Nutritional and Medicinal Value of Specialty Mushrooms

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ABSTRACT

Although the button mushroom (Agaricus bisporus) accounts for slightly over half of total world mushroom production, specialty mushrooms, e.g., shiitake (Lentinula edodes), straw (Volvariella volvacea), oyster (Pleurotus spp.), and enokitake (Flammulina velutipes), are increasing in popularity. These species contain moderate quantities of good quality protein and are good sources of dietary fiber, vitamin C, B vitamins, and minerals. Lipid levels are low, but unsaturated to saturated fatty acid ratios are high (about 2.0 - 4.5:1). Some species (e.g., shiitake) accumulate cadmium and selenium and other heavy metals, and some may contain toxic substances such as the heat labile cardiototoxic proteins volvatoxin in the straw mushroom and flammutoxin in enokitake. Extensive clinical studies, primarily in Japan, have clearly demonstrated that a number of species have medicinal and therapeutic value, by injection or oral administration, in the prevention/treatment of cancer, viral diseases (influenza, polio), hypercholesterolemia, blood platelet aggregation, and hypertension. Most of the studies have focused on shiitake, enokitake, Pleurotus spp., and on the generally nonculinary Ganoderma spp. Many of the active substances which include polysaccharides (e.g., β-glucans), nucleic acid derivatives (the hypcholesterolermic eritadenine), lipids, peptides, proteins, and glycoproteins, have been isolated and identified. Some of the mechanisms of activity have been elucidated, e.g., antiviral activity via stimulation of interferon production in the host. Additional medical claims less well documented may nonetheless have some validity and merit further study.

The total annual world production of cultivated mushrooms is estimated at well over 1.2 million metric tons (6,92). The 1986 world production of cultivated mushrooms was about 2.2 million metric tons (fresh equivalent weight), with the common button mushroom (Agaricus bisporus) accounting for 56% of total production. Other important species include shiitake (Lentinula edodes), 14%; straw mushroom (Volvariella volvacea), 8%; oyster mushroom (Pleurotus spp.), 8%; wood ear mushroom (Auricularia spp.), 6%; enokitake (Flammulina velutipes), 5%, and all other species, 3% (4).

An estimated 314,000 metric tons of shiitake were produced in 1986; major producing countries were Japan (51%), China (38.3%), Taiwan (10.2%), Korea (0.3%), and United States (0.1%) with the remaining 0.1% spread among Canada, Singapore, Holland, Philippines, Finland, Thailand, and Belgium. In 1986, China was the major producer of straw mushrooms, Pleurotus spp. and Auricularia spp. with 56.3%, 59.0%, and 67.2%, respectively, of total world production (4). In 1974, Japan and Taiwan produced 90% and 10%, respectively, of the world crop of enokitake (13). It should be noted that much of the success by the Japanese in the expansion of specialty mushroom cultivation can be traced to the efforts of the late Dr. Kisaku Mori who established the Mushroom Research Institute of Japan (39,46).

Agaricus bisporus is the predominant mushroom grown and consumed in the United States. Although most of these specialty mushrooms are grown and consumed primarily in the Far East, there is a definite potential for their expanded production in the West (5,14).

This paper will address the nutritional value and medicinal properties of the second most popular mushroom in the world, shiitake, as well as those of V. volvacea, Pleurotus spp., F. velutipes, and other species including wild types, where appropriate.

Part I. Nutritional Value

A comprehensive review of the nutritional value of mushrooms was presented by Crisan and Sands (12). They noted the problem of evaluating data published by different investigators working with even the same species of mushrooms, since the composition of a given species is affected by many variables. Composition, per se, cannot be translated directly into nutritional value because of such things as differences in digestibility of components, relative availability of nutrients, and inherent inaccuracies of analytical procedures.

Moisture. Fresh mushrooms generally contain 85-95% moisture, whereas commercially available, air-dried specimens contain 5-20% moisture, depending on duration and conditions of storage prior to analysis. On average, however, fresh and air-dried mushrooms contain about 90% and 10-12% moisture, respectively (12). Published data on composition of mushrooms are often expressed on a dry weight basis. As a rule of thumb, assuming 10% dry matter content in fresh mushrooms, data can be converted from fresh weight to dry weight basis and vice versa by multiplying or dividing by 10, respectively.
Protein. Mushrooms are considered to be good sources of protein. Crisan and Sands (12) have pointed out some special considerations relating to the protein content of mushrooms. The crude protein content of most foods is calculated from nitrogen content \((N \times 6.25)\), assuming that the protein contains 16% nitrogen, that it is digestible, and that it contains negligible amounts of nonprotein nitrogen. However, mushrooms contain significant amounts of nonprotein nitrogen in the form of chitin in their cell walls. Therefore, mushroom protein as \(N \times 6.25\) has been reported to be only 34-89% digestible, with a number of studies indicating 60-70% digestibility. The conversion factor \(N \times 4.38\) has been adopted for mushrooms in several food composition tables based on 70% protein digestibility \((0.7 \times 6.25 = 4.38)\). Recent studies (54, 66) have supported the adoption of \(N \times 4.38\). USDA Handbook No. 8-11 (19) used the factor \(N \times 6.25\) but reported that the amino acid profile for shiitake was based on 59% of total nitrogen as protein nitrogen. On the other hand, at least one study has indicated that a purified mushroom protein isolate contained only 11.79% nitrogen which would call for a conversion factor of 8.48, if one considers only "true" protein (12).

In data compiled by Crisan and Sands (12), protein content as percentage of dry weight varied from 4-9% for Auricularia spp. to as high as 44% for Agaricus spp. Protein content was 24 to 44% in A. bisporus, 10-17% in L. edodes, 21-30% in V. volvacea, 10-30% in Pleurotus spp., and 18-22% in F. velutipes. Handbook 8-11 (19) reported 10.6% protein, dry basis, in shiitake mushrooms calculated as \(N \times 6.25\).

Wahid et al. (92) found 19% protein, dry weight basis, in Pleurotus ostreatus; they did not specify a nitrogen conversion factor. Rai et al. (66) analyzed seven different Pleurotus spp. grown under identical conditions. They determined protein content by micro-Kjeldahl using both \(N \times 6.25\) and \(N \times 4.38\); by Lowry’s method and by a dye binding method. They found excellent agreement between Lowry’s method and Kjeldahl \(N \times 6.25\); values by dye binding method were lower and those by Kjeldahl \(N \times 6.25\) were higher. Actual protein contents (Lowry’s) were 1.6-2.5%, wet weight basis, and 20-32%, dry weight basis, across the seven species. Soluble protein accounted for 26-35% of total protein. Li and Chang (41) reported 46 and 59% protein in two strains of L. edodes; 26 and 28% protein, respectively, in less mature and more mature Pleurotus ostreatus; 40 and 25% protein, respectively, in less mature and more mature Pleurotus sajor-caju; and 46 and 32% protein, respectively, in “button” and “elongated” V. volvacea. All values were on dry weight basis with analysis by the Lowry method.

