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Original article

The fatty acid composition in some economic and wild edible mushrooms in Turkey

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Summary. The aim of this study was to determine the fatty acid composition of different mushroom species collected from the Yozgat and Tokat region in Turkey. Fatty acid composition was determined in the mushroom species (*Morchella elata*, *Macrolepiota procera, Lactarius delicious, Helvella lacunosa, Boletus edulis, Cantharellus cibarius, Bovista plumbea, Agaricus bisporus)*. The fatty acids copmpsition in mushrooms were identified and quantified by gas chromatography. The amounts % of fatty acids in species were different, Fatty acids with 14-24 carbons were occured in mushrooms samples linoleic acid was the major fatty acid detected in all species linoleic acid respectively in species " *Bovista plumbea, Agaricus bisporus, Macrolepiota procera*" were higher than other mushrooms. Percentage of linoleic acid (ω6) in species varied from 10 % to 51 %. The other major fatty acids were respectively, palmitic, stearic, oleic acids other abundant fatty acids in the mushrooms. These four fatty acids were present in all of the mushrooms examined. The high level of docosadienoic acid (22:2) detected in *Morchella elata* is remarkable. When fatty acid composition results are compared as saturated and unsaturated, the fatty acid composition of the mushrooms showed that the unsaturated fatty acids are in higher proportions than the saturated fatty acids.

Key words: edible mushroom, fatty acid composition, GC-MS

Introduction

Fatty acids are the basic building block of many lipids. Polyunsaturated fatty acids such as omega-3 and 6 have many biological properties and are biosynthetic precursors of eicosanoids. Fatty acid levels in blood are closely related to many diseases such as cardiovascular diseases, blood pressure and arthritis (1). These fatty acids act as regulators in cellular functions by participating in the structure of membrane phospholipids and other components.

Two fatty acids are dietary essentials in humans because of our inability to synthesize them: linoleic acid and linolenic acid. Linoleic acid is the precursor of ω-6 arachidonic acid, the substrate for prostaglandin synthesis. α-linolenic acid is the precursor of other ω-3 fatty acids important for growth and development. Plants and mushrooms provide us with the essential fatty acids.

Lack of essential fatty acid and effective metabolism of diet plays an important role in the etiology and progression of many diseases (2).

The consumption of wild mushrooms is increasing with the understanding of human nutrition and pharmacological properties (3). Mushrooms have a low in calories and fats, essential fatty acids, contain vegetable proteins are also important food for human beings due to containing valuable vitamins and minerals (4-11).

Many mushrooms have been used for medical purposes until now to prevent diseases such as hy-

pertension, hypercholesterolemia, atherosclerosis and cancer. The reason for this is the height of the essential unsaturated fatty acid levels (12).

Most researchers have examined the fatty acid composition of various mushroom and have clarified the importance of a diet containing mushroom (3,13,14). Many wild mushrooms have been used since ancient times for medicinal purposes due to their beneficial components and their biological activity. But consumers have been consumed fewer mushrooms to eat because of their relative shortages and some difficulties in the supply. For easier access and commercialization of wild mushrooms, many research groups have focused on the development of artificial production methods using a wide variety of materials and conditions (15).

Most of the studies on fatty acids found in mushroom are limited to certain well-known types of mushroom. However, studies have shown that wild edible mushroom, which are accessible and economically important, contain significant amounts of valuable fatty acids. For this reason, studies on fatty acid contents of all edible mushroom should be made.

Matherials and Methods

The following Table 1 contains information on the characteristics of the mushroom specimens; names, habitat, coordinate, edibility and localite. All samples were collected from of Tokat or Yozgat province in Turkey in 2015. Then the mushrooms were identified. Finally, all samples were dried and ground in appropriate conditions in the laboratory. Prepared samples were stored in the refrigerator until the time of analysis.

Lipid Extraction and Analysis of Fatty Acid

The conventional method of total lipid extraction described by Folch et al. (1957) was used for the dried mushroom. Derivatization of the fatty acids to methyl esters was performed by adding 500 µl of HCSM (hexane/chloroform/sodium methoxide, 75/20/5, v/v/v, Sigma, GC grade) solution to the sample vials (16).

