

Total, Soluble, and Insoluble Dietary Fibre Contents of Wild Growing Edible Mushrooms

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Abstract

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Mushrooms have been long valued as tasty and nutritional foods for human beings and assumed to contain beneficial fibres, so the objective of this study was to analyse 20 species of wild growing edible mushrooms for their total dietary fibre (TDF), insoluble dietary fibre (IDF), and soluble dietary fibre (SDF) contents. The TDF, IDF, and SDF contents ranged between 24–37, 12–21, and 2–4 g/100 g dry weight, respectively. The SDF as % of TDF was low in *Phellinus florida* (5.5%) and *Phellinus rimosus* (5.8%), and high in *Sparassis crispa*, *Lentinus squarrulosus*, and *Lactarius sanguifluus* (12.5%). Interestingly, the majority of the mushrooms had 10–11% of TDF as SDF. The TDF was high in *Pleurotus djamor* (37%) *Cantharellus cibarius*, *Cantharellus clavatus*, and *Phellinus florida* (36%), and low in *Lactarius sanguifluus* (24%). Also, the majority of mushrooms had average 31.6% TDF and 2.85% SDF. These results indicate that mushrooms such as *Sparassis crispa*, *Lentinus squarrulosus*, *Lentinus delicious*, and *Cantharellus clavatus* are rich sources of TDF and SDF.

Keywords: mushroom; fibers; food; composition

Mushrooms have long been valued as tasty and nutritional foods by many societies throughout the world and appreciated for their flavour and texture as vegetables (BARROS *et al.* 2008; FERREIRA *et al.* 2009). Mushrooms provide a wealth of protein, fibre, vitamins, and minerals. On average, dried mushrooms contain ~22% protein, which includes most of the essential amino acids, ~5% fat, mostly in the form of linoleic acid (the essential fatty acid not synthesised in the human body), ~63% carbohydrates including fibre, and ~10% minerals as ash, and they are a good source of several vitamins including thiamine, riboflavin, niacin, and biotin (MATTILA *et al.* 2000). Mushrooms probably contain every mineral present in their growth substrate including substantial quantities of potassium, lesser amounts of calcium and iron. Mushrooms appear to be an excellent source of vitamins, especially thiamine (B₁),

riboflavin (B₂), niacin, biotin, and ascorbic acid (vitamin C). Mushrooms contain all the main classes of the lipid compounds including free fatty acids, mono-, di-, and triglycerides, sterols, sterol esters, and phospholipids (MALLAVADHANI *et al.* 2006). Mushrooms have been also shown to accumulate a variety of secondary metabolites including phenolic compounds, polypeptides, terpenes, steroids, etc. Mushroom phenolics have been found to be the excellent antioxidants (LI *et al.* 2005). The consumption of wild edible mushrooms is increasing due favourable contents of proteins and trace minerals. Mushrooms are valuable healthy foods, low in calories, fats, and high in proteins, vitamins and minerals (AGRAHAR-MURUGKAR & SUBBULAKSHMI 2005). The mineral concentrations in mushrooms are considerably higher than those in agricultural crops. Mushrooms possess a very effective mechanism that enables them

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readily to take up some minerals from the ecosystem compared to green plants growing in similar conditions (SVOBODA *et al.* 2000). Thus, they might be used directly in diet and promote health, taking advantage of the additive and synergistic effects of all the bioactive compounds present (VAZ *et al.* 2010; PEREIRA *et al.* 2012). The content of carbohydrates, which are mainly present as polysaccharides or glycoproteins, ranges at 50–90%; the most abundant polysaccharides are chitin, α - and β -glucans, and hemicelluloses (e.g. mannans, xylans, and galactans). The polysaccharides in mushrooms are present mostly as glucans with different types of glycosidic linkages, such as branched (1 \rightarrow 3), (1 \rightarrow 6)- β -glucans and linear (1 \rightarrow 3)- α -glucans, but some are true heteroglycans (WASSER 2002). Mushrooms are therefore a potential source of dietary fibre (DF) due to the presence of such non-starch polysaccharides. Little information is available on the total dietary fibre (TDF) content and composition of edible mushrooms. Most literature values reported were based on the crude fibre or detergent fibre methods (BARROS *et al.* 2008; FERREIRA *et al.* 2009), which underestimated the TDF content of mushrooms. Total dietary fibre (TDF) in mushrooms is the sum of intrinsic non-digestible carbohydrates, mainly chitin. Mushroom glucans are also components of soluble (SDF) or insoluble (IDF) dietary fibres (VETTER 2007). Their solubility in water strongly depends on the molecular structure and conformation. Biologically active glucans themselves or their complexes with proteins and other polysaccharides isolated from the fruiting bodies of these species are interesting for the preparation of novel food supplements. Dietary fibre plays an important role in decreasing the risks of many disorders such as constipation, diabetes, cardiovascular diseases (CVD), diverticulosis and obesity (SPILLER 2001). A great variability can also be observed among mushrooms in the dietary fiber supply. In general, a remarkably high or appreciable level of total fiber ranging from 5.5 to 42.6% DW (dry weight) was obtained from the wild growing edible mushrooms in which β -glucans were the major fiber polysaccharides together with chitin (MANZI *et al.* 2001, 2004). Dietary fiber in mushrooms shows higher levels of IDF (2.28–8.99 g/100 g edible weight) than SDF (0.32–2.20 g/100 g edible weight) (MANZI & PIZZOFERRATO 2000; MANZI *et al.* 2001). β -Glucans represent from 4% to 13% of the TDF with a variability of the dietary fiber fractions depending on the mushrooms species. In this context, β -glucans from mushrooms are considered as functional compounds because they appear to stimulate

