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Fatty acid composition in some wild edible mushrooms growing in the middle Black Sea region of Turkey

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Abstract

The fatty acids in *Agaricus bisporus*, *Agaricus campestris*, *Boletus edulis*, *Coprinus comatus*, *Pleurotus ostreatus*, *Oudemansiella radicata* and *Armillaria mellea* species were obtained by a Soxtec system extracted with chloroform/methanol (2:1) and derivation of their methyl ester forms. The fatty acids were identified and quantified by gas chromatography. The fatty acid compositions mushrooms were studied using fruit body and stems. Fatty acid composition varied among species. The dominant fatty acid in fruit body and stem of all mushroom species was linoleic acid (18:2). Percentage of linoleic acid in species varied from 13% to 59%. Linoleic acid levels were higher in the stem of *O. radicata* than in the stems of other mushroom species. The other major fatty acids were, respectively, palmitic, oleic, stearic and arachidic acids. Linolenic acid levels were low in all species. Fatty acids analysis of the mushrooms showed that the unsaturated fatty acids were at higher concentrations than saturated fatty acids.

Keywords: Wild edible mushroom; Fatty acid; Turkey

1. Introduction

Structurally, fatty acids which are the straight-chain monounsaturated and polyunsaturated and branched-chain building blocks of dietary fats and oils, have the potential to regulate lipid metabolism at different levels (Wolfrum & Spener, 2000). Linoleic and linolenic acids are two long-chain fatty acids that are fundamental to human diets. They are termed essential fatty acids (EFA). As such, a lack of dietary EFA on their inefficient metabolism has been implicated in the etiology and progression of disease (Brownn, 2005).

Wild edible mushrooms have a worldwide distribution. Wild edible mushrooms are traditionally used by many Asian countries as food and medicine (Manzi, Aguzzi, Vivanti, Paci, & Pizzoferrato, 1999; Sanmee, Dell, Lumyong, Izumori, & Lumyong, 2003). It is known how many mushroom species exist; some investigators estimate that they number tens of thousands. It has been claimed that <10% of mushrooms species are edible; a roughly equal proportion of them is considered to be poisonus (Mossberg, Nilsson, & Person, 1999; Toth, 1995).

Mushrooms are valuable health foods, low in calories, fats, and essentials fatty acids, and high in vegetable proteins, vitamins and minerals. (Agrahar-Murugkar & Subbulakshmi, 2005; Bobek, Ginter, Jurcovicova, & Kuniak, 1991; Breene, 1990; Crisan & Sands, 1978; Kurasawa & Sugahara, 1982; Manzi, Gambelli, Marconi, Vivanti, & Pizzoferrato, 1998; Manzi, Aguzzi, & Pizzoferrato, 2001; Sanmee et al., 2003).

Fruit body of mushrooms is appreciated, not only for texture and flavour but also for its chemical and nutritional properties. Mushrooms have also been reported as therapeutic foods, useful in preventing diseases such as

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hypertension, hypercholesterolemia, atherosclerosis and cancer. These functional characteristics are mainly due to their chemical composition (Crisan & Sands, 1978; Kurasawa & Sugahara, 1982; Manzi et al., 2001). Studies have shown cholesterol-lowering, antitumor, antiviral, antithrombotic and immunomodulating (Mau, Lin, & Chen, 2002) effects of mushrooms. It has been demonstrated that the lowering of serum cholesterol (especially LDL cholesterol) levels can prevent, arrest and even reverse coronary atherosclerosis (Barter & Rye, 1996; Breene, 1990; LaRosa, 1994; Rosenfeld, 1989). In fact, the inclusion of edible mushrooms in a natural hypercholesterolemic and antisclerotic diet has been used in Oriental medicine (Sun, Xiao, Zhang, Liu, & Li, 1984). The hypcholesterolemic effects of a few mushrooms have been studied using rats (Bobek et al., 1991; Cheung, 1996a, 1996b, 1996c; Cheung & Chan, 1995; Cheung & Tsui, 1995; Kaneda & Tokuda, 1966).

