Review

Nutrition from mushrooms, understanding and reconciling available data

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Mushrooms are nutritionally valuable foods. They are high in proteins, including most essential amino acids and high in most water soluble vitamins and probably in pro-vitamin D. However, there have been many reports suggesting that they had little or no value. While the reports of little value were erroneous, other reports have claimed greater nutritional value than can be substantiated. Moreover, most of our knowledge of the nutritional value of mushrooms is based on chemical analysis. Some of the nutrients may be destroyed or unavailable to consumers. This paper looks at the available information and tries to reconcile it.

Key Words——*Agaricus*; human nutrition; *Lentinula*; mushrooms; *Pleurotus*.

When we eat, most of us think primarily of the flavor and texture of the food. Yet in the process we usually consume some poison, some pharmacologically active compounds, some nutrients, some water and some fiber or other material that is not taken up into our systems. It is often assumed that the only poisons in food are pesticides and other man-made materials, or possibly those produced by contaminating organism, such as aflatoxin or botulinum toxin. However, most food from plants contains natural poisons. For example potatoes contain solanine. The spices in particular are sources of pharmaceuticals. Oil of clove is a local anesthetic. Some animals produce very toxic substances. More generally, meats contain things that are more like our own bodies, but today many people fear eating cholesterol and do not realize that they, themselves, make large quantities.

The natural poisons in our foods are so well distributed that we can not hope to avoid them. However, most of the poisons that we eat are either eaten in small amounts or are not very toxic. Our livers and kidneys destroy and eliminate most of them from our systems. It also seems prudent to eat a diverse diet, so that no single poison is eaten in excess.

Only the nutritional value of mushrooms and other properties that might affect the nutritional value of mushrooms will be discussed in this paper. Others have reviewed the pharmacological properties of edible mushrooms and poisonous constituents of edible mushrooms do not appear to be well defined.

Many species of mushroom are cultivated or collected for food. A few species are more in demand than others, but availability is often of much greater importance than what is favored by the pallet. For example, in autumn, in the open market in Helsinki, and in the woods of Finland one can find *Lactarius* and *Cantharellus*. Most *Lactarius* are poisonous, but are easily rendered safe by boiling and discarding the water. The boiling process also removes much of the flavor. *Lactarius* is much more abundant in the woods and much cheaper in the market. Although *Cantharellus* is preferred, most of the wild mushrooms consumed are *Lactarius*.

The situation in Finland illustrates a principle that applies to other places throughout the world. Thus, most of the mushrooms consumed and most nutritional research has been on cultivated species, so they are the only ones we will consider.

In the past, the popular press has suggested that mushrooms have no nutritional value. Some scientific publications have used unrealistic conversions and suggested that mushrooms have greater nutritional value than the facts could support. Those extremes are rather easily corrected, but the exact nutritional value is more difficult to determine.

The science of human and even animal nutrition is at best, a difficult subject. Nutritional value may be determined by chemical analysis, animal feeding or human feeding experiments. The most common method is chemical analysis and the least common is human feeding. Chemical analysis is the easiest, and is capable of obtaining results that can be reproduced with good accuracy. However, we can not assume that all nutrients that are present will be used. The obvious solution is to feed mushrooms and determine the condition of the animals that have been fed. Rat feeding trials have been used to determine the nutritional value of mushrooms. The rats used in such experiments are easily handled and

uniform in every possible way. At the end of the experiment the rats can be autopsied and examined for any abnormalities or pathologies. Unfortunately, the digestive system of rats is quite different from the human digestive system.

Proximal Analysis

A number of investigations have made proximal determinations of the content of mushrooms (Table 1). Water or dry matter is the most commonly determined constituent. It is a necessary starting point, but with mushrooms it should be regarded as otherwise meaningless. Unlike most foods, mushrooms, have no natural vapor barrier. From the time a mushroom basidiocarp begins to form, its dry weight is a function of the humidity of its environment as well as moisture available from the substrate. If the moisture is too low during the development of the basidiocarp, it may die, but physiological requirements are somewhat flexible. Once the gills are exposed, the amount of surface in contact with the environment is especially great and evaporation can proceed rapidly.

The complexity of understanding the nutritional value of mushrooms is further complicated by almost all mushrooms being consumed moist. Yet, their moisture content when consumed is close to neither that of the mushroom when they were picked nor when they were purchased. That would be true for both fresh and dried mushrooms. If there is an exception it would be canned mushrooms when purchased and eaten. All cooking processes cause mushrooms to lose water. Dried mushrooms are normally rehydrated as the first step in preparation. However, water added by rehydration is never equal to the water in fresh mushrooms.