the immunomodulatory response, modulate humoral and cellular immunity, and thereby have a beneficial effect in fighting against infections. Moreover, these substances also exhibit hypocholesterolemic effects (HETLAND *et al.* 2008; MANTOVANI *et al.* 2008) and are also promising candidates as anticoagulant agents (CHANG *et al.* 2006). Recently, they have been demonstrated to have anti-cytotoxic, antimutagenic and anti-tumorogenic properties, being promising candidates for pharmacological agents (HETLAND *et al.* 2008).

Since a variety of health benefits have been attributed to the consumption of mushrooms rich in fibre content and as there are no data available on TDF, IDF and SDF contents of most of the common edible mushrooms, the present study has been undertaken to evaluate the TDF, IDF, and SDF contents of twenty species of wild growing edible mushrooms.

MATERIAL AND METHODS

Materials. Twenty species of mushroom fruiting bodies were collected from natural growth places from different geographic locations of different states of India (Maharashtra, Andhra Pradesh, Kerala, Himachal Pradesh, Nagaland, and Madhya Pradesh) at different time intervals during 2011. These species were botanically authenticated by Prof C.N. Khobragade and deposited in the Department of Botany, SRTM, University, Nanded, India as specimen vouchers. The fully developed, non-infected 10 fruiting bodies of each of the mushroom species were taken for the study. Each fruiting body of the mushrooms was disinfected using 1% HgCl₂ solution before analysis.

Sample preparation. All procured and selected mushroom fruiting bodies were cleaned to remove any residual and soil particles. The mushrooms were trimmed and peeled to remove any non-edible portion. The mushrooms were subsequently air-dried overnight in an oven at 45°C. All of the dried mushrooms were ground to fine powder (ca. 1 mm size) and stored in airtight plastic bags in desiccators at room temperature for further analysis. Ten grams of each of the dried mushroom sample was mixed with 100 ml of boiled water for 5 minutes. The samples were stirred for 15 min for effective extraction and centrifuged at 5000 g for 15 minutes. The supernatants were collected and stored at 4°C until the completion of the analysis. The yield of extraction was expressed in percent on a dry weight basis (NETHRAVATHI *et al.* 2006; RITTERA & SAVAGE 2007).

Moisture content. The moisture content of each sample of the dried edible mushrooms was determined by overnight drying to constant weight in an oven (Bio-Era Equipments, Mumbai, India) set at 125°C to a constant weight. The samples on watch glass were cooled at room temperature in desiccators before weighing, the weight loss in the samples being regarded as the moisture content (NILE & KHOBRADE 2009). All determinations were performed in triplicates.

Determination of TDF, IDF, and SDF. The mushroom fats were removed. The mushroom samples (2 g) were extracted with hexane as the extraction solvent using a Soxhlet apparatus. The extracts were dried over anhydrous sodium sulphate, filtered, and concentrated ($\leq 30^\circ\text{C}$) in a rotary evaporator under vacuum (PEDNEAULT *et al.* 2006). The extracts and fat-free mushroom samples were analysed for their TDF, IDF, and SDF contents by enzymatic and gravimetric methods. The soluble and insoluble dietary fibres were determined according to the AOAC enzymatic-gravimetric methods, using an enzymatic treatment with protease, omitting α -amylase, and amyloglucosidase since the analysed samples did not contain starch (WONG & CHEUNG 2005). The obtained residue was dialyzed at 25°C for 48 h instead of using ethanolic precipitation to avoid losses of soluble dietary fibre (SDF), as reported by PETROVSKA *et al.* (2001). Soluble fibre was subjected to acidic hydrolysis with 1M sulphuric acid (100°C, 1.5 h). Neutral sugars (NS) in the hydrolysates were quantified by gas liquid chromatography (GLC). Uronic acid (UA) was determined spectrophotometrically with 3,5-dimethylphenol as

the reagent and galacturonic acid as a standard. SDF was calculated as the sum of NS plus UA. TDF, IDF, and SDF contents of the various analysed mushrooms were calculated and expressed on fresh weight basis (Figure 1) (RAMULU & RAO 2003). All determinations were performed in triplicates.

