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Fat and fatty acids of Indian edible mushrooms

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Abstract

Twenty-three species of naturally grown and collected mushroom fruiting bodies, from different geographic locations of India, were analysed for their total fat and fatty acid contents. On a dry weight basis, the mushroom species were found to contain 0.6–4.7% total fat. The mushroom species were high in unsaturated fatty acids (52–87%), compared to saturated fatty acids. Oleic acid was the major monounsaturated fatty acid in all the species studied, while linoleic acid was the major polyunsaturated fatty acid. Linolenic acid was in significant quantity in *Hydnum repandum* and *Macrolepiota procera*. Linoleic:oleic acid ratios of the mushroom species varied considerably (0.48–10.58).

Keywords: Edible mushrooms; Wild mushrooms; Lipids; Fatty acid composition; Linoleic acid; India

1. Introduction

The constituents of lipids in the cultivated mushroom *Agaricus bisporus* have been investigated quite extensively (Weete, 1980). The acids include C_{12}–C_{20} even-numbered fatty acids (Holtz & Schisler, 1971; Prostenik et al., 1978; Weete, Furthe, Haenseler, & Rast, 1985) and C_{16}–C_{24} hydroxy fatty acids (Prostenik et al., 1978), with oleic, linoleic, and palmitic acids predominating. These acids may exist in their free form or be conjugated to other lipid constituents. Byrne and Brennan (1975) have reported on levels of palmitic, stearic and oleic acids in the free form, and Stancher, Procida, and Calabrese (1992) expanded the observed range of free and bound fatty acids to include C_8 and C_{13}–C_{17} odd-numbered acids. A preliminary study was reported by Hugues (1962), who identified 10 fatty acids, among which, linoleic acid (18:2) varied from 63% to 74% with strain. The chief unsaturated fatty acid of mushroom lipids, linoleic acid, is the precursor of the mushroom alcohol (1-octen-3-ol) (Grosch & Wurzenberger, 1984; Mau, Beelman, & Ziegler, 1992 Tressl, Bahri, & Engel,1982; Tressl et al., 1982; Wurzenberger & Grosch, 1982). This alcohol, together with the two associated C_8 ketones (1-octen-3-one, 3-octanone), constitute the main volatiles and are considered the major contributors to the characteristic mushroom flavour (Cronin & Ward, 1971; Maga, 1981; Pyysalo, 1976).

In most countries, there is a well-established consumer acceptance for cultivated mushrooms (*Agaricus bisporus*, *Pleurotus* spp., *Lentinus edodes*, *Volvariella volvacea*, *Auricularia* spp., etc.). However, wild edible mushrooms have been traditionally eaten by specific groups of people (local people, enthusiasts and gourmets) and seasonally. Nevertheless, wild mushrooms are becoming more and more important in our diet for their nutritional (Breene, 1990; Coli, Maurizi, Granetti, & Damiani, 1988; Crisan & Sands, 1978), organoleptic (Maga, 1981) and pharmacological (Bobek, Ginter, Jurcovicova, & Kunia, 1991) characteristics. Several studies have been carried out on the chemical composition and nutritional qualities of different species of wild mushrooms (Aletor, 1985; Alofe, Odeyemi, & Oke, 1996; Coli et al., 1988; Gonzalez, Trevino, & Garcia,

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1971; Senatore, 1992; Senatore, Dini, & Marino, 1988; Senatore, Dini, Cerri, & Schetino, 1987). Wild edible mushrooms are traditionally used by many Asian countries as food and medicine (Manzi, Aguzzi, Vivanti, Paci, & Pizzoferato, 1999; Sanmee, Dell, Lumyong, Izumori, & Lamyong, 2003; Vetter, 1993).

Twenty-three species of edible fruiting bodies of naturally grown mushrooms from four geographic regions of India were collected and dried. Detailed analysis of fat and fatty acids of these species was performed and the results should serve as a useful database for any taxonomic/nutritional/nutraceutical evaluation of these species.

2. Materials and methods

2.1. Mushroom Samples

Edible fruiting bodies of 23 species of mushrooms collected from forest areas of Shimla in Himachal Pradesh, Jabalpur in Madhya Pradesh, Udaipur in Rajasthan and Thiruvananthapuram in Western Ghats (Table 1), were used for the study. The air-dried mushrooms received from these locations were further dried at room temperature using desiccants. The dried mushroom samples were powdered to ~1 mm particle size and used for analysis.