Dietary fat, a major constituent of the normal diet, and thus a tight feedback regulator, is necessary to ensure balanced lipid homeostasis. Generally, lipid content of mushroom species is low. It is reported that, in fresh mushrooms belonging to different species, the lipid proportion per 100 g is 1.75–15.5% in dried mushroom since fresh ones contain high amounts of water (Hong et al., 1988; Hiroi & Tsuyuki, 1988). Although the edible wild mushrooms command higher prices than cultivated mushrooms, people prefer to consume them due to their flavour and texture. Wild edible mushrooms are becoming increasingly important in our diet for their nutritional and pharmacological characteristics (Bobek et al., 1991; Breene, 1990; Crisan & Sands, 1978; Manzi et al., 2001). Therefore, it is necessary to investigate the levels of chemical and biochemical compounds in wild edible mushrooms, because many wild edible mushroom species are known to store high levels of several unsaturated fatty acids. Results from several papers, dealing with fatty acid composition in edible mushrooms, show that polyunsaturated fatty acids (PUFA) are of importance. Turkey has a large edible mushroom potential and is becoming an exporter of wild mushrooms (Turkekul, Elmastas, & Tuzen, 2004). People living in this region of Turkey (Tokat) widely consume wild edible mushrooms because of their abundance. Although there are many studies on cultivated and wild edible mushrooms in the northern hemisphere, there is little information available about fatty acid composition of wild edible mushrooms of Turkey.

Our objective was to identify and determine fatty acids in some widely consumed wild edible mushroom spices.

2. Material and methods

Edible fungi grow naturally during the rainy season on dead pieces of wood, buried or on exposed roots of trees at different stages of decay.

The mushroom species used in this study were collected, fresh, from forests and steps in Tokat (in the middle Black sea region of Turkey) province in spring and autumn. The colours, odour, other apparent properties and vegetation of mushroom samples were noted.

For the identification of specimen, the habitat and morphological characteristics of the mushrooms found in the localities were recorded and photographed. The mushroom samples were transported to the laboratory, where samples were stored.

The habitat, edibility and the families of mushrooms used are given in Table 1.

All reagents used for the extractions and derivations were of analytical reagent grade. Mushroom samples were used for fatty acid analysis. Each fresh sample was weighed (100 g) for extraction. Sample extraction was performed using methods described by Folch, Lee, and Sloane-Stanley (1957). The stems and fruit bodies of each mushroom sample were separated, minced in a chloroform/methanol (2:1 v/v) mixture using a high speed blender, and filtered through Whatman paper. Extraction solvent (chloroform/methanol 2:1 v/v) volume was 105 ml for each sample. The fatty acid methyl esters for gas chromatograph analysis were prepared according to Leimer, Rice, and Gherke (1977). Samples were analyzed in triplicate. Extracted samples were methylated in a BF_3–CH_3OH mixture for separation of fatty acids. Briefly, the fatty acids (in the hydrolyzed and derived methyl ester forms) were obtained with 1 ml of NaOH/methanol at 90 °C for 10 min and then a complete derivation was assured with 1 ml BF_3 at 90 °C for 10 min. The methyl esters were purified with 1 ml (2×) of hexane and 1 ml of water. Individual samples were passed through an anhydrous Na_2SO_4 column and then evaporated to dryness under a steam of nitrogen and redissolved in 100 μl of isooctane.

In analysis, the HP-Innowax chromatography column (30 m × 0.32 mm ID × 0.25 μm film thickness) and helium as the carrier gas were used. Clarified and methylated

