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Nutrient Compositions of Culinary-Medicinal Mushroom Fruiting Bodies and Mycelia

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ABSTRACT: Mushrooms (including fruiting bodies and mycelia) are a food with high nutritional value. This article summarizes the results of proximate composition studies of 38 fruiting bodies and 19 mycelia of 32 species of culinary-medicinal mushrooms from genera *Agaricus*, *Agrocybe*, *Antrodia*, *Auricularia*, *Boletus*, *Clitocybe*, *Coprinus*, *Cordyceps*, *Trametes*, *Dictyophora*, *Flammulina*, *Ganoderma*, *Grifola*, *Hericium*, *Hypsizygus*, *Inonotus*, *Lentinus*, *Morchella*, *Pleurotus*, *Sparassis*, *Termitomyces*, *Tremella*, and *Tricholoma.* Based on the proximate composition, most fruiting bodies and mycelia are low in fat and rich in protein and dietary fiber (DF); however, some are rich in soluble polysaccharides and others are rich in crude fiber. Due to the high amount of DF present, the energy provided by 100 g of dry fruiting bodies and mycelia is 46.96–292.37 kcal and 195.84–373.22 kcal, respectively. The energy (100 g) is classified into four levels: first level of > 300 kcal, second level of 200–300 kcal, third level of 100–200 kcal, and fourth level of < 100 kcal. Most fruiting bodies are listed in the third level; nine mycelia are listed in the first level and ten in the second level. Overall, the information about the proximate composition and energy are of great interest for fruiting bodies and mycelia to be used as foods or food-flavoring materials or in the formulation of health foods.

KEY WORDS: culinary-medicinal mushrooms, fruiting body, mycelium, proximate composition, energy, protein, dietary fiber, polysaccharides

ABBREVIATIONS: AOAC: Association of Official Analytical Chemists; **DF:** dietary fiber; **GI:** glycemic index; **RS:** reducing sugars; **SP:** soluble polysaccharides

I. INTRODUCTION

Mushrooms, the edible species of a large group of the higher fungi, are valuable produce with high quality and high economic value. Mushrooms have been used as foods and food flavoring materials in soups and sauces for centuries, due to their unique and subtle flavor. Generally, mushrooms possess all four functionalities of food, which are nutritional value, tastyness, physiological effects, and cultural aspects.[1,2] For the nutritional values, mushrooms are rich in polysaccharides, proteins, chitin, vitamin D_2, and minerals; low in fat, calories; and contain no cholesterols.[3,4] For the taste, mushrooms contain volatile eight-carbon compounds such as 1-octen-3-ol and 1-octen-3-one, and water-soluble taste components including free amino acids and 5′-nucleotides, which contribute to the umami taste.[1] For the physiological effects, mushrooms become a valuable health food because of their several physiologically active substances.[5] For the cultural aspects, some mushrooms are recognised by their use in cuisine, and as home remedies in different countries and regions,[2] such as *Antrodia camphorata* in Taiwan and *Agaricus brasiliensis* (= *A. blazei* sensu Heinem.) in Brazil.

Generally, edible mushroom products are available in fresh or air-dried forms of fruiting bodies as food sources or as food additives for cooking, whereas medicinal mushrooms are obtained in the form of mycelia due to their rare and expensive nature. The production of mycelia in submerged culture has been developed as a faster and more easily controllable method than the procedure for production of fruiting bodies, which is time-consuming and labor intensive. The mycelia can be used as food and food-flavoring materials, and also in the formulation of nutraceutical and functional foods. In addition, some mushrooms are consumed in the form of sclerotia, such as truffle and *Grifola umbellata*, while some species of mushroom spores are ground into broken products for use in pharmaceutical formulation, such as *Ganoderma lucidum*. Due to increased health awareness, it appears that the production and consumption of mushroom fruiting bodies and mycelia has increased in recent years.

II. PROXIMATE COMPOSITION AND ENERGY

The proximate composition in mushrooms includes ash, fat, protein, and total carbohydrate. Moisture, crude ash, crude fat, and crude protein are usually determined according to the methods of the Association of Official Analytical Chemists (AOAC).[6] The nitrogen conversion factor used for crude protein calculation is 4.38 instead of 6.25 because mushrooms usually contain a high amount of chitin, a biopolymer of *N*-acetylglucosamine, which interferes with the total nitrogen determination.[3] The total carbohydrate content is calculated by subtracting the contents of ash, fat, and protein from 100.