Table 1
Geographical location, natural habitat and fat content of the mushroom species studied

Mushroom species	Natural habitat	Geographic location	Fat (% dry wt.)[a]
Auricularia polytricha (Mont.) Sacc.	Saprophytic (dead branches of *Ficus benghalensis*)	Forests of Himachal Pradesh	2.6[a]
Boletus edulis Bull. Fr.	Saprophytic (on ground in open forests)	Forests of Himachal Pradesh	3.3
Cantharellus cibarius Fr.	Saprophytic	Forests of Himachal Pradesh	2.3
Cantharellus clavatus Fr.	Saprophytic (on the ground under *Picea smithiana*)	Forests of Madhya Pradesh	4.0
Geastrum arinarius Lloyd.	Saprophytic	Forests of Madhya Pradesh	4.1
Helvella crispa Scop. Fr.	Saprophytic (under the shade of trees, damp places in pine forests)	Forests of Himachal Pradesh	3.1
Hyd Hydnum repandum	Saprophytic	Forests of Himachal Pradesh	4.7
Lactarius deliciosus(L.ex Fr.) S.F.Gray	Saprophytic (Coniferous wood land especially pine)	Forests of Himachal Pradesh	4.1
Lactarius sanguifluus Peck.	Saprophytic (Coniferous wood land especially pine)	Forests of Himachal Pradesh	2.7
Lentinus sajor-caju (Fr.).	Saprophytic (decaying plants of *Euphorbia royleana*)	Forests of Kerala	0.6
Lentinus squarrulosus Mont.	Saprophytic	Forests of Kerala	1.4
Macrolepiota procera (Scop.ex Fr.) Sing.	Saprophytic (on soil, pastures, lawns, in woods)	Forests of Madhya Pradesh	2.9
Morchella angusticeps PK.	Saprophytic	Forests of Himachal Pradesh	2.6
Morchella conica Pers.	Saprophytic (on sandy loam rich in organic substances in deodar forest)	Forests of Himachal Pradesh	2.6
Pleurotus djamor Sacc.	Saprophytic (dead trunks of living trees)	Forests of Kerala	0.5
Pleurotus sajor-caju (Fr.) Singer	Saprophytic (on dead trunks)	Forests of Kerala	0.8
Russula brevepis Peck	Saprophytic (under *Picea smithiana and Pinus wallichiania*)	Forests of Himachal Pradesh	2.4
Sparassis crispa Wulf. Fr.	Saprophytic	Forests of Himachal Pradesh	2.1
Termitomyces heimii Natarajan	Symbiotic (in association with termite nests)	Forests of Himachal Pradesh	1.9
Termitomyces microcarpus (Berk. & Br.) Heim.	Symbiotic (in association with termite nests)	Forests of Kerala	2.3
Termitomyces mummiformis Heim.	Symbiotic (in association with termite nests)	Forests of Himachal Pradesh	3.3
Termitomyces shimperi Heim	Symbiotic (in association with termite nests)	Forests of Himachal Pradesh	2.1
Termitomyces tylerance Heim	Symbiotic (in association with termite nests)	Forests of Himachal Pradesh	2.2

[a] Each value is the mean of three replicate determinations.

2.2. Chemicals

All the solvents and chemicals used were of analytical grade.

2.3. Determination of water and fat contents

The water content was determined by weighing, after drying, 10 g of the sample in an oven at 103 ± 2 °C, according to AOCS method (1998). Fat was extracted in a Soxhlet apparatus using petroleum ether. Determinations were carried out in triplicate.

2.4. Transesterification of fatty acids

Fatty acid methyl esters (FAME) were prepared by boron trifluoride-catalysed transesterification, according to AOCS method (1998). Methyl heptadecanoate was used as the internal standard.

2.5. Gas chromatography

FAMEs were analysed on a Fisons 8000 series gas chromatograph (M/S.Fison Co., Italy), equipped with a hydrogen flame ionisation detector (FID). Separation was performed using a fused silica capillary column (100 m × 0.25 mm i.d.), coated with 0.20 μm SP2560 (Supelco Inc., Bellefonte, PA) as the stationary phase. The oven temperature was programmed at 140 °C for 5 min, and then ranged from 140 °C to 240 °C at a rate of 4 °C per min. The injector and FID were at 260 °C. A reference standard quantitative FAMEs mix (Supelco Inc.) was analysed under the same operating conditions to determine the peak response factor, for identification and quantification.