Table 1
Families, habitat and edibility of mushroom species

Class, family and species of mushrooms	Habitat	Edibility
Agaricus bisporus (Lange) Pilát	On manure heaps, garden waste and roadsides	Edible
Agaricus campestris L. ex. Fr.	On soil among grass in field	Edible
Pleurotus ostreatus (Jacp. ex Fr.) Kummer	Often in large clusters on stumps and fallen or standing trunks, usually of deciduous trees	Edible
Armillaria mellea (Vahl. Ex Fr.) Kummer	In dense clusters on or around trunks or stumps of deciduous and coniferous trees	Edible
Coprinus comatus (Müler. ex.Fr) S.F.Gray	Under *Salix* sp. in gardens	Edible
Oudomensiella radicata (Rehl ex. Fr) Sing	Under or near deciduous trees, especially beec, attched to roots or buried wood	Edible
Boletus edulis Bull. ex. Fr.	In mixed woods	Edible

samples were run on a GC column containing polyethyleneglycol chromatography medium. The identification and quantitation of fatty acids were performed by gas chromatography using an Agilent 6890 series GC system and Agilent 5973 N Mass selective detectors. Identifications of the peaks were carried out through a Wiley library databank search. Relative percentages of the fatty acids detected, along with SEM values, were established from total ion chromatograms by the computerized integrator. The column temperature was held 50 °C for 1 min, then with the first temperature gradient of 8 °C/min to 220 °C for 5 min, the second temperature(finally) gradient was 2 °C/min to 250 °C and held for 7.75 min. Injector temperature was 250 °C. In analysis, GC gas flow rate was 1.3 ml/min and injection volume was 1 μl.

3. Results and discussion

The fatty acid compositions of the wild edible mushrooms analyzed are shown in Figs. 1–7.

The compositions of the most abundant fatty acids of the wild edible mushrooms studied are shown in Table 2.

In the present work, fatty acid compositions of stems and fruit bodies of seven edible mushroom species: *Agaricus bisporus*, *Agaricus campestris*, *Coprinus comatus*, *Boletus edulis*, *Pleurotus ostreatus*, *Oudemansiella radicata* and *Armilleria mellea*, were investigated. The fatty acid compositions were different among all species. Unsaturated fatty acid levels were higher than saturated. The carbon chain lengths of fatty acids were from 8 to 24. Linoleic acid was the major fatty acid detected in all species. In addition to linoleic acid, palmitic acid, oleic acid, stearic acid and arachidic acids were the other abundant fatty acids in the mushrooms. These four fatty acids were present in all of the mushrooms examined. Similar observations have been made in other mushrooms (Longvah & Deosthale, 1999; Senatore, Dini, & Marino, 1988, 1990).

The lipid extracted from *A. bisporus* consists to a high degree of unsaturated acids and the main constituent fatty acid was linoleic acid (Mau, Beelman, Ziegler, & Royse, 1991; Prostenik et al., 1983; Weete, Furter, & Hander, 1985). Other fatty acids were also detected but were generally less than 7% of the total fatty acid content.

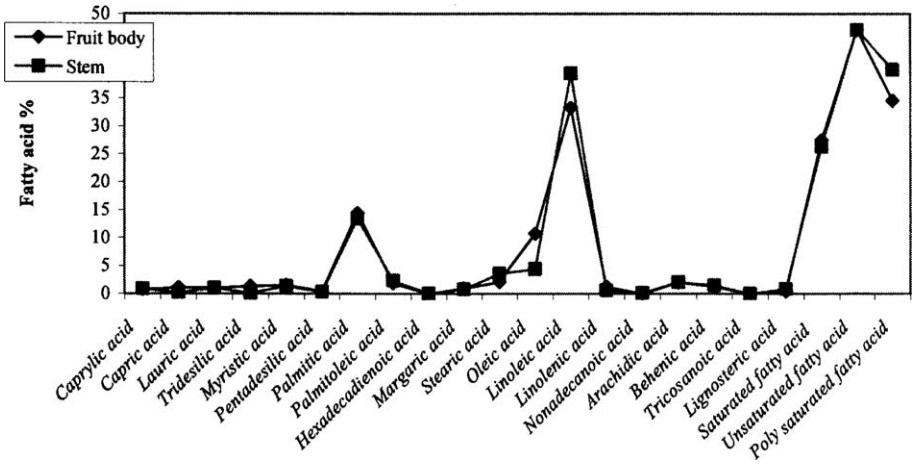

Fig. 1. The fatty acid composition of *Agaricus bisporus*.

