fig trees	Edible
6	*Rhizopogon roseolus* (Corda) T: M: Fries.	Yaraş village, Muğla	Pinus forests	Edible
7	*Russula albonigra* (Krombh.) Fr.	Arpacık village, Fethiye- Muğla	Pinus forests	Edible
8	*Russula delica* Fr.	Çayköy village, Eğirdir-Isparta	Pinus forests	Edible
9	*Sparassis crispa* (Wulfen) Fr	Gölcük, Ödemiş-İzmir	Forest clearing	Edible
10	*Suillus collinitus* (Fr.) Kuntze	Aşağı gökdere village, Eğirdir-Isparta	Pinus forests	Edible
11	*Volvariella gloiocephala* (DC: Fr.) Boekhout & Enderle	Between Ula and Muğla	Meadows	Edible

Table 2: Fatty acid composition (%)[a] of different mushroom species

Fatty acids	Mushroom species										
	1	2	3	4	5	6	7	8	9	10	11
C 12:0	0.15±0.03c	0.26±0.01b	0.70±0.01a	0.03±0.01f	0.08±0.01de	0.02±0.01f	0.05±0.01ef	0.05±0.01ef	0.01±0.01f	0.10±0.01d	0.11±0.01cd
C 14:0	0.90±0.01b	0.16±0.01g	1.18±0.01a	0.08±0.02h	0.20±0.01f	0.07±0.01h	0.29±0.01d	0.28±0.01d	0.41±0.01c	0.23±0.01ef	0.24±0.01e
C 15:0	2.19±0.06c	1.17±0.01e	1.60±0.01d	0.01±0.01j	3.19±0.02a	0.65±0.01g	0.54±0.01h	0.42±0.01i	2.97±0.01b	0.96±0.01f	1.10±0.02e
C 16:0	24.38±0.02b	15.40±0.05e	30.84±0.06a	17.77±0.08c	11.08±0.05i	9.94±0.01j	12.50±0.01g	14.91±0.04f	8.95±0.01k	17.57±0.02d	12.15±0.02h
C 17:0	0.45±0.02a	0.27±0.03cd	0.22±0.03d	0.01±0.01f	0.30±0.01cd	0.08±0.01ef	0.22±0.01d	0.12±0.02e	0.40±0.01ab	0.23±0.04d	0.33±0.03bc
C 18:0	6.25±0.04e	1.89±0.01j	10.24±0.03c	3.11±0.04i	1.06±0.03k	3.22±0.01h	45.84±0.03a	30.65±0.01b	3.79±0.01f	8.17±0.01d	3.56±0.01g
ΣSFA[b]	34.31±0.15d	19.14±0.04g	44.78±0.12c	21.00±0.16f	15.89±0.10j	13.97±0.01k	59.44±0.05a	46.42±0.01b	16.53±0.04i	27.25±0.08e	17.48±0.06h
C 14:1ω5	0.15±0.04a	0.03±0.01c	0.02±0.01c	0.03±0.01c	0.01±0.01c	0.01±0.01c	0.14±0.04ab	0.05±0.01c	0.01±0.01c	0.04±0.01c	0.07±0.01bc
C 15:1ω5	0.11±0.01b	0.06±0.01bcd	0.09±0.04bc	0.01±0.01d	0.01±0.01d	0.01±0.01d	0.01±0.01d	0.02±0.01d	0.02±0.01d	0.05±0.02cd	0.20±0.01a
C 16:1ω7	0.80±0.12c	0.13±0.02fg	1.14±0.03b	2.34±0.01a	0.34±0.01d	0.14±0.01fg	0.24±0.01df	0.36±0.01d	0.27±0.01df	0.74±0.01c	0.07±0.01g
C 17:1ω8	0.05±0.02abc	0.03±0.01bc	0.01±0.01c	0.01±0.01c	0.07±0.01ab	0.04±0.01bc	0.03±0.01bc	0.02±0.01c	0.08±0.01a	0.05±0.02abc	0.07±0.01ab
C 18:1ω9	32.74±0.40e	0.71±0.09j	23.58±0.11f	39.40±0.02d	8.81±0.01i	46.68±0.04b	22.31±0.03g	39.61±0.04d	55.07±0.01a	42.37±0.05c	21.00±0.02h
ΣMUFA[b]	33.84±0.35f	0.94±0.05k	24.84±0.16g	41.78±0.04d	9.24±0.01j	46.88±0.05b	22.73±0.01h	40.05±0.07e	55.44±0.01a	43.23±0.01c	21.40±0.02i
C 18:2 ω6	27.40±0.10h	79.41±0.04a	22.12±0.04i	37.09±0.15e	74.60±0.11b	38.53±0.06d	17.30±0.02j	13.17±0.01k	27.78±0.01g	29.03±0.07f	60.56±0.01c
C 18:3 ω6	1.11±0.01a	0.18±0.06cde	0.26±0.01bcd	0.09±0.04de	0.04±0.01e	0.48±0.04b	0.38±0.13bc	0.20±0.06cde	0.17±0.06cde	0.43±0.01b	0.07±0.06de
C 18:3 ω3	3.35±0.10b	0.35±0.01d	8.01±0.01a	0.06±0.01f	0.24±0.01de	0.15±0.01ef	0.16±0.04ef	0.18±0.01ef	0.09±0.01f	0.06±0.01f	0.51±0.01c
ΣPUFA[b]	31.86±0.21f	79.93±0.01a	30.39±0.04g	37.23±0.12e	74.88±0.09b	39.16±0.04d	17.84±0.06j	13.54±0.06k	28.04±0.05i	29.52±0.10h	61.13±0.04c
ΣUFA[b]	65.70±0.15h	80.87±0.04e	55.23±0.12i	79.00±0.16f	84.11±0.10b	86.03±0.01a	40.57±0.05k	53.59±0.01j	83.48±0.04c	72.75±0.08g	82.53±0.06d
EFA[b]	30.75±0.20f	79.76±0.05a	30.13±0.06g	37.14±0.16e	74.84±0.11b	38.68±0.07d	17.46±0.06j	13.34±0.01k	27.87±0.01i	29.09±0.08h	61.06±0.01c
Σω3	3.35±0.10b	0.35±0.01d	8.01±0.01a	0.06±0.01f	0.24±0.01de	0.15±0.01ef	0.16±0.04ef	0.18±0.01ef	0.09±0.01f	0.06±0.01f	0.51±0.01c
Σω6	28.51±0.11g	79.58±0.03a	22.38±0.03i	37.17±0.11e	74.64±0.10b	39.01±0.02d	17.68±0.11j	13.36±0.07k	27.95±0.04h	29.46±0.08f	60.63±0.05c
Oil	0.13	0.83	0.69	0.95	1.26	2.23	1.15	1.05	2.90	2.20	1.75

