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Nutritional value of mushrooms widely consumed in Italy

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Abstract

With the aim of extending knowledge on chemical and nutritional characteristics of commercial mushrooms widely consumed in Italy, fresh and processed mushrooms (*Agaricus bisporus, Pleurotus ostreatus* and *Boletus* group) were analysed fresh or after cooking. Results show that botanical variety, processing and cooking are all effective determinants of mushroom proximate composition. Dried mushrooms (*Boletus* group) after cooking show the highest nutritional value, essentially due to insufficient rehydration. Dietary fibre, chitin and beta glucans, all functional constituents of mushrooms, are present in variable amounts. Chitin level ranges from 0.3 to 3.9 g/100 g, while beta glucans, which are negligible in *Agaricus*, range from 139 to 666 mg/100 g in *Pleurotus ostreatus* and *Boletus* group. On average, a serving (100 g) of mushrooms guarantees from 9 to 40% of the daily recommendation of dietary fibre.

Keywords: Edible mushrooms; Chemical composition; Cooking; Technological process

1. Introduction

More than 2000 species of mushrooms exist in nature but only approximately 22 species are intensively cultivated, for commercial purposes, on ground or wood and utilising particular environmental and nutritional conditions. Mushroom mycelia (vegetative phase) are important in the ecosystem because they are able to biodegrade the substratum and therefore use the wastes of agricultural production. Fruit bodies (reproductive phase) are appreciated, not only for texture and flavour but also for their chemical and nutritional characteristics (Manzi, Gambelli, Marconi, Vivanti & Pizzoferrato, 1999).

Mushrooms have also been reported as therapeutic foods, useful in preventing diseases such as hypertension, hypercholesterolemia and cancer (Bobek & Galbavy, 1999; Bobek, Ozdyn & Kuniak 1995). These functional characteristics are mainly due to the presence of dietary fibre and, in particular, chitin (Manzi, Aguzzi, Vivanti, Paci & Pizzoferrato, 1999), a structural polysaccharide of cellular walls, and beta glucans (Manzi & Pizzoferrato, 2000; Mullins, 1990), homo- and hetero-glucans with β(1-3), β(1-4) and β(1-6) glucosidic linkages.

The aim of this research was to extend knowledge on nutritional quality of commercial mushrooms. First, the chemical composition, with reference to the contents of protein, fat, carbohydrate and ash, has been analysed. Among the functional components, dietary fibre and its fractions (soluble and insoluble), chitin and beta glucans have been considered. The study addressed the modifications induced by technological treatments (deep-freezing, canning and drying) and/or cooking. Finally, on the basis of the composition of the cooked samples, an estimate of the nutritional role of mushrooms in the diet has been made.

2. Materials and methods

2.1. Samples

Mushroom species, frequently consumed in Italy, were identified and the following fresh and processed mushrooms were selected:

1. *Agaricus bisporus*: fresh;
2. *Agaricus bisporus*: deep-frozen;
3. *Agaricus bisporus*: canned (ingredients: *Agaricus bisporus*, water, salt and citric acid);
4. *Pleurotus ostreatus*: fresh;

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5. *Boletus* group (*B. aereus, B. pinicola, B. reticulatus*): dried (U% = 12.5% according to the Italian law DPR 14/7/1995 N°376).

Mushroom quality is strictly influenced by different parameters, such as the stage of development and pre- and post-harvest conditions. To overcome this variability, commercial samples were purchased on different days and prepared by collecting weighed amounts of analogous products from local markets and big stores.

Mushrooms, when necessary, were submitted to the customary procedures of cleaning and cutting. All the samples were grilled for 10 min without addition of other ingredients. Dried samples of *Boletus* group, before cooking, were re-hydrated, as directed on the label.

2.2. Chemicals

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).

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

2.3. Methods

Samples of mushrooms, cooked and raw, were analysed for chemical composition (protein, fat, carbohydrates and ash) using the AOAC procedures (1995).

Total energy was calculated according to the following equations (Italian Law, 1993):

$$\text{Energy (kcal)} = 4 \times (\text{g protein} + \text{g carbohydrate}) + 9 \times (\text{g lipid});$$

$$\text{Energy (kJ)} = 17 \times (\text{g protein} + \text{g carbohydrate}) + 37 \times (\text{g lipid}).$$

Dietary fibre, (soluble and insoluble fraction), 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 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 analysis by Manzi and Pizzoferrato (2000).

3. Results and discussion

The amount of cooked food obtained from 100 g of raw food, as reported in Table 1, varies from 57.4% (*Agaricus* deep frozen) to 87.1% (*Boletus* group). The highest value of the cooking yield in *Boletus* was expected taking into account the difficulty of full rehydration. This is confirmed in Table 2 where the chemical compositions and the energy contributions of the raw and cooked mushrooms are reported. Indeed, the drying process does not allow the complete reconstitution of the product and the water contents of the raw and cooked *Boletus* group are 73.3 and 69.4 g/100 g respectively, while the values for the other mushrooms range from 88.2 to 94.8 g/ 100 g.