Crisan and Sands (12) presented amino acid profiles of more than 20 different cultivated and wild mushrooms, including L. edodes and Pleurotus species, from 14 different literature sources. They concluded that mushrooms contain all of the essential amino acids which comprise 25-40% of the total amino acid content. Handbook 8-11 (19) listed glutamic acid as constituting over 25% of the total protein amino acids in shiitake mushrooms; essential amino acids constituted about 32% of the total. Essential amino acids accounted for about 40% of the total in P. ostreatus (31).

Approximately 25-35% of the total amino acids occur in the free state (12). The limiting amino acids reported in mushrooms across 14 different literature reports were, in order of decreasing frequency, methionine, cystine, leucine, isoleucine, valine, lysine, phenylalanine, tyrosine, threonine, and tryptophan (12). Lentinula edodes was limited in methionine, cystine, valine, and isoleucine; P. ostreatus was limited in methionine, cystine, tryptophan, lysine, leucine, phenylalanine, and tyrosine. Calculated protein nutritional scores based on amino acid profiles showed a high degree of variability within as well as among species, thus pointing out the impossibility of making general statements extolling mushrooms as a source of dietary protein.

Ogawa et al. (54) determined the amino acid profiles of the protein and nonprotein nitrogen (NPN) fractions of four different cultivated mushrooms, including F. velutipes; they concluded that mushroom proteins are relatively abundant in essential amino acids except for methionine and cystine. The predominant “protein amino acids” (i.e., amino acids normally occurring in protein) in the NPN fraction were alanine, glutamic acid, and glutamine. About 38% of the nitrogen in F. velutipes existed as NPN. Other workers have published amino acid profiles for P. ostreatus (16, 31, 92). A so-called naturally isolated P. ostreatus strain had a total amino acid content 2-3 times higher than the other four strains tested, i.e., 27 versus 8-14 g/100 g dry matter (16).

Yamashita et al. (95) determined the free amino acid profile of shiitake mushrooms before and after storage in air or in modified atmosphere (MA) packaging. The predominant protein amino acids were glutamine, glutamic acid, aspartic acid, alanine, and arginine. They noted increases in most amino acids as duration of storage increased. A 185% increase was noted in the total quantity of free amino acids after 7 d storage in air at 10°C but only a 3% increase after 21 d storage under MA conditions at 1°C.

Sato et al. (68) reported total free amino acid contents ranging from 0.06 to 730 μmol/g dry matter in 113 different kinds of mushrooms; L. edodes, P. ostreatus and F. velutipes contained 128, 289, and 532 μmol/g, respectively. Alanine, glutamic acid, and glutamine predominated. No obvious correlation could be found between the free amino acid pool and taxonomic groups of mushrooms. Oka et al. (60) found that alanine, glutamic acid, proline, and arginine were the predominant free protein amino acids in A. bisporus. Rai et al. (66) reported free amino acid contents of 237-502 mg/100 g (fresh weight basis) in seven species of Pleurotus.

The bottom line on the nutritional value of mushrooms, from a protein standpoint, is that 1) protein content varies considerably among and within species; 2) mushrooms are generally limiting in the sulfur-containing amino acids (methionine and cystine) and in several other essen-
tial amino acids; and 3) mushrooms contain a substantial proportion of protein amino acids in the free form. Crisan and Sands (12) concluded their review with the comment that edible mushrooms are usually considered for their flavor and condiment value, but that it may become increasingly important in the future to consider their nutritional value.

Fat. Crude fat in mushrooms contains all classes of lipid compounds including free fatty acids, mono-, di-, and triglycerides, sterols, sterol esters, and phospholipids. It can comprise from less than 1% to as high as 15-20% of the dry weight with 2-8% as an average range (12). Values were reported of 1.2-8.0% in L. edodes, 5.7-10.1% in V. volvacea, 1.0-7.2% in Pleurotus spp., 2.1-8.3% in Auricularia spp., and 1.9-5.8% in F. velutipes, all on a dry weight basis (12). Fat contents of 2.5-15.6% were reported in the dry matter of 10 different mushrooms species; L. edodes and F. velutipes contained 5.3 and 5.0%, respectively (96). The dry matter of seven Pleurotus species contained 1.4-1.9% fat (66). The cap (pileus) and stalk (stipe) portions of shiitake mushrooms contained 0.50% (4.58%, dry basis) and 0.45% (2.65%, dry basis) total lipid, respectively (18). Within the lipid fraction, neutral lipids (about 48%) and phospholipids (about 43%) were high and glycolipids (about 9%) were low. Among neutral lipids, the distribution was: triglycerides, 58%; sterol esters, 17%; sterols, 16%; diglycerides, 6%; and monoglycerides, 1%; and among phospholipids: phosphatidyl ethanolamine, 60%; phosphatidyl choline (lecithin), 18%; cardioliipin, 13%; and lysophosphatidyl choline, 6%. The main fatty acid was C 18:2 (linoleic) followed by C 16:0 (palmitic) and C 18:1 (oleic). The ratios of unsaturated to saturated fatty acids in the cap and stalk were 3.4:1 and 4.5:1, respectively, in agreement with values published by others (5,12). Handbook 8-11 (19) reported 11% total lipid, dry weight basis, in shiitake mushrooms, but a somewhat lower ratio of unsaturated to saturated fatty acids of 1.8:1.

Hiroi (21) studied wild and cultivated strains of P. ostreatus and found little difference in their total lipid content; both contained 3-5% total lipid, dry basis. However, the total lipid content was generally higher in the cap than in the stalk. In general, neutral lipid, glycolipid, and phospholipid contents constituted 20-30%, about 10% and 60-70%, respectively, of total lipids, and linoleic acid constituted 70-80% of total fatty acids. Phosphatidyl choline and phosphatidyl ethanolamine were the principal phospholipids.

Koyama et al. (37) analyzed 44 different mushroom species and found 3.38 and 6.91% total lipid in the dry matter of shiitake and enokitake, respectively. Fatty acids common to all species included the 18:2, 18:1, 18:0, and 16:0 acids. In shiitake, C 18:2 and C 16:0 comprised 73% and 15%, respectively, of the total fatty acids. Enokitake was the only species to contain an appreciable quantity of linolenic acid (18:3); the 18:2, 18:3, and 16:0 fatty acids made up 46, 30, and 12%, respectively, of the total fatty acids. Similar values were reported for enokitake fruit bodies, but linolenic acid was much lower (2-8% of total fatty acids) in the mycelia (20). According to Handbook 8-11 (19), shiitake mushrooms contained 18:1, 18:2, 16:0, 18:0, and 18:3 fatty acids in quantities of 19, 18, 16, 7, and 2%, respectively, of the total fatty acids.