Statistical analysis. The values were expressed as means \pm standard deviations. The data were analysed using SAS (Statistical Analysis System) software. The analysis of variance (ANOVA) and Duncan's multiple range tests were used to compare the significance of the difference between the samples.

RESULTS AND DISCUSSION

Moisture content and extraction yield. The results for the extraction yield were expressed as percent on the dry weight basis, which was found to be on average 10.35% (g/100 g of dry mushroom). The

Table 1. Moisture content and yield of mushroom in water extracts

Sr. No.	Mushroom species	Moisture content [#] (g/100 g FW)	Yield of extract* (g/100 g DW)
1	<i>Agaricus bisporus</i>	89	9 \pm 0.1
2	<i>Auricularia polytricha</i>	84	10 \pm 2.0
3	<i>Boletus edulis</i>	90	6 \pm 0.2
4	<i>Cantharellus cibarius</i>	93	8 \pm 0.1
5	<i>Cantharellus clavatus</i>	86	8 \pm 0.2
6	<i>Ganoderma lucidum</i>	84	12 \pm 2.7
7	<i>Gastrum arinarius</i>	88	14 \pm 1.5
8	<i>Helvella crispa</i>	94	6 \pm 0.4
9	<i>Hericium erinaceus</i>	92	12 \pm 1.2
10	<i>Hydnum repandum</i>	90	9 \pm 0.1
11	<i>Lactarius deliciosus</i>	87	5 \pm 0.3
12	<i>Lactarius sanguifluus</i>	92	15 \pm 2.1
13	<i>Lentinus squarulosus</i>	86	12 \pm 1.9
14	<i>Morchella conica</i>	85	14 \pm 2.4
15	<i>Phellinus florida</i>	88	13 \pm 3.1
16	<i>Phellinus rimosus</i>	90	9 \pm 0.2
17	<i>Pleurotus djamor</i>	92	14 \pm 3.2
18	<i>Pleurotus sajor-caju</i>	85	13 \pm 1.8
19	<i>Russula brevipes</i>	89	8 \pm 0.2
20	<i>Sparassis crispa</i>	90	10 \pm 1.3

*each value is the mean of three replicate determinations \pm standard deviation; [#]moisture content expressed as the sum of losses during pre-drying and final drying; FW – fresh weight; DW – dry weight

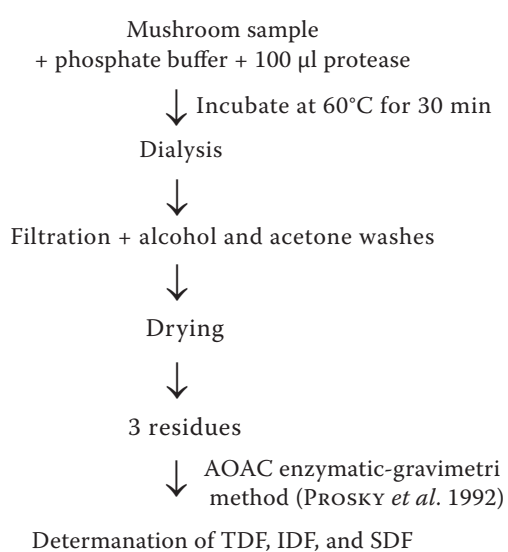


Figure 1. Analytical scheme for TDF, IDF, and SDF procedure

Table 2. Total, insoluble, and soluble dietary fibre contents (in (g/100 g) in dry weight of edible mushrooms*

Sr. No	Mushroom species	TDF	IDF	SDF	SDF as % TDF
1	<i>Agaricus bisporus</i>	31 ± 1.4	14 ± 1.9	2	6.4
2	<i>Auricularia polytricha</i>	32 ± 2.3	17 ± 1.8	3	9.3
3	<i>Boletus edulis</i>	28 ± 2.1	13 ± 2.3	3	10.7
4	<i>Cantharellus cibarius</i>	36 ± 2.1	20 ± 2.4	3	8.3
5	<i>Cantharellus clavatus</i>	36 ± 1.7	12 ± 1.6	4	11.1
6	<i>Ganoderma lucidum</i>	35 ± 1.7	20 ± 3.4	3	8.5
7	<i>Geastrum arinarius</i>	28 ± 1.2	21 ± 2.6	2	7.1
8	<i>Helvella crispa</i>	28 ± 2.4	21 ± 3.2	3	10.7
9	<i>Hericium erinaceus</i>	30 ± 2.3	14 ± 1.2	3	10.0
10	<i>Hydnum repandum</i>	33 ± 1.4	17 ± 1.8	3	9.0
11	<i>Lactarius deliciosus</i>	34 ± 1.4	17 ± 2.4	4	11.7
12	<i>Lactarius sanguifluus</i>	24 ± 1.1	18 ± 1.5	3	12.5
13	<i>Lentinus squarrulosus</i>	32 ± 3.1	14 ± 1.3	4	12.5
14	<i>Morchella conica</i>	30 ± 1.8	16 ± 3.2	2	6.6
15	<i>Phellinus florida</i>	36 ± 1.9	20 ± 2.6	2	5.5
16	<i>Phellinus rimosus</i>	34 ± 2.1	15 ± 1.7	2	5.8
17	<i>Pleurotus djamor</i>	37 ± 2.6	21 ± 2.6	3	8.1
18	<i>Pleurotus sajor-caju</i>	27 ± 2.1	12 ± 2.3	2	7.4
19	<i>Russula brevipes</i>	29 ± 3.1	13 ± 2.7	2	6.8
20	<i>Sparassis crispa</i>	32 ± 1.6	15 ± 1.5	4	12.5

