The Possible Role of Mushrooms in Maintaining Good Health and Preventing Diseases

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Abstract: According to the principles of orthomolecular medicine, which was established by Linus Pauling in the 1960's, a well balanced diet is a significant precondition for maintaining good health and preventing diseases. Based on the results of our own investigations and those of other authors, there is no doubt that edible mushrooms represent a highly nutritious foodstuff. Contrary to a widespread view held especially in the western world, which counts mushrooms among the tasty but otherwise quite insignificant food, it is necessary to revise our standpoint. Appreciation of edible mushrooms will increase in the future due to new data now available on their nutritional value, and they will also become of more and more interest to health-conscious consumers. Consumers will highly appreciate at least the following attributes: their low calorie, purine, glucose and sodium concentration as well as high content of several vitamins, potassium, phosphorus and of some trace elements. We believe that edible mushrooms should be considered as part of the orthomolekulare medicinal praxis similar to vegetables or fruits. After they have become part of the context of orthomolekulare medicine, their health value will be known and accepted by consumers. This information may also be beneficial for mushroom growers who should start a worldwide aggressive promotional effort pointing out the attributes of mushrooms for maintaining good health and preventing diseases. This strategy will help to increase mushroom consumption.

Key words: *Agaricus bisporus, Pleurotus* spp., *Lentinula edodes,* mushroom consumption, nutritional value, health value, orthomolecular medicine

1 Introduction

The mean reason for the stagnation of mushroom production in western countries is the fact that mushroom consumption takes place only spontaneously. Mushrooms, in general, are not consumed consciously and systematically like fruit and vegetables. In recommendations regarding a healthy diet, given by doctors, nutritionists as well as by many health organizations, mushroom are - as a rule - not included. In this situation the questions we have to ask are: (1) what are mushrooms able to provide, (2) for what are mushrooms useful, and (3) what shall we do to change the present situation?
The only reliable way to increase mushroom production significantly would be a considerable increase in mushroom consumption per capita. How can you increase mushroom consumption? Dr. David Foot, Professor of economics at the University of Toronto stated in his excellent lecture at the 14th North American Mushroom Conference at Toronto 1999 that: (a) we live in a generation which is growing older and older; (b) members of the older generation spend a smaller percentage of their income on a house, a car and other long-term investments and more money on health care and on maintaining good health. The consequence for mushroom producers is to make it well-known how healthy mushrooms are and, in fact, just how beneficial is mushroom consumption
How healthy are mushrooms in fact? In order to answer this question we investigated the nutritional value of several strains of white mushroom (*Agaricus bisporus*), two strains of oyster mushroom (*Pleurotus ostreatus*)

and one each of the king oyster mushroom (*P. eryngii*) and shiitake (*Lentinula edodes*) and discussed the results also under aspects of orthomolecular medicine. Orthomolecular medicine, established by Linus Pauling,[1] has become a worldwide accepted medical area. The merit of orthomolecular medicine is the specific application of vitamins, minerals, trace elements and other nutrients for the prevention and treatment of sicknesses caused by diet and environment.

2 Materials and Methods

2.1 Mushroom species and sample types

The following species and/or strains were investigated:
(1) *Agaricus bisporus,* Sylvan A-15, closed fruit bodies; (2) *Agaricus bisporus,* Sylvan 608, closed fruit bodies; (3) *Agaricus bisporus,* LeLion C-9, closed fruit bodies; (4) *Agaricus bisporus,* LeLion C-9, opened fruit bodies; (5) *Agaricus bisporus,* white, closed fruit bodies prior to canning; (6) *Agaricus bisporus,* white, closed fruit bodies after canning; (7) *Pleurotus ostreatus,* Somycel HK-35; (8) *Pleurotus ostreatus,* Amycel 3015; (9) *Pleurotus eryngii;* and (10) *Lentinula edodes,* Sylvan 4087
Each batch investigated consisted of 5 kg of fruit bodies. With one exception, fruit bodies of each species or strain of mushroom were taken on the first harvesting day of the first flush. On the bed from which sample number 3 was taken, we left the mushrooms on an area of approx. 0.5 m^2 and harvested them three days later after the fruit bodies had opened. These fruit bodies constituted sample number 4. The origin of the mushrooms in sample number 5 was unknown. What is important here, however, is that sample number 6 came from the same batch as sample no. 5 and was taken immediately after the latter had been canned and filled into jars. We did this in order to establish the effects of canning on the nutritional value of mushrooms. After the sample was taken, the fruit bodies were cut into 3 to 4 mm thin slices and carefully dried at 38ºC max. and with intensive air circulation. The dried mushrooms were then sealed in plastic bags and retained in this manner until the end of the chemical analyses.