3. Results and discussion

The present investigation measured fatty acids in different mushroom species located in different geographic regions of India (Table 1). The total fat content varied from 0.5% in *P. djamor* to 4.7% in *L. deliciosus*. The distribution of fatty acids varied across different genera and also amongst different species of the same genus. All species were characterised by high concentrations of unsaturated fatty acids amounting to 52–87% of the total fatty acid content. It is an interesting observation that odd carbon-number fatty acids such as pentadecanoic acid were observed in *P. sajor-caju*, *T. microcarpus* and *T. tylerance*, and in traces in *C. cibarius*, *C. clavatus*, *H. repandum*, *L. deliciosus* and *L. sanguifluus*, *P. djamor*, *T. mummiformis* and *T. shimperi*. Similarly heptadecanoic acid was noticed in *L. deliciosus*, *L. sanguifluus* and in traces in *H. crispa*, *H. repandum*, *L squarrulosus*, *R. brevepis*, *S. crispa* and *T. tylerance* (Table 2). This observation is similar to the report of Stancher et al. (1992).

Table 2a
Fatty acid composition (% total fatty acid methyl esters) of uncultivated edible mushroom species

Fatty acids	*Auricularia polytricha*	*Boletus edulis*	*Cantharells cibarius*	*Cantharellus clavatus*	*Geastrum arinarius*	*Helvella crispa*	*Hydnum repandum*
<C14:0	12.6[a]	1.7	6.6	7.9	Nd[b]	Nd	5.3
C14:0	0.8	Nd	8.0	7.2	Nd	Nd	1.6
C15:0	Nd	Nd	0.1	0.4	Nd	Nd	0.8
C16:0	11.2	21.6	18.3	24.7	19.9	10.6	15.7
C17:0	Nd	Nd	Nd	Nd	Nd	0.7	0.3
C18:0	10.2	9.1	6.0	8.1	8.3	Nd	0.9
C20:0	1.0	Nd	Nd	Nd	2.9	0.4	Nd
C22:0	2.0	1.0	Nd	Nd	0.4	0.1	Nd
C24:0	2.0	Nd	Nd	Nd	2.2	1.0	Nd
Total saturated	39.8	33.4	39.0	48.3	33.7	12.8	24.6
C14:1	Nd	Nd	8.3	5.0	Nd	Nd	0.5
C16:1	Nd	Nd	Nd	Nd	0.5	Nd	0.7
C18:1 cis-9	27.1	31.1	35.4	25.9	55.1	22.7	26.4
C18:1 isomer	Nd	Nd	Nd	Nd	1.2	0.4	0.3
C20:1 cis-11	Nd	Nd	Nd	Nd	3.0	1.1	Nd
Total monounsaturated	27.1	31.1	43.7	30.9	59.8	24.2	27.9
C18:2	29.5	33.8	17.3	20.8	5.4	62.7	27.2
C18:3	3.6	1.7	Nd	Nd	1.1	0.3	20.3
Total polyunsaturated	33.1	35.5	17.3	20.8	6.5	63.0	47.5
UFA:SFA ratio	1.51	1.99	1.56	1.07	1.96	6.81	3.06
Linoleic:oleic ratio	1.08	1.08	0.48	0.80	0.09	2.76	1.03

[a] Each value is the mean of three replicate determinations.
[b] Not detected.

Table 2b
Fatty acid composition (% total fatty acid methyl esters) of uncultivated edible mushroom species