The sterol compositions of 10 different mushroom species were determined (96). Ergosterol, the most important of the pro-vitamins D, occurred in all 10 species and comprised more than 70% of total sterols in all but two. Ergosterol represented 84 and 45%, respectively, of the total sterols in L. edodes and F. velutipes. The latter contained substantial proportions (10-30% of total sterols) of three other sterols. Ergosterol levels among 44 different mushroom species ranged from 19 mg/100 g mushroom dry matter in Auricularia auricula to 780 mg/100 g in Grifola frondosa. Shiitake and enokitake contained 325 and 272 mg/100 g, respectively (37). Dry basis ergosterol contents of 350, 420, and 570 mg/100 g, respectively, were found in pileus, stipe, and gill portions of shiitake mushrooms (62). About 55-65% of it occurred in the free form with the remainder in the ester form.

The lipid fraction is a minor quantitative fraction in mushrooms and, therefore, it is of relatively minor importance nutritionally except, perhaps, for the ergosterol (pro-vitamin D) component. The good news is that on a qualitative basis, the fatty acids are predominantly unsaturated in nature.

Carbohydrate and fiber. Fresh mushrooms contain 3-28% carbohydrate and 3-32% fiber on a dry weight basis (12). A. bisporus, which has been studied extensively, contains pentoses (xylose, ribose), hexoses (glucose, galactose, mannose), sucrose, sugar alcohols (mannitol, inositol), sugar acids (galacturonic, glucuronic), methyl pentoses (rhamnose, fucose), and amino sugars (glucosamine, N-acetylglucosamine). As mentioned above, chitin, a polymer of N-acetylglucosamine, is a structural component of cell walls. Since most studies of different mushroom species have indicated a remarkable similarity in overall composition, nearly all of these substances are probably common to most species. Handbook 8-11 data (19) apparently included fiber in the carbohydrate component, reporting 83% total carbohydrate and 13% fiber, dry basis, in shiitake mushrooms.

Wahid et al. (92) reported 57% and 14% carbohydrate and crude fiber contents, respectively, in the dry matter of P. ostreatus. Rai et al. (66) found 20-32% carbohydrate and 10-13% crude fiber, dry basis, in seven different Pleurotus species. Because of the recent surge of interest in dietary fiber, Kurasawa et al. (38) analyzed 26 species of mushrooms for crude fiber (CF), lignin, and pectin as well as neutral detergent fiber (NDF) and acid detergent fiber (ADF). This also enabled them to estimate cellulose and hemicellulose contents and to calculate the ratios of total dietary fiber (TDF) to total crude fiber. All of their values were reported on the dry basis. Ranges in values were: crude fiber, 1.1-16.4%; lignin, 0.6-6.1%; pectin, 1.0-9.1%; NDF, 16.4-50.5%; ADF, 2.0-24.7%; TDF, 18.4-55.5%; cellulose, 0-21.0%; hemicellulose, 7.7-38.4%; and ratio, TDF:CF, 1.7-44.3. Among mushrooms of primary interest
in this review, total crude fiber ranged from 7.4% (shiitake) to 12.2% (enokitake); total dietary fiber contents were 37.5, 38.5, 46.1, and 47.5% in shiitake (Donko), enokitake, shiitake (Koshin), and *P. ostreatus*, respectively. The mean ratio of TDF:CF was 5.7 compared to a range of 1.5-2.6 for other vegetables and a mean ratio of 2.8 for 35 kinds of edible wild plants studied. Thus, a large proportion of the carbohydrate of mushrooms consists of dietary fiber.

**Ash and minerals.** Mushrooms probably contain every mineral present in their growth substrate including substantial quantities of phosphorus, potassium, a lesser amount of calcium, and a very low amount of iron (12). Total ash content was 7.6 to 10.4% in seven different *Pleurotus* species (66) and 8% in *P. ostreatus*, dry weight basis (93). These are somewhat higher than the 5% total ash (dry basis) given in Handbook 8-11 (19) for shiitake mushrooms.

Kikuchi et al. (36) examined 21 different species of edible mushrooms for their contents, on wet basis, of 18 different mineral elements. Three metals, vanadium, tin, and antimony, were not detected in any of the samples at the respective detection limits of 2, 2, and 0.8 μg/g of fresh mushrooms. Cobalt was detected in *Ramaria botrytis* (0.19 μg/g), selenium in *Sarcodon asperatus* (6-10 μg/g), nickel in *Naematoloma sublateritium* and *R. botrytis* (0.2-1.3 μg/g), chromium in *S. asperatus*, a *Tricholoma* sp. and *R. botrytis* (0.16-0.22 μg/g), and lead in *Lepista nuda*, *Hygrophorus poetaurum*, *N. sublateritium*, and *R. botrytis* (0.4-2.0 μg/g). Cadmium was detected in all but one species (*Suillus bovinus*) at 0.04 to 1.02 μg/g of mushrooms. Nine other metals, in decreasing order of concentration (μg/g), were detected in all species: potassium (946-3500), magnesium (59-274), sodium (8-396), calcium (5-78), aluminum (1.2-98), iron (3.5-27), zinc (3.3-19.5), copper (0.4-26.6), and manganese (0.8-7.4). Only these nine plus cadmium were detected in *P. ostreatus*, *L. edodes*, and *F. velutipes* from 4, 3, and 2 sampling areas, respectively. *Lentinula edodes* was generally low in sodium and iron, high in calcium and aluminum, and average in cadmium, zinc and manganese. *Flammulina velutipes* was generally low in cadmium, zinc, copper, iron, manganese, calcium, aluminum and sodium, average in potassium, and high in magnesium. *Pleurotus ostreatus* was generally low in calcium, aluminum and sodium, average in iron, manganese and potassium, and high in zinc, copper and magnesium.

Kawai et al. (35) analyzed 24 species of wild edible mushrooms and 5 species of cultivated mushrooms, including *P. ostreatus*. Their values for *P. ostreatus* contents of K, Na, Ca, Mg, Fe, Cu, Zn, Mn, Cd, and Pb agreed closely with those of Kikuchi et al. (36). In addition, they assayed for phosphorus, arsenic, and mercury which were detected in *P. ostreatus* (86.6% moisture) at levels of 1406 mg/100 g and 2.7 and 0.1 μg/g, respectively, dry weight basis.

Handbook 8-11 (19) presented contents of six minerals in dried shiitake mushrooms (9.5% moisture) in mg/100 g: calcium, 11; iron, 1.72; magnesium, 132; phosphorus, 294; potassium, 1534; and sodium, 13. These values compare reasonably well with those of Kikuchi et al. (36) for shiitake.

