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Mushrooms: sources for modern western medicine
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MUSHROOMS: SOURCES FOR MODERN WESTERN MEDICINE

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ABSTRACT

Fungi and especially mushrooms are rich sources of many things that are important to our health. They are a good source of proteins that are important to all body functions. Their proteins are of very high quality and are rich in the most important protein building blocks, the essential amino acids. They are an excellent source of most B-vitamins and the primary natural source of ergosterol or pro-vitamin D. While many people who eat balanced diets receive all of the needed minerals, some get more sodium than they need. Mushrooms have the double benefit of low sodium and more potassium and iron than most foods. Chitin is the primary structural material in mushrooms and has been shown to be of value as dietary fiber. It can also be hydrolyzed to glucosamine, which is widely accepted by orthopedic physicians as a valuable food supplement for the prevention and alleviation of osteoarthritis.

Key words: chitin, chitosans, dietary fiber, essential amino acids, glucosamine, osteoarthritis, vitamins.

INTRODUCTION

In modern western medicine, drugs must undergo extensive testing before they are acceptable. Many things from living things are considered food supplements and are acceptable because they have been tested from other sources. Mushrooms contain many things that fit the definition of food supplements. One kind of mushroom may be richer in one of these materials while another kind will be richer in another. However, mushrooms are generally similar to each other in special food values.

Food supplements might further be described as natural things that are used to prevent or at least lessen the chance of pain and disease. Unlike true medicines, they derive their benefit from promoting natural body functions and not from selective...
poisoning. That is not to say that they can never be poisonous. For example, high doses of niacin and other vitamins are poisonous, but food supplements do not derive benefit from the properties that make them poisonous.

Our primary interest is in things that are normally found in much great amounts in mushrooms than in most foods, and even in things not found at all in other foods. However, we also want to mention that mushrooms are very good nutritionally and to explain what makes them so good. Any food with high nutritional value, must be considered a “health food.” A number of reviews have been published on the nutritional value of mushrooms, so we shall not dwell on the subject here. However, a number of papers on the nutritional value of mushrooms has been published since those reviews and we will comment on some of those.

In many languages the words for fungi and mushrooms are synonyms, so some information on other fungal foods or ones that contain fungi have been included. The British are often considered mycophobes, yet in his diary, as early as 1621, Governor William Bradford of Plimoth Colony made it very clear that he considered beer to be a health food. He certainly did not understand that yeast increased the nutritional value of the barley and hops, but he did understand that people who drank beer in moderation were healthy people.

**EVERYTHING IS POISON!**

Saying everything is poison, may be an exaggeration, but it is less so than most believe. Liener found that ordinary beans contain hemagglutinins which cause malabsorption. Hemagglutinins have also been found in mushrooms. It is likely that other mushrooms contain them as well. All mushrooms that have been studied for thiaminase contain it. Thiaminase destroys vitamin B1.

Although both hemagglutinin and thiaminase may be considered poison, they offer only a minor danger. Both of these poisons are proteins and as long as mushrooms (and beans) are cooked, their hemagglutinin and thiaminase activity will be destroyed. Once cooked the poison principals will do no harm at all, in fact they have food value as proteins. Even a few raw mushrooms will do no perceptible harm to a healthy person.

Many other poisons are found in mushrooms, plants and animals. Some of those poisons may be concentrated in the preparation of extract or other mushroom products.

**VALUABLE FIBER - SUPPLEMENTS**

The fiber of plants is cellulose, lignin and hemicellulose. The fiber of mushrooms is chitin. Often times chitin is referred to as “cellulose-like.” Chitin and cellulose do have many chemical and mechanical properties in common, but they are also quite different from each other. Chitin is also the material that makes up the horny shells of crabs, lobsters, shrimp, and other arthropods. Of course, those shells are not eaten, but they are processed into food supplements, those supplements bring high prices (Figs. 1, 2). If the garbage from shellfish can be processed and sold at high prices as food supplements why not use mushroom wastes? After all, mushroom wastes are food that just does not look good;
it may be dirty, or damaged mushrooms, or their “roots.” Arthropod shells are not food at all, and they are certainly not clean.

When chitin is purified it is always somewhat degraded, so all shellfish chitin that has been studied is degraded, generally, most mushroom chitin that is eaten, would be in or at least nearly in its natural state. However, if we wish to process it, it should be easier to purify than shellfish chitin.

Chemically, cellulose is poly-ß-(1->4)-D-glucose, while chitin in poly-ß-(1->4)-2-
acetomindo-2-deoxy-D-glucose or more simply poly-N-acetyl-D-glucosamine (Fig. 3). If chitin loses its acetyl groups through hydrolysis, it is called chitosan. That hydrolysis is quite easily accomplished under alkaline conditions.

