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On the composition of nutrients in wild and cultivated mushrooms

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The basic composition and the contents of amino acids and fatty acids and eight minerals of nine wild and two cultivated mushrooms were investigated. On a dry matter basis, the protein content of the mushrooms studied (Total N x 6.25) varied between 12 % and 31 %, the fat content between 1.2 % and 8.9 % and the ash content between 5.7 % and 12.8 %. The amount of essential amino acids (excluding Try) varied between 2.6 % and 7.6 % of the dry matter.

The fat content of the mushrooms, which in fresh mushroom is 0.2 - 0.5 %, was on the average 4.5 % of the dry material. The fatty acid composition resembled the general composition of vegetable fats, because there was plenty of oleic and linoleic acid.

The mineral composition of the mushrooms studied was complex. It seems that they are good sources of Cu and fairly good sources of Zn as compared with other foodstuffs, provided that there are no remarkable differences in their availability.

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The present efforts to collect more effectively wild mushrooms and to process the mushroom crop into all-year foodstuffs has increased interest in the study of mushrooms. The present investigation deals with the nutrient composition of mushrooms and the possibilities to produce mushrooms by cultivation.

The digestibility of the protein of mushrooms was studied about 100 years ago by for example Sokolov (1870), Saltet (1885), Strohmer (1886), Mörner (1886) and Uffelmann (1887) (these cited in Rautavaara 1947). According to their studies the digestibility of mushroom protein varied between 41 % and 79 %. At the beginning of this century Loewy et al. (1915, in Rautavaara 1947) obtained results showing a digestibility of up to 80 % for mushroom protein. According to later studies by Lintzel (1943) the digestibility was considerably lower, varying between 17 and 46 %. The protein content of mushrooms calculated on a dry weight basis was 11–52 %; that of potato, used for comparison, being 8 %. The above studies represent earlier mushroom research which dealt with other nutritive factors than protein as well.

Besides the nutritional significance of mushrooms, scientists have always been interested in the poisonous compounds found in certain mushrooms and in their toxicological and pharmacological effects. One of the latest studies in this field is the dissertation work of Nieminen (1976) on the effect of the kidney poison of *Cortinarius* on rats.

In the laboratory of the Foundation for Chemical Research the amino acid, fatty acid and mineral contents of certain wild and two cultivated mushrooms have been studied. The results are tentative because of the small number of the samples.

Materials and methods

The wild mushrooms were collected from around Tampere in western Finland. The samples came to the laboratory predried, so that the dry matter content in the original samples is not known.

The mushrooms were predried using two methods: *Boletus edulis, Albatrellus ovinus, Gyromitra esculenta, Craterellus cornucopioides, Cantharellus cibarius, Cantharellus tubaeformis* and *Armillariella mellea* at 50–55° C and *Boletus edulis, Albatrellus ovinus, Ramaria flava* and *Lactarius trivialis* by lyophilization (freeze drying). The samples of *Boletus edulis* and *Albatrellus ovinus* dried by different methods were obtained from various portions.

Flammulina velutipes, the mycelium of which was obtained from Japan and *Pleurotus ostreatus* were grown in the laboratory of the Foundation for Chemical Research and dried by lyophilization of the fresh material.

The dry matter of the mushrooms was determined by drying the samples finally at 105°C to constant weight. The sample was ashed in a quartz crucible with an

electrical ash apparatus and after that in a muffle furnace for two hours at 500°C. Total nitrogen was determined by a micro-Kjeldahl method and the protein content was calculated from Total N x 6.25. The amino acid contents were determined by hydrolysing mushroom powder in a closed ampoule with 6N hydrochloric acid for 20 h at 105°C. The determination was made using an automatic Amino Acid Analyzer, BioCal 201. Tryptophan was not determined. The free amino acids were determined as above from a 70 % ethanol extract purified by an ion exchanger. The minerals were determined with Perkin-Elmer atomic absorption equipment according to the instructions (Analytical Methods for Atomic Absorption Spectrophotometry, Perkin-Elmer 1973).