Bisaria et al. (3) studied the influence of 13 different lignocellulosic agro-residues (e.g., straw, leaves) on the mineral composition (P, K, Na, Mg, Fe, Mn, Zn, Cu, Ca) of *Pleurotus sajor-caju* mushrooms. In general, substrates higher in a particular mineral produced mushrooms relatively high in their content of that mineral. Values agreed well with those of other workers (35,36) except that sodium contents were much higher and zinc and copper contents were lower.

The above results agree quite well with values compiled from eight literature sources for mineral content of *A. bisporus* and about 20 other wild and cultivated species, including *L. edodes*, *P. ostreatus*, and *F. velutipes* (12). In addition to the elements already discussed, that compilation included the contents (mg/100 g, dry basis) in *L. edodes* of silicon (262), sulfur (237), and chlorine (73).

Several mineral elements have received special attention. Crisan and Sands (12) noted that mushrooms have been analyzed for their content of undesirable minerals such as lead, cadmium, and selenium. However, Finnish workers (64) analyzed 38 different mushroom species for selenium content in the hope that they might help to alleviate a deficiency of selenium in the Finnish diet. Selenium content, on a fresh weight basis, ranged from 0.2 μg/100 g in *Hydnum repandum* to 190 μg/100 g in *Boletus edulis*; *A. bisporus* and *L. edodes*, respectively, contained 7 and 0.5 μg/100 g.

Ohe et al. (35) reported that the mean level of cadmium in shiitake mushrooms, at 0.17 μg/g of fresh product, was about six times that found in 37 different species of vegetables. Of six different metals (Cd, Zn, Cu, Fe, Mn, Ni) in the growth media (wood), Cd and Zn were concentrated about six and three times (ppm metal in mushrooms/ppm metal in wood), respectively. Concentration factors ranged from 0.01 (Ni) to 0.70 (Cu) for the other four metals. They isolated two cadmium binding components from shiitake; one had a molecular weight of about 3,500 daltons and other had a molecular weight of about 40,000 daltons. The chemical form of the former could not be determined; the latter was a glycoprotein high in acidic amino acid content (56).

Zurera-Cosano et al. (100) examined eight species of edible mushrooms, including *P. ostreatus*, for lead and cadmium contents; ranges in caps were 0.12 to 0.77 μg/g lead and 0.04 to 3.48 μg/g cadmium on a fresh weight basis. Cultivated *P. ostreatus* contained 0.29 μg/g lead and 0.07 μg/g cadmium. *Psalliota campesi* contained the highest levels of both metals. On average, caps contained 1.43 times as much lead as stems; the ratio was 1.57 for cadmium. These authors concluded that levels of Cd and Pb in mushrooms are species-factor dependent but could not identify a responsible factor or mechanism.

As sources of mineral nutrition, mushrooms in general and shiitake in particular bring both good and bad news, the bad news being the accumulation of cadmium and perhaps other heavy metals.
Vitamins. Mushrooms appear to be good sources of thiamin (B_1) riboflavin (B_2), niacin, biotin, and ascorbic acid (vitamin C), but a great deal of species specificity exists. Vitamins A and D are relatively uncommon although several species contain detectable amounts of f-carotene and many contain ergosterol, which converts to active vitamin D when subjected to ultraviolet radiation (12).

Crisan and Sands (12) listed thiamin, riboflavin, niacin, and ascorbic acid values in mg/100 g, dry basis, from eight literature sources for about 20 different mushrooms species. Among species of interest in the present review, values were given for L. edodes, P. ostreatus, and F. velutipes. In fresh, raw samples of these three species, thiamin content ranged from 4.8 to 7.8 mg/100 g, riboflavin from 4.7 to 4.9 mg/100 g, and niacin from 55 to 109 mg/100 g, all on dry basis. Only F. velutipes contained ascorbic acid, at 46 mg/100 g dry matter. Handbook 8-11 (19) gave values (mg/100 g) for these vitamins, on as is basis, for cooked shiitake (83% moisture): thiamin, 0.04; riboflavin, 0.17; niacin, 1.5; ascorbic acid, 0.3 and for dried shiitake (9.5% moisture, as is basis) vitamin contents (mg/100 g) were thiamin, 0.3; riboflavin, 1.3; niacin, 14, and ascorbic acid, 3.5. In approximately ten-fold greater concentrations in the dried product are partially a reflection of its higher solids content.

Differential pulse polarography was used to determine the ascorbic acid contents of fresh samples of two different strains of shiitake and one each of P. ostreatus, P. sajor-caju, and V. volvacea of two different maturities (41). Ascorbic acid content (mg/100 g, dry basis) was highest in shiitake (40-60), only slightly lower in the Pleurotus species (36-58), and much lower in V. volvacea (8-10). These results were contrary to earlier reports (12,45) that shiitake mushrooms did not contain vitamin C.

Irradiation of shiitake mushrooms containing about 0.5% ergosterol, dry basis, with a fluorescent sunlamp, caused similar electrocardiographic changes, depressing the ST segment and inverting the T wave. They also had antitumor activity against Ehrlich ascites tumor cells. Toxicity and biological activities were eliminated by heating at 100°C for 20 min. Cochran (9) cautioned those responsible for breeding stocks to be on the alert for mutants producing high concentrations of such cardiotoxins.

In summary, edible mushrooms, while certainly adding variety, flavor and eye-appeal to our foods, are also nutritious, containing moderate quantities of good quality protein and a generally high content of dietary fiber along with vitamin C, B vitamins, and minerals.

Part II. Medicinal Value

It is interesting to note that the popular cultivated mushroom species have been shown to contain substances that prevent or alleviate cancer, heart disease, and diseases caused by viral infections, certainly three of the greatest scourges of mankind. Much of the credit for initiating research into the medicinal value of mushrooms, as well as for providing the impetus for the development of the specialty mushroom industry to its present state, must go to the late Dr. Kisaku Mori. Dr. Mori, in his book “Mushrooms as Health Foods” (45), recalled that he was inspired to improve cultivation methods when he came upon a Buddhist priest and some shiitake growers who were entreating: “Grow, please, shiitake mushrooms, or we shall have to leave the village.” In 1936, Dr. Mori founded what is now The Mushroom Research Institute of Japan. His nephew, Dr. Kanichi Mori, is its present Director of Laboratory.

While there is an element of folklore and traditional medicine associated with the medicinal properties of mushrooms, a vast body of information exists in the scientific literature, going back to the 1940s and 1950s. Dr. Cochran (University of Michigan), one of the premier U.S. researchers in this area, who has collaborated with Japanese scientists, including Dr. Mori, reviewed the medical effects of mushrooms up until 1978. Dr. Mori (45) related that he was contacted by Dr. Cochran in 1963 which marks the beginning of the modern-day research on the effects of mushrooms on cancerous tumors, suppression of viral diseases, and lowering of blood serum cholesterol levels, among others. Vo (91) prepared a concise but comprehensive review (unpublished) of research on the medicinal effects of exotic mushrooms.