[a]Values expressed are means±S.D. of three parallel measurements; in the same row, data marked different letters indicate significant difference ($p<0.05$). [b]SFA: Saturated fatty acids. MUFA: Monounsaturated fatty acids. PUFA: Polyunsaturated fatty acids.UFA: Unsaturated fatty acids. EFA: Essential fatty acids. *1. Auricularia auricula-judae , 2. Collybia dryophila ,3. Flammulina velutipes ,4. Helvella lacunosa , 5. Polyporus squamosus , 6. Rhizopogon roseolus , 7. Russula albonigra, 8. Russula delica , 9. Sparassis crispa, 10. Suillus collinitus , 11. Volvariella gloiocephala*

in the literature (Kavishree et al., 2008; Barros et al., 2007; Heleno et al., 2009).

The highest level of linoleic acid was detected in *C. dryophila* with 79.41% of total fatty acids followed by *P. squamosus* (74.60%), *V. gloicephala* (60.56%) and *R. roseolus* (38.53%). These presence of high contents of linoleic acid in mushroom is reported earlier (Heleno et al., 2009; Heleno et al., 2012; Pedneault et al*.,* 2007; Yilmaz et al., 2006). Meanwhile, *R. delica* contained the less linoleic acid (13.17%) than did other mushrooms. 1-octen-3-ol is formed during oxidative breakdown of linoleic acid. This aromatic compound is also present in many fungi and might contribute to mushroom's flavouring properties (Maga, 1981). Moreover, linoleic and α-linolenic acid are considered as essential fatty acids due to the fact that these cannot be synthesized by the human organism due to the lack of desaturase enzymes required for their production. Therefore, the levels of these essential fatty acids (EFAs) are very important from the nutritional quality view-point. In this direction, the amount of EFAs was between 13.34% and 79.76% in the studied mushrooms. Again, *C. dryophila* contained the highest level EFAs with high concentration of linoleic acid. Significantly ($p<0.05$) higher proportions of α-linolenic acid (C 18:3 ω3) were observed in *F. velutipes* (8.01%) and *A. auricula-judae* (3.35%) when compared with other mushrooms. In all the tested mushrooms, γ-linolenic acid (C 18:3 ω6) was detected to be less than 2%.