Gas chromatography-mass spectrometry (GC-MS) analyses of the methyl derivatives of fatty acids were performed by Agilent 7890 GC /5970 MS Series gas chromatography system (Agilent, Santa Clara, CA, USA) with a FID and MS and a fused (88% - Cyanopropy) aryl-polysiloxane and high polarity capillary column (HP-88, 100 m x 0.25 mm, 0.20 um film (Part no: 112-88A7, Agilent, Santa Clara , CA, USA) was used injector and detector temperatures were 250 and 270 ˚C, respectively, carrier gas was He at a flow rate of 1.0 mL/min; sample volume 1.0 µL; split ratio 20:1. The detector gas was dry air set at 350 mL min^{-1}, and H_2 gas was set at 35 mL min^{-1}. The detector makeup gas was N_2 at 35 mL min^{-1}. The initial oven temperature was held at 120 ˚C for 5 min, then increased up to 250 °C with 5 °C/min increments and held at this temperature for 16 min. Injection system with auto sampler was used. The injector was rinsed with hexane 5 times before and after each injection to prevent contamination. The relative percentages of separated

Table 1. Information on the Chracteristics of the Mushroom Species

Mushroom samples	Habitat	Coordinates	Edibility	Localite
Morchella elata	In conifers woods	39°34'N-35°58'E	Edible	Yozgat
Macrolepiota procera	Under or near deciduous trees, especially beec or buried wood	39°57'N-35°24'E	Edible	Yozgat
Lactarius delicious	In conifers woods	40°07'N-35°19'E	Edible	Yozgat
Helvella lacunosa	In mixed woodland especially on burnt ground	40°21'N-36°38'E	Edible	Tokat
Boletus edulis	In mixed woods	40°30'N-36°40'E	Edible	Tokat
Cantharellus cibarius	In all kinds of woodland	40°33'N-36°36'E	Edible	Tokat
Bovista plumbea	Amongst short grass, on lawns	39°39'N-35°55'E	Edible	Yozgat
Pleurotus ostreatus	Often in large clusters on stumps and usually of deciduous trees	40°38'N-36°59'E	Edible	Tokat
Agaricus bisporus	On manure heaps, garden waste and roadsides	40°32'N-36°37'E	Edible	Tokat

compounds were calculated by using GC data analysis computer program (FID: flame ionization dedector, MS: mass spectrometry). The results were interpreted by the software recorded in the system.

The fatty acid methyl ester(FAME) results were reported in percent. All samples were studied three times and averaged.

Results and Discussion

In the present study, fatty acid composition of nine species of mushroom namely *Morchella elata, Macrolepiota procera, Lactarius delicious, Helvella lacunosa, Boletus edulis, Cantharellus cibarius, Bovista plumbea, Pleurotus ostreatus, Agaricus bisporus* mushrooms were analyzed. The results for fatty acid composition, total saturated fatty acids (SFA), monounsaturated fatty acids (MUFA), polyunsaturated fatty acids (PUFA), total unsaturated fatty acids(∑UFA) and total unsaturated fatty acids to total unsaturated fatty acids ratio (∑UFA/SFA) of the studied mushrooms are shown in Table 2. The major fatty acids found in the studied samples were linoleic acid (C18:2 n-6) and oleic acid (C18:1 n-9), followed by palmitic acid (C16:0) and stearic acid (18:0). All of these results are shown in Table 3 and Figures 2 and 3. An example of the GC-MS chromatogram is given in Figure 4.

Table 2. Distribution According to % Fatty Acid Saturations in Mushroom Samples

Name of mushroom	SFA	MUFA	PUFA	∑UFA	∑UFA/ SFA
Morchelle elata	**48.74**	**22.19**	**29.08**	**51.27**	**1.051**
Macrolepiota procera	38.33	12.23	48.55	60.78	1.585
Lactarius delicious	**44.91**	**39.54**	**15.54**	**55.08**	**1.226**
Helvella lacunosa	30.56	46.94	22.49	69.40	2.270
Boletus edulis	**32.17**	**25.90**	**41.99**	**67.89**	**2.110**
Cantharellus cibarius	29.13	32.33	38.54	70.87	2.432
Bovista plumbea	**32.56**	**13.83**	**53.61**	**67.44**	**2.071**
Pleurotus ostreatus	42.77	24.13	40.31	64.44	1.506
Agaricus bisporus	**46.24**	**4.02**	**49.74**	**53.76**	**1.162**