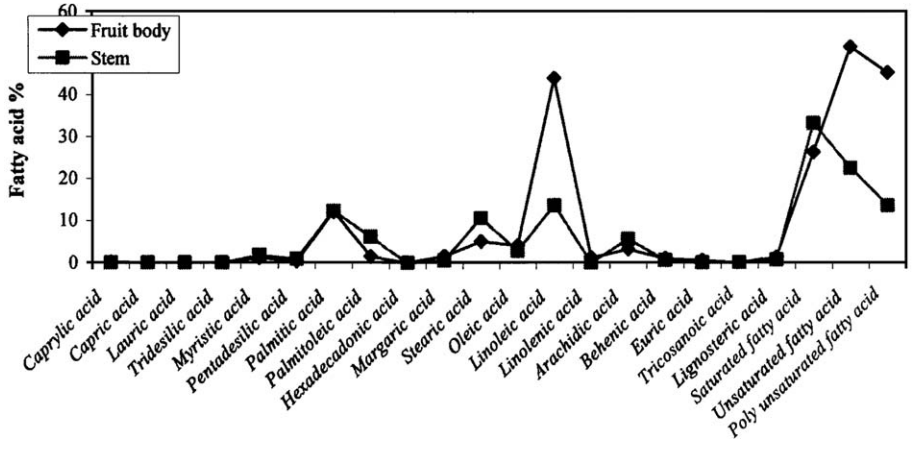

Fig. 2. The fatty acid composition of *Agaricus campestris*.

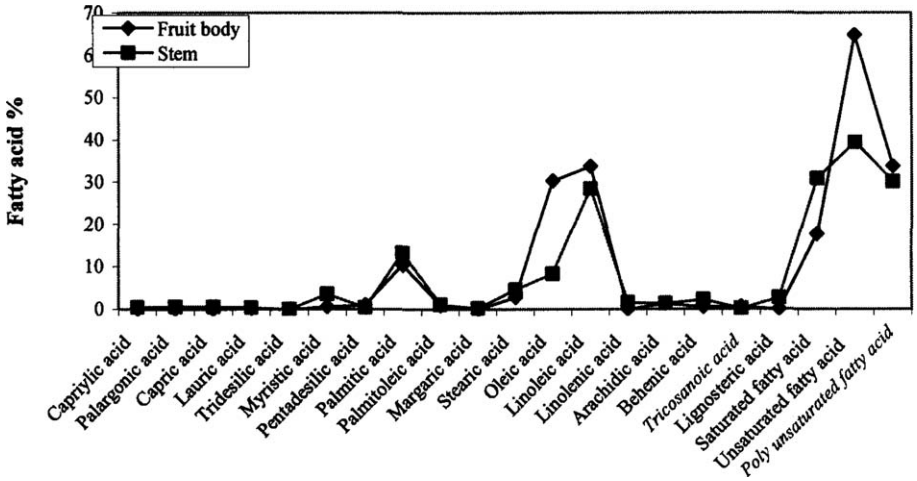

Fig. 3. The fatty acid composition of *Boletus edulis*.

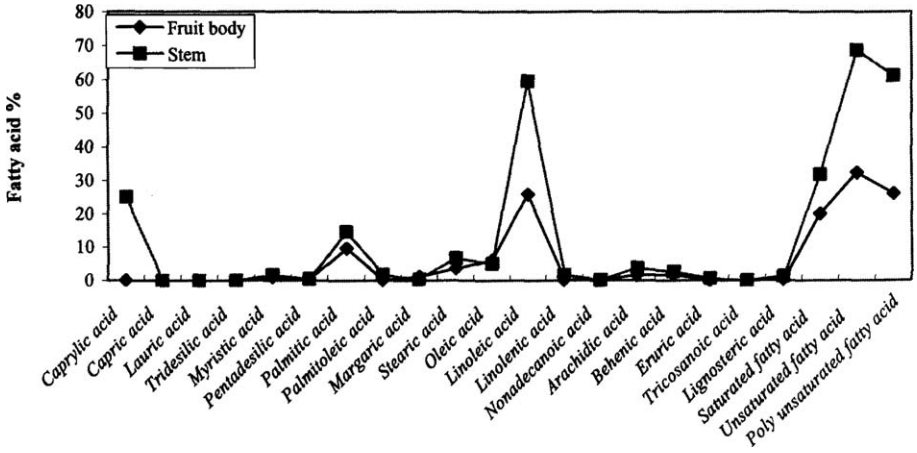

Fig. 4. The fatty acid composition of *Coprinus comatus*.