Results and discussion

In Table 1 the basic composition of the mushrooms studied, and also that of egg, milk and potato for comparison are given. The Table also contains the analytical results of Kurkela (1972) on seven mushrooms and those of Aalto and Kreula (1972) on four mushrooms.

The protein content of the mushrooms varied between 12 and 31 % of the dry material. The corresponding figures of Kurkela (1972) were 15–42 %, those of Aalto and Kreula (1972) 17–32 % and those of Hattula (1969) given in her study of 1969 16–55 %. The protein content of the same mushroom species varied considerably according to the different studies. In the present work the protein content of *Boletus edulis* proved to be 22 and 23 %, whereas Aalto and Kreula (1972) obtained 32 %, Kurkela (1972) 37 % and Hattula (1969) 34 %. In other respects the composition may be very much the same. The protein content of *Cantharellus cibarius* in the present work was 17 %, in the studies of Kurkela (1972) 15 % and Aalto and Kreula (1972) 17 %.

The average ash content of the mushrooms in our study was 7.9 % (5.7 - 12.8) of the dry material. In the other studies the corresponding figures were 8.1 % (6 – 13) (Kurkela 1972), 8.1 % (6.6 - 8.8) (Aalto & Kreula 1972) and 7.9 % (5 - 11) (Hattula 1969).

The average fat content of the mushrooms calculated on a dry matter basis was 4.5 % (1.2 - 8.9). In the other studies the corresponding figures were 3.1 % (2 - 6) (Kurkela 1972) and 1.7 % (1.4 - 2.1) (Aalto & Kreula 1972). The basic composition of the cultivated mushrooms did not essentially differ from that of the wild mushrooms.

Table 2 shows the contents of the essential amino acids of mushrooms, egg, milk and potato, and the total number of the amino acids of the mushrooms as % on a dry matter basis, including also other nitrogen-containing compounds, such as glucosamine. The content of glucosamine varied in different mushrooms between 0.2 % and 8.6 %. The average contents of the essential amino acids of the mushrooms were closer to those of potato than egg and milk. The methionine content was lowest of all. Egg and milk contained larger amounts of all essential amino acids than the mushrooms. In various mushroom species the amounts of individual amino acids varied considerably: for example the lysine content between 0.4 and 1.5 % and the leucine content between 0.5 and 1.4 % of the dry material.

The total amount of the essential amino acids, excluding tryptophan, as it was not determined in this study, varied in the mushrooms between 2.6 and 7.6 %. In potato the corresponding figure was 3.1 %, in egg 21.8 % and in milk 10.4 %. The amino acid contents of both wild and cultivated mushrooms corresponded relatively well to those given in the SFK food component table (Souci et al. 1969). The mushrooms contained 1.5 % - 3.5 % free amino acids of the dry material.

Jandaik & Kapoor (1976) have observed that although mushrooms, like most vegetables and fruit, contain plenty of water, they contain more protein in their dry material than vegetables and fruit.

Table 3 shows the fatty acid composition (% w/w) of mushrooms, and for comparison also of egg, milk and potato. The $C_{10:0}$ - $_{17:1}$ fatty acids with the exception of $C_{16:0}$, and the $C_{20:0}$ - $_{24:0}$ fatty acids were combined into two groups, since there was so little of them. The fatty acid composition of the mushrooms varied considerably, but resembled the general composition of vegetable fats in that the amounts of oleic and linoleic acids were comparatively large: the average figure for oleic acid was 33 % (8–68) and for linoleic acid 42 % (13–73) of the total amount of fatty acids. The result is in agreement with those obtained earlier by Aalto and Kreula (1972) and Shaw (1967). The fat content of the mushrooms was 0.2 % - 0.5 %, calculated on a wet weight basis. Therefore the composition of the fat is not significant from a nutritional point of view. In cultivating mushrooms the study of the composition of their fat may be important because the addition of fats to the substrate seems to accelerate the growth of mycelium and spore cases (Holtz & Schisler 1971).

Table 4 gives the contents of calcium, iron, manganese, zinc and copper per mg/kg dry material in the mushrooms and the contents of magnesium, sodium and potassium per g/kg dry material. For comparison the table also gives the mineral contents of mushrooms found in the literature, and also the corresponding figures for egg, milk, potato and vegetables. The contents for vegetables were obtained by calculation from the figures given in the study of Koivistoinen et al. (1974). The mineral contents of the mushrooms studied were very much the same as given in the literature.

