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Commercial mushrooms: nutritional quality and effect of cooking

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Abstract

With the aim of extending knowledge on chemical composition of mushrooms, commercial samples, widely consumed in Italy (*Boletus* group, *Agrocybe aegerita* and *Pleurotus eryngii*) have been examined to determine proximate composition and some components of nutritional interest such as dietary fibre, chitin, beta glucan and total phenols in raw and cooked samples. The moisture values ranged from 67.2 to 91.5 g/100 g edible weight in the raw samples, and from 71.9 to 90.4 g /100 g edible weight in the cooked samples. The lipid fraction was not relevant. Proteins, higher in *Boletus* group dried samples than in the other mushroom species (*Agrocybe aegerita* and *Pleurotus eryngii*), ranged from 1.5 to 7.9 g/100 g edible weight, while the ash content varied between 0.5 and 2.0 g/100 g of edible weight. Dried and re-hydrated *Boletus* samples showed higher levels of soluble and insoluble dietary fibre than the other samples. The amount of beta glucans varied within the same species (*Boletus* group samples) and represented from 2 to 13% of total dietary fibre. The chitin content ranged from 0.5 to 3.3 g/100 g edible weight. Finally, total phenols varied widely among different mushroom species, from 51.4 to 403.8 mg/100 g edible weight and from 70.4 to 301.6 mg/100 g edible weight, respectively, for raw and cooked samples.

Keywords: Edible mushrooms; Chemical composition; Functional compounds

1. Introduction

Edible mushrooms are characterized by a short shelf life (1–3 days at room temperature), linked to the occurrence of post-harvest changes (Czapski & Szudyga, 2000). These changes are due to the high moisture content of the carpoforus and to the high activity of enzymes such as protease or polyphenol oxidase, responsible for protein and sugar decrease and for a browning reaction during storage. The drying process is by far the most widely used method for guaranteeing long term storage. In Italy, dried mushrooms are regulated by a national law (DPR 14/7/1995 n. 376) and the term ''*Boletus* group'' comprises different species, such as *Boletus aereus*, *Boletus pinicola*, *Boletus reticulatus* and *Boletus edulis*.

Apart from this tecnique, the deep-freezing process has been used and represents another common way to increase storage stability and facilitate mushroom consumption without seasonal constraints.

From a nutritional point of view, mushrooms are not rich in protein or fat but they contain appreciable amounts of dietary fibre (Manzi, Aguzzi, & Pizzoferrato, 2001), particularly important for the regulation of physiological functions in the human organism. Functional compounds in mushrooms have recently been highlighted (Manzi, Aguzzi, Vivanti, Paci, & Pizzoferrato, 1999; Manzi & Pizzoferrato, 2000; Mattila, Suonpaa & Piironen, 2000). These substances are able to lower cholesterolemia, modulate the immune system and inhibit tumoral growth (Zhang, Cheung, & Zangh, 2001).

In particular, chitin (*N*-acetyl-D-glucosamine polymer), a nitrogen-containing polysaccharide of the fungal cell walls, and chitosan, its deacetylated derivative, are responsible for decreasing the physiological cholesterol pool (Bobek & Galbavy, 1999; Bobek, Ginter, & Ozdin, 1993; Bobek, Ozdyn, & Kuniak, 1995).

Other functional compounds in mushrooms are beta glucans, particularly effective in lowering blood cholesterol levels and glycemic response in vivo but scant information is available about the amounts that exist in edible mushrooms (Bobek, Nosalova, & Cerna, 2001; Cheung, 1998).

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Recently, some studies have been carried out to evaluate the antioxidant activity of speciality commercial mushrooms (Mau, Chao, & Wu, 2001; Mau, Lin, & Song, 2002). Phenolic substances, probably responsible for scavenging effects on radicals, are the major naturally occurring antioxidant components found in mushrooms (Yang, Lin, & Mau, 2002).