Fatty acids	*Lentinus sajor-caju*	*Lentinus squarrulosus*	*Lactarius deliciosus*	*Lactarius sanguifluus*	*Macrolepiota procera*	*Morchella angusticeps*
<C14:0	2.3[a]	0.5	1.7	1.0	7.2	2.2
C14:0	2.0	1.0	2.0	0.3	2.8	1.3
C15:0	Nd[b]	Nd	0.9	0.3	Nd	Nd
C16:0	15.4	16.6	16.3	23.1	4.6	8.3
C17:0	Nd	0.7	1.5	1.6	Nd	Nd
C18:0	Nd	1.4	6.1	4.9	Nd	6.0
C20:0	Nd	0.8	Nd	Nd	5.6	0.7
C22:0	0.2	4.9	Nd	Nd	Nd	1.1
C24:0	0.1	4.7	Nd	Nd	Nd	2.5
Total saturated	20.0	30.6	28.5	31.2	20.2	22.1
C14:1	Nd	Nd	0.5	0.2	Nd	Nd
C16:1	0.1	0.5	0.9	1.1	Nd	0.8
C18:1 cis-9	23.5	5.8	33.0	32.4	17.2	10.7
C18:1 isomer	Nd	Nd	Nd	Nd	Nd	Nd
C20:1 cis-11	1.5	0.5	Nd	Nd	Nd	1.6
Total monounsaturated	25.1	6.8	34.4	33.7	17.2	13.1
C18:2	54.9	61.4	37.1	35.1	47.0	64.6
C18:3	Nd	1.2	Nd	Nd	15.6	0.2
Total polyunsaturated	54.9	62.6	37.1	35.1	62.6	64.8
UFA:SFA ratio	4.00	2.26	2.50	2.20	3.95	3.52
Linoleic:oleic ratio	2.33	10.58	1.12	1.08	2.73	6.03

[a] Each value is the mean of three replicate determinations.
[b] Not detected.

Table 2c
Fatty acid composition (% total fatty acid methyl esters) of uncultivated edible mushroom species

Fatty acids	*Morchella conica*	*Pleurotus djamor*	*Pleurotus sajor-caju*	*Russula brevepis*	*Sparassis crispa*
<C14:0	1.4[a]	4.5	3.9	6.1	2.6
C14:0	Nd[b]	1.6	0.6	2.3	2.0
C15:0	Nd	0.4	1.5	Nd	Nd
C16:0	8.5	15.8	13.9	8.0	10.4
C17:0	Nd	Nd	Nd	0.8	0.4
C18:0	5.4	Nd	3.4	4.5	1.7
C20:0	0.6	0.2	0.6	Nd	Nd
C22:0	0.7	1.4	1.3	Nd	1.3
C24:0	1.9	1.2	1.9	Nd	0.6
Total saturated	18.5	25.1	27.1	21.7	19.0
C14:1	Nd	Nd	Nd	2.8	Nd
C16:1	1.4	Nd	Nd	2.4	0.2
C18:1 cis-9	11.3	28.8	16.4	39.2	49.0
C18:1 isom.	Nd	Nd	Nd	Nd	0.5
C20:1 cis-11	0.2	0.6	2.7	Nd	Nd
Total monounsaturated	12.9	29.4	19.1	44.4	49.7
C18:2	68.6	45.5	53.8	33.9	31.3
C18:3	Nd	Nd	Nd	Nd	Nd
Total polyunsaturated	68.6	45.5	53.8	33.9	31.3
UFA:SFA ratio	4.40	2.98	2.69	3.60	4.26
Linoleic:oleic ratio	6.07	1.57	3.28	0.86	0.63

[a] Each value is the mean of three replicate determinations.
[b] Not detected.

Amongst the mono-unsaturated fatty acids, oleic acid predominated in all the species studied. Myristoleic acid was present in considerable quantities in *C. cibarius*, *C. clavatus*, *R. brevepis* and in trace amounts in *H. repandum*, *L. deliciosus*, and *L. sanguifluus*, whereas, in other species it was not detected. Similarly palmitoleic acid

Table 2d
Fatty acid composition (% total fatty acid methyl esters) of uncultivated edible mushroom species

Fatty acids	*Termitomyces heimii*	*Termitomyces mummiformis*	*Termitomyces microcarpus*	*Termitomyces shimperi*	*Termitomyces tylerance*
<C14:0	5.4[a]	0.3	Nd[b]	8.2	8.5
C14:0	0.6	0.2	1.8	5.0	1.8
C15:0	Nd	0.3	1.9	0.8	1.1
C16:0	19.7	16.0	21.8	14.6	20.4
C17:0	Nd	Nd	Nd	Nd	0.8
C18:0	4.8	4.9	7.7	10.4	5.0
C20:0	Nd	0.1	Nd	Nd	Nd
C22:0	2.0	0.2	Nd	Nd	Nd
C24:0	3.4	0.2	Nd	Nd	Nd
Total saturated	35.9	22.2	33.2	39	37.6
C14:1	Nd	Nd	Nd	Nd	Nd
C16:1	Nd	0.1	0.5	0.6	1.1
C18:1 cis-9	28.1	18.2	34.2	25.7	33.8
C18:1 isomer	Nd	1.3	0.2	0.2	0.8
C20:1 cis-11	0.8	0.2	Nd	Nd	Nd
Total monounsaturated	28.9	19.8	34.9	26.5	35.7
C18:2	35.2	58.0	31.9	34.5	26.7
C18:3	Nd	Nd	Nd	Nd	Nd
Total polyunsaturated	35.2	58.0	31.9	34.5	26.7
UFA:SFA ratio	1.78	3.50	2.01	1.56	1.65
Linoleic:oleic ratio	1.25	3.18	0.93	1.34	0.78