Compared with mushrooms the animal products egg and milk are poor sources of Mn and Cu, and milk also of Fe. Also the content of potassium was significantly

Table 1. Basic composition of certain mushrooms, egg, milk and potato. * Indicates dry matter content of predried mushroom.

Species and drying	Dry material %	Protein % of dm.	Fat % of dm.	Ash % of dm.	Reference
Wild mushrooms					
Boletus edulis 50–55°C	91 *	23	2.1	6.6	
» lyophil.	95 *	22	1.2	5.7	
»	10	37	2	8	Kurkela 1972
»	8	32	1.6	8.2	Aalto & Kreula 1972
Albatrellus ovinus 50–55°C	94 *	12	7.1	7.0	
» lyophil.	92 *	12	4.6	6.0	
Ramaria flava »	96 *	24	2.0	6.0	
Lactarius trivialis »	93 *	21	6.0	6.2	
»	7	22	4	6	Kurkela 1972
»	7	28	2.1	8.6	Aalto & Kreula 1972
Gyromitra esculenta 50–55°C	92 *	31	3.4	10.2	
Craterellus cornucopioides 50–55°C	93 *	17	4.9	10.4	
Cantharellus cibarius »	93 *	17	3.9	12.8	
»	10	15	6	10	Kurkela 1972
»	9	17	1.4	8.8	Aalto & Kreula 1972
Cantharellus tubaeformis 50–55°C	90 *	18	8.9	5.1	
Armillariella mellea »	93 *	22	6.5	10.1	
Clitocybe nebularis	12	38	2	6	Kurkela 1972
Lactarius torminosus	8	21	2	7	»
»	7	19	3	7	»
»	8	22	1.9	6.6	Aalto & Kreula 1972
Tricholoma nudum	6	42	3	13	Kurkela 1972
Boletus suillus	6	22	3	8	»
Cultivated mushrooms					
Flammulina velutipes lyophil.	16	29	5.3	8.7	
Pleurotus ostreatus »	13	22	2.6	8.4	
Egg	26	50	43	4	Souci & al. 1969
Milk	13	24	29	5	»
Potato	22	9	0.7	6	»

Table 2. Contents of essential amino acids and their total amount as % of dry matter in certain mushrooms, egg, milk and potato.

Species and drying	Ile	Leu	Val	Met	Phe	Thr	Lys	Total	Try	Total amount of amino acids
Wild mushrooms										
Boletus edulis 50–55°C	0.6	0.8	0.6	0.3	0.5	0.6	0.7	4.1	–	18.7
» lyophil.	1.1	0.9	0.7	0.4	0.5	0.6	0.9	5.1	–	14.1
Albatrellus ovinus 50–55°C	0.3	0.5	0.4	0.1	0.5	0.4	0.4	2.6	–	10.2
» lyophil.	0.5	0.6	0.5	0.2	0.4	0.4	0.4	3.0	–	9.6
Ramaria flava »	0.7	1.1	0.8	0	0.8	1.0	0.9	5.3	–	23.9
Lactarius trivialis »	1.1	1.3	1.0	+	0.9	0.9	0.8	6.0	–	17.6
Gyromitra esculenta 50–55°C	1.1	1.6	1.4	+	1.1	1.0	1.4	7.6	–	25.0
Craterellus cornucopioides 50–55°C	0.5	0.7	0.6	+	0.5	0.7	0.7	3.7	–	16.4
Cantharellus cibarius »	0.5	0.8	0.6	0	0.5	0.5	0.7	3.6	–	10.6
Cantharellus tubaeformis »	0.5	0.7	0.6	0.1	0.5	0.6	0.7	3.7	–	15.4
Armillariella mellea »	0.8	1.3	0.9	0.4	0	0.9	0.9	5.2	–	19.4
Cultivated mushrooms										
Flammulina velutipes lyophil.	0.7	1.1	0.7	0.4	0.7	0.7	1.2	5.5	–	15.4
Pleurotus ostreatus »	0.9	1.4	1.0	0.3	0.9	0.9	1.5	6.9	–	19.4
Mean value	*0.7*	*1.0*	*0.7*	*0.2*	*0.6*	*0.7*	*0.9*	*4.8*	–	*16.6*
SFK-data (Souci et al. 1969)										
Boletus edulis	0.3	1.1	0.7	0.5	0.9	1.0	1.7	6.2	1.9	
Lactarius deliciosus	1.3	0.9	0.8	0.1	0.1	0.1	0.6	3.9	+	
Boletus rufescens	0.3	0.9	0.4	+	0.6	0.7	0.4	3.3	0.2	
Boletus aurantiacus	0.4	1.4	0.7	0.1	0.7	0.7	1.2	5.2	0.4	
Cantharellus cibarius	0.4	1.2	0.7	0.1	1.0	1.4	0.4	5.2	0.5	
Mean value	*0.5*	*1.1*	*0.7*	*0.1*	*0.7*	*0.8*	*0.9*	*4.8*	*0.7*	
Egg	3.5	4.2	4.0	2.6	2.9	2.0	2.6	21.8	0.7	
Milk	1.5	2.4	1.7	0.6	1.2	1.1	1.9	10.4	0.3	
Potato	0.5	0.6	0.5	0.2	0.4	0.4	0.5	3.1	0.1	