The main objective of this study is to evaluate different mushroom species (*Boletus* group; *Agrocybe aegerita* and *Pleurotus eryngii*) after different industrial processes (frozen, dried or fresh); chemical and nutritional characteristics of mushrooms are closely linked to species and processing (Bano & Rajarathnam, 1988; Diez & Alvarez, 2001; Justo, Guzman, De Mejia, & Diaz, 1998; Leon-Guzman, Silva, & Lopez, 1997; Longvah & Deosthale, 1998; Manzi, Gambelli, Marconi, Vivanti, & Pizzoferrato, 1999). In particular, the proximate composition and functional components, such as dietary fibre, chitin, beta glucan and total phenols, has been studied in mushrooms (both raw and submitted to traditional home cooking).

2. Materials and methods

2.1. Samples

Fruit bodies of different species of mushrooms were collected from different local grocery stores and supermarkets of Italy according to this plan:

Samples	Species	Industrial treatment
A	*Boletus* group	Dried
B	*Boletus* group	Dried
C	*Boletus* group	Dried
D	*Boletus* group	Dried
E	*Boletus* group	Dried
F	*Boletus* group	Dried
G	*Boletus* group	Dried
H	*Boletus* group	Dried
I	*Boletus* group	Frozen
K	*Agrocybe aegerita*	Fresh
L	*Pleurotus eryngii*	Fresh

According to the Italian law (1995), *Boletus* group is made up of different *Boletus* species (*Boletus edulis*; *Boletus areus; Boletus pinicola* and *Boletus reticulatus*): the accurate proportions of the *Boletus* mixture is not mentioned explicitly (Sitta, 2000) and for this reason different commercial brands have been selected.

All dried samples were rehydrated, as indicated in the label, while fresh mushrooms were submitted to the customary procedures of cleaning, removing of pileus and cutting.

After these procedures, all the samples were grilled for 10 minutes without addition of other ingredients. Raw and cooked samples were analysed in triplicate.

2.2. Chemicals

All reagents (Carlo Erba, Milan) were of analytical or HPLC grade, as required.

The enzyme kit, containing alpha-amylase, amyloglucosidase and protease, according to the official method for dietary fibre (Association of Official Analytical Chemists, 1995) and gallic acid standard were from Sigma (Milano, I).

Lichenase [EC 3.2.1.73] 1000 U/ml, beta glucosidase [EC 3.2.1.21] 40 U/ml, and glucose standards were obtained from Megazyme Int. (Ireland Ltd).

2.3. Methods

Water, protein (N×4.38) according to Crisan and Sands (1978), fat and ash contents were determined according to the AOAC procedures (1995). Total carbohydrates were calculated by difference.

Total energy was calculated according to the following equations (Dir. 90/496/CEE):

Energy (kcal) = 4×(g protein + g carbohydrate) + 9×(g lipid);

Energy (kJ) = 17×(g protein + g carbohydrate) + 37×(g lipid).

Dietary fibre, as soluble and insoluble fractions, was determined according to the enzymatic-gravimetric method of Prosky, Asp, Schweizer, De Vreis, and Furda (1988).

The determination of chitin was carried out as N-glucosamine, after acid hydrolysis with 6N HCl, following a colorimetric reaction according to the method of Ride and Drysdale (1972).

Beta glucans were determined according to the method of McCleary and Holmes (1985) slightly modified for mushroom analyses by Manzi and Pizzoferrato (2000).

Total phenols were determined according to the method of Capannesi, Palchetti, Mascini and Parenti (2000) with the Folin-Ciocalteau reagent and gallic acid in methanol was used as standard. The spectrophotometric analysis was performed at 765 nm.

3. Results and discussion

Table 1 lists the proximate composition of raw mushrooms. Moisture values range from 67.2 to 91.5 g/100 g edible weight. The fat level is quite low and ranges from 0.6 to 1.5 g/100 g edible weight while the protein content is 5.4 g/100 g, on average. The ash content ranges from 0.5 to 2.0 g/100 g of edible weight and total

carbohydrate concentration, calculated by difference, varies from 5.9 to 21.6 g/100 g edible weight.

