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Oil content and fatty acid compositions of some edible macrofungi

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Abstract

The oil content and fatty acid compositions of some edible macrofungi (*Agaricus campestris*, *Boletopsis leucomelaena*, *Chroogomphus helveticus*, *Chroogomphus rutilus*, *Coprinus micaceus*, *Lactarius deliciosus*, *Lactarius semisanguifluus*, *Lactarius vellereus*, *Lepista nuda*, *Morchella conica*, *Morchella esculenta*, *Rhizopogon roseolus*, *Suillus luteus*, *Terfezia boudieri* and *Terfezia* sp.,) growing in Turkey were determined. The oil content and free fatty acidity values of the fresh macrofungi samples were found between 0.47-2.71 g and 0.015-0.087 g, respectively. The most abundant fatty acids were linoleic, palmitic and oleic acids in 12 taxa, two taxa and one taxon macrofungi oils, respectively. Total unsaturated fatty acid ratios of different species were found between 44.82 % and 79.76 %. The highest unsaturated fatty acids were found in the composition of *Terfezia* sp.

Keywords: oil**,** fatty acid composition, macrofungi, gas chromatography

1. Introduction

Mushrooms are valuable health foods because they have low in fats and by having high essential fatty acids, and high in proteins, vitamins and minerals [1]. It is known that oil content of mushroom is very low [2-4]. Generally amount of unsaturated fatty acids were found higher than saturated fatty acids. Palmitic (16:0), oleic (9-cis 18:1) and linoleic acids (9-cis, 12-cis 18:2) were found as the main fatty acids of different mushroom species [5-8]. Long chain fatty acids have important role on regulating lipid metabolism, on immune system and hormone system functions [9]. Linoleic and linolenic acids are known as essential fatty acids (EFA) have beneficial effects on human health [10,11].

Total lipid and fatty acid contents of samples vary depending on the type of the fungi, their growing conditions and developmental phase [2]. Wild edible macrofungi have important nutritional features and an important food source for forest villagers in Turkey as being in most countries [5].

There is little information about the lipid contents and fatty acid compositions of different wild edible macrofungi species growing in Turkey. This study is important in terms of defining nutritional value of these edible species and comparing them with similar species in terms of fatty acid composition, whose use in chemotaxonomy was stated earlier.

In this study, total lipid, free fatty acid and fatty acid compositions of different macrofungi species growing in Konya province were determined. Since these are edible species and consumed freshly, fresh macrofungi were used in the analysis to evaluate lipid amounts and fatty acid compositions in terms of nutritional value.

2. Material and methods

2.1.Obtaining the specimens

The macrofungi specimens were collected from Konya province in Turkey and from other places where the macrofungi can be found. Identification of the samples was made according to morphological and microscopic features.

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Diagnoses were made with the help of field, laboratory data and the relevant literature [12-15]. The macrofungi habitats and regional names are given in Table 1.

2.2.Oil extraction

Choroform/methanol (2/1) mixture was added to each macrofungi species until covering to all sample and samples were homogenized. After homogenizing the mixture was filtered with Whatman No: 40 filter paper, the solvent was vaporized and was kept in a desiccator until it reached the stable weight. This stable weight was noted as the total lipid content of the sample. Total lipid and fatty acid extractions were conducted using the methods of Folch, Lees, & Stanley [16], and fatty acids were methoxylated with the method of Moss, Lambert, & Mervin [17]. For the saponification of the lipids, 10ml KOH (6 % in methanol) mixture was used and this application was performed at 95 °C in boiler for one hour. Choroform/hexan (1/4) (10 ml) mixture was added and saponificated fatty acid mixture was separated. By adding H_2SO_4 (8N) into saponificated material, we obtained the free fatty acids mixture and then we added 10 ml Choroform/Hexan (1/4) to separate the free fatty acids. Total fatty acid content was noted after keeping the material in dessicator. BF_3-methanol mixture (14 %) was added on free fatty acids and boiled at 95 °C in boiler for 15 min for the fatty acid methylation. Methylated fatty acids were separated by adding 5ml saturated NaCl solution and 5 ml Choroform/hexan (1/4). All seperation methods were repeated for three times.