Table 1
Cooking-related yield loss of mushrooms

Mushrooms	Cooking yield (%)
Agaricus bisporus	77.3
A. bisporus deep-frozen	57.4
A. bisporus canned	76.4
Pleurotus ostreatus	69.7
Boletus group dried	87.1

Protein, carbohydrate and ash contents, as reported in Table 2, are significantly affected by technological process ($P < 0.05$) as can be observed after analysing the commercial *Agaricus* sample fresh, deep frozen or canned, but proximate composition also depends on the species. (Manzi, Gabbelli et al., 1999). Cooking procedures significantly increase nutrient concentration ($P < 0.05$), by decreasing the water content; nevertheless, if values are calculated on a dried basis, a significant ($P < 0.05$) cooking-related protein and fat loss can be observed in the deep-frozen *Agaricus* sample. Probably the structural damage of the vegetable cells, occurring during deep-freezing/thawing processes, promotes the nutrient loss and causes the small cooking yield (57%).

The energy provided by the cooked mushrooms analysed ranges, as shown in Table 2, from 34 to 131 kcal/100 g edible portion (144 to 554 kJ/100 g); as already discussed, the highest energy value in *Boletus* raw and cooked (112 and 131 kcal, respectively) depends on the low water content of these samples.

Table 3 shows soluble, insoluble and total dietary fibre contents. The values of the total dietary fibre in the cooked mushrooms range between 2.6 and 12.1 g/100 g of edible portion while, in the raw samples, they vary from 1.5 to 8.7 g/100 g.

The *Boletus* group, raw and cooked, shows the highest values (8.7 and 12.1 g/100 g, respectively), again justifiable by the small content of water in the product ready for consumption. In this case it is, however, interesting to note that the soluble fraction of dietary fibre is particularly high, even if it is calculated on a dried basis: 9.0 g/100 g in the cooked *Boletus* vs. 3.0–5.5 in the other cooked samples. On the whole, an increased level of dietary fibre in cooked mushrooms can be observed and the ratio between total fibre in cooked and raw samples ranges from 1.3 to 1.7, confirming the

Table 2
Chemical composition (g/100 g edible weight) and energy contribution of mushrooms (data are means of triplicate analyses)

Mushrooms		Water		Protein		Fat		Carbohydrate[a]		Ash		Energy	
		Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	kcal	kJ
Agarious bisporus	Raw	92.81	0.40	1.63	0.06	0.33	0.01	5.24	0.06	0.82	0.05	30	129
	Cooked	90.70	0.21	2.01	0.02	0.45	0.02	6.85	0.01	1.05	0.02	39	167
A. bisporus frozen	Raw	94.76	0.34	1.30	0.01	0.22	0.01	3.73	0.01	0.62	0.03	22	94
	Cooked	91.85	0.41	1.90	0.06	0.26	0.03	6.01	0.01	0.98	0.02	34	144
A. bisporus canned	Raw	93.63	0.38	1.53	0.02	0.33	0.03	4.50	0.01	0.77	0.01	27	115
	Cooked	91.54	0.10	2.04	0.01	0.42	0.07	6.00	0.06	1.09	0.03	36	152
Pleurotus ostreatus	Raw	91.34	0.24	1.61	0.02	0.36	0.02	6.69	0.01	0.89	0.01	36	154
	Cooked	88.18	0.01	2.53	0.01	0.48	0.00	8.81	0.01	1.08	0.05	50	211
Boletus group dried	Raw	73.32	0.04	6.22	0.12	1.08	0.13	19.46	0.16	1.71	0.13	112	477
	Cooked	69.35	0.25	6.77	0.16	1.64	0.11	22.24	0.17	1.80	0.07	131	554

[a] Calculated values.

Table 3
Dietary fibre (g/100 g edible weight) in mushrooms. (data are means of triplicate analyses)

Mushrooms		Soluble		Insoluble		Total		
		Mean	S.D.	Mean	S.D.	Mean	S.D.	Cooked/raw
Agaricus bisporus	Raw	0.32	0.01	1.66	0.18	1.98	0.17	1.3
	Cooked	0.51	0.03	2.09	0.02	2.61	0.01	
A. bisporus deep frozen	Raw	0.19	0.02	1.32	0.02	1.51	0.03	1.7
	Cooked	0.25	0.11	2.39	0.03	2.63	0.09	
A. bisporus canned	Raw	0.15	0.02	2.51	0.08	2.67	0.10	1.4
	Cooked	0.26	0.02	3.42	0.01	3.68	0.03	
Pleurotus ostreatus	Raw	0.43	0.00	3.67	0.00	4.10	0.06	1.3
	Cooked	0.60	0.09	4.65	0.10	5.24	0.01	
Boletus group dried	Raw	2.08	0.10	6.66	0.30	8.74	0.21	1.4
	Cooked	2.77	0.02	9.32	0.01	12.09	0.02	

results of other authors (Lintas & Cappelloni, 1988) which emphasise this behaviour of mushrooms (reported ratio of 1.5), different from that of the other vegetables analysed (reported ratio close to 1.0).