All samples were analysed after being cooked for 10 min without other ingredients. The cooking yield in weight (%), the proximate composition of cooked samples and the relevant energy values are listed in Table 2.

On average, 76.6 g of cooked mushrooms are obtained from 100 g of fresh mushrooms. Going into detail, the cooking yield is 79.0 and 70.7%, respectively, for *Agrocybe aegerita* (sample K) and *Pleurotus eryngii* (sample L) while, for the *Boletus* group samples (A–I), it is, on average, 76.9%.

The moisture values range from 71.9 to 90.4 g/100 g edible weight, the fat ranges from 0.7 to 1.5 g/100 g edible weight, the protein content is on average 5.3 g/100 g edible weight and ash content ranges from 0.6 to 2.0 g/100 g edible weight. Total carbohydrate content, calculated by difference, varies from 6.6 to 18.1 g/100 g edible weight.

On the basis of the proximate analysis, it can be calculated that an edible portion of 100 g of cooked mushrooms assures, on average, 50 kcal (212 kJ). The highest values are guaranteed by dried and rehydrated mushrooms (from A to H), while fresh (K and L) and frozen (I) mushrooms give the lowest energy contribution (Table 2). These results do not depend on the mushroom species and are much more affected by the industrial technology utilised in the mushroom preparation (dried or frozen).

Table 3 shows dietary fibre (total, soluble and insoluble), beta glucans, chitin and total phenol contents in raw mushrooms.

In particular, samples from A to H (dried and rehydrated *Boletus* group) show higher levels of soluble and insoluble dietary fibre than other samples (I, K and H), probably due to incomplete rehydration during reconstitution of the dried samples with water.

Table 1
Proximate composition (g/100 g edible weight) of raw mushrooms. Analytical data are means of triplicate analyses±standard deviation

	Raw samples	Moisture[a] (%)	Fat (%)	Protein[b] (%)	Ash (%)	Carbohydrates[c] (%)
A	*Boletus* group dried	75.7±0.1	1.1±0.0	6.2±0.1	2.0±0.0	15.0±0.1
B	*Boletus* group dried	75.0±0.1	1.0±0.0	5.6±0.0	1.5±0.1	16.8±0.1
C	*Boletus* group dried	74.0±0.1	1.5±0.2	6.4±0.1	1.6±0.1	16.4±0.2
D	*Boletus* group dried	73.4±0.0	1.3±0.0	6.1±0.0	1.6±0.1	17.7±0.1
E	*Boletus* group dried	70.5±0.2	1.4±0.1	6.8±0.1	1.7±0.1	19.6±0.1
F	*Boletus* group dried	74.4±0.2	0.8±0.1	5.7±0.1	1.5±0.2	17.6±0.0
G	*Boletus* group dried	67.2±0.0	1.4±0.0	7.9±0.1	1.9±0.1	21.6±0.2
H	*Boletus* group dried	73.6±0.1	1.3±0.2	6.7±0.0	1.5±0.0	16.9±0.0
I	*Boletus* group frozen	91.5±0.2	0.6±0.0	1.5±0.0	0.5±0.0	5.9±0.0
K	*Agrocybe aegerita* fresh	87.4±0.2	0.8±0.0	3.9±0.0	1.2±0.0	6.7±0.0
L	*Pleurotus eryngii* fresh	86.6±0.2	0.8±0.0	2.2±0.1	1.2±0.1	9.6±0.1

[a] Moisture of raw dried mushrooms was analysed after rehydration as recommended in the label.
[b] N×4.38.
[c] Calculated by difference.