2.2 Analyses

The following chemical analyses were carried out in duplicate:

2.2.1 Major components

Dry matter, crude protein, crude fat, raw fiber, chitin in the raw fiber fraction and ash

2.2.2 Minerals

Aluminum (Al), Arsenic (As), Boron (B), Barium (Ba), Calcium (Ca), Cadmium (Cd),
Cobalt (Co), Chromium (Cr), Copper (Cu), Iron (Fe), Potassium (K), Magnesium (Mg),
Manganese (Mn), Molybdenum (Mo), Sodium (Na), Phosphorus (P), Mercury (Hg), Selenium (Se), Strontium (Sr), Titanium (Ti), Vanadium (V), Zinc (Zn)

2.2.3 Vitamins

Vitamins A, B-1, B-2, B-6, D-2 and D-3.

The applied processes were of the latest state of the art in analysis technology and may be obtained from the

authors on request.

3 Results

Table 1 summarizes the content of the main nutrients of the investigated species and strains of mushrooms. The extremely high content of dry substance in *P. eryngii* is remarkable. The extremely low content of dry substance of the *A.bisporus* sample that was examined immediately prior to canning is primarily due to the fact that the fruit bodies were intensively saturated with water prior to the canning process. The *A. bisporus* sample that was investigated before and after canning had the highest content of raw fiber, chitin and ash. It is noteworthy that both *P. ostreatus* samples were rather poor in crude protein and crude fat. Samples of *A. bisporus* were clearly superior to *P. ostreatus* with regard to the raw fiber, chitin and ash contents. The dry matter content of the *L. edodes* sample was surprisingly small. Apart from crude protein, *L. edodes* contained rather small quantities of the main nutrients in the dry matter.

Table 2 (a-c) shows a summary of the extensive mineral analyses. Aluminum concentration was lowest in *L. edodes*. Arsenic could not bedetected in any of the samples. The boron content was strikingly small in *P. ostreatus* samples. There was no significant difference in barium levels among the mushroom strains. The

Table 1. Nutritive value of mushrooms
Main components in mushroom samples expressed as (%) of dry matter

Mushroom strain	Dry matter	Crude protein	Crude fat	Raw fiber	Chitin	Ash
1	8,66	23,86	1,72	9,27	8,68	11,86
2	8,71	21,44	1,89	9,45	8,16	11,95
3*	7,33	21,89	2,07	9,48	8,88	12,23
4**	9,28	22,65	1,44	8,47	7,31	10,53
5***	6,68	20,28	2,01	13,31	10,81	13,29
6****	8,15	20,28	2,06	16,60	12,16	13,07
7	8,22	17,67	1,67	8,28	4,77	7,60
8	7,75	17,32	1,56	7,98	4,95	9,42
9	15,44	25,02	2,95	6,04	4,77	10,05
10	7,66	21,73	1,66	6,12	5,84	7,41

*) closed fruit bodies **) opened fruit bodies ***) before canning ****) after canning

different species had a well-balanced calcium content although it is conspicuous that values of *A. bisporus* showed an approximate 3-fold increased value after canning. This is due to the Ca content of the water that was used in the canning process. Cadmium was not found in *A. bisporus*. However, we found Cd in all *Pleurotus* samples and also in *L. edodes*. Cobalt was not detectable except in the canned *A. bisporus* sample. In the canned white mushrooms, the Co presumably came from the material of the canning machinery. The may also explain why canned white mushrooms contained two to seven times more chromium than unpreserved samples and other species and strains. As regards copper, we found the highest value with *L. edodes*. The lowest contents were established in the *Pleurotus* species and with *A. bisporus* after canning. By far the highest iron content was found in *P. ostreatus*, Somycel HK-35. *Pleurotus ostreatus*, Amycel 3015, was also quite rich in Fe. In the case of *A. bisporus* Sylvan 608 and the canned sample showed the highest Fe content. The Fe content seems to increase as a result of the canning process. In our case it increased by more than 100 %. By far the highest potassium content was found in the *A. bisporus* samples; however, this decreased dramatically during the canning process. The lowest K content was detected in *L. edodes*. The magnesium content was evenly balanced among the mushroom species and strains. However, it decreased dramatically during canning. The highest content of manganese was detected in *P. eryngii* and *L. edodes*. All other mushroom species and strains had Mn values that were up to 75 % lower. With *A. bisporus*, the canning process caused a reduction in the Mn content