Anticancer/antitumor effects. Cochran (9) traced the history of research on antitumor effects of mushrooms beginning with the some work in the late 1950s showing
that a substance called calvacin in *Calvatia gigantea*, the giant puffball, was a possible antitumor agent.

Most of the research on antitumor effects of mushroom species tested highly inhibited growth of tumors (by 72-92%, versus controls) arising from Sarcoma 180 ascites cells implanted in Swiss albino mice. These species were *L. edodes* (81%), *F. velutipes* (81%), *P. ostreatus* (75%), *P. spodoleucus* (72%), Pholiota nameko (86%), and *Tricholoma matsutake* (92%). *A. auricularia* showed only 43% inhibition. *Tricholoma matsutake* is considered to be the most prized edible mushroom in Japan but has not yet been successfully cultivated. A giant puffball, was a possible antitumor agent.

In further studies at the National Cancer Center (8), the antitumor material in shiitake was separated into six fractions which were purified and tested for antitumor activity. One fraction, called lentian, markedly inhibited the growth of Sarcoma 180 implanted in mice, inducing almost complete regression of tumors when given (i.p.) in 10 doses of 1 mg/kg body weight, with no sign of toxicity. Lentian was shown to be a β-(1 —> 3)-glucan (17). Evidence suggested that lentian acted via immunological response of the host animal, perhaps by interferon induction.

As work continued at the National Cancer Center, antitumor polysaccharides were extracted from *F. velutipes* and *P. ostreatus* and shown to be capable of in vitro inactivation of the hemolytic activity of the C3 component of complement in guinea pig serum (61). The active antitumor component of a water-soluble extract of *P. ostreatus* was characterized as consisting of a (1 —> 3)-β-glucan skeleton, probably having branches of galactose and mannose residues and also containing acidic sugars (97,98). One antitumor component of the aqueous extract of *F. velutipes* (enokitake), called EA₃, was shown to be a β-(1 —> 3) glucan (24) and other (EA₅) was a polymer of glucose (45%), galactose (32%), mannose (13%), arabinose (7%), and xylose (2%) (29,99). EA₅ stimulated histamine production in tumor tissue but had no effect on serotonin levels (26). Lentian exhibits its host-mediated antitumor activity by restoring the immune response of thymus, or T-cells, after it has been lowered by the cancer (17).

Subsequent research at the National Cancer Center, Tohoku University, Kumamoto University, Hokushin General Hospital, Toyama Medical and Pharmaceutical University, Kobe University, Kobe Women's College of Pharmacy, The Mushroom Research Institute, and several industrial laboratories have focused primarily on shiitake and enokitake. Researchers in the Department of Medical and Pharmaceutical Development at Kirin Brewery Co. described an antitumor polysaccharide extracted from *L. edodes* mycelia (not fruit bodies) grown on stillage from whiskey manufacture (15). The substance, called KS-2, consisted mainly of α-linked mannose and a small amount of peptide composed mainly of serine, threonine, and alanine. The molecular weight of KS-2 was estimated at 60,000-95,000 daltons. Oral as well i.p. administration of KS-2 suppressed the growth of Ehrlich ascites and Sarcoma 180 tumors in mice with concomitant induction of interferon in the sera. This is interesting because lentian was not as effective when administered orally (17,25).

Work was also done with extracts of shiitake mycelia, using a mixture (5:1, m/m) of bagasse and defatted rice bran as a growth medium. A water-soluble fraction called LEM and two alcohol-insoluble fractions called LAP and LAPI (73) were obtained. All three fractions exhibited antitumor activity against Sarcoma 180 tumors in mice increased with increasing molecular weight. The fraction with the highest activity contained 42.3% D-glucose, 17.3% D-galactose, 14.7% L-arabinose, 12.2% D-mannose, and 6.7% D-xylose. Fraction EA₅ of *F. velutipes* extract, which exhibited only weak antitumor activity, markedly augmented the antitumor effects of cryosurgery when administered i.p. to Sarcoma 180 bearing mice (58). Similar results were reported when rabbits with Vx2 carcinoma tumors were treated with cryosurgery and orally administered EA₅ (57). Orally administered EA₅ combined with cryosurgery augmented the immune response of Sarcoma 180 bearing mice (59). EA₅ was described as a protein-bound polysaccharide containing 3.82% nitrogen as peptides (29,99). EA₅ also augmented the antitumor activity of a murine leukemia (L1210) vaccine when given i.p. at 40 mg/kg after injection of the vaccine into mice implanted with the leukemia cells (63).

Virus-like particles were observed to occur in normal mycelia and fruit bodies of *L. edodes* (47) in three basic shapes: spherical (S), filamentous (F), and rod-shaped (R). Purified S and F particles and the double-stranded RNA extracted from S particles had antitumor activity against Ehrlich ascites carcinoma in mice when administered i.p. (79). All three induced interferon production in mouse sera; S-derived RNA was most active and F particles were least active.

Most of the research on antitumor effects of mushrooms until the 1980s involved administration to test ani-
mals by intraperitoneal injections, although some intravenous (i.v.) and subcutaneous (s.c.) injections were also made. Indeed, lentinan and various polysaccharides were ineffective when administered orally. In September 1982, Dr. Ikekawa of the National Cancer Center presented a paper (27) at the 13th International Cancer Congress in Seattle in which he described a new oral antitumor agent (proflamin, or PRF) extracted from the mycelia of *F. velutipes*.

The preparation, physicochemical properties, and antitumor activity of proflamin have been described (25). Proflamin is a weakly acidic glycoprotein containing more than 90% protein and less than 10% carbohydrate and having a molecular weight of 13,000 ± 4,000 daltons. Major amino acid components were glutamic and aspartic acids, alanine, leucine and glycine, and major sugars were glucose, galactose and mannose. At an oral dosage in mice of 10 mg/kg body weight over 10 d, proflamin suppressed the growth of the syngeneic tumors, B-16 melanoma and adenocarcinoma 755 and also Lewis lung carcinoma tumors (25,27). Proflamin had no demonstrable *in vitro* or *in vivo* toxicity; its oral LD$_{50}$ was greater than 20 g/kg for mice (27).

Some of the most recent studies on antitumor activity have involved oral administration of powdered, dried mushroom fruit bodies, and powders from which the carbohydrate fraction (B-glucan) and/or lipid fraction was removed (48,49,50). The mushroom powders were added to commercial laboratory mouse food at 10-30%. Initial results indicated suppression of Sarcoma 180 tumors in mice fed rations containing *L. edodes* or *Grifola frondosa*. Results of the tests with extracted powders at 20% of the ration indicated that, for *L. edodes*, growth of the tumors was inhibited 67% by the whole powder, 57% by defatted powder, 39% by powder free of polysaccharides, and 0% by powder free of both lipid and carbohydrate. Addition of extracted lipid increased tumor growth inhibition by 25%.