Table 2
Cooking yield (%), proximate composition (g/100 g edible weight) and energy value (kcal/100 g and kJ/100 g) of cooked mushrooms. Analytical data are means of triplicate analyses±standard deviation

	Cooked samples	Cooking yield (%)	Moisture[a] (%)	Fat (%)	Protein[b] (%)	Ash (%)	Carbohydrates[c] (%)	Energy kcal/100 g	kJ/100 g
A	*Boletus* group dried	76.7	77.8±0.1	0.8±0.0	6.0±0.1	1.3±0.1	14.2±0.0	48.1±0.3	203.5±1.5
B	*Boletus* group dried	74.1	76.4±0.1	1.2±0.0	5.8±0.0	1.0±0.0	15.7±0.0	51.2±0.3	216.1±1.1
C	*Boletus* group dried	80.8	76.0±0.2	1.0±0.0	5.4±0.1	1.1±0.1	16.4±0.1	57.5±0.4	243.0±1.9
D	*Boletus* group dried	74.0	74.1±0.1	1.2±0.0	6.3±0.0	0.9±0.1	17.5±0.1	60.0±0.3	253.4±1.3
E	*Boletus* group dried	75.1	74.2±0.3	1.5±0.0	6.2±0.1	1.2±0.0	16.8±0.1	57.7±0.2	243.3±0.9
F	*Boletus* group dried	68.5	74.9±0.1	0.8±0.1	5.2±0.1	0.9±0.0	18.1±0.3	54.5±0.5	230.5±2.0
G	*Boletus* group dried	81.3	71.9±0.1	1.5±0.1	7.0±0.1	2.0±0.1	17.7±0.1	63.7±0.6	268.9±2.5
H	*Boletus* group dried	85.5	78.2±0.1	1.2±0.0	6.3±0.1	0.8±0.0	13.5±0.1	59.7±0.2	252.1±0.9
I	*Boletus* group frozen	76.9	90.4±0.2	0.7±0.0	1.8±0.0	0.6±0.0	6.6±0.1	22.5±0.1	94.6±0.4
K	*Agrocybe aegerita* fresh	79.0	84.6±0.2	1.0±0.0	4.7±0.1	1.5±0.0	8.2±0.1	30.8±0.1	129.9±0.4
L	*Pleurotus eryngii* fresh	70.7	82.1±0.2	1.0±0.1	3.1±0.1	1.4±0.1	12.9±0.1	46.5±0.5	196.2±0.9

[a] Moisture of raw dried mushrooms was analysed after rehydration as recommended in the label.
[b] N×4.38.
[c] Calculated by difference.

Beta glucans, functional compouds within the dietary fibre fraction, vary in mushrooms, apparently without any correlation to species or technological processes. To this end, further studies are in progress in order to confirm the hypothesis that beta glucans can be related to the life-stage of mushrooms. Beta glucan levels range from 245 to 1110 mg/100 g edible weight, representing from 4 to 13% of the total dietary fibre.

The chitin contents (reported as glucosamine) are shown in Table 3. In dried and rehydrated mushrooms (from A to H samples), the chitin level, because of an incomplete rehydration, as already discussed, is higher (from 1.8 to 3.3 g/100 g edible weight) than in the frozen and fresh samples (I, K, and L). Chitin represents, on average 25% of the total dietary fibre.

The amount of total phenols, also, varies widely among different mushroom species but, in particular, the dried *Boletus* group samples contained the greatest amount of these compounds, from 235.9 to 403.8 mg/100 g of edible weight.

Table 4 shows soluble, insoluble and total dietary fibre, beta glucans, chitin and total phenols of cooked samples. Total dietary fibre ranges from 4.27 to 12.09 g/100 g edible weight, while soluble and insoluble fibre varies from 0.58 to 2.73 g/100 g edible weight and from 3.69 to 10.18 g/100 g edible weight, respectively.

According to Italian recommended nutrient intakes (LARN, 1996), the daily requirement of dietary fibre for an adult (30–59 years) is 30 g: mushrooms could be considered a good source of fibre because a portion of 100g of cooked mushrooms guarantees, on average, 32% of the daily requirement of dietary fibre. The percent contribution ranged from 14% in the frozen *Boletus* group sample (I) to 40% in the E sample (*Boletus* group dried and rehydrated).