SFA; Saturated Fatty Acid, MUFA; Monounsaturated Fatty Acid, PUFA: Polyunsaturated Fatty Acid, ∑UFA: Total Unsaturated Fatty Acid, ∑UFA/SFA: Total Unsaturated Fatty Acid to Saturated Fatty Acid ratio

∑UFA/SFA ratio was observed the highest in H. lacunosa and the lowest in M. elata in our samples.

Nervonic acid (C24:1) was detected as 7.22% in *Pleurotus ostreatus* only. This result is consistent with the results of the study of Karine 2007 but higher than it.

Lignoceric acid (C24:0) was detected as 0.71% in *Macrolepiota procera* only. Although amount of this fatty acid is very low, it can be an important finding.

In this study, highest SFA is % 46.24 in *Agaricus bisporus*, lowest SFA is %29.13 in *Cantharellus cibarius*, highest MUFA is % 46.94 in *Helvella lacunosa*, lowest MUFA is % 4.02 in *Agaricus bisporus*, highest PUFA is %53.61 in *Bovista plumbea*, lowest PUFA is %22,49 in *Helvella lacunosa*, highest ∑UFA is % 70.87 in *Cantharellus cibarius*, lowest ∑UFA is % 51.27 in *Morchella elata*, highest ∑UFA/SFA is 2.432 in *Cantharellus cibarius*, lowest ∑UFA/SFA is 1.051 in *Morchella elata* were obtained. All of these results are shown in Table 2.

Results reveal that levels of unsaturated fatty acid were higher than saturated ones in nine mushrooms. These results is in agreement with the earlier findings that unsaturated fatty acid content were predominating fatty acid in different species of mushrooms as compared to saturated ones (17).