Although I am talking about food, I want to mention one new use for mushroom chitosan that is not food. *Ganoderma* wastes have been converted to chitosan and used as dressing on human wounds. It appears to be very effective. Possibly chitosans made from edible mushrooms will work equally well. Others have studied “water-soluble chitin” as a wound dressing. We might note that while acetylation is the primary difference between chitin and chitosans, chitosans are water soluble below pH 6.0, chitins are not.

However, at the moment we want to talk about food uses. Both chitin and chitosans from shellfish have been studied as dietary fiber. Fibers help us clean our digestive tracks. In so doing, we reduce chances of cancer and also heart disease and stroke. The studies suggest that chitin and chitosans are excellent hypocholesteroleemics, that is they reduce cholesterol. It is by the reduction in cholesterol that they reduce heart disease and strokes. Reports differ on which is more effective, chitin or chitosans. In part the evaluations may be confused because of problems in extracting them, “it is doubtful whether a pure, undegraded product is normally obtained”.

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**Fig. 3.** Chemical structure of chitin (top) and chitosan (bottom).
It has been suggested that chitosans and to a lesser degree chitin may chelate some undesirable nutrients. Most recent studies, however, have investigated only chitosans. Experiments suggest that chitosans capture cholesterol and bile in the intestines and carry them out so that the body can not absorb or reabsorb them. Bile is required by the intestines, cholesterol and recycled bile are the normal sources of material to supply bile, so if the liver can not get bile or cholesterol from the intestines, it uses cholesterol from the blood, thus reducing the amount there. However, that may not be the mechanism.

One drug, “WelChol®,” used to reduce cholesterol, is referred to as colesvealam HCl or chemically as poly-allylamine hydrochloride, although it is apparently somewhat more complex. In common with chitosan, it is a polymeric amine, so it might act in the same manner. The standard dose of poly-allylamine is 3.8 g/day which experiments show reduces LDL (“bad cholesterol”) 15% and increases HDL (“good cholesterol”) 3% after 24 weeks. The retail cost per person was USD$ 965 for medicine used. A 100 day supply is USD$ 600-700. Two other synthetic drugs are also somewhat similar, Cholestyramine and Renagel. However, the uses for Renagel are quite different and not for cholesterol.

Dietary fiber supplements are sold, especially to elderly and people on restricted diets who may have problems with constipation. Selling processed mushroom wastes for fiber is one of the possible uses for culls and trimmed mushroom butts.

The laws in each country are somewhat different from others. In the U.S., people have paid large fines for making claims about chitosans for use in reducing weight, etc. As a result one must tread lightly, even though experiments have shown that 6 g/day of chitosans after two weeks lowers LDL (“bad cholesterol”) 6% and increases HDL (“good cholesterol”) 10%. Another experiment used only 1.2 g each of chitosan and Propol™ glucomanan daily for 28 days. Total serum cholesterol decreased 7%, LDL 10% and HDL 5%. Much is made of oat bran for lowering cholesterol. It requires 84 g of dry oats or a 750 ml serving every day to reduce cholesterol by 6 mg/dL (ca. 2%).

One laboratory has studied mushrooms and mycelium as hypocholesteroleemics in rats and hamsters and found a significant decrease in serum total and HDL (“good cholesterol”) in those with the mushroom diet.

In calling it fiber, we are saying that it is not digested and so has no proper nutritional value, however, the fact that it goes through the gut without being digested means that it can carry things through that are not good for you. Experiments with oats also show that it moves other unhealthy materials out of the human system. We can expect that more experiments with chitin and chitosans would give similar benefits. While chitin and other fibers have no nutritional value, they have great dietary, or health value. Yet, if chitin could be digested, the sugars that make up would be of considerable nutritional value. Like cellulose, chitin can not be digested in our gastrointestinal track, but also like cellulose, chemical digestion is possible. However, unlike glucose, the product of the chemical digestion of cellulose, glucosamine, the product of chemical digestion of chitin, has more nutritional value than just calories.
Osteoarthritis is becoming a more common problem than ever before. In the U.S.A. many thousands of people have complete hip and knee replacements every year. Those operations are generally very successful, but there is always considerable pain before the operations are performed and recovery always involves some pain. Osteoarthritis is the loss of joint cartilage, so that instead of the cartilage at the ends of the bones rubbing as the joint moves, the bones of the joint rub directly on one another\(^7\). Like chitin, cartilage is primarily acetylglucosamine and a similar sugar acetylgalactosamine. Enzymes normally hydrolyze damaged cartilage so that it can be disposed of by the body. If everything is working well, new cartilage replaces the damaged material. However, often athletes and older people begin to lose cartilage faster than they replace it. Glucosamine often with chondroitin has become a very common, but expensive, food supplement (Figs. 1, 2). It is generally recommended in the U.S.A. by orthopedic physicians. I have only mentioned humans, but it is sold for dogs and other pets as well. One orthopedic surgeon, who performs many hip and knee replacements every week told me he takes it and so does his dog. Mushroom growers everywhere are throwing away valuable materials that could be sold as food supplements.