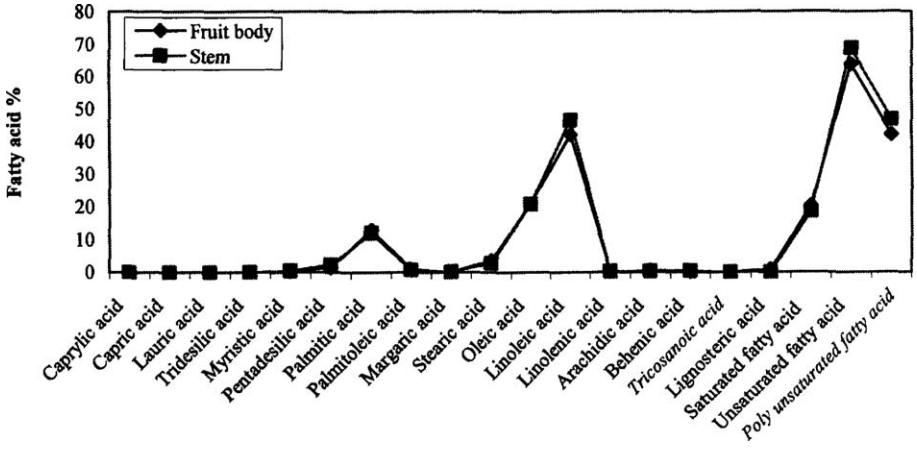

Fig. 5. The fatty acid composition of *Pleurotus ostreatus*.

Myristic acid (14:0) content was greater than that of linolenic acid in seven species. Palmitic acid levels in stems of *A. bisporus*, *A. campestris*, *C. comatus*, *B. edulis* and in stems and fruit bodies of *O. radicata*, *A. mellea* were greater than oleic, stearic and arachidic acids. Sepcic et al. (2003) have detected very low amounts of myristic, palmitic and stearic acids in *P. ostreatus*. Tridesilic acid (13:0), pentadesilic acid (15:0), margaric acid (17:0), tricosanoic acid (23:0) are members of the odd carbon fatty acid series. Tridecilic acid was found only

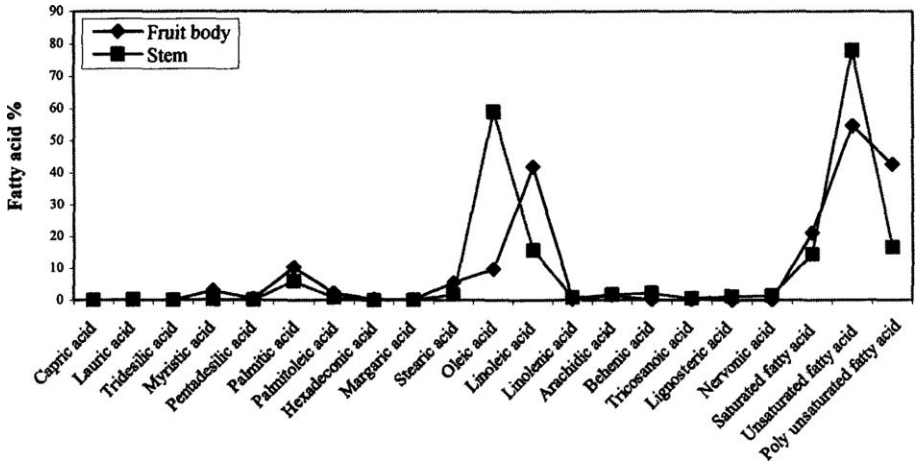

Fig. 6. The fatty acid composition of *Oudemensiella radicata*.