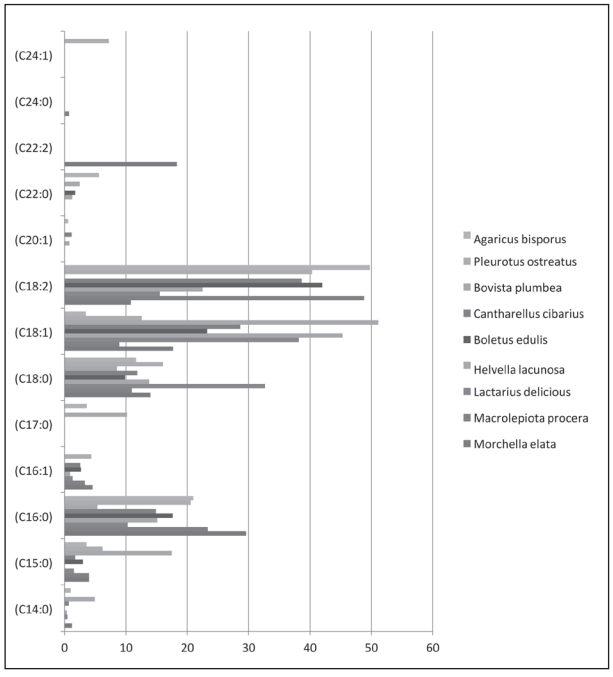

Figure 1: Fatty Acid Distribution in Mushroom Samples

Table 3: % Fatty Acid Distribution in Mushroom Samples

	M. elata	*M. procera*	*L. delicious*	*H. lacunosa*	*B. edulis*	*C. cibarius*	*B. plumbea*	*P. ostreatus*	*A. bisporus*
Myristic acid (C14:0)	1.20	nd	0.45	0.36	nd	0.67	4.93	nd	0.96
Pentadecanoic acid (C15:0)	3.96	3.95	1.53	nd	2.97	1.74	17.46	6.18	3.54
Palmitic acid (C16:0)	29.57	23.32	10.26	15.10	17.61	14.86	5.31	20.54	20.97
Palmitoleic acid (C16:1)	4.54	3.30	1.33	0.88	2.69	2.54	nd	4.34	Nd
Margaric acid (C17:0)	Nd	nd	nd	nd	nd	nd	10.17	nd	3.58
Stearic acid (C18:0)	14.01	10.95	32.67	13.82	9.83	11.86	8.52	16.05	11.61
Oleic acid (C18:1)	17.65	8.93	38.21	45.32	23.21	28.62	51.15	12.57	3.46
Linoleic acid (C18:2)	10.78	48.85	15.54	22.49	41.99	38.64	nd	40.31	49.74
Arachidonic acid (C20:1)	Nd	nd	nd	0.75	nd	1.17	nd	nd	0.56
Behenic acid (C22:0)	Nd	nd	nd	1.28	1.70	nd	2.46	nd	5.58
Docosadienoic acid (C22:2)	18.30	nd	nd	nd	nd	nd	nd	nd	Nd
Lignoceric acid (C24:0)	Nd	0.71	nd	nd	nd	nd	nd	nd	Nd
Nervonic acid (C24:1)	Nd	nd	nd	nd	nd	nd	nd	7.22	Nd