Refining the butts and culls into glucosamine requires sophisticated processing\(^6\); it could only pay on a very large farm, or an organization that collected from many smaller farms. We could start with something as simple as mixing the butts and culls with mature \textit{Coprinus}. The deliquescing \textit{Coprinus} would hydrolyze the mushroom chitin, but it would look little better than inky soup (Fig. 4).

The production of dietary fiber need not be as sophisticated. For example, most customers would prefer not to have oyster mushroom stems that must be discarded. If the mushrooms are trimmed well, the mushrooms are a premium product and the stems can become another product. The stems might be processed into a tasteless supplement pills, a fiber-paste or maybe into a tasty gravy or other gourmet sauce. Such a sauce might be labelled to emphasize its high fiber content. In all cases, mushrooms and edible mushroom products should be sold as healthy, nutritious food, if they are sold for maximum profit they should also appeal to gourmets.

\begin{center}
\textbf{Fig. 4.} \textit{Coprinus comatus}, a source of chitin and chitin hydrolyzing enzymes.
\end{center}
Although the production of glucosamine from wastes is a somewhat greater problem, than fibers, it may well be worth the effort. In the U.S. the product will be accepted in the market, if it is clean, and pure and cleanliness is more important than purity. All products currently on the market carry a warning for people allergic to shellfish. Mushroom glucosamine might find people with such allergies to be ready customers. Since glucosamine is accepted as an over-the-counter food supplement, it might be sold to pill makers rather than making any effort at all to sell to the general public. One can also be assured that considerable research has been done and more is being done. For example, With more people exercising regularly, future interest in and the need for glucosamine would seem assured.

NUTRITION

If you are going to tell everyone that your product is nutritious you need to know what its food value is. So let us now switch to the more general nutritional value of mushrooms. Most of the data I have is taken from published work by others. Unfortunately, not all published values are as carefully done, or described as we might prefer. In my tables blank spots means that no data was published. An asterisk means that they did not describe how they determined the data.

One very important thing to be aware of is that solid matter in g/100 g is 100 g minus moisture. Thus 93.5 moisture means that the solid matter is only 6.5 g/100 g (or 6.5%). While 81.8 moisture means the solid matter is 18.2 g/100 g (or 18.2%). That means that data for solid matter recorded from various authors in Table 1 varies not by just 11.7%, but rather by 280%. Yet we can not judge the authors, on that basis. The age of the mushrooms, the growing environment and the post harvest environment can all have a large effect on both moisture and solid matter.

PROTEINS

The proximate values for protein, shown in Table 1, except those with asterisks are Kjeldahl nitrogen times 5.0. Most figures you will see are nitrogen times 6.25. Some others have used 6.25 times 0.666 (4.165) for mushrooms. We can be certain that both of those factors are incorrect. While the 5.00 factor may also be incorrect, I will justify my use of it.

First, why not use the standard 6.25 factor. The simplest answer is that it is probably always wrong, no matter what the source of protein. More important, chitin is 6.89% nitrogen and DNA is about 21.28% nitrogen. Fungi are the only organisms that have chitin that can not easily be removed from the edible protein and mushrooms have more DNA than most plants and animals. Most important, analysis for all amino acids in mushrooms have shown that they total about 5.162 grams per gram of nitrogen. The amino acids each gained water during hydrolysis, so the 0.162 was subtracted to account for the 18.0 formula weight of water. Amino acid analysis will generally show somewhat less than the actual amount, due to losses, so the factor 5.00 should represent a minimum figure of protein calculated from nitrogen.

Based on similar reasoning, Mattila et al. has chosen a factors of 4.50 to 4.97 for various species. They did not analyse for...
### Table 1. Proximate composition of mushrooms, g per 100 g fresh weight. Minerals mg per 100 g fresh weight.