of the dry substance by approximately 15 %. Molybdenum was not traceable in *P. ostreatus*, Amycel 3015. In the remaining samples the values were between 0.60 and 1.66 mg/kg dry material. *Pleurotus* species and *L. edodes* were particularly low in particularly poor. Fresh white mushrooms contain up to 3.5 times more Na. The increase in the Na content of *A. bisporus* during canning is dramatic. With phosphorus, the opposite is true. The highest values were found in *A. bisporus* samples. However, as a result of canning, the P content decreased to less than half the original value. The mercury content was significantly higher in *A. bisporus* than in the *Pleurotus* samples and in *L. edodes*. It is striking, however, that most of the Hg disappeared from the fruit bodies as a result of canning because it was apparently washed out. *A. bisporus* strains are rich in selenium. Mushrooms grown on wood contained less selenium with *L. edodes* showing very low selenium levels. The strontium content in the canned sample of *A. bisporus* was conspicuously high while the values in the remaining batches were quite well balanced. Titanium was detectable at about the same low overall concentrations in all mushroom samples. The same applies to vanadium. In *P. ostreatus*, Somycel HK-35 and in *L. edodes*, vanadium was not detectable at all. The zinc content in the mushroom species grown on wood was consistently at least 30 % higher than in the *A. bisporus* samples.

The vitamin contents of the mushroom samples are shown in Table 3. Vitamin A levels were evenly balanced among all mushroom species and strains. Mushrooms grown on wood contained less vitamin B-1 and B-2 than *A. bisporus* strains. Vitamin B-6 values were again well-balanced, while wood-inhabiting mushrooms were significantly superior in terms of vitamin D-2 and D-3 compared to *A. bisporus* strains. It is noteworthy that the canning process led to a partly significant loss of vitamins in *A. bisporus*.

Table 2a. Mineral and trace element content of mushroom samples (mg/kg dry matter)

Mushroom strain	Al	As	B	Ba	Ca	Cd	Co
1	20.6	<0.05	17.2	1.51	765	<0.002	<0.002
2	21.4	<0.05	14.9	1.67	781	<0.002	<0.002
3*	23.1	<0.05	31.9	1.55	785	<0.002	<0.002
4**	22.9	<0.05	30.6	1.37	816	<0.002	<0.002
5***	19.9	<0.05	17.84	1.28	693	<0.002	<0.002
6****	22.5	<0.05	11.54	2.00	1808	<0.002	0.77
7	22.3	<0.05	3.23	1.57	538	1.12	<0.002
8	16.3	<0.05	4.97	1.42	684	0.59	<0.002
9	13.4	<0.05	16,45	1.52	687	1.56	<0.002
10	11.2	<0.05	20.14	1.50	807	2.19	<0.002

Table 2b. Mineral and trace element content of mushroom samples (mg/kg dry matter)-(continued)

Mushroom strain	Cr	Cu	Fe	K	Mg	Mn	Mo
1	1.58	24.3	47.2	45883	1239	6.6	0.60
2	1.74	38.9	83.3	46380	1284	6.45	0.69
3*	4.84	28.1	45.7	48356	1329	6.97	0.95
4**	1.48	27.3	58.2	43656	1254	7.36	0.91
5***	1.55	27.3	41.3	51983	1495	6.14	1.54
6****	10.24	14.6	88.5	15596	746	5.33	1.66
7	2.60	13.8	108.0	26960	1295	8.76	1.12
8	1.17	10.8	77.5	34846	1643	9.14	<0.005
9	1.34	16.2	42.0	35750	1595	13.00	0.84
10	1.29	40.7	40.6	25992	1585	19.50	1.44

Table 2c. Mineral and trace element content of mushroom samples (mg/kg dry matter) -(continued)

Mushroom strain	Na	P	Hg	Se	Sr	Ti	V	Zn
1	677	9896	1.42	2.97	5.66	0.23	0.12	60.0
2	637	10450	1.40	3.19	5.14	0.49	0.23	56.2
3*	575	10750	1.55	1.81	5.78	0.33	0.13	52.0
4**	629	11020	0.56	3.25	6.07	0.23	0.20	52.9
5***	874	11366	1.02	1.52	5.50	0.13	0.13	52.7
6****	27020	5347	0.16	1.86	16.02	0.35	0.17	53.5
7	205	6300	0.94	1.60	4.64	0.58	<0.005	79.8
8	189	7461	0.45	0.50	5.80	0.43	0.16	80.2
9	251	9995	0.59	1.42	6.54	0.37	0.12	80.7
10	195	6040	0.99	0.57	6.48	0.25	<0.005	80.2