Beta glucans (Table 4) are on average 415.5 mg/100 g and represent 4.8% of the total dietary fibre. In Table 4, chitin (referred to as glucosamine) in cooked mushrooms is also listed. The chitin content ranges from 0.6 to 3.2 g/100 g edible weight and represents from 9.1 to 26.0% of the total dietary fibre.

Total phenols Table 4, are higher in the *Boletus* group dried samples (on average 237.9 g/100 g edible weight)

Table 3
Contents of soluble dietary fibre (S.D.F.), insoluble dietary fibre (I.D.F.), and total dietary fibre (T.D.F), beta glucans, chitin and total phenols in raw mushrooms. Beta glucans and chitin levels are also expressed as% of T.D.F. Data are expressed as mg/100 g or g/100 g edible weight (e.w.)

	Raw samples	S.D.F. (g/100 g e.w.)	I.D.F. (g/100 g e.w.)	T.D.F. (g/100 g e.w.)	Beta glucans (mg/100 g e.w.)	T.D.F. (%)	Chitin (g/100 g e.w.)	T.D.F. %	Total phenols (mg/100 g e.w.)
A	*Boletus* group dried	1.58±0.04	6.04±0.04	7.62±0.08	352.5±18.0	4.6	2.4±0.0	31	269.1±10.4
B	*Boletus* group dried	1.35±0.06	5.68±0.00	7.03±0.06	405.3±2.3	5.8	2.0±0.0	29	246.2±0.6
C	*Boletus* group dried	1.22±0.05	6.63±0.48	7.85±0.52	309.5±8.8	3.9	2.2±0.0	28	299.4±1.3
D	*Boletus* group dried	2.20±0.0	7.37±0.24	9.57±0.24	1110.3±63.4	11.6	2.1±0.0	22	403.8±9.7
E	*Boletus* group dried	1.75±0.09	7.89±0.36	9.64±0.45	489.3±24.4	5.1	3.0±0.0	31	311.7±3.6
F	*Boletus* group dried	2.03±0.21	7.38±0.52	9.40±0.73	n.d.	n.d.	1.8±0.0	19	235.9±5.2
G	*Boletus* group dried	1.72±0.16	8.99±0.31	10.71±0.47	435.9±13.6	4.1	3.3±0.0	31	314.8±4.6
H	*Boletus* group dried	1.11±0.05	5.92±0.19	7.04±0.24	358.7±2.5	5.1	2.0±0.0	28	349.4±5.1
I	*Boletus* group frozen	0.32±0.05	2.28±0.08	2.60±0.13	245.7±3.8	13.3	0.7±0.0	28	97.5±0.8
K	*Agrocybe aegerita* fresh	0.96±0.11	4.11±0.13	5.07±0.25	302.5±3.2	6.0	0.8±0.0	16	190.3±1.5
L	*Pleurotus eryngii* fresh	0.53±0.19	4.11±0.38	4.64±0.58	413.8±53.3	8.9	0.5±0.1	11	51.4±15.5

n.d. Not detected.

Table 4
Contents of soluble dietary fibre (S.D.F.), insoluble dietary fibre (I.D.F.), and total dietary fibre (T.D.F), beta glucans, chitin and total phenols in cooked mushrooms. Beta glucans and chitin levels are also expressed as% of T.D.F. Data are expressed as mg/100 g or g/100 g edible weight (e.w.)