2.3.Gas chromatography analyses

Gas chromatography analysis was performed using a HP6890 model Hewlett Packard Agilent gas chromagrophy automatic injector device with FID detector. A 60 m Supelco SP2380 capillary column was used for the analysis. The temperature of the injector block was 280 ºC and that of the detector block was 300 ºC. A heat program was applied to the column. Initial temperature of 120 ºC was increased by 10 ºC till it reached to 230 ºC and was kept at 230 ºC for 20 min. Velocity of gas flow of the dedector was applied as follows: hydrogen 32 ml/min, dry air 370 ml/min and nitrogen (make up flow) 32 ml/min. Hydrogen was used as the carrier gas. The velocity of hydrogen flow was 0.8 ml/min and the pressure of the gas was 12.10 psi. For each analysis, 1 µl methylated fatty acid sample was injected into the gas chromatography device. Identification of fatty acid methyl esters was accomplished by comparison of their retention times with those of standarts obtained from Supelco (18919 FAME). In this standart mixture, there were 37 different fatty acid methyl esters between butyric (C4:0) and lignoceric (C24:0).

The statistical analysis of the obtained data was performed using variance analysis in SPSS 10 program. Tukey's HSD test was used to check the difference among averages and 0.05 was accepted as the significance level.

Table 1. Family, habitats and local names of macrofungi defined in the field

Species	Family	Habitat	Local Name	Locations
Morchella conica	*Morchellaceae*	Pine Forest	Kuzu Göbeği	Kestel
Morchella esculenta	*Morchellaceae*	Pine Forest	Kuzu Göbeği	Kestel
Terfezia boudieri	*Terfeziaceae*	Step	Domalan	Beyşehir
Terfezia sp.	*Terfeziaceae*	Step	Domalan	Beyşehir
Rhizopogon roseolus	*Rhizopogonaceae*	Pine Forest	Yalancı Domalan	Kestel
Boletopsis leucomelaena	*Thelephoraceae*	Mixed Forest	------	Hadim
Agaricus campestris	*Agaricaceae*	Meadow	Çayır Mushroom	Selçuklu
Coprinus micaceus	*Coprinaceae*	Near Stream	Mürekkep Mushroom	Kestel
Lepista nuda	*Tricholomataceae*	Pine Forest	Mor Mushroom	Kestel
Chroogomphus helveticus	*Gomphidiaceae*	Pine Forest	-------	Kestel
Chroogomphus rutilus	*Gomphidiaceae*	Pine Forest	-------	Kestel
Suillus luteus	*Boletaceae*	Pine Forest	-------	Kestel
Lactarius delicious	*Russulaceae*	Pine Forest	Çam Mantarı, Çıntar, Melki, Espit, Kanlıca	Kestel
Lactarius semisanguifluus	*Russulaceae*	Pine Forest	Çam Mantarı, Çıntar, Melki, Espit, Kanlıca	Kestel
Lactarius vellereus	*Russulaceae*	Pine Forest	Çam Mantarı, Çıntar, Melki, Espit, Kanlıca	Kestel

Table 2. Total lipid and free fatty acid contents of the different macrofungi samples as a gram of wet weight [xy]