The analyses in Table 1 show moisture contents from 87.2 to 93.5%, a difference of 6.3%. That may seem of little significance; however, what we are really interested in is the dry matter, and the dry matter varies from 6.5 to 12.8%. That is, given 100 g of mushrooms one will contain 12.8/6.5=1.97 times as much food as the other. The extremes shown in Table 1 are from two independent experiments. However, in the same experiment that detected 87.2%, 93.0% was detected. That experiment was intended to determine extremes in moisture content of growing mushrooms that differed only in water stress. The 93.0% was from a well-watered tray and the 87.2% was from a tray that had restricted watering. The fresh weights were determined within 30 min of picking, so both moistures are from growing material.

Nitrogen vs. Protein

Another common analysis is Kjeldahl nitrogen. On a fresh weight basis, Kjeldahl nitrogen amounts to 0.25 to 0.80 g per 100 g of mushrooms (Table 1). With a water content of 87.2 to 93.5%, the nitrogen converts to 2.94 to 9.84 g per 100 g dry weight. The Association of Official Analytical Chemists specifies the factor 6.25 to con-

Table 1. Proximate composition of mushrooms, g per 100 g fresh weight. Minerals mg per 100 g fresh weight.

Species and Ref.	Moisture	Ash	Nitrogen	Protein $N \times 5.0$	Fat	Crude fiber	Na	K	Ca	Fe	P
Agaricus bisporus[a]	89.7	0.82	0.78	3.90	0.20	0.38					
A. bisporus[b]	89.5	1.26	0.61	3.07	0.19	1.09					
A. bisporus[c]	90.4	0.9	0.64	3.24	0.30	0.80	14.98	414.0	6.05	0.797	116.0
A. bisporus[d]	88.7	0.9	0.62	3.08	0.90	0.80	11.98	322.0	8.02	0.938	103.1
A. bisporus[e]	93.0		0.57	2.83				371.5	9.3	0.25	71.3
A. bisporus[f] High	93.0	1.40									
A. bisporus[f] Low	87.2	0.87									
A. bisporus[g] High	93.5	0.9[3]	0.64	3.20	0.5[3]	1.00	5.40	389	5.03	1.20	124.4
A. bisporus[g] Low	90.5	0.6	0.43	2.16	0.2	0.500[3]	3.90	329	1.48	0.420	92.6
A. bisporus[g] Label				2.23	2.23	0.558	4.46	357			
Lentinula edodes[h]	90.3	0.62		2.43[1]		0.98	8.25	229.5	1.1	0.39	57.5
L. edodes, logs[h]	88.3	0.59		2.60[1]		1.21	9.71	231.4	4.3	0.47	54.3
Pleurotus ostreatus[i]	92.5		0.34	1.72							
P. ostreatus "florida"[j]	91.5	0.79	0.25	1.25	0.14	1.01					
P. ostreatus[k]	88.9	0.44		4.71[1]	0.20	1.23	8.21	301.9	0.4	0.89	117.8
P. citrinopileatus[l]	90.2			1.67[2]	0.57		60.63	560.0	3.1	1.15	165.0
P. sajor-caju[l]	90.75			1.66[2]	0.36		26.8	628.0	2.8	0.89	149.0
Grifola frondosa[k]	90.9	0.60		2.31[1]	0.30	1.50	7.83	291.7	1.7	0.55	101.5
Volvariella volvacea[a]	88.4	1.46	0.80	3.99	0.74	1.38					

1) Basis of calculation not known. 2) Colorimetric. 3) Exact values in three or more composite samples.
References: a) Chang, 1972. b) Esselen and Fellers, 1946. c) Watts and Merrill, 1963. d) FAO, 1972. e) Bakowski et al., 1986.
f) Kurtzman, 1993. g) Contractor's report to Produce Marketing Association, 1982. (Private communication.) h) Aoyagi et al., 1993.
i) Kalberer and Kunsch, 1974. j) Bano et al., 1981. k) Kawai et al., 1994. l) Gosh et al., 1991.

vert yeast nitrogen (the only fungus they mention) to protein (A.O.A.C., 1990). On that basis, mushrooms have from 18.4 to 61.5 g protein per 100 g dry weight. The lower protein content suggests that they are a good source of protein and the higher value suggests that they are excellent.