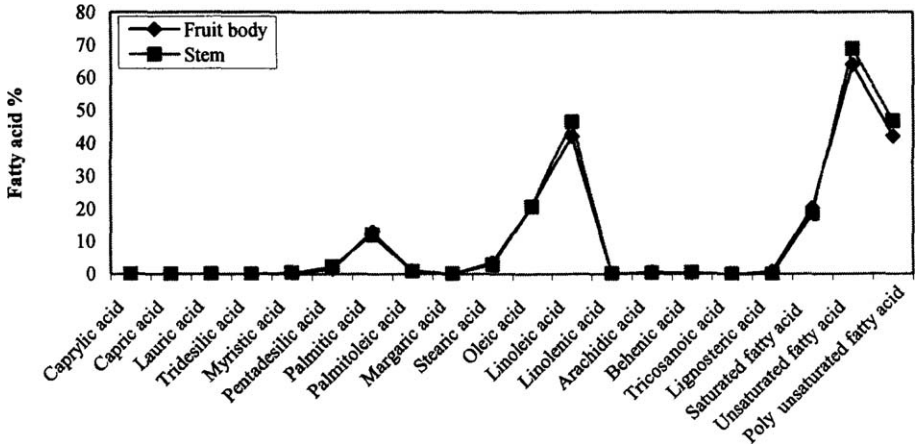

Fig. 7. The fatty acid composition of *Armillaria mellea*.

Table 2
The concentrations of saturated, monounsaturated and polyunsaturated fatty acids in mushrooms studied (as percentages)

Mushroom species	Saturated fatty acids (SFA)		Monounsaturated fatty acids (MUFA)		Polyunsaturated fatty acids (PUFA)	
	Fruit body	Stem	Fruit body	Stem	Fruit body	Stem
Agaricus bisporus	27.6	26.3	47.2	47.2	34.5	40.1
Agaricus campestris	26.4	33.3	51.6	22.6	45.4	13.6
Boletus edulis	17.7	30.8	64.7	39.4	33.6	30.0
Coprinus comatus	20.0	31.8	32.3	68.63	26.0	61.8
Pleurotus ostreatus	20.2	18.5	63.9	68.3	42.1	46.8
Oudemansiella radicata	21.2	14.6	54.7	78.0	42.7	16.7
Armillaria mellea	20.6	18.5	56.1	33.6	50.6	25.6

in *A. bisporus*. Pentadecilic acid was present, but in low amounts, in all species. No margaric acid occurred in fruit body of *B. edulis* on stem of *O. radicata*. Tricosanoic acid was detected in *B. edulis*, and in fruit body of *O. radicata*.

Surprisingly, the amount of linolenic acid (18:3) was between 0.121% and 1.64% in the species and very low as compared to other fatty acids. Moreover, linolenic acid (18:3) was not found in the stems of *A. campestris* or *A. mellea*, or in the fruit body of *B. edulis*.

All the mushrooms analyzed contained large quantities of essential fatty acids. Essential fatty acids common to all species included the 18:1 and 18:2. Linoleic acid (18:2) was obtained in high amounts in both parts of *P. ostreatus* (42.0%, 46.6%). Linoleic acid occurred in large amounts in the stem of *C. comatus* (59.5%) and fruit body of *A. mellea* (49.6%) compared to other fatty acids. The stem of *A. campestris* contained less linoleic acid (18:2) than did other mushrooms (13%). The percentages of oleic acid in the stem of *O. radicata*, *B. edulis* and in fruit body of

Table 3
The compositions of the most abundant fatty acids in mushrooms (as percentages)