[a] Each value is the mean of three replicate determinations.
[b] Not detected.

was present in significant quantities in *M. conica*, *L. sanguifluus*, *R. brevepis* and in trace amounts in *G. arinarius*, *H. repandum*, *L. sajor-caju*, *L. squarrulosus*, *L. deliciosus*, *M. angusticeps*, *S. crispa* and Termitomyces species (except *T. tylerance*).

Amongst the polyunsaturated fatty acids, linoleic acid was the major acid predominant in most of the species studied, but was at low levels in *G. arinarius*. Linolenic acid was present in significant quantities in *H. repandum*, *M. procera*, and in trace amounts in *A. polytricha*, *B. edulis*, *G. arinarius*, *H. crispa* and *L. squarrulosus*, whilst it was not detected in other species. The linoleic:oleic acid ratio could provide an important criterion from a chemo-taxonomic viewpoint and could be useful for the taxonomical differentiation between species of the same genus. The linoleic:oleic acid ratios depicted in Table 2 are comparable with literature values (Diez & Alvarez, 2001). The linoleic:oleic acid ratios were below 1 for *C. cibarius*, *C. clavatus*, *G. arinarius*, *R. brevepis*, *S. crispa*, *T. microcarpus*, *T. tylerance* and the highest value of 10.6 was observed for *L. squarrulosus*. Palmitic and stearic acids were the prominent saturated fatty acids. However, stearic was not detected in *H. crispa*, *L. sajor-caju*, *M. procera*, *P. djamor* and was at very low concentrations in *H. repandum* and *L. squarrulosus*.

Senatore et al. (1988) observed in 11 species of mushrooms, high levels of unsaturated fatty acids, linoleic acid being predominant. Hiroi and Tsuyuki (1988) showed that in 20 species of edible mushrooms, lipid content varied from 3.2% to 15.5% in caps on a dry weight basis; based on the fatty acid composition, the species were classified into five groups. *P cystidiosus* was reported to contain 48% and 25% of linoleic and oleic acids, respectively; saturated fatty acids accounted for ~27% (Takenaga, Tanaka, Itoh, & Tsuyuki, 1988a). In *A. polytricha*, a wood inhabitant, linoleic and oleic acid were found at 54% and 26%, respectively; total saturated fatty acids were ~20% (Takenaga, Tanaka, Itoh, & Tsuyuki, 1988b). Linoleic and palmitic acids were the predominant fatty acids of both glycolipids and phospholipids in *P. florida* (Kwon & Uhm, 1984). Oleic acid was the predominant unsaturated fatty acids in *P. ostereatus* (Solomko, Panchenko, & Silchenkova, 1984). *Hirneola auricula* contained 34% linoleic, 16% palmitic 5% stearic, 16% oleic and 11% unsaturated fatty acid; whilst *Gyrophora esculenta* comprised 47% linoleic, 32% palmitic, 17% oleic and 15% unknown acids (Nam & Ko, 1980). Sixteen species of wild edible mushrooms found in Poland contained 66–82% linoleic acid and 10–20% palmitic acid; whereas, lauric, myristic, stearic, arachidic, oleic, palmitic and linoleic acids were in smaller fractions (Szymczak, 1978).

Thus, the studied mushroom species resemble many of the species analysed and reported in the literature. The studied wild edible mushroom species can be regarded as health foods i.e., low in fat. In addition, the high content of polyunsaturated fatty acids, particularly the essential fatty acid linoleic, contribute to the recommendations of mushrooms in the diets of people with high blood cholesterol.

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