The result of multiplying nitrogen by 6.25 is referred to as crude protein. Conversion of nitrogen into crude protein assumes that the average amino acid residue is 16.0% nitrogen. That is the average molecular weight would be 87.5 per nitrogen. Table 2 shows some actual molecular weights, percent nitrogen and the crude protein that would be calculated if 100 g of the single amino acid residue was analyzed for Kjeldahl nitrogen. The true protein content is also decreased from the crude protein by nucleic acids in most foods, by acetylglucosamine in fungi and by various other nitrogen containing compounds found in foods. Consideration of Table 2 makes it clear that 6.25 will very rarely give a crude protein that is close to actual protein. The factor is too high for many things and too low for a very few others. All living cells contain nucleic acid and the nitrogen from the nucleic acid is included in the analysis of foods. Foods containing rapidly multiplying cells will be high in nucleic acids. The structural carbohydrate of most fungi is poly-acetyl-gucosamine or chitin. Mushrooms cells divide at a slower rate than yeast, but more rapidly and have more nucleic acid than the cells of many other foods. Like yeast, mushrooms have poly-acetylglucosamine in their cell walls.

The properties of amino acids and other metabolites shown in Table 2 illustrate the problems that make the 6.25 factor so arbitrary. However, it gives no information that will allow the calculation of a good conversion factor. Mushroom protein has been reported as 4.17 times nitrogen, but that factor was based upon no data (Watts and Merrill, 1963). A minimum conversion factor is easily calculated from amino acid analysis. Doesburg and Meijer (1965) analyzed the amino acids in Agaricus bisporus (Lange) Singer and found a total of 5.126 g per g of Kjeldahl nitrogen. That must be regarded as a minimum because some losses are certain to have

occurred during analysis. However, proteins are made up of amino acid "residues," amino acids minus water. The minimum conversion factor should be about 5.0, based upon their amino acid analysis. It is reasonable to apply the same factor to other species, unless analyses provide a better factor. The 5.0 figure is considerably less than 6.25, often used and greater than the 4.17 that has been arbitrarily used for mushrooms.

The properties of adenosine deoxyriboside monophosphate, shown in Table 2, illustrate the influence that nucleic acids have on the nitrogen of rapidly developing cells. Glucosamine represents the contribution of chitosans and acetylglucosamine the contribution of chitin to crude protein.

Protein Quality

While the amount of protein is of importance the quality of protein is also important. Cows' milk is used as a protein quality standard. Ratios of the essential amino acids from several analyses of mushrooms to those in milk are shown in Table 3. Tryptophan and cystine are particularly difficult and were not always analyzed. Large differences in those amino acids might be expected, but other amino acids are also not consistent from one analysis to the next. Yet, there are some similarities even between species. The first column, was calculated from the results of Doesburg and Meijer (1965). Their results were based on ten replicate analyses of Agaricus and are used by FAO (1970). Cystine has the lowest ratio to milk and it represents 0.32 in their results. Bakowski et al. (1986) did extensive analysis of mushrooms at different stages and under various growing conditions, their data is similar. Fewer analyses of other mushrooms have been published, but the protein of the others seems generally to be of good quality. The poorest ratio is for cystine in Pleurotus ostreatus (Jacq.: Fr.) Kummer at 0.13. However, as already mentioned, cystine is difficult to analyze. All of the mushroom analyses gave ratios better than 1 for methionine, the other sulfur amino acid.

Table 2. Calculating "crude protein" from nitrogen in individual amino acids and other nitrogen constituents.

	M.W.	Residue M.W.	Residue %N	"Crude protein" Calc., g/100 g
Arginine[a] (4N)	174.2	156.18	35.88	224.2
Tyrosine[b]	181.19	163.18	6.88	53.7
Glutamic acid	147.13	115.99	10.85	67.8
(Iso)Leucine[a,b]	131.17	113.16	12.39	77.4
Proline[b]	115.13	97.12	14.42	90.1
Phenylalanine[a,b]	165.19	147.18	9.52	59.5
Acetylglucosamine	221.21	203.20	6.89	43.1
Glucosamine	179.17	161.16	8.69	54.3
Deoxyadenylic acid (DNA)	347.23	329.22	21.28	133.0

a) Essential amino acid. b) Often increases when total protein decreases.

Table 3. Ratios of essential amino acids in mushrooms to those in Cows' milk.