nd: not detected

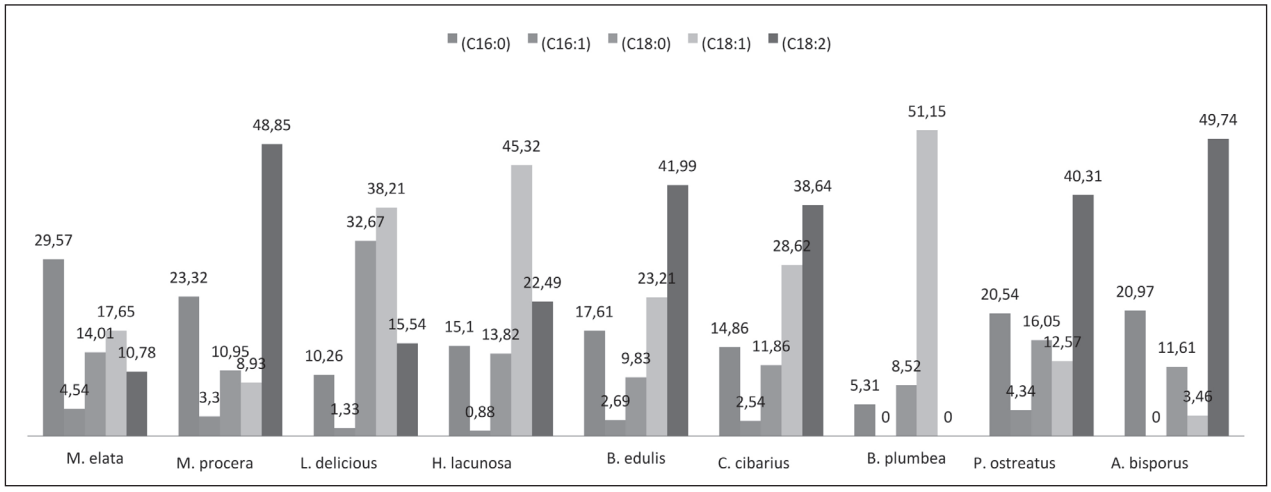

Figure 2: Distribution of the major fatty acids in mushrooms

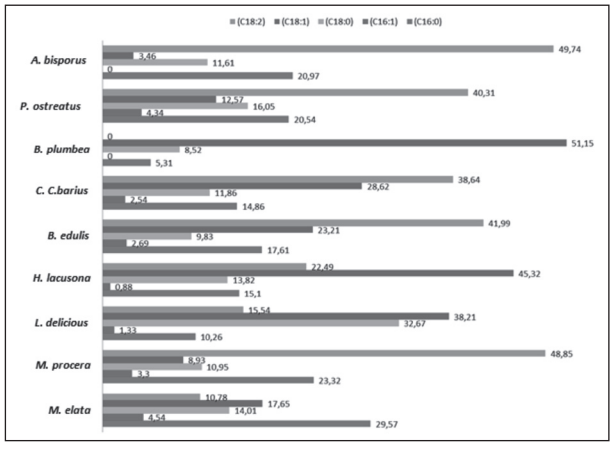

Figure 3: Distribution of the major fatty acids in mushrooms

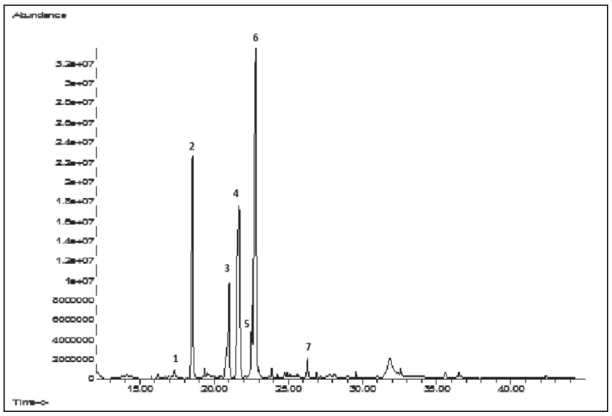

Figure 4: GC-MS chromatogram of *Boletus edulis*: number of 1.C15:0, 2.C16:0, 3.C16:1, 4.C18:0, 5.C18:1, 6.C18:2, 7.C22:0.

Linoleic acid is called an essential fatty acid because it can not be synthesized by the human organism. So it should be derived from diet and a series of ω-6 fatty acids containing γ-linolenic, dihomo-γ-linolenic and arachidonic acids (18). Essential fatty acids are the kind of fatty acids that a living thing needs to take but can not synthesize in their own body (19).

Conclusion

In this study, linoleic acid was the major fatty acid detected in all species of mushroom and it is one of the important essential fatty acid.

The analysis of the obtained profiles showed that linoleic (10.78 to 51.15%..) oleic (3.46-45.32 %), and, to a lesser extent, palmitic (10.26-29.57%) and stearic acids (9.83-32.67%) were the main fatty acids in the studied species in Table 3. This is in agreement with the results reported for other edible mushrooms (20,21). Linoleic amounts varied between 10.78 and 51.15%. The least was in (10.78%), the most in *Bovista plumbea* (51.15%)

Linoleic acid was the preponderant fatty acid in *Macrolepiota procera, Helvella lacunosa, Boletus edulis, Cantharellus cibarius, Bovista plumbea, Pleurotus ostreatus, Agaricus bisporus* in Table 2.

Cis-linoleic acid (18:2) was obtained in high amounts in *Bovista plumbea* (51.15%), *Agaricus bisporus* (49.74%). These results have shown that, in the many of previous reports, the majority of mushroom have higher levels of unsaturated fatty acids, especially linoleic acid (22,23).

Oleic acid is a monounsaturated fatty acid and is found in the ω-9 family. Since people have the enzymes necessary for the synthesis of oleic acid, this fatty acid is not regarded as essential. Under the severe conditions of essential fatty acid deficiency, the mammals elongate and desaturate oleic acid to produce eicosatrienoic acid (C20:3 n-9) (18). It is known that oleic acid which on olive oil has a positive effect human plasma cholesterol levels (24,25).

Other ω-9 fatty acid, such as, nervonic acid was also identified in *Pleurotus ostreatus* in Table 3.

Palmitic acid was found in the highest amounts in *Morchella elata and Macrolepiota procera* species. Stearic acid was found to be the highest amount (32.67%) in *Lactarious delicious*.

Pamitoleic acid was detected in all species except one, as shown in Table 3. As is known, arteriosclerosis can be treated by long-term use of palmitoleic acid.

As seen in Table 2, SFA's were generally found more than MUFA's and PUFA's. But UFA's were found to be higher than SFA's in all mushroom species.

Characterization of saturated, monounsaturated and polyunsaturated fatty acid profiles are shown in Table 2. The total fatty acid content for SFA, MUFA and PUFA was 29.13-48.74%, 4.02-46.94%, 15.54-53.61%.

SFA content was higher in *M. elata* due to palmitic acid (48.74%, 46.24) and in *L. delicious* as result of the high levels of both stearic acids and palmitic (45% of total compounds) in Table 3. The high linoleic acid content contributes to the overall increase in PUFAs, while oleic acid raises MUFAs levels.