Table 3. Fatty acid composition (% w/w) in certain mushrooms, egg, milk and potato.

Species and drying	$C_{4:0-8:0}$	$C_{10:0-17:1}$*	$C_{16:0}$	$C_{18:0}$	$C_{18:1}$	$C_{18:2}$	$C_{18:3}$	$C_{20:0-24:0}$	Reference
Wild mushrooms									
Boletus edulis 50–55°C		3.3	11.5	1.1	16.9	62.7	2.4	1.9	
» lyophil.		3.6	8.8	0.8	13.3	62.5	3.9	7.3	
Albatrellus ovinus 50–55°C		5.8	6.8	2.0	32.0	52.5	0.4	0.8	
» lyophil		5.4	7.2	1.6	18.1	52.1	0.9	14.8	
Ramaria flava »		2.2	8.4	3.0	51.1	27.7	1.0	6.5	
Lactarius trivialis »		3.7	2.6	1.9	36.9	20.1	0.4	34.5 **	
Gyromitra esculenta 50–55°C		3.9	13.1	–	8.1	72.9	0.5	1.6	
Craterellus cornucopioides 50–55°C		3.2	6.6	5.4	67.9	12.6	2.1	3.4	
Cantharellus cibarius »		4.8	9.1	3.8	41.2	37.0	1.2	3.0	
» *tubaeformis* »		2.3	15.3	1.6	56.4	19.2	2.0	3.3	
Armillariella mellea »		9.8	10.9	1.9	43.2	32.9	0.4	0.9	
Cultivated mushrooms									
Flammulina velutipes lyophil.		5.9	11.4	10.0	31.6	39.0	0.8	1.2	
Pleurotus ostreatus		2.7	14.3	1.7	14.8	60.6	0.7	5.1	
Mean value		*4.4*	*9.7*	*2.9*	*33.2*	*42.5*	*1.3*	*6.5*	
Literature data									
Agaricus campestris		6.4	11.9	5.5	2.6	63.4	–	9.0	Shaw 1967
Amanita muscaria		3.5	10.1	8.0	39.6	52.7	–	–	»
Tricholoma nudum		1.5	25.4	9.5	33.0	29.5	1.1	–	
Mean value		*3.8*	*15.8*	*7.7*	*25.1*	*48.5*			
Egg		3.7	22.2	7.7	36.8	11.2	0.3	1.2	Posati & al. 1975
Milk	5.9	24.8	25.3	9.2	30.9	3.6	–	2.6	Ammon 1968
»	8.3	21.3	25.1	10.0	23.1	3.0	1.0	–	Antila 1974
Potato		–	18.7	4.3	0.7	47.7	28.5	–	Lepage 1968

* C_{16} separately ** Unidentified component emerging after $C_{22:1}$, 32.5 %

Table 4. Contents of Ca, Fe, Mn, Zn and Cu (mg/kg dry matter) and contents of Mg, Na and K (g/kg dry matter) in certain mushrooms. For comparison the corresponding figures (mean value) of egg, milk, potato and 17 vegetables are given.