Samples	Total lipid (%)	Free fatty acid (%)
Morchella conica	2.30 ± 0.65 a	0.015 ± 0.02a
Morchella esculenta	2.41 ± 0.51 ab	0.068 ± 0.03bc
Terfezia boudieri	2.21 ± 0.53 a	0.087 ± 0.01d
Terfezia sp.	1.64 ± 0.60 c	0.055 ± 0.02e
Rhizopogon roseolus	1.34 ± 0.59 cde	0.023 ± 0.02f
Boletopsis leucomelaena	1.47 ± 0.83 cde	0.075 ± 0.05cd
Agaricus campestris	1.58 ± 0.75 cd	0.015 ± 0.02a
Coprinus micaceus	0.47 ± 0.68 f	0.024 ± 0.01f
Lepista nuda	1.30 ± 0.45 de	0.083± 0.04d
Chroogomphus helveticus	2.12 ± 0.35 a	0.056 ± 0.03be
Chroogomphus rutilus	2.71 ± 0.75 b	0.070 ± 0.04c
Suillus luteus	0.95 ± 0.50 gh	0.022 ± 0.02f
Lactarius deliciosus	1.63 ± 0.61 c	0.048 ± 0.02eg
Lactarius semisanguifluus	1.25 ± 0.68 eh	0.035 ± 0.02fg
Lactarius vellereus	0.83 ± 0.33 g	0.025 ± 0.02 f

[x] Data are means ± SE (Standart Error) of three replicates.

[y] Means in the same vertical column and group followed by the same letter (a-h) are not significantly different from each other (Tukey's HSD test: $P > 0.05$).

3.Results and discussion

The amount of total oil and free fatty acids of the macrofungi samples are presented in Table 2. Total lipid amounts of different macrofungi samples were found between 0.47 and 2.71%. While the highest lipid content is found in *Chroogomphus rutilus*, the lowest was found in *Coprinus micaceus*. The free fatty acid values of samples were found between 0.015 and 0.087 %. It was found that the values of free fatty acid of *Terfezia boudieri* and *Lepista nuda* were higher than the other species. The lowest values of free fatty acids were found in *Morchella conica* and *Agaricus campestris* oils.

The fatty acid compositions of tested macrofungi species were given in Table 3. The most abundant fatty acid was linoleic acid in 12 taxa, palmitic acid in two taxa (*L. nuda* and *L. vellereus)* and oleic acid in one taxon (*B. leucomelaena*) oils. Total unsaturated fatty acid ratios of different species were found between 44.82 % and 79.76 %. The highest unsaturated fatty acids ratio is found in the composition of *Terfezia* sp. while the lowest ratio was found in *L. nuda* and *L. Vellereus* oils.

In this study, oil content, free fatty acid values and fatty acid compositions of the defined macrofungi were determined. The total lipid contents in each 100 g fresh mushroom of the 15 analyzed species were between 0.47 g and 2.71%. In previous studies, the amount of total lipid of various species varied between 0.18 % and 1.58 %, and the amounts of total lipid in the dry weight of these fungi reached from 1.75 % to15.5 % [2,18-23].

The lipid content of the same species may change depending on the growing conditions and method of analysis. For example, in different studies carried on *Agaricus campestris* it was reported that the amount of lipid in 100 g varied between 0.31 and 1.10 g [24]. In our study, the amount of total lipid of *A. campestris* was 1.58 g. In a previous study with *Morchella conica*, it was found that the amount of lipid in 100 g dry mushroom was 2.90 g [3]. In the present study, the amount of total lipid of the same species of fresh macrofungi was 2.30 g. Previous studies have generally focused on defining the amount of total lipid. We did not encounter any studies that tried to define the amount of total fatty acid. According to the results obtained in this study, it was found that the percentages of total fatty acid in terms of total lipid varied between 0.65 and 3.94%. These values are within the values that Weete [25] stated.

In the materials examined, it was determined that the most abundant fatty acid was linoleic acid in twelve mushroom species. Previous studies showed that linoleic acid was the most abundant fatty acid in many species of *Basidiomycetes* [25]. Pedneault et al., [26] studied on the fatty acid compositions of 11 different species belonging to the family Boletaceae and found that unsaturated fatty acids (about 83 %) and mainly linoleic acid and oleic acid ratios were high. Linoleic acid is an essential polyunsaturated acid and used in the biosynthesis of arachidonic acid and prostaglandins.