*) closed fruit bodies; **) opened fruit bodies; ***) before canning; ****) after canning

Table 3. Vitamin content of mushroom samples (per kg dry matter)

Mushroom strain	Vit. A (µg/kg)	Vit. B-1 (mg/kg)	Vit. B-2 (mg/kg)	Vit. B-6 (mg/kg)	Vit. D-2 (µg/kg)	Vit. D-3 (µg/kg)
1	22.1	7.1	16.7	6.3	81.5	138.9
2	28.5	6.3	10.7	5.1	75.9	141.5
3*	32.3	6.5	13.4	6.6	89.3	188.8
4**	20.4	6.9	9.8	7.1	67.2	132.1
5***	33.7	9.5	16.3	6.0	90.1	189.8
6****	21.3	7.2	6.3	4.8	80.4	136.7
7	36.5	6.1	2.7	6.5	35.7	212.3
8	35.2	5.7	7.1	5.5	91.7	235.9
9	37.1	5.1	2.0	3.8	84.8	187.6
10	31.0	5.9	3.6	4.0	90.5	200.5

*) closed fruit bodies; **) opened fruit bodies; ***) before canning; ****) after canning

Table 4 shows, on the basis of the analysis results, what percentage of the daily adult demand for important nutrients are provided by a normal 150 g portion of fresh white mushrooms. A particularly high percentage of the daily vitamin D, potassium, phosphorus, copper and selenium demand is provided. An even more remarkable provision is seen in the case of vitamins B-1, B-2 and B-6, iron and zinc. On the other hand, we established only a very low fulfilment of the demand for energy, vitamin A and sodium.

Table 4. Provision of the daily demand for some essential nutrients by 150g (corresponding to a normal daily portion) fresh *A. bisporus* mushrooms

Mushrooms (150 g) daily containing on average		Daily average demand female/male (*)	Provision of the demand (%)
137.26 g water			
12.73 g dry matter			
90 J		**7500/10000 J**	**1.8-2.5**
protein	2.85 g	47/60 g	4.8-6.1
crude fiber	1.12 g	20/35 g	3.2-5.6
Vit. A	0.32 µg	800/1000 µg	0.03-0.04
Vit. B-1	0.085 mg	1.2/1.4 mg	6.1-7.1

Table 4

Mushrooms (150 g) daily containing on average		Daily average demand female/male (*)	Provision of the demand (%)
137.26 g water			
12.73 g dry matter			
90 J		**7500/10000 J**	**1.8-2.5**
Vit. B-2	0.16 mg	1.5/1.7 mg	9.4-10.7
Vit. B-6	0.08 mg	1.2/1.5 mg	5.3-6.7
Vit. D-2 & 3	17.15 µg	5/10 µg	171-343
K	585 mg	2000/4000 mg	14.6-29.3
Na	8.00 mg	2000 mg	0.4
P	134.1 mg	600 mg	22.4
Fe	0.75 mg	12/15 mg	5.0-6.3
Mn	0.09 mg	3/4 mg	2.2-3.0
Mg	16.2 mg	300/350 mg	4.6-5.4
Cu	0.38 mg	1.2/1.4 mg	27.1-31.7
Zn	0.70 mg	9/13 mg	5.4-7.8
Se	36.0 µg	50/70 µg	51.4-72.0

(*) Recommended by the German Nutrition Society

Table 5 shows the effect of a common canning process on the nutritive and health value of *A. bisporus* based on the analysis results. We found that the vitamin content, as well as the content of copper, potassium, phosphorus and magnesium, was reduced considerably in some cases. Iron, chromium and strontium contents increased significantly. There was a dramatic increase in the sodium content of canned *A. bisporus*. Dry matter, raw fiber

Table 5. Changes in the nutritive value during processing

Components in the dry matter	Content before processing	Content after processing	Change (%)
dry matter in %	6.68	8.15	+ 22.0
crude protein in %	20.28	20.28	0.0
fat in %	2.01	2.06	+ 2.5
raw fiber in %	13.31	16.60	+ 24.7
chitin in %	10.80	12.16	+ 12.6
Vit. A µg/kg	33.70	21.30	- 36.8
Vit. B-1 mg/kg	9.50	7.20	- 24.2
Vit. B-2 mg/kg	16.30	6.30	- 61.3
Vit. B-6 mg/kg	6.00	4.80	- 20.0
Vit. D-2 µg/kg	90.10	80.40	- 10.8
Vit. D-3 µg/kg	189.80	136.70	- 28.0
Ca mg/kg	693.00	1808.00	+ 160.0
Cr mg/kg	1.55	10.24	+ 658.1
Cu mg/kg	27.30	14.60	- 46.5
K mg/kg	51986.00	15596.00	- 69.9
P mg/kg	11366.00	5347.00	- 52.9
Na mg/kg	874.00	27020.00	+ 3091.0
Mg mg/kg	1465.00	746.00	- 50.1
Ni mg/kg	2.86	6.82	+ 138.4
Sr mg/kg	5.50	16.02	+ 291.3

and chitin contents also rose by up to 24.7 %. The only value that remained unchanged was the crude protein content and the fat content increased only slightly.