Oleic acid is the main monounsaturated fatty acid and is known for its effectiveness in reducing cholesterol levels (Ribeiro et al., 2009). Oleic acid was major fatty acid in five mushrooms samples (*S. crispa, R. roseouls, S. collinitus, R. delica* and *H. lacunosa*). The results were in agreement with the previous reports which reveal that mushroom species had high proportions of oleic acid (Teixeria et al., 2012; Ozturk et al., 2014; Barros et al., 2008). The levels of oleic acid in the mushrooms ranged from 0.71 (*C. dryophila*) to 55.07% (*S. crispa*). Likewise, oleic acid was previously reported as main fatty acid in *H. lacunosa* (43.82%) (Leal et al., 2013), *S. crispa* (49%) (Kavishree et al., 2008) and *R. delica* (41.20%) (Heleno et al*.,* 2009). Contrary to our findings, Ergonul et al. (2013) reported a lower content of oleic acid in the oil of *S. collinatus* (32.59%). In the present study, a small quantity of cis-9 myristoleic acid (C 14:1 ω5), cis-10 pentadecenoic acid (C 15:1 ω5), cis-9 palmitoleic acid (C 16:1 ω7) and *cis*-9 heptadecanoic acid (17:1 ω8) was also detected.

Among the saturated fatty acids, palmitic and stearic acids predominated in all the species studied. The levels of palmitic varied between 8.95 % in *S. crispa* and 30.84% in *F. velutipes* while stearic acid ranged from 1.06% in *P. squamosus* to 45.84% in *R. albonigra*. The studied mushrooms oils have lower concentration of the remaining SFAs (lauric (C12:0), myrtistic (C 14:0), pentadecanoic (C15:0) and heptadecanoic acid (C 17:0)). In line with our results, Barros et al. (2007) reported that palmitic acid was the major component of the saturated fatty acids of the most mushrooms oils.

The total fatty acid contents for SFAs, MUFAs and PUFAs ranged from 13.97 to 59.44%, 0.94 to 55.44% and 13.54 to 79.93%, respectively. Again, the PUFAs level was higher than SFAs and MUFAs in three mushrooms (*C. dryophila* (79.93%), *P. squamosus* (74.88%) and *V. gloiocephala* (61.13%)). SFA content was higher in *R. albonigra* (59.44%), *R. delica* (46.42%) and *F. velutipes* (44.78%) as a result of the high level of both palmitic and stearic acids. The higher level of MUFAs were observed in *S. crispa* (55.44%), followed by *R. roseolus* (46.88%) and *S. collinitus* (43.23%).The contents of UFAs predominated over SFA in all the studied species, with exception of *R. albonigra* and were ranged from 40.57 to 86.03% of total fatty acids. The highest proportion of UFAs was detected in *R. roseolus* oil. From this point, the high linoleic and oleic acids content contributed to overall increase in UFAs, while palmitic and stearic acid raised SFAs amounts. Our results are inconsistent with the observations that, in mushrooms, unsaturated fatty acids predominate over the saturated, in total fatty acid content (Barros et al., 2008; Ribeiro et al., 2009). Presence of unsaturated fatty acids is valuable with regard to high nutritional value of the studied mushrooms. Considering total UFAs content, two edible mushrooms (*R. roseolus* and *S. crispa*) possessed the highest nutritional value among others.