Linoleic acid has vital functions in the human body and has beneficial effects on optimal health [27]. Many studies show that oleic acid has modulatory effects and beneficial effects on cancer, autoimmune and inflammatory diseases, and wound healing [28]. In our study, while linoleic acid was the most common fatty acid in specimens of the *Ascomycetes*, the second most abundant fatty acid is oleic acid and the third was palmitic acid. In eight species of *Basidiomycetes* the most common was linoleic acid whereas palmitic acid was the most abundant in two species and was oleic acid in the other one. These results are consistent with many previous studies [18, 22,29-31].

Qualitative and quantitative similarities were determined in the fatty acid compositions of specimens of taxonomically related species. Fatty acid compositions of *Morchella conica* and *Morchella esculenta* showed similarities with *Terfezia boudieri* and *Terfezia* sp. species. Similarly, fatty acid compositions of *Chroogomphus helveticus* and *Chroogomphus rutilus* species and *Lactarius delicious* and *Lactarius semisanguifluus* species were quantitatively and qualitatively close to each other.

These results are consistent with previous studies. Biochemical composition of macrofungi changes according to growing conditions and could have species-specific features. In this study, while fatty acid compositions of *Lactarius delicious* and *Lactarius semisanguifluus* are found qualitatively and quantitatively similar, significant differences were determined in *Lactarius vellereus*.

The differences among the free fatty acid and fatty acid compositions in different studies conducted on the same species can be explained in various ways such as the growing conditions, phases of the analyzed material, the material's being dry or wet and differences in analysis methods.

In this study, it was found that the total unsaturated fatty acids ratios of different macrofungi species studied were generally over 50 % of the total fatty acid composition except of *L. nuda* (44.82 %), *L. vellereus* (45.52 %), *R. roseolus* (47.47 %) and *L. semisanguifluus* (48.12 %). The highest total unsaturated fatty acids ratio was belonging to *Terfezia sp.* (79.76 %).

Table 3.[1] Fatty acid composition (%) of the macrofungi [xy]

Fatty acids	*M. conica*	*M. esculenta*	*T. boudieri*	*Terfezia sp.*	*R. roseolus*	*B. leucomelaena*	*A. campestris*
8:0	3.41±0.17a	0.70±0.03bd	-	-	-	0.48±0.06b	1.44±0.12c
10:0	6.65±0.17a	0.84±0.04bc	0.30±0.03b	0.33±0.06b	10.72±0.19d	4.88±0.21ef	2.38±0.09g
12:0	1.51±0.06a	0.48±0.04b	-	0.34± 0.10b	-	-	3.01±0.20c
14:0	4.09±0.07a	1.26±0.04bg	0.24±0.04c	0.57±0.10de	6.60±0.18f	0.41±0.08cd	1.09±0.13g
14:1	0.74±0.14abd	0.36±0.02a	0.52±0.02ad	0.38±0.06a	-	1.02±0.02bc	1.46±0.12c
16:0	12.52±0.39a	18.14±0.03b	22.34±0.14c	13.13±0.09a	10.34±0.13df	12.14±0.16ae	10.45±0.20df
16:1	2.28±0.10a	1.18±0.09bcd	1.44±0.06c	1.22±0.12cd	-	1.25 0.07cd	0.96±0.12bde
17:0	2.49±0.06a	2.34±0.02a	0.98±0.06bf	0.68±0.06b	7.25±0.14c	2.49±0.10a	4.10±0.37dg
18:0	8.47±0.06ag	7.78±0.04a	4.29±0.06bf	2.06±0.06c	12.04±0.26d	4.79±0.07b	13.60±0.46e
18:1	21.52±0.04a	25.77±0.50b	23.75±0.08c	14.47±0.16d	11.42±0.18e	32.43±0.12f	14.60±0.20d
18:2	23.56±0.04a	36.36±0.09bh	33.75±0.38cıi	59.04±0.66d	26.78±0.46e	31.67±0.15c	34.30±0.52bıi
20:0	1.82±0.05a	0.70±0.03bc	0.61±0.10bc	0.72±0.04bc	-	0.44±0.03b	2.24±0.13d
18:3	1.41±0.01a	0.80±0.03bc	1.17±0.07ac	0.72±0.06b	-	2.22±0.11dg	3.60±0.12e
20:1	0.31±0.01ab	0.34±0.03ab	0.45±0.10ab	0.85±0.10cd	-	1.41±0.09e	0.65±0.10bc
21:0	2.46±0.04ae	0.88±0.01b	1.45±0.13cg	1.01±0.05bc	2.05±0.11ad	2.49±0.04ae	0.97±0.13b
20:2	3.42±0.10a	0.69±0.14b	0.56±0.10b	0.80±0.24b	7.77±0.28c	0.36±0.13b	0.61±0.11b
22:0	0.52±0.06ab	0.41±0.03a	0.52±0.08ab	0.36±0.07a	-	-	1.73±0.19c
22:1	-	-	0.54±0.03ae	0.31±0.05ab	-	0.18±0.02b	-
22:2	-	-	1.45±0.06a	0.68±0.04be	-	0.45±0.04bd	-
24:0	1.48±0.01a	0.60±0.04bh	2.54±0.02cı	1.04± 0.05df	3.53±0.19e	0.33±0.04b	1.17±0.09af
24:1	1.34±0.03ad	0.37±0.07b	3.10±0.14c	1.29±0.06ad	1.50±0.12d	0.56±0.06be	1.64±0.12d
∑UFAs	**54.58±0.21a**	**65.87±0.18b**	**66.73±0.23b**	**79.76±0.32c**	**47.47±0.33d**	**71.55±0.12e**	**57.82±0.28a**