	Cooked samples	S.D.F. (g/100 g e.w.)	I.D.F. (g/100 g e.w.)	T.D.F. (g/100 g e.w.)	Beta glucans (mg/100 g e.w.)	T.D.F. (%)	Chitin (g/100 g e.w.)	T.D.F. (%)	Total phenols (mg/100 g e.w.)
A	*Boletus* group dried	1.53±0.15	8.40±0.17	9.93±0.32	442.1±22.5	4.5	2.2±0.0	22	220.6±3.9
B	*Boletus* group dried	2.15±0.08	9.13±0.30	11.29±0.22	332.9±10.5	2.9	2.2±0.0	20	211.4±2.5
C	*Boletus* group dried	1.61±0.15	8.22±0.50	9.83±0.35	373.9±10.8	3.8	2.3±0.0	24	207.3±4.6
D	*Boletus* group dried	2.73±0.41	8.76±0.18	11.49±0.23	938.9±7.5	8.2	2.4±0.0	21	301.6±1.2
E	*Boletus* group dried	1.91±0.10	10.18±0.17	12.09±0.07	362.7±11.7	3.0	3.0±0.0	25	243.5±9.6
F	*Boletus* group dried	2.38±0.04	9.14±0.35	11.52±0.31	n.d.	n.d.	2.5±0.0	21	163.2±0.9
G	*Boletus* group dried	2.11±0.08	9.95±0.26	12.06±0.34	305.6±16.0	2.5	3.2±0.0	26	254.8±2.5
H	*Boletus* group dried	1.10±0.07	6.52±0.35	7.62±0.42	154.7±18.1	2.0	2.0±0.0	26	300.7±1.9
I	*Boletus* group frozen	0.58±0.01	3.69±0.09	4.27±0.10	359.9±27.6	8.4	0.9±0.0	21	109.2±0.6
K	*Agrocybe aegerita* fresh	1.37±0.00	6.02±0.02	7.39±0.02	367.2±3.2	5.0	0.9±0.0	13	181.2±2.5
L	*Pleurotus eryngii* fresh	0.80±0.21	5.84±0.82	6.65±0.19	516.7±46.5	7.8	0.6±0.1	9	70.4±13.1

n.d. Not detected.

Table 5
Recovery (%) of nutrients after cooking, on a dry basis, in dried and frozen/fresh mushrooms

Nutrients	Dried mushrooms mean value	Fresh or frozen mushrooms mean value
Weight	77	76
Water	80	73
Dry matter	70	94
Fat	72	90
Protein	72	94
Ash	53	89
Carbohydrate	71	93
Soluble dietary fibre	92	121
Insoluble dietary fibre	98	114
Total dietary fibre	96	114
Chitin	83	94
Beta glucans	67	88
Total phenols	61	86

than fresh (K and L) and frozen (I) samples (on average 20.3 g/100 g edible weight).

To summarise, nutrient concentration, in both raw and in cooked samples, is higher in dried mushrooms (A–H) than in the frozen (I) or fresh (samples K and L) ones. These results are probably due to incomplete reconstitution of the dried products (samples A–H) more than to interspecies differences.

The effect of the cooking process is generally explained as a decrease (evaporation) in the water content of the raw sample and, consequently, in nutrient concentration. Nevertheless, a decrease in the nutrient amounts can also be hypothesized to be due to interactions between different compounds, chemical reactions and/or thermal degradation.

With the aim of understanding whether these reactions really occur, a calculation of the yield, after cooking, of each compound analysed in this study has been performed. The relevant results are shown in Table 5.

Weight recovery after cooking is 77% for dried and rehydrated mushrooms and 76% for fresh/frozen samples. The recovery of all chemical components of cooked samples, in respect to raw samples, is generally less than 100%, particularly in dried samples. Dry matter, fat, protein and carbohydrates show a significant decrease after cooking (70–72%) in dried samples and a concentration increase (90–94%) in fresh/frozen samples. In particular, ash content, if compared with the other components shows, a higher loss (53%) in dried mushrooms.

In these dried mushrooms, a general concentration effect can be observed for the dietary fibre fraction (92–97% vs 77%) and chitin (83%). Beta glucan and total phenols seem to be more affected by the heat treatment (67 and 61%, respectively). In fresh/frozen mushrooms, the concentration increases of dietary fibre (114–121%), beta glucans (88%), chitin (94%) and total phenols (86%) are more evident.

The apparent greater stability of nutrients in fresh/frozen mushrooms is probably due to the absence of industrial treatments or to the mild processing, promoting—if compared with the more severe drying treatment—nutrient integrity.

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