PUFAs amount was higher in *B. Plumbea, A. Bisporus, M. Procera* species, in which linoleic acid was the main compound, and MUFA were present in highest levels in *H.lacunosa, L.delicious, C.cibarius* species, due to oleic acid.

These results are consistent with the fact that ratio of unsaturated fatty acids in total fatty acids in mushroom reported in previous studies is higher than saturated fatty acids (26-28).

Increasing the ratio of unsaturated fatty acids in the diet is very important because it leads to an increase in HDL levels, known as good cholesterol, and a decrease in LDL levels and triacylglycerol, also known as bad cholesterol (29).

In addition, it has been proven to be correlated with the increase in atherosclerosis, cardiovascular and other related diseases, with a saturated fat-rich diet (30). Therefore, the consumption of *L. Delicious, H.lacunosa, B.edulis, C.cibarius, B.plumbea, P.ostreatus* species is important for health.

The fatty acid compositions of different mushroom species were different from each other.

Although oleic acid and linoleic acid were in all mushrooms species, linoleic acid was the major compound in *B. plumbea* and *A. bisporus* species. It has been observed that there is a great difference between these compounds of mushroom species. These may be dif-

ferent in the synthesis of the genes responsible for the enzymes involved in the synthesis of fatty acids (31).

Karine et al. examined temperature-related fatty acid composition of *P. ostreatus* collected from Canada in 2007. In this mushrooms of *P. ostreatus* grown at 12, 17, 21 and 27 ^{0}C, changes in SFA, MUFA and PUFA ratios were observed. 18.8-22.9%, 10.1-14.3% and 71-62.8% SFA, MUFA and PUFA respectively were detected. It was determined that SUFA and MUFA ratio gradually increased with temperature and PUFA ratio decreased. This study is significant in terms of explaining the effect of ambient temperature on the changes in the fatty acid composition in this mushroom (32). According to the results of this study, our findings were lower than SFA and MUFA and higher than PUFA. The reason for the difference is thought to be caused by temperature.

Kayode et al. examined the fatty acid composition of *P. ostreatus* collected from Nigeria in 2015. In this study, fatty acid ratios were determined SFA 9.56%, MUFA 49.02% and PUFA 41.43%. PUFA levels are similar to our study. According to our study it was observed that SFA was lower but PUFA was higher than (33). These differences are thought to be caused by climate and environmental factors. On the other hand, Zengin et al. examined the fatty acid levels of *H.lacunosa* collected different from Turkey in 2015. In this study, fatty acid ratios were observed SFA 21.06%, MUFA 41.78 % and PUFA 37.23 % (34). Additionally, Riberio et al. examined the fatty acid profiles of *C.cibarius and B. edulis* collected northeastern of Portugual in 2009 (1). The fatty acid ratios of *C.cibarius, B. edulis* and *H.lacunosa* mushrooms are similar to our same mushrooms results.

Sagia et al. observed the fatty acid composition of *A. bisporus* collected the plains of Punjab, Pakistan in 2008. In this study, unsaturated fatty acid ratio, like our study, was observed to be more dominant in wild edible mushrooms (35).

Abugri et al. observed the fatty acid levels of *Agaricus sp*. And *Lactarius sp.* purchased commercially in the USA in 2016 (36). Oleic acid (C18:1) was no detected in the cultivated species, but in the wild species it detected 20.66 to 37.21 percentage of total fatty acids. This results similar to ours.

The fatty acid levels of the mushroom species in Table 3 can be different from those reported in the literature. These differences can be from different extraction methods, quantification methods, or derivatization of fatty acids.

In previous studies of the same region, it was observed that the fatty acid profile was different in the wild edible mushroom samples (1,2,11,12,20,23,27,28,37).

Rathore 2017, one of his studies, reported that the *Agaricus bisporus* had insulin secretion and anti-aging properties, and *Pleurotus* species also has positive effects on the usage of glucose and HbA_{1C} levels in human body (38).

In another study of the same region, the fatty acid results of the *Lactarius delicious* are similar to ours (39).

Due to its low saturated fatty acid content, fungi are excellent nutrients that can be used in low-calorie diets. For this reason, it can be consumed by humans for low cholesterol levels. Mushrooms are important for human health due to the unsaturated fatty acid variety. Therefore, they can be used as food supplements by the food industry.

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