	Palmitoleic acid	Palmitic acid	Stearic acid	Oleic acid	Linoleic acid	Arachidic acid
Agaricus bisporus						
Fruit body	14.4	1.93	2.11	10.7	33.3	2.05
Stem	13.4	2.3	3.5	4.74	39.4	2.06
Agaricus campestris						
Fruit body	12.1	1.47	5.12	4.17	44.0	3.23
Stem	12.2	6.09	10.6	2.84	13.6	5.64
Boletus edulis						
Fruit body	10.3	0.942	2.88	30.2	33.6	1.37
Stem	13.2	1.08	4.6	8.3	28.4	1.40
Coprinus comatus						
Fruit body	9.63	0.199	3.46	6.17	25.8	1.66
Stem	14.6	1.77	6.6	5.07	59.5	3.69
Pleurotus ostreatus						
Fruit body	12.90	0.961	3.58	20.80	42.0	0.452
Stem	12.0	0.828	5.80	20.7	46.6	0.292
Oudemansiella radicata						
Fruit body	10.3	2.22	5.60	9.79	41.9	1.57
Stem	6.06	0.834	1.89	59.0	15.8	1.76
Armillaria mellea						
Fruit body	10.9	1.04	4.05	4.55	49.6	3.01
Stem	7.08	1.25	2.23	6.72	2.56	2.92

P. ostreatus were 59.0%, 30.29% and 20.8%, respectively. The lowest level of oleic acid was in the stem of *A. campestris* (2.84%). Linoleic and linolenic acids were detected in ppm level with NMR by Bonzom, Nicolaou, Zloh, Baldeo, and Gibbons (1999) in *A. bisporus*. Linoleic acid/oleic acid ratio could constitute and important parameter from a chemotaxonomic viewpoint and could be useful for the taxonomical differentiation between species of the same genus (Diez & Alvarez, 2001). Erucic acid was determined only in the stem of *A. campestris*, and in fruit body of *C. comatus*. Fatty acids with more than twenty carbons were not detected in some species.

Concentrations of polyunsaturated, unsaturated and saturated fatty acids in the mushrooms samples were determined (Table 3). Fatty acid analysis of the mushrooms showed that the unsaturated fatty acids higher than the saturated (Table 3). The highest (61.8%) and the lowest (13%) levels in polyunsaturated fatty acids occurred in the stems of *C. comatus* and *A. campestris*, respectively. High levels of mono and polyunsaturated fatty acids were found in both parts of *P. ostreatus*. The percentages of monounsaturated fatty acids in the stem of *O. radicata*, *C. comatus* and *P. ostreatus* were 78.0%, 68.6% and 68.3%, respectively. This agrees with the observations that, unsaturated fatty acids predominate over saturated in mushrooms (Beuchat, Brenneman, & Dove, 1993; Senatore et al., 1988).

The concentration of unsaturated fatty acids in these mushrooms is very important from a nutritional standpoint. As shown in Table 3, percentages of saturated fatty acids in stems of *A. bisporus*, *A. campestris*, *C. comatus* and *B. edulis* were higher than in stems of the other species.

Unsaturated fatty acid-rich olive oils and polyunsaturated fatty acid-rich sunflower oils, corn oils and soy bean oils are considered as healthy oils for nutrition. Oils with high linoleic and oleic acid levels are very important for human health. These oils reduce atherosclerosis by interacting with HDL in the blood.

All of the species of mushrooms included in this study had disparate overall fatty acid compositions but could be differentiated from one another on the basis of individual fatty acid contents and relative amounts. In general, approximately 80% of fatty acids were the same in all species. In addition, results indicated that mushrooms were rich in polyunsaturated fatty acids, especially 18:2. It is known that low calorie and low fat diets are recommended for people with high blood cholesterol. In addition to their low calories and low fat, mushrooms are rich in essential fatty acids and therefore should be contained in the diet.

4. Conclusion

Edible mushrooms can be regarded as healthy foods-poor in fat. Low-calorie and low-fat diets are recommended for people with high blood cholesterol. Therefore mushrooms are perfect, because of their low calories, low-fat composition and high essential fatty acid levels. Most of the studies on mushroom fatty acids are limited to certain mushroom species. However, the present results indicate that economically important and edible mushrooms contain significant amounts of valuable fatty acids. Therefore, studies should be performed on fatty acid contents of other economically important and edible mushrooms.

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