4 Discussion

During the last few years, several authors have also investigated the nutritive value of edible mushrooms. For example, Mattila et al.[2] were especially interested in the vitamins, minerals and trace elements of *A. bisporus, P. ostreatus* and *L. edodes*. Vetter and Lelley[3] looked at the selenium content of different cultivated species. Falandysz[4] did the same with different wild living mushrooms (*Boletus edulis, Leccinum scabrum, Macrolepiota procera, Amanita muscaria and Paxillus involutus*). Mattila et al.[5] also detected the Vitamin D-2 and the ergosterol (a precursor of Vitamin D-2) content in some wild and cultivated mushrooms. He and co-workers[6] also investigated the basic constituents and the amino acid content of *A. bisporus, P. ostreatus* and *L. edodes*. Dabbour and Takruri[7] checked the protein quality of *Terfezia claveryi, P. ostreatus, Tricholoma terreum* and *Agaricus macrosporus*. The nutrient content of some *Termitomyces* species was analysed by Kansci et al.[8] Savage et al.[9] checked the content of soluble and insoluble oxalate of different fresh and prepared mushroom samples.

Mattila et al.[10] had already pointed out that mushrooms can be considered to have potential as a functional food. However, in order to understand and to appreciate the importance of mushrooms for our diet, we also have to reflect on these results under orthomolecular medical aspects. In the past, these assessments have been made only sporadically.[3, 11, 12] According to the principles of orthomolecular medicine, a healthy diet is an important component in health care and the prevention of illnesses. As a consequence of the results obtained from our investigations we can say that edible mushrooms are, in principle, very valuable for health-conscious people. This is true in general and for the older generation in particular.

Foot[13] has already pointed out that an important objective of consumer education and promotion for edible mushrooms should be winning the older generation as consumers. This generation spends a significant part of its financial resources on health care and the prevention of illnesses, and has an above-average interest in relevant information. Such information with regard to edible mushrooms has also become available. They are definitely suitable to be considered from several points of view as very valuable food, for maintaining good health and preventing sicknesses. They have a low energy level that is beneficial for weight reduction, a low purine level that is beneficial for the diet of persons suffering from metabolic diseases (gout, rheumatism), and a low glucose level and more mannitol which is especially suitable for diabetics.[14] In addition, mushrooms have a very low sodium concentration that is suitable for the diet of persons suffering from hypertension, a high content of some vitamins (vitamin B-2, vitamin D and others) which is an important orthomolecular aspect. That means that a significant part of the daily requirement for different vitamins can be met by consuming mushrooms. Furthermore, mushrooms have a high content of some minerals (potassium, phosphorus), which is also an important orthomolecular aspect, as well as a high content of some trace elements, especially selenium which is regarded as an excellent antioxidant

A significant increase in mushroom consumption could be achieved by stressing and publicizing the health-promoting effects much more forcefully than has been the case up until now. The objective should be to create awareness among consumers that mushrooms - in the same way as vegetables - should be consumed not only because of their taste but also because of their health-promoting properties.

An increase in mushroom consumption would also be advisable from the viewpoint of orthomolecular medicine that helps to prevent and treat illnesses by the specific use of vitamins and other nutrients. We have found that edible mushrooms contain remarkably high percentages of many vitamins, minerals and trace elements, and also have other health-promoting properties. For this reason, they should in future also be included in the recommendations of orthomolecular medicine in addition to fruit, vegetables, fish and other healthy foodstuffs. Spreading the knowledge about the health benefits of mushrooms and the increased mushroom consumption

resulting from this would boost mushroom production. Such a development would benefit the mushroom producers who are located near the markets and supply these with fresh mushrooms. This is particularly important in view of the fact that the favorable health-promoting properties are mainly contained in fresh mushrooms. Conventionally, although canned mushrooms can be obtained from a greater distance or even from abroad, they must be regarded as rather inferior on account of the present analyses. However, we are very optimistic that consideration of these aspects of mushrooms, and efforts to broadcast this knowledge, can significantly increase mushroom consumption and can also help to promote mushroom production.

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