With respect to the most abundant fatty acids, *C. dryophila* has significantly higher proportion of linoleic acid than *R. delica*, *R. albonigra* and *F. velutipes*. Relatively higher proportions of oleic acid were observed in *S. crispa* when compared with *C. dryophila, P. squamosus* and *V. gloiocephala*. The highest proportions of palmitic acid were found in *F. velutipes* and *A. auricular-judae* when compared with *S. crispa, R. roseolus* and *P. squamosus*. In agreement with the present data, similar variations in major fatty acids have been observed for different mushroom species in the literature (Pedneault et al., 2006). Such qualitative and quantitative differences in the fatty acid compositions of mushrooms species may be attributed to agroclimatic (altitude, humidity, rainfall etc.) and genetic factors (Turhan et al., 2010; Barros et al., 2008; Saiqa et al., 2008).

Overall, the fatty acid composition and especially the high content of unsaturated and essential fatty acids in the studied mushroom oils, support their potential uses as ingredient of functional food and nutraceuticals.

Authors' Contributions

G. Z. and C. S made major contribution to the paper. A. A., S. U., R. C., F. A. and M. H. S. was involved in overall planning and supervision.

REFERENCES

Akyuz, M., A. N. Onganer, P. Erecevit and S. Kırbag. 2010. Antimicrobial activity of some edible mushrooms in the eastern and southeast Anatolia region of Turkey. Gazi Univ. J. Sci. 23: 125-130.

Barros, L., B. A. Venturini, P. Baptista, L. M. Estevinho and I. C. F. Ferreira. 2008. Chemical composition and biological properties of portuguese wild mushrooms: a comprehensive study. J. Agric. Food Chem. 56: 3856-3862.

Barros, L., M. J. Ferreira, B. Queiros, I. C. F. Ferreira and P. Baptista. 2007. Total phenols, ascorbic acid, carotene and lycopene in porteguese wild edible mushrooms and their antioxidant activities. Food Chem. 103: 413-419.

Barros, L., P. Baptista, D. M. Correia, S. Casal, B. Oliveira and I. C. F. Ferreira. 2007. Fatty acid and sugar compositions, and nutritional value of five wild edible mushrooms from Northeast Portugal. Food Chem. 105: 140-145.

Barros, L., T. Cruz, P. Baptista, L. M. Estevinho and I. C. F. Ferreira. 2008. Wild and commercial mushrooms as source of nutrients and nutraceuticals. Food Chem. Toxicol. 46: 2742-2747.

Brondz I, K. Høiland and D. Ekeberg. 2004. Multivariate analysis of fatty acids in spores of higher basidiomycetes: A new method for chemotaxonomical classification of *fungi*. J. Chromatogr. B. 800: 303-307.

Ergönül, P. G., B. Ergönül, F. Kalyoncu and I. Akata. 2012. Fatty acid compositions of five wild edible *Mushroom Species* collected from Turkey. Int. J. Pharmacol. 8: 463-466.

Ergönül, P.G., I. Akata, F. Kalyoncu and B. Ergönül. 2013. Fatty acid compositions of six wild edible mushroom species. Scientific World J. 2013: 1-4.

Gursoy, N., C. Sarikurkcu, B. Tepe and M. H. Solak. 2010. Evaluation of antioxidant activities of 3 edible mushrooms: *Ramaria flava* (Schaef: Fr.) Quél., *Rhizopogon* roseolus (Corda) TM Fries., and *Russula delica* Fr. Food Sci. Biotechnol. 19(3): 691-696.

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

Heleno, S. A, L. Barros, M. J. Sousa, A. Martins and I. C. F. Ferreira. 2009. Study and characterization of selected nutrients in wild mushrooms from Portugal by gas chromatography and high performance liquid chromatography. Microchem. J. 93: 195-199.

Heleno, S. A., I. Barros, A. Martins, M. J. R. Queiroz, C. Santos-Buelga and I. C. F. Ferreira. 2012. Phenolic, polysaccharidic, and lipidic fractions of mushrooms from Northeastern Portugal: chemical compounds with antioxidant properties. J. Agric. Food Chem. 60: 4634-4630.

IUPAC. 1979. In: Paquot, C., (Ed.). Standards methods for analysis of oils, fats and derivatives. 6th ed. Oxford: Oxford Pergamon Press. Pp59-66.

Kalac, P. 2009. Chemical composition and nutritional value of European species of wild growing mushrooms: A review. Food Chem. 113: 9-16.