Moreover, this trend is not completely due to the loss of water during cooking; in fact it can also be observed when the fibre contents are reported on dried weight. Probably processing can, in any case affect dietary fibre content, in *A. bisporus* deep frozen, where the fat and protein losses cause an increase of the concentration of the other constituents, and the highest ratio (1.7) can be calculated. This last result and the high level of the soluble fraction in the dried sample might suggest the occurrence, during severe industrial treatment and/or during cooking, of cross-linking reactions among oligosaccharides, monosaccharides and proteins, leading to indigestible products analytically measured in the fibre fraction. Indeed, mushrooms are a rich source of oligosaccharides, but no experimental support for this hypothesis is at present available.

Table 4 shows the contribution of a portion of 100 g of cooked mushrooms to the energy and nutrient daily allowances. These data are calculated on the basis of the daily intake recommended to an adult man of 70 kg body weight with a light physical activity and a diet of 2800 kcal/day (LARN, 1996). The results show that a serving of 100 g of edible mushrooms provided only from 1.4 to 4.4% of the daily requirement of energy, from 0.3 to 2.1% of the fat and from 3.6 to 12.9% of the protein. According to the daily recommendations for dietary fibre in the Italian population (LARN, 1996), a value of 30 g of dietary fibre is considered optimal. On this basis it is possible to estimate a dietary fibre contribution of a serving of mushrooms ranging from 8.7% (*Agaricus* fresh) to 40.3% (*Boletus* group). These data also confirm that mushrooms can be positively used in particular low-fat and low-energy diets.

Some functional compounds, whose importance in the dietary field is in the course of investigation, are present in the dietary fibre fraction of mushrooms

Table 4
Contribution (%) of 100 g of cooked mushrooms to the energy and nutrient daily allowances recommended for an adult man, moderate physical activity, 70 kg body weight (LARN, 1996)

Mushrooms	Contribution (%)				
	Energy	Protein	Fat	Carbohydrate	Dietary fibre
Agaricus bisporus	1.4	3.8	0.6	1.8	8.7
A. bisporus deep frozen	1.2	3.6	0.3	1.6	8.8
A. bisporus canned	1.3	3.9	0.5	1.6	12.3
Pleurotus ostreatus	1.8	4.8	0.6	2.3	17.5
Boletus group dried	4.7	12.9	2.1	5.8	40.3

Table 5
Levels of chitin (expressed as glucosamine) and beta-glucans in mushrooms[a]

Mushrooms		Chitin (as glucosamine)			Beta glucans		
		(g/100 g) Mean	S.D. (g/100 g)	% TDF	(mg/100 g) Mean	S.D. (mg/100 g)	% TDF
Agaricus bisporus	Raw	0.60	0.04	30.2	1.4	0.2	0.1
	Cooked	0.70	0.04	26.9	4.2	0.3	0.2
A. bisporus deep frozen	Raw	0.34	0.01	22.4	1.2	0.6	0.1
	Cooked	0.52	0.02	19.6	3.2	0.8	0.1
A. bisporus canned	Raw	0.61	0.05	22.9	1.7	0.2	0.1
	Cooked	0.74	0.06	20.1	0.8	0.4	0.0
Pleurotus ostreatus	Raw	0.32	0.05	7.8	139.2	1.7	3.4
	Cooked	0.63	0.07	12.0	217.8	14.5	4.2
Boletus group dried	Raw	2.60	0.03	29.8	548.8	26.1	6.3
	Cooked	3.86	0.14	31.9	666.4	2.4	5.5

[a] Data, means of triplicate analyses, are referred to100 g of edible weight and to 100 g of total dietary fibre (TDF)

(Manzi, Aguzzi et al., 1999; Manzi & Pizzoferrato, 2000). In particular, in the insoluble fibre fraction, there is chitin, a structural polymer of the fungal cell. It is a nitrogen-polysaccharide that consists of monomers of N-acetyl-glucosamine. The content of chitin, reported in Table 5 as glucosamine, ranges between 0.3 and 3.9 g/100 g of edible portion (from 7.8 to 32% of total dietary fibre) *Boletus* being the richest source. In this case, differences between cooked and raw samples depend exclusively on the water content; in fact no significant difference can be observed if values are reported on dried weights but, even in this case *Boletus* has the highest chitin level.

Similar conclusions can be drawn for beta glucans (Table 5). In particular in *Agaricus* species, even if significant differences can be observed among samples undergoing different technologies, the contents of these functional compounds can be considered negligible. On the other hand, in *Pleurotus* and *Boletus*, beta glucans are present in a good amounts, ranging from 139 to 666 mg/100 g edible portion and representing from 3.4 to 5.5% of the total dietary fibre. After cooking, beta glucan levels generally increase, with the exception of canned sample. In this case, as already stated, the beta glucan content is negligible and the canning procedure has probably already caused any possible modifications of the product.

This research shows that the technological treatments and cooking to which mushroom are usually submitted, do not harm the nutritional quality. Mushrooms prove to be excellent foods that can be used in well-balanced diets for their low contents of fat and energy and high contents of dietary fibre and functional compounds.

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