Amino Acid	Agaricus bisporus[a]	Agaricus bisporus[b]	Lentinula edodes[c]	Pleurotus ostreatus[d]	Volvariella diplasia[e]
Iso-leucine	0.868	0.583	0.766	0.634	1.166
Leucine	0.681	0.552	0.607	0.502	0.367
Lysine	0.758	0.875	0.372	0.413	0.550
Phenylalanine	0.708	0.598	0.810	0.485	0.911
Tyrosine	0.673	0.529	0.609	0.444	0.337
Threonine	0.921	0.878	0.978	0.730	0.946
Tryptophan	1.136			0.693	0.784
Valine	0.812	0.630	0.751	0.630	1.174
Cystine	0.318			0.127	0.917
Methionine	1.725	1.471	1.784	1.333	1.098
Total essential	0.766	0.622	0.630	0.530	0.744
Total amino acids	0.799	0.810	0.799[1]	0.603	

1) Total amino acids assumed to be 5,162 mg per g nitrogen, for calculations.
a) Doesburg and Meijer, 1965. b) Bakowski et al., 1986. c) Sugimori et al., 1971.
d) Kalberer and Kunsch, 1974. e) Bano et al., 1981.

Fat

At one time the official U.S. value for the fat content of *Agaricus* mushrooms was 2.23 g per 100 g fresh weight (Contractor's repor to Produce Marketing Association, 1982 (Private communication)). However, the greatest reported fat analysis is 0.9 g per 100 g fresh weight or 7.96 g per 100 g dry weight. Some analyses suggest that the primary fatty acid is linoleic, but more recent analysis found only saturated fatty acids (Abdullah et al., 1994).

Fat analyses have been very variable in mushrooms. There is no apparent reason, but it represents a small part of the mushroom. I am aware of no study that has tried to elucidate factors that might influence fat content.

Minerals

As with many foods, minerals are highly variable. Ash analysis varies from 0.6 to 1.46 g per 100 g fresh weight (Table 1). Analyses of one mushroom variety, all grown on the same compost, varied from 0.87 to 1.40 g per 100 g fresh weight or 6.80 to 14.87 g per 100 g dry weight (Kurtzman, 1993). It is interesting that mushroom with the least solid matter had the greatest ash. Mushrooms, like all living things, have a good mix of minerals. Potassium seems to be the most abundant among the minerals (Table 1).

The environment influences mineral content, but most of the values, even for different species are similar for the minerals. Both ordinary *Agaricus* compost and casing contain large quantities of calcium (Kurtzman, 1979, 1991). It is no surprise that analysis of *Agaricus* shows larger amounts of calcium than other mushroom species. It is rather surprising that there is so little calcium. Most data does not indicate if the composition of the substrate influences the mineral content of the mushroom. In the case of calcium we can state that the

presence of high concentrations in the substrate has little effect on the mushrooms. Other ions and pH might affect the calcium.

Vitamins

An important factor in the overall nutritional value of a food is its vitamin content. Yeast has been sold as a B-vitamin supplement. In Australia, Great Britain and New Zealand it is sold as a spread for breakfast toast. Table 4 compares the vitamins found in mushrooms with those found in two yeasts (Kurtzman, 1975). Notice that the yeasts are dry and all mushrooms except *Lentinula* are moist. We do not know the moisture contents, but the values for *Agaricus* need to be multiplied by 10 to 20 to be compared to the dry yeast. After multiplication the values for *Agaricus* seem very comparable, except for thiamine. The *Lentinula* had been irradiated with ultra-violet light. Most fungi produce ergosterol, which is converted to vitamin D by sunlight or ultraviolet irradiation.

At best, thiamine in *Agaricus* represents only about one-tenth of that in yeast. Thiamine is required for biological decarboxylation and it is a necessary metabolic function. Why are mushrooms so low in such a necessary vitamin?

Anti-Nutritional Factors

The low levels of thiamine may be due to thiaminase (Wakita, 1976). Apparently mushrooms contain both the base transferase and the hydrolase types of thiaminase (Wittliff and Airth, 1970a, b). Both thiaminases destroy thiamine and may be responsible for the small quantities of that vitamin that has been found by analysis. Cooking destroys both thiaminases. Other foods including fresh-water fish contain thiaminases, so there is no cause for alarm.

Hemagglutinins have been reported in several

Table 4. Vitamins in mushrooms and yeasts. Quantities per 100 g.