Kalogeropoulos, N., A. E. Yanni, Koutrotsios and M. Aloupi. 2013. Bioactive microconstituents and antioxidant properties of wild edible mushrooms from the island of Lesvos, Greece. Food Chem. Toxicol. 55: 378-385.

Kavishree, S., J. Hemavathy, B. R. Lokesh, M. N. Shashirekha and S. Rajarathnam. 2008. Fat and fatty acids of Indian edible mushrooms. Food Chem. 106: 597-602.

Leal, A. R., L. Barros, J. Barreira, M. J. Sousa, A. Martins, C. Santos-Buelga and I. C. F. R. Ferreira. 2013. Portuguese wild mushrooms at the "pharma–nutrition" interface: nutritional characterization and antioxidant properties. Food Res. Int. 50: 1-9.

Lindequist U, T. H. J. Niedermeyer and W. D. Julich. 2005. The pharmacological potential of mushrooms. eCAM. 2: 285-299.

Maga, J. A. 1981. Mushroom flavor. J. Agric. Food Chem. 29: 1-4.

Mau, J. L., H. C. Lin and C. C. Chen. 2002. Antioxidant properties of several medicinal mushrooms. J. Agric. Food Chem. 50: 6072-6077.

Ouzouni, P. K., D. Petridis, W. D. Koller and K. A. Riganakos. 2009. Nutritional value and metal content of wild edible mushrooms collected from West Macedonia and Epirus, Greece. Food Chem. 115: 1575-1580.

Ozturk, M., G. Tel, F. A. Ozturk and M. E. Duru. 2014. The cooking effect on two edible mushrooms in Anatolia: fatty acid composition, total bioactive compounds, antioxidant and anticholinesterase activities. Rec. Nat. Prod. 8: 189-194.

Ozyurek, M., M. Bener, K. Guclu and R. Apak. 2014. Antioxidant antiradical propertied of microwave-assited extracts of three wild edible mushrooms. Food Chem. 157: 323-331.

Pedneault, K, P. Angers, T. J. Avis, A. Gosselin and R. J. Tweddell. 2007. Fatty acid profiles of polar and non-polar lipids of *Pleurotus ostreatus* and *P. cornucopiae* var. *"citrino-pileatus*" grown at different temperatures. Mycol. Res. 11: 1228-1234.

Ribeiro, B., D. P. Guedes, P. B. Andrade, P. Baptista and P. Valentao. 2009. Fatty acid composition of wild edible mushrooms species: A comparative study. Microchem. J. 93: 29-35.

Saiqa, S., N. B. Haq, A. H. Muhammad and M. A. Ali. 2008. Studies on chemical composition and nutritive evaluation of wild edible mushrooms. Iran. J. Chem. Chem. Eng. Res. Note. 24: 151-154.

Sarikurkcu, C., B. Tepe and M. Yamac. 2008. Evaluation of the antioxidant activity of four edible mushrooms from the Central Anatolia, Eskisehir–Turkey: *Lactarius deterrimus, Suillus collitinus, Boletus edulis, Xerocomus chrysenteron.* Bioresour. Technol. 99: 6651-6655.

Sesli, E. and C. M. Denchev. 2008. Checklists of the myxomycetes, larger ascomycetes, and larger basidiomycetes in Turkey. Mycotaxon. 106: 65.

Teixeira, R. D. S., P. R. Rocha, H. C. Polonini, M. A. F. Brandão, M. D. G. Chaves and N. R. B. Raposo. 2012. Mushroom tyrosinase inhibitory activity and major fatty acid constituents of Amazonian native flora oils. Brazil. J. Pharm. Sci. 48: 399-404.

Turhan, H., N. Citak, H. Pehlivanoglu and Z. Mengul. 2010. Effects of ecological and topographic conditions on oil content and fatty acid composition in sunflower. Bulg. J. Agric Sci. 16: 553-558.

Wasser, S. P. and A. L. Wies, 1999. Medicinal properties of substances occurring in higher basidiomycetes mushrooms: Current perspectives (Review). Int. J. Med. Mushrooms. 1: 31-62.

Yilmaz, N., M. Solmaz, I. Turkeul and M. Elmastas. 2006. Fatty acid composition in some wild edible mushrooms growing in the middle Black Sea region of Turkey. Food Chem. 99: 168-174.