Species and drying	Ca	Fe	Mn	Zn	Cu	Mg	Na	K	Reference
	mg/kg					g/kg			
Boletus edulis 50–55°C	120	49	18	72	24	0.5	1.0	29	
» lyophil.	180	99	14	100	26	0.5	0.8	23	
Albatrellus ovinus 50–55°C	110	50	11	55	18	0.7	0.6	33	
» lyophil.	93	47	9	38	13	0.8	0.4	30	
Ramaria flava »	670	100	72	89	34	1.3	0.7	23	
Lactarius trivialis »	130	57	15	76	25	1.1	0.8	23	
Gyromitra esculenta 50–55°C	120	140	26	110	85	1.0	0.8	44	
Craterellus cornucopioides 50–55°C	280	79	64	130	35	1.0	0.9	52	
Cantharellus cibarius »	220	93	29	110	46	1.1	0.6	53	
» *tubaeformis* »	280	120	65	61	34	0.5	0.9	41	
Armillariella mellea »	79	110	21	88	26	1.5	0.5	53	
Mean value	*207*	*86*	*31*	*84*	*33*	*0.9*	*0.7*	*37*	
Literature data									
Boletus edulis	110	56	9	130	67	1.0	–	–	Hinneri 1975
»	–	32	12	182	21	0.6	–	–	Sassi pers.comm.
»	–	52	11	–	49	–	–	–	Kurkela 1972
Albatrellus ovinus	–	25	9	40	3	0.6	–	–	Sassi pers.comm.
Ramaria flava	–	51	20	109	46	0.9	–	–	»
Lactarius trivialis	–	40	19	151	28	1.2	–	–	»
»	–	33	13	–	26	–	–	–	Kurkela 1972
Gyromitra esculenta	–	181	29	97	93	1.0	–	–	Sassi pers.comm.
Craterellus cornucopioides	850	78	12	52	15	1.0	–	–	Hinneri 1975
Cantharellus cibarius	140	76	11	200	35	0.9	–	–	»
»	–	67	30	96	23	1.1	–	–	Sassi pers.comm.
»	–	78	31	–	43	–	–	–	Kurkela 1972
Mean value	*367*	*64*	*17*	*117*	*37*	*0.9*			
Egg	2154	81	1	52	5	0.5	5.5	6	Souci & al. 1969
Milk	9846	11	1	27	2	1.3	3.6	12	»
Potato	591	41	7	1	7	1.5	0.9	24	
Mean value of 17 vegetables	3308	51	37	38	6	1.8	–	25	Koivistoinen & al. 1974

smaller in animal products than in mushrooms. On the other hand the contents of calcium and sodium were many times greater in animal products than in mushrooms. When comparing the average mineral contents of 17 vegetables with the corresponding contents of mushrooms, it is observed that there are no detectable differences in the contents of potassium, iron and magnanese in the dry material. In contrast, the calcium content of the vegetables was about tenfold and that of magnesium twofold compared with those of mushrooms. In mushrooms, however, the content of zinc was twofold and that of copper about fivefold compared with the corresponding contents in vegetables.

The mushrooms analysed in the present study, with the exception of the cultivated ones, were collected from around Tampere, those of Sassi (personal communication) from eastern Finland and those of Hinneri (1975) from the islands of south-western Finland. Taking this into consideration the results obtained in the different studies concerning the mineral contents of mushrooms were rather similar (Hinneri 1975, Kurkela 1972, Sassi pers. comm.).

Mushrooms are palatable and cheap material to be used to supplement basic food. As with other vegetable products also, mushrooms add to the amount of water-soluble nutrients in the diet. However, the variation in the yield of mushrooms in different years from the very heavy to the almost insignificant limits the effective use of mushrooms as a raw material for the food industry.

In order to ensure all-year-round processing it would be important to study in greater detail the possibilities of producing also other species than *Agaricus* by cultivation.

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