Further study (49,50) showed suppression of Sarcoma 180 tumor growth in mice by feeding *L. edodes* as well as eight other species (20% of ration); *L. edodes* (78%), *G. frondosa* (86%), *A. bisporus* (71%), *P. ostreatus* (63%), *F. velutipes* (62%), *Pholiot a glutinosa* (63%), *Tremella fuciformis* (81%), * Auricularia minor* (68%), and *V. volvacea* (68%). The fact that the inhibition rate (%) was greater when mushrooms were fed over a longer period of time suggested that ingredients present may activate the cellular immune system.

Mori et al. (49,50) also tested six mushroom species against MM-46, IMC-carcinoma, and Lewis lung carcinoma in mice at 20% of ration. All suppressed growth of MM-46 tumors; *P. glutinosa* (99%), *A. bisporus* (98%), *P. ostreatus* (90%), and *T. fuciformis* (79%) were most effective and *A. minor* and *V. volvacea* were least effective. *Pleurotus ostreatus* was most effective against IMC-carcinoma (66%) and none suppressed Lewis lung carcinoma. Oral feeding of *L. edodes* fruit bodies increased antitumor effect and phagocytic activity of macrophages as well as production of superoxide in one strain of mice (C3H) but only weak antitumor effect and no change in phagocytic activity or superoxide production in another strain (CDF1) (50). Research at Kobe Women’s College of Pharmacy also demonstrated antitumor effects of fruit bodies of *L. edodes* (51,53), *G. frondosa* (22), and *A. bisporus* (52) given orally to tumor bearing mice. Mechanisms appeared to involve activation of various effector cells to attack the cancer cells and prevention of the decreased immune function which accompanies tumor growth.

It is interesting that the antitumor components of mushrooms vary in their chemical nature, including polysaccharides, proteins, glycoproteins, nucleic acids and lipids. It is yet unknown whether specialty mushrooms will someday provide therapeutic control over the most dreaded of human diseases, cancer, but the studies to date do show some potential. It does appear that the inclusion of cultured mushrooms, particularly shiitake and enokitake, in the diet is likely to provide some protection against some manifestations of the disease.

Antiviral effects. Cochran (9) summarized work on the antiviral effects of mushrooms, including *L. edodes’* activity against influenza virus. Cochran and Lucas (10) evaluated several mushroom extracts for antiviral activity expressed as survival index. This index consisted of the ratio of the harmonic mean survival time of the treated groups of test animals to that of control groups. Indices greater than 1.0 indicated antiviral activity. *Agaricus campestris* had a survival index of 1.6 against polio virus. These authors pointed out that some overlapping is apparent of the two areas of antiviral and antitumor activity.

Cochran et al. (11) examined extracts of different parts of many different plants and fungi for activity against influenza virus *in vitro* and *in vivo* in mice. About 70 species including apples, beans and spinach had no antiviral activity. Of the basidiomycetes (mushrooms) tested, shiitake had a level of activity (expressed as percent decrease in lung lesion score compared to control) of 46%. For comparison purposes, amantadine hydrochloride, a drug commonly prescribed for influenza, had a score of 40%.

A white powder isolated from a water extract of dried shiitake by acetone precipitation, called Ac2P (94), was found by *in vitro* and *in vivo* (i.p. injection in mice) tests to be a selective inhibitor of orthomyxoviruses (e.g., influenza viruses). It was active only when present in virus-infected cultures and had no effect when treatment was limited to periods before infection. Ac2P did not produce detectable interferon activity *in vitro* or *in vivo*. Ac2P was a high molecular weight polysaccharide composed mainly of pentose sugars; it was distinctly different from lentinan. The LD$_{50}$ values in mice were over 1,000 mg, 1,500 mg, and 150 mg per g body weight by intravenous, intraperitoneal or subcutaneous, and intracerebral single-dose injections, respectively.

The S and F virus-like particles described by Mori and Mori (47) were found by them to induce interferon production in sera of rabbits after intravenous injection. Suzuki et al. (76) extracted double-stranded RNA from...
speres of *L. edodes*. Eleven mice received a single i.p. injection of 8 mg/kg of the RNA 1 h before being infected intranasally with A/Swine/Iowa/15/30 (Hsw/Ni) strain of influenza virus. As a negative control, 22 mice received an equal volume of saline and as a positive control, 11 mice received i.p. 8 mg/kg of amantadine hydrochloride 3 1/2 h before and 1 and 3 h after virus infection and once daily for 4 consecutive days. All control mice died within 10 d, whereas the single dose of mushroom RNA produced a survival rate of 60% compared to 18% for amantadine treatment. Tests with rabbits demonstrated that the RNA induced interferon production.

F and S virus-like particles were purified and double-stranded RNA was extracted from the S particles; F and S particles and RNA were evaluated for antiviral activity (78,90). *In vitro* tests with rabbit kidney (RK-13) cells showed that all three entities induced interferon production with S particles being more effective than F particles and the extracted RNA being much more effective than either. *In vivo* studies showed that a single i.p. administration of S particles prior to virus challenge significantly reduced the mortality of mice infected with western equine encephalitis virus. Again, F particles had some antiviral effect but were considerably less effective than S particles. In subsequent work (80), RNA having the same molecular weight as that extracted from the S particles of *L. edodes* spores was derived from *L. edodes* fruit bodies. The fruit body RNA (Fr-RNA) inhibited viral growth *in vitro* as did the S-RNA but less effectively; the same was true for *in vitro* induction of interferon.

The so-called peptidomannan, KS-2, extracted from mycelia of *L. edodes* (15) also was shown to have antiviral activity (77). KS-2, when administered orally or i.p. to mice infected intranasally with influenza virus, afforded significant protection by therapeutic as well as prophylactic treatment. The mechanism of its effect was via its interferon inducing activity. However, a diet containing 5% dried shiitake was ineffective in protecting mice against the viral disease scrapie (93).

Recently, it was reported that a "sugar protein" (glycoprotein) extract of shiitake mycelia was found by researchers at Yamaguchi University to be more effective than azidothymidine (AZT) in the treatment of AIDS (2). This substance was said to be free of side effects and might replace AZT in treatment of AIDS. The National Institutes of Health (NIH) has issued a permit for clinical testing of shiitake extracts. According to Toby Farris of Carolina Agro-Tech Corp. (Personal Communication), hospitals in New York and California, in collaboration with a Japanese pharmaceutical company, will be testing sulfated β-glucans from shiitake for their effectiveness against the AIDS virus.