Table 3. *continued...*

Fatty acids	*C. micaceus*	*L. nuda*	*C. helveticus*	*C. rutilus*	*S. luteus*	*L. deliciosus*	*L. semisanguifluus*	*L. vellereus*
8:0	0.59±0.06b	0.66±0.05bd	-	-	1.12±0.11cd	-	-	-
10:0	6.28±0.12ah	1.26±0.06c	5.74±0.10fı	5.13±0.06fı	4.32±0.05e	20.68±0.26i	19.85±0.14j	4.35±0.05e
12:0	4.56±0.20d	0.32±0.02b	0.71±0.15b	-	1.38±0.19a	1.33±0.09a	2.23±0.14e	4.48±0.11d
14:0	1.83±0.09h	1.01±0.03gı	1.13±0.05g	1.61±0.07ih	5.36±0.05j	1.03±0.13ıg	0.77±0.09eı	1.49±0.11bi
14:1	0.88±0.12bd	1.35±0.06c	-	-	0.72±0.14abd	0.54±0.11ad	0.66±0.09abd	0.44±0.12ad
16:0	9.31±0.17fg	32.62±0.63h	9.54±0.10fg	8.67±0.07g	11.06±0.13de	6.40±0.10ı	6.40±0.08ı	22.12±0.12c
16:1	2.45±0.19a	0.55±0.08e	2.26±0.06a	2.39±0.03a	2.32±0.02a	1.52±0.04c	0.72±0.08be	2.99±0.02f
17:0	4.27±0.12d	2.09±0.03ae	0.73±0.15b	1.94±0.03ae	2.58±0.04a	1.52±0.15ef	0.72±0.11b	3.56±0.04g
18:0	3.40±0.16f	8.58±0.17ag	3.80±0.17bf	5.08±0.04b	3.88±0.06bf	9.27±0.57g	17.78± 0.45h	12.31±0.06de
18:1	8.50±0.17gi	25.33±0.59b	19.55±0.08h	28.61±0.11ı	19.98±0.23h	7.90±0.46g	9.42±0.09i	19.52±0.14h
18:2	24.65±0.65ae	10.90±0.52f	31.60± 0.29c	29.41±0.17g	37.17±0.22h	35.60±0.68bhı	32.33±0.63ci	18.87±0.17j
20:0	2.77±0.12e	0.43±0.06b	1.82±0.05a	1.36±0.09f	0.66±0.05bc	0.96±0.06c	-	2.92±0.03e
18:3	3.85±0.12e	1.88±0.08d	2.88±0.05f	2.43±0.05g	1.18±0.06ac	2.01±0.06d	0.73±0.09b	-
20:1	0.36±0.08ab	0.11±0.01a	1.19±0.10def	0.93±0.02cdf	0.95±0.10cdf	0.25±0.03a	-	1.29±0.07ef
21:0	6.51±0.18f	6.36±0.08f	2.85±0.11e	2.07±0.04ad	1.88±0.07dg	0.99±0.06bc	0.92±0.09b	1.12±0.06bc
20:2	2.38±0.08dh	4.31±0.30e	1.97±0.03fh	1.38±0.09g	2.51±0.15d	0.86±0.15b	0.81±0.19b	1.54±0.19fg
22:0	1.69±0.17c	0.95±0.04b	2.01±0.09c	-	0.35±0.04a	0.65±0.10ab	0.75±0.11ab	1.66±0.04c
22:1	-	0.13±0.01b	2.42±0.10c	2.16±0.07c	-	0.77±0.08de	-	0.87±0.17d
22:2	2.94±0.22c	0.11±0.01d	1.86±0.08a	-	0.97±0.05e	1.60±0.05a	0.66±0.13be	-
24:0	5.37±0.08g	0.90±0.02dfh	2.92±0.04ı	2.56±0.06cı	0.69±0.06bdh	2.52±0.11cı	2.46±0.13c	0.47±0.06bh
24:1	7.41±0.12f	0.15±0.02b	5.02±0.16g	4.27±0.26h	0.92±0.02ae	3.60±0.01ı	2.79±0.07c	-