	Thiamin (mg)	Riboflavin (mg)	Niacin (mg)	Ascorbic acid (mg)	Vit. K	Pantothenic acid (mg)	Biotin (mg)	Pyridoxin (mg)	Folic acid (mg)	Vit. D (IU)
Torula yeast,										
dry[a]	14.01	5.60	44.4	trace	—	—	—	—	—	—
Brewer's yeast,										
dry[a]	15.61	4.28	37.9	trace	—	—	—	—	—	—
Agaricus bisporus,										
fresh[a]	0.10	0.46	4.2	3.0	—	—	—	—	—	—
canned[a]	0.02	0.25	2.0	2.0	—	—	—	—	—	—
fresh[b]	0.12	0.52	5.85	8.6	+	2.38	0.018	(0.45)	(0.98)	—
Lentinula edodes,										
dry[c]	+	+	+	—	—	—	—	—	—	40,000

+ =Present, no indication of quantity. — =No data.
a) Watts and Merrill, 1963. b) Esselen and Fellers, 1946. c) Ono et al., 1974.

mushrooms (Kogure, 1975; Ortiz et al., 1992; Presant and Kornfeld, 1972). It is likely that other mushrooms contain them as well. Hemagglutinins cause malabsorption. They are also known to occur in beans (Liener, 1975). They are destroyed by heating. Thiaminase and hemagglutinins are proteinaceous; so once cooked, they are nutritious, but in other respects might be looked upon as natural poisons.

Carbohydrates

The carbohydrates of mushrooms include some mono- and di-saccharides and sugar alcohols (Kalberer, 1990), as well as glycogen and chitin. Chitin contains 6.9% nitrogen (Table 2). In mushrooms, chitin would be expected to be represented by the major constituent of the "crude fiber." However, the analysis would be expected to degrade chitin to chitosan, which contains up to 8.7% nitrogen. Determinations of crude fiber have shown it to represent 3.39 to 15.38 g per 100 g dry weight (calculated from Table 1). That means it represents 0.29 to 1.34 g of nitrogen per 100 g dry weight or 1.8 to 8.4 g of the crude protein as calculated using 6.25. Yeasts have a similar chitin content, making the recommended nitrogen-to-protein factor, more curious. It appears that the nitrogen to crude protein factor should be approximately 5.4, based upon the nitrogen content of the crude fiber.

Structure-Fibers

It may also be necessary to look at the way nature packaged the nutrients. Most foods of animal origin have a cellular structure primarily of protein; even dairy butter is fat in a protein emulsion. Most food of plant origin has a rigid structure of cellulose plus some hemicellulose and lignin.

Mushrooms and fungi in other foods, while they may have some cellulose, generally have a structure primarily made of chitin. Crab, lobster, shrimp and other arthropods also have chitin, but it is the horny exoskeleton

material that is not eaten. Thus chitin is a relatively unusual dietary material and studies of its dietary effects have been limited. Chitin is poly-β-(1->4)-2-acetomido-2-deoxy-D-glucose or poly-*N*-acetyl-D-glucosamine and it is often passed over simply as "cellulose-like." However, it differs from cellulose in many ways.

Before trying to understand the research that has been done on the dietary influence of chitin we note that, "it is doubtful whether a pure, undegraded product is normally obtained" (Foster and Webber, 1960). Even worse, for us, as mycologists, almost all studies have been done with arthropod chitin. It has been said that there is a difference between arthropod and fungal chitin, yet little difference has ever been shown between purified materials from the two sources (Foster and Webber, 1960). As we have said, both would be expected to be degraded, so the differences may be lost in preparation.

In edible fungal species, fungal chitin is part of the relatively soft mass. We can not be certain how purified arthropod exoskeleton chitin relates to natural mushroom chitin.

It may seem strange that nutritional experiments with chitin have all been done with arthropod chitin, while all natural dietary chitin is fungal. The reason is that lobster and crab chitins are available in large quantities as waste from fisheries. Apparently, researchers have not understood that fungal chitin is discarded in large quantities by mushroom farms as trimmed butts and culls.

While chitin is always a degraded material, some work has been with chitosans, which are somewhat more degraded. The only difference between chitin and chitosans is the degree of deacetylation and chitosans are soluble below pH 6.0 while chitins are not (Foster and Webber, 1960). Some experimental data shows hypocholesterolemic activity for chitosan, but no physiological activity for chitin (Furda, 1983). However, that is not a universal result (Austin et al., 1981). Other experiments show that chitosan tends to reduce the absorption of nutrients more than chitin, which has a great-

Table 5. Protein efficiency ratio (PER) and digestibility in rats, Tunnel-dried mushrooms.