TDF – total dietary fibre; IDF – insoluble dietary fibre; SDF – soluble dietary fibre (SDF = TDF – IDF); *each value is the mean of three replicate determinations ± standard deviation

mean residual moisture content of the twenty edible mushrooms was 88.7%, which is typical for dietary foods and vegetables (Table 1).

TDF, IDF, and SDF contents. The TDF, IDF, SDF, and SDF contents expressed in per cent of TDF of the tested mushrooms are presented in Table 2. The SDF content ranged from 2% to 4% DW in all mushrooms. The SDF as percentage of TDF was low in *Phellinus florida* (5.5%) and *Phellinus rimosus* (5.8%); high in *Sparassis crispa*, *Lentinus squarrulosus*, and *Lactarius sanguifluus* (12.5%). Interestingly, the majority of the mushrooms contained 10–11% of SDF in TDF. The total soluble fibres percentage was high in *Pleurotus djamor* (37%) *Cantharellus cibarius*, *Cantharellus clavatus*, and *Phellinus florida* (36%), while low in *Lactarius sanguifluus* (24%). Interestingly, the majority of the mushrooms had on average 30–31% of TDF. Previous studies on the mushroom fibre content were very limited; the literature data on the fibre content of mushroom mycelia were not available. In the fruiting bodies of *Lentinula edodes*, crude fibre content ranged from 6.5% to 14.7% dry matter, and neutral detergent fibre content varied from 34.8% to 44.8% dry matter (WASSER 2002; BAR-

ROS *et al.* 2008; FERREIRA *et al.* 2009). With regard to TDF content of the fruiting bodies and mycelia, *Volvariella volvacea* and *Pleurotus sajor-caju* had, respectively, the least amounts of IDF. The dry matter values of the mushrooms bodies (pilei and stems) ranged from 9.0% to 14.3%, confirming the high moisture content of these samples (MANZI *et al.* 2001). The TDF contents were 34.5–63.1% in pilei and 38.9–64.8% on dry weight basis in stems. The comparative report (MANZI *et al.* 2004) on dietary fibre content in fresh fruiting bodies of different mushrooms like *Pleurotus ostreatus* (47.3% TDF, 42.4% IDF, and 5.0% SDF) and *Pleurotus eryngii* (34.6% TDF, 30.7% IDF, and 4.0% SDF) was similar to this study if expressed on dry matter basis. Thus, our results are comparable with the literature data, although the previously studied mushroom samples showed significantly higher values of TDF and IDF which could be explained by the mushroom specificity. Both American Dietetic Association (ADA) and Dietary Guidelines for Americans recommended the inclusion of a variety of grains, mushrooms, vegetables, and fruits for an active and healthy life (JOHNSON & KENNEDY 2000). The source of daily

TDF intake through foods in diet in the developed countries is very low when compared to the developing and underdeveloped countries and therefore emphasis was laid on increasing the intake of TDF in the developed countries (NRC 1989). The results of the present study will be useful to dieticians and for revising dietary guidelines by recommending mushrooms rich in SDF to the world population.

CONCLUSIONS

The analyses of wild growing edible mushrooms revealed that they are rich in total and soluble dietary fibre, thus they might be used as a rich source of beneficial dietary fibre. The data generated in the present study on TDF, IDF, and SDF contents of twenty species of wild growing edible mushrooms will be useful in selecting appropriate mushroom species rich in soluble dietary fibre for inclusion into the human diets to promote healthy life. They can also be incorporated in the food composition tables, which in turn help dieticians to plan high soluble dietary fibre containing diets for diabetic and hyperlipidemic subjects. In addition, they shall also help in computing the correct values for the available carbohydrates from these different mushrooms. Further, work is now being carried out to isolate, characterise, and evaluate the dietary fibre components of these mushrooms.

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