**Hypolipidemic activity.** Cochran (9) noted that the ability of various edible fungi to lower blood serum cholesterol, like antitumor activity, was uncovered through verification of folklore. Initial work on the cholesterol lowering effects of mushrooms was done at Tohoku University in Sendai, Japan, by Dr. Takashi Kaneda and his coworkers. Their progress was reported in a series of papers published over a period of almost a decade (32,69,70,81,83,84,86, 87,88). This work was summarized in English (33,74,82).

Kaneda’s group fed rats for 10 weeks on a control diet, diets containing 1% added cholesterol alone or together with either 5% ground dried shiitake mushroom or 0.5% ergosterol, and a diet containing no added cholesterol but 5% ground dried shiitake. The ergosterol was included because shiitake contains about 0.3% ergosterol (dry basis) and because phytosterols have been known to reduce cholesterol levels in rats. Mean serum cholesterol levels (8 rats/group) were 119 mg/100 ml in the control, 185 mg/100 ml for the 1% cholesterol diet, and only 100 mg/100 ml for the cholesterol plus shiitake caps (Donko type) diet. Koshin caps were less effective (121 mg/100 ml) as were Donko stems (131 mg/100 ml). Interestingly, *Agaricus bisporus* (117 mg/100 ml cholesterol) was about as effective in a 1% cholesterol diet as shiitake. *Auricularia polytricha* (149 mg/100 ml) and *F. velutipes* (159 mg/100 ml) showed some activity. Ergosterol had no effect. Cholesterol content and total lipid of the livers of mushroom-fed animals were higher than those of the controls.

The active hypcholesterolemic substance was eventually isolated and identified (81,82) as eritadenine. Other Japanese workers had also isolated this compound from shiitake. In 1969, Kamiya and co-workers gave it the name "lentysine" and Chibata and co-workers called it "lentinacin"; eritadenine is the name in current use (74). The structure of eritadenine is given in Fig. 1. Two other compounds related to eritadenine were isolated from shiitake; deoxyeritadenine and 9-(3-carboxypropyl)-adenine had no hypcholesterolemic activity.

It is now known why *A. bisporus* was almost as effective as *L. edodes*. Subsequent work has been concentrated almost entirely on shiitake, although a very low concentration (dry basis) of eritadenine (0.7 mg/100 g) was reported in *A. bisporus* compared to 60-70 mg/100 g in shiitake stem (67); *F. velutipes* and *A. auricula-judae* were devoid of eritadenine.

The chemical nature of eritadenine has been described by Tokita et al. (82) and a detailed review of the compound, the history of its discovery, and its chemistry has been presented by Suhadolnik (74). The latter is particularly useful because it integrates a great deal of information, much of which was originally published in Japanese.

Kaneda’s group at Tohoku University studied the mechanism of eritadenine in reducing cholesterol levels (74,85,89). Eritadenine was shown to lower all lipid components of serum lipoproteins (i.e., chylomicron, VLDL, HDL) in animals and man. Eritadenine had very low toxicity in rats. It had no hypcholesterolemic activity in rabbits. Eritadenine exerts its activity in rats without causing fatty livers. It is effective when administered orally to rats although only 10% of it is absorbed from the intestinal tract. The effect continues when it is removed from the diet. Japanese researchers showed that eritadenine treatment remained effective in maintaining lowered cholesterol levels for up to one year; in other words, metabolism in test animals did...
Figure 1. Eritadenine.

not adapt to minimize the hypocholesterolemic effectiveness over time. This was confirmed by feeding mice for 14 months on a diet containing 5% dried shiitake (93). Intravenously administered eritadenine is ineffective; it is rapidly cleared from circulation and excreted through the kidneys. Of 124 derivatives or eritadenine synthesized and tested, the most active were the carboxylic acid esters with short-chain monohydroxy alcohols. They were up to 50 times more active in lowering serum cholesterol in rats at a dose of 0.0001% in the diet when compared to eritadenine. It appears that a carboxyl group and one hydroxyl group along with the intact adenine ring are necessary for biological activity. Eritadenine has no effect on the endogenous synthesis of cholesterol from [1-14C] acetate; its hypocholesterolemic activity is due to increased excretion of cholesterol into feces.

Suzuki and Ohshima (75) of the National Institute of Nutrition in Tokyo stated that tests were made repeatedly on the effectiveness of shiitake mushrooms on blood serum cholesterol in human subjects since 1967. They found that 90 g/day of fresh shiitake, 9 g/day of dried shiitake, and 9 g/day of ultraviolet-irradiated dried shiitake for 7 d lowered mean blood serum cholesterol levels in young women (10 group) by 12, 7, and 6%, respectively. Similar tests were run with 30 people, 60 years or more of age; the three diets all decreased serum cholesterol levels by 9% in 7 d. However, rather than declining steadily over time as with young women, levels dropped sharply between 5 and 7 d. It was speculated that this may have been due to slower response in older people. In another experiment, butter (60 g/d) in the diet increased the mean serum cholesterol level by 14% in one week, but a diet of 60 g butter plus 90 g shiitake/day decreased the mean cholesterol level by 4%.

Because shiitake mushrooms are a rich source of dietary fiber, Kurasawa et al. (38) fed rats for (presumably) 10 d on a standard control diet and one containing 1% cholesterol along with 10% whole shiitake (presumably dried) or 2.5, 5.0, 7.5, or 10.0% neutral detergent fiber (NDF) extracted from shiitake and measured cholesterol contents of serum and livers. The NDF was free of eritadenine. They were able to demonstrate that the shiitake NDF had a cholesterol lowering effect distinct from that of eritadenine. The minimum effective dosage was 5% of the diet. Hypocholesterolemic activity was attributed to the binding of cholic acid salts to NDF.

Antithrombotic effects. Workers at the Cancer Center of Hawaii (23) discovered that low molecular weight compounds extracted from L. edodes, Auricularia species, and A. bisporus were capable of inhibiting aggregation of blood platelets. The highest yield of the inhibitors was obtained from shiitake. Inhibition was measured as 50% inhibition concentration (IC 50). The IC 50 was lowest (highest inhibition effect) for Auricularia polytricha (10 μg/ml), followed by L. edodes (80 μg/ml). Agaricus bisporus had an IC 50 of 3300 μg/ml. The active compounds were believed to be nucleosides and/or other nucleic acid derivatives.