∑UFAs[z]	**53.42±0.36a**	**44.82±0.24f**	**68.75±0.33be**	**71.58±0.18e**	**66.72±0.15b**	**54.65±0.13a**	**48.12±0.09d**	**45.52±0.22f**

[x] Data are means ± SE (Standart Error) of three replicates.

[y] Means in the same horizontal row and group followed by the same letter (a-j) are not significantly different from each other (Tukey's HSD test: $P > 0.05$).

[z] UFAs, unsaturated fatty acids.

The fact that the amount of lipid was low and the amounts of linoleic acid, oleic acid and total unsaturated fatty acid were high emphasizes that macrofungi are important in the pharmaceutical sector both for their nutritional and commercial value. Fats that contain unsaturated fatty acids in high percentages are accepted as beneficial and are important for human health. The fact that the ratio of unsaturated fatty acids are higher than saturated fatty acids in the food taken is a major factor in lowering plasma cholesterol concentration and is acknowledged to be important in preventing coronary heart diseases [27,28].

Since their overall lipid content is lower, macrofungi are an ideal food, especially for those who prefer low calorie diets. Besides their low lipid content, edible mushrooms are rich in proteins, vitamins and minerals, especially potassium and phosphorus [26]. According to our study, most of the mushroom species we analyzed are rich in linoleic acid, oleic acid and total unsaturated fatty acid amount which mean that they have a good nutrional value.

In conclusion, it was studied on oil content and fatty acid compositions of the macrofungi growing in Konya province in Turkey, and clearly indicate that they provide unsaturated fatty acids that beneficial for health.

We recommend to consume sufficient amounts of macrofungi in our diet to lead a healthy life.

Compliance with Ethics Requirements. Authors declare that they respect the journal's ethics requirements. Authors declare that they have no conflict of interest and all procedures involving human or animal subjects (if exist) respect the specific regulation and standards.

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