<table>
<thead>
<tr>
<th>Species and ref.</th>
<th>Moisture</th>
<th>Ash</th>
<th>Nitrogen</th>
<th>Protein N X 5.0</th>
<th>Fat</th>
<th>Crude fiber</th>
<th>Na</th>
<th>K</th>
<th>Ca</th>
<th>Fe</th>
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*aBasis of calculation not known. **Colorimetric. #Exact values in three or more composite samples.

Tryptophan and their analyses of other essential amino acids are considerably different than obtained by other authors (Table 2).

### MINERALS

I mentioned that a number of minerals in mushrooms are desirable. Sodium is generally low, potassium is high and iron is high. Phosphorus is good, but not outstanding. Calcium might be expected to be high in *Agaricus*, since it is used in compost and especially in the casing, but unfortunately it is not high. Some minerals are controlled by the organism, and others by the substrate. Apparently, calcium is controlled by the organism and most likely sodium is controlled by the substrate.
However, if the osmotic pressure of the substrate becomes high, it is the growth of the mushrooms that will be reduced by the substrate. It might be well to quickly review the importance of minerals. Potassium is important in many enzymatic and muscle functions, calcium is required for bones and teeth. Apparently childbearing and lactation require that the calcium metabolism of women must be quite different from men and so women require more calcium.

Iron is required for blood, liver, and muscle formation. Once again women of all ages require more iron than men. It takes little knowledge to understand one reason women of childbearing age require more iron, since it is normal for them to lose more blood than men. However, it is also true that older women require more than men of the a similar age.

Phosphorus is also required for bones and teeth, but it is of great importance in all tissues. It is used to transfer energy within the body and for genetic information. The primary function of sodium is in osmotic balance. Analysis for sodium in Agaricus has been reported to vary from 3.90 to 14.98 mg/100 g, a factor of just over 4 times. Even from different flushes of the same crop of Agaricus, an extreme of 0.87% and 1.40% ash has been recorded.

**AMINO ACIDS – VALUE IN PROTEINS**

Many amino acids can be easily formed within the body, but the essential amino acids are needed to build the proteins that make our bodies function. Those called the essential amino acids must be in the food we eat, however, some can replace others to some degree. As a generalization mushrooms supply about half as much of each of the essential amino acids supplied by milk (Table 2). In most mushrooms, cystine is low and methionine is high, compared to milk. Fortunately, methionine can substitute to a large degree for cystine.

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**Table 2.** Ratios of essential amino acids in mushrooms to those in cows’ milk.

<table>
<thead>
<tr>
<th>Amino acid</th>
<th>Agaricus</th>
<th>Lentinula edodes</th>
<th>Pleurotus ostreatus</th>
<th>Volvariella diplasia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Isoleucine</td>
<td>0.868</td>
<td>0.766</td>
<td>0.634</td>
<td>0.506</td>
</tr>
<tr>
<td>Leucine</td>
<td>0.681</td>
<td>0.607</td>
<td>0.502</td>
<td>0.424</td>
</tr>
<tr>
<td>Lysine</td>
<td>0.758</td>
<td>0.372</td>
<td>0.413</td>
<td>0.478</td>
</tr>
<tr>
<td>Phenylalanine</td>
<td>0.708</td>
<td>0.810</td>
<td>0.485</td>
<td>0.600</td>
</tr>
<tr>
<td>Tyrosine</td>
<td>0.673</td>
<td>0.609</td>
<td>0.444</td>
<td>0.337</td>
</tr>
<tr>
<td>Threonine</td>
<td>0.921</td>
<td>0.978</td>
<td>0.730</td>
<td>0.693</td>
</tr>
<tr>
<td>Tryptophan</td>
<td>1.136</td>
<td>0.784</td>
<td>0.784</td>
<td>0.784</td>
</tr>
<tr>
<td>Valine</td>
<td>0.812</td>
<td>0.751</td>
<td>0.630</td>
<td>0.563</td>
</tr>
<tr>
<td>Cystine</td>
<td>0.318</td>
<td>0.127</td>
<td>0.917</td>
<td>1.000</td>
</tr>
<tr>
<td>Methionine</td>
<td>1.725</td>
<td>1.784</td>
<td>1.333</td>
<td>0.407</td>
</tr>
<tr>
<td>Total essential</td>
<td>0.766</td>
<td>0.630</td>
<td>0.530</td>
<td>0.599</td>
</tr>
<tr>
<td>Total amino acids</td>
<td>0.799</td>
<td>0.799*</td>
<td>0.603</td>
<td>0.643</td>
</tr>
</tbody>
</table>

*Total amino acids assumed to be 5162 mg per gram nitrogen, for calculations.
They are both sulfur-containing. Based on amino acid composition, mushrooms are excellent food. Some authors make a strong differentiation between protein and free amino acids. Free amino acids may be important to taste and large quantities may cause undesirable effects on some people. However, normal levels in foods are metabolized in exactly the same manner as their minus-H$_2$O residues in protein.