Other medicinal effects. In addition to the antitumor, antiviral, anticholesterol, and antithrombotic effects of mushrooms and of shiitake in particular, which are documented by sound scientific data, many health and medicinal claims are made which are not so strongly supported. Some of these are more in the realm of folklore but may very well have some validity. Supporting evidence is usually anecdotal. Dr. Mori (45) hyped shiitake in his book, often with little or no supporting evidence. He stated, for example, that shiitake can help prevent high blood pressure, atherosclerosis (which it might do by lowering cholesterol levels), softening of the brain, kidney ailments, diabetes, cataracts, neuralgia, gallstones, numbness of the hands and feet, and hemorrhoids. Shiitake imparts long life and vigor. Shiitake consumption assists people in recovering from fatigue. An intoxicated person who has eaten shiitake remains in good spirits and never becomes obnoxious. Shiitake consumption prevents hangovers and relieves allergies and constipation, probably due to its high content of fiber. And, of course, no worthwhile medicinal food would be really worthwhile if it did not improve sexual powers. Shiitake does. Dr. Mori supported some of these claims by anecdotal evidence, some by referring to experiments that were perhaps not published or were perhaps published in Japanese in journals not readily available in the United States. However, the basis for many of these claims is the
cholesterol lowering effect of shiitake, which will prevent atherosclerosis which will prevent high blood pressure and improve circulation which will prevent diabetes, etc., which may very likely be true, but for which little clinical supporting data exist. Recent research has shown clinical evidence of an agent in the ether-soluble fraction of *Griptula frondosa* fruit bodies that lowered blood pressure in spontaneously hypertensive rats (1).

**Medicinal aspects of *Ganoderma* species.** This paper would not be complete without some discussion of the medicinal value of *Ganoderma* spp. *Ganoderma* spp. are not normally eaten as a food item but have a long history of use as traditional medicine in China and Japan (30,44,65). These mushrooms belong to the order Aphyllorhales and are generally called polypores. They differ from ordinary mushrooms belonging to the order Agaricales in that they have pores rather than gills on the under surfaces of the fruit bodies. The fruit bodies are usually tough and leathery, reddish in color and grow as shelf-like forms on tree trunks, logs and stumps. Common species are *G. lucidum,* *G. applanatum,* and *G. japonicum.* They are called Ling-Zhi in China and mannentake in Japan. Other names include Reishi, Rokukakushi, and Fushisou (30,65). A common or usual name for *Ganoderma* is “monkey’s seat” or “monkey’s chair,” and indeed, they may actually serve that purpose. The term “elixir of life” is often used in connection with *Ganoderma,* as is also true for shiitake. The fruit bodies have traditionally been used for medicinal purposes. Powdered, dried fruit bodies may be taken in hot water or whiskey or they may be boiled in water to produce a “tea” (65).

Quimio (65) has pointed out that both the mycelia and fruit bodies can be used for medicine and has briefly described how they are cultivated in Japan and China. *Ganoderma* medicines have been offered for sale in the United States. According to a “press release” dated March 15, 1982, the Kinoko Company of San Francisco, Dr. Henry Mee, President, offered LING-ZHI Herbal Tea under the trade marked name Kinoko’s Happy Herb. It was described as a powder consisting of 40% red Ling-Zhi (*G. lucidum*), 40% white Ling-Zhi (*Cortiolus versicolor*), and 20% *L. edodes.* The press release noted that white Ling-Zhi contains CRESTIN, also called PS-K, which is a polysaccharide. CRESTIN was described as a product of Kureha Chemical Co. of Japan, marketed by Sankyo Industry as an anticancer drug. It reportedly has been licensed to nine major Japanese pharmaceutical firms and during 1980 reached sales of over $100 million (U.S.) in Japan. Red Ling-Zhi, according to the press release, is used in China to treat neurasthenia, insomnia, coronary heart disease, hypercholesterolemia, chronic hepatitis, bronchial asthma, stomach ulcers and indigestion, chronic inflammation of the liver, kidney and bone joints (sic), and high blood pressure.

An article obtained from Dr. T. H. Quimio (not dated) entitled “Efficacious *Ganoderma lucidum*” and apparently issued by Korea Industrial Technology Corp., Pyongyang, stated that the mushroom contains much steroid, flavonoid, glycoside, saponin, coumarin, phenolic compounds, fat, and various microelements. Added to the previous list of ailments that it relieves are angina pectoris, arthritis, cerebral embolism, apoplexy, lumbago, hemorrhoids, constipation, headache, shoulder pain, cough and phlegm, and depression of gonadotropic function.

Because much of the clinical research on *Ganoderma* has been published in Chinese, it is difficult to determine the extent of it. Ito et al. (30) found that four different polysaccharides (containing small amounts of protein) extracted from *G. lucidum* were highly effective against Sarcoma 180 tumors in mice when administered i.p. These substances were not toxic. Liu et al. (44) reported that many authors have demonstrated the effectiveness of *Ganoderma* against chronic bronchitis and viral hepatitis, coronary heart disease, granulocytopenia, chronic Keshan disease, and neurasthenia. Liu’s group at the Chinese Academy of Medical Sciences, Beijing, have made injectable solutions from *Ganoderma* for trial on human patients with progressive muscular dystrophy, atrophic myotonia, and certain neurological diseases with some good results. The studies reported in detail by this group (44) showed that water soluble preparations of the spores of *G. lucidum* and of the mycelium of *G. capense,* when administered to mice, decreased spontaneous motor activity, prolonged barbiturate sleeping time, prevented nicotine convulsions, and inhibited pilocarpine-induced salivary secretion.

The ether-soluble mycelial extract had no such actions but did lower elevated SGPT levels induced by carbon tetrachloride, promoted regeneration of the liver in partially hepatectomized mice, and reduced the mortality rate of mice intoxicated by large doses of indomethacin. The water-soluble preparation lacked these functions. It appeared that the water-soluble substances acted mainly on the central nervous system and the ether-soluble substances on the liver.

A Japanese Company, Reishisogokenyujo Ltd., in Tokyo, produced a Ling-Zhi product in the form of a tablet during the early 1980s and attempted to find U.S. markets for it through one of the large Japanese trading companies. In this connection some English language reports exist but are apparently “unpublished” in the academic sense and thus cannot be properly referenced. This work is credited to S. Arichi and co-workers and M. Kubo and co-workers at Kinki University and N. Kirigaya of Morinaga & Co., Ltd. They conducted studies which indicated that *G. lucidum* relieved or corrected both hypertension and hypotension and were effective in treating almost all of the ailments listed in the Kinoko press release mentioned above. The effective ingredient was identified as a 8-(1 —>3)-D-glucan having a molecular weight of 300,000-400,000 daltons and containing 45-50% sugars as well as amino acids.

In summary, it is quite obvious that mushrooms contain some unique and interesting chemical compounds that have been shown in carefully controlled clinical studies at prestigious research institutions to be effective in treating the diseases responsible for the majority of suffering and
death in the developed countries of the world. It is hoped that this line of research will continue and that inclusion of more shitake and other specialty mushrooms in peoples’ diets as well as the development of life-extending and life-saving medications based on the research will eventually occur.

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