Expt. No.[a]	Dietry protein 10% of diet[b]	Final body wt. (g)[c]	Total feed consumed[c]	PER[e]		% Digestibility[f]		
				Actual[d]	Adjusted	Diet	N	5.0/6.25
1	Casein (ANRC)	201±9	436±36	3.35±.13	2.50	93	91	
1	A. bisporus	141±7	286±19	3.01±.10	2.81	88	65	81
2	Casein (ANRC)	183±11	372±24	3.42±.09	2.50	94	92	
2	A. bisporus	116±4	278±12	2.18±.05	1.99	82	59	74

a) The diets used in experiments No. 1 have less mushrooms and dextrose, but more oil, water, salts and cellulose than No. 2.
b) The 10% protein is based on $N \times 6.25$.
c) Mean±S.E. All values within each experiment are significantly different: Duncan's multiple range test, $P<0.01$.
d) Mean±S.E. All values within experiments are significantly different: Duncan's multiple range test, Expt. No. 1 $P<0.05$. Expt. No. 2 $P<0.01$.
e) PER (Protein Efficiency Ratio)=Weight gain/protein intake. "Adjusted" equivalent with casein reduced to standard 2.5 and mushroom protein = $5.0 \times N$.
f) Digestibility: Diet=(feed intake−fecal weight)/feed intake × 100. N=(N intake−fecal N)/N intake × 100. "5.0/6.25"=(N intake−fecal N)/N intake × 5/6.25 × 100. Pooled data, day 7 through day 14.
Male, Sprague-Dawley rats, initial age 21 d, initial weight 55 g.

er effect than cellulose (Gordon and Williford, 1983).

Of more importance is the effect, if any, that the naturally combined chitin has upon nutrition. Unfortunately, little seems to have been done on the subject. Chitins are often combined with proteins and other nutrients. Free amino groups may chemically combine with other nutrients and even acetylated chitin may be able to chelate or otherwise capture some nutrients (Austin et al., 1981; Furda, 1983).

Evaluation by Feeding

After our consideration of chemical and biochemical materials in mushrooms, it is evident that we do not completely understand their nutritional value. It would seem to be ideal to feed humans for nutritional studies. Humans can not be examined as thoroughly as rats after the experiments, but they can tell the experimenter if they feel any discomfort. Human subjects are also more difficult to get and much more expensive to maintain than rats. However, one experiment with humans has been reported (Imaki et al., 1991).

Often young rats are used and growth measured as the primary factor. Almost all human subjects are young adults and the primary measurement is balance as determined by dietary consumption versus fecal and urinary loss. Humans are not uniform and often those who seem similar turn out to be very different.

The standard scientific method requires that all known factors, but one, should be held constant. Each natural food includes many nutrients; all of those will be altered when that food is added to a diet. Usually calories and vitamins will be held constant, but if protein is being studied, fat, carbohydrate or both will be changed to maintain constant calories.

With all the problems, feeding experiments are a reasonable way to determine the nutritional value of mushrooms. Some years ago, we fed Agaricus mushrooms plus methionine to rats and determined the Protein Efficiency Ratio (P.E.R.) (Kurtzman, 1993) (Table

5). Two slightly different experimental diets were tested. The only things that were kept completely equal in the casein controls and both experimental diets were nitrogen, vitamins and corn starch. That means that the rats fed mushrooms received less protein than those fed casein. It also means that the mushroom diets contained less corn oil, dextrose, salt, and cellulose. When all adjustments were made, the rats on the mushroom diet containing the largest amount of corn oil (8.4% less than controls), gave a P.E.R. of 2.81 compared to the casein standard of 2.50. Rats receiving mushrooms, but 14% less oil than controls gave a P.E.R. of only 1.99. The P.E.R. determinations depend on body weight, so all energy sources are of considerable importance. The mushrooms, supplemented with methionine, appeared to be slightly better nutritionally than casein.

Conclusions

From available data we know that mushrooms are nutritious foods. They are high in protein and have a good balance of vitamins and minerals. They contain little fat and digestible carbohydrate, making them suitable for low calorie diets.

Analyses seem to vary quite widely on all constituents. The water content is particularly variable. The variation in water results in solid matter varying by up to 200% even in mushrooms on the same substrate and of the same commercial variety. Thus, it is impossible to state the exact nutritional value without an analysis of the individual crop.

There is relatively little information on the digestibility of mushrooms and on the value of their fiber content. While raw mushrooms contain anti-nutritional factors, they cause no apparent problem in small quantities and are rendered harmless by cooking.

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