**VITAMINS**

In the 1940’s “Ironized Yeast Tablets” were a highly advertised food supplement in the U.S.A. Today in the United Kingdom, Australia and New Zealand, one will generally find “Vegemite” and “Marmite” served as a spread for toast at breakfast. Both are pastes made from yeast and are intended as food supplements. Table 3 shows why you might do better with a mushroom sandwich than with Vegemite. A search of the internet will also suggest that the mushrooms will taste far better. Almost all vitamins are found in greater amounts in mushrooms (Table 3). Unfortunately, the thiamin is low in the mushrooms. Apparently it is due to the natural thiaminase.$^{58, 61, 62}$

Niacin is very high in mushrooms. It is the anti-pellagra vitamin, but it is also recommended for controlling blood cholesterol. However, it appears to be effective, only in massive doses 1 to 5 g/day$^{45}$, thus one would need to eat about 20 kg of fresh mushrooms every day. Even doses as low as 50 mg of niacin can cause severe flushing, so there are real dangers with its use.$^1$

<table>
<thead>
<tr>
<th>Table 3. Vitamins in mushrooms and yeasts. Quantities per 100 g.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Thiamin</strong></td>
</tr>
<tr>
<td>(mg)</td>
</tr>
<tr>
<td>Torula yeast, dry$^{99}$</td>
</tr>
<tr>
<td>Brewer’s yeast dry$^{99}$</td>
</tr>
<tr>
<td>Agaricus bisporus, fresh$^{49}$</td>
</tr>
<tr>
<td>canned$^{49}$</td>
</tr>
<tr>
<td>fresh$^{14}$</td>
</tr>
<tr>
<td>fresh$^{41, 43}$</td>
</tr>
<tr>
<td>fresh$^{41, 43}$</td>
</tr>
<tr>
<td>Pleurotus ostreatus, fresh$^{41, 43}$</td>
</tr>
<tr>
<td>Lentinula edodes, fresh$^{41, 42}$</td>
</tr>
<tr>
<td>dry$^{98}$</td>
</tr>
</tbody>
</table>

$^+ =$ Present, no indication of quantity. $— =$ No data.

Vitamin D is particularly confusing in mushrooms and other fungal foods. Apparently all fungi produce ergosterol. Ergosterol is provitamin D, it becomes vitamin D when it is exposed to ultraviolet radiation. That radiation can occur in the mushroom, after it is harvested, or in the human who eats the mushroom. Sunlight is the normal source of the ultraviolet.

Some doubt has often been expressed about the availability of nutrients found in mushrooms. A preliminary experiment was done, feeding humans Cantharellus tubaeformis with vitamin D$_2$. Others receive the same dose without mushrooms and a third group received no vitamin D. There was no significant difference between the groups receiving the vitamin, but the group that received none showed less in their serum at the end of the study$^{52}$. 

OTHER FUNGAL FOODS

We have already mentioned beer, but modern beer is filtered and so the yeast is removed. However, soft cheeses, including blue cheese all include mycelium and analyses shows that they are high in B vitamins as compared to other cheeses$^{59}$. The Mongols drink “airag” and the Kazakhst drink “kumys,” fermented mares milk. One can find very limited information on these products and the accuracy of that information must be questioned. However, the label from a bottle of “ASKAR” brand Kumys produced in Semipalatinsk, Kazakhstan, indicates that it is pH 4.0 and acidity as determined by my palate agrees. Such a pH is difficult for organisms, others than fungi to attain. Another characteristic is that it is highly carbonated and seems to be capable of additional carbon dioxide formation days after the bottle is opened. That is, it appears that the fermenting organisms are still alive. The label also claims that it contains many vitamins including “D, B$_1$-B$_{15}$”. Fresh mares’ milk would not have such a generous range of vitamins, however, fungi would be capable of contributing them.

Mushrooms contain many things that make them true health foods. Some of the things that make mushrooms so healthy can be retrieved from things that are now discarded by farms. In some cases the recovered material may be more valuable as food supplements, already recommended by physicians, than the mushrooms they are a byproduct of. Like almost all foods, mushrooms also contain materials that can be poisonous, yet all known poisonous materials in commercially grown mushrooms are completely harmless when the mushrooms are prepared in a customary manner.

LITERATURE CITED