Total carbohydrate can be subdivided into reducing sugars (RS) and dietary fiber (DF), which consists of soluble polysaccharides (SP) and crude fiber. Reducing sugars are determined using the 3,5-dinitrosalicylic acid method.[7] Crude fiber is determined according to the AOAC methods.[6] Thus, soluble polysaccharide content is calculated by subtracting the contents of reducing sugars and crude fiber from the total carbohydrate content. In addition, only the reducing sugars in mushrooms can be utilized in the human body to produce energy. Thus, the energy provided by 100 grams of dry mushrooms is calculated as follows:

Energy (kcal/100 g) = RS × 4 + fat × 9 + protein × 4.

III. PROXIMATE COMPOSITION OF FRUITING BODIES

Currently, there are many varieties of fresh and dried mushrooms available in Taiwan. The article summarizes the results of proximate composition of 38 fruiting bodies and 19 mycelia from about two decades of research, presented in Tables 1 and 2, respectively. In order to show the comparison on the same basis, the data calculated are presented based on dry matter. The composition of mushrooms can vary considerably from species to species and strain to strain. In addition, the cultivation techniques, including use of different substrates, maturity at harvest, and methods of analysis also result in different compositions. However, the results reported herein can provide basic information about these mushrooms for practical use or nutritional consideration.

Most fresh mushrooms contain 85% to 93% moisture, generally around 90%.[3] In converting of the dry basis to the fresh basis, the moisture content of mushrooms is arbitrarily assigned to be 90%. Thus, the ash, carbohydrate, fat, fiber, and protein contents shown in Table 1 can be converted to a fresh basis by a factor of 0.1, i.e., one log reduction or one decimal reduction.

A. Protein

Generally, mushrooms are a good source of protein in the diet, and their protein contents range from 19% to 35% dry weight.[3] Mushroom protein is of good quality in vegetable protein in addition to legume protein. Besides, no limiting amino acids are found in mushroom protein when compared with the FAO/WHO reference protein pattern.[8] In Table 1, only northern *Cordyceps* contains 36.36% of protein, whereas the protein contents of most fruiting bodies are 10.26 to 26.74%. However, species of genera *Auricularia*, *Ganoderma*, and *Inonotus* are poor sources of protein and their contents are less than 10%.

B. Fat

Fat is determined by ether extract from the Soxhlet apparatus following the standard procedure.[7] The fat content in mushrooms ranges from 1.1% to 8.3% dry weight, with the mean being ~4.0%.[3] In Table 1, only northern *Cordyceps* contains 10.06% of fat. The fat contents of most mushrooms are 1.57% to 9.23%, but stipes of *Lentinus edodes*, *Tremella fuciformis*, *Clitocybe maxima*, *Trametes versicolor* (= *Coriolus versicolor*), *Auricularia mesenterica*, and *A. polytricha* are below 1.5%.

C. Ash

Ash is the inorganic residue remaining after burning at 550–600ºC, and ash content represents the total mineral content in mushrooms. In Table 1, the ash contents of all mushrooms are below 10%, whereas those of *Ganoderma* and *Auricularia* are 1.69%–3.29%. It seems that the ash contents of

TABLE 1. Proximate Composition of Fruiting Bodies of Studied Culinary-Medicinal Mushrooms

Species/Fruiting body	Common name	Ash (%)	Carbohydrate (%) RS [a]	SP [a]	Fiber	DF [a]	Total	Fat (%)	Protein (%)	Energy [b] (kcal/100 g)	Ref.
Agaricus bisporus MS	Button mushroom	8.78	13.91	27.85	20.44	48.29	62.20	2.53	26.49	184.37	12
Agaricus brasiliensis (=*A. blazei*)	Brazilian mushroom	6.81	10.71	34.81	18.31	53.12	63.83	2.62	26.74	173.38	13
Agrocybe cylindracea brown	Willow-pine mushroom	7.90	14.73	28.85	22.80	51.65	66.38	3.54	22.18	179.50	14
Agrocybe cylindracea yellow	Willow-pine mushroom	6.65	7.88	45.83	19.54	65.37	73.25	3.63	16.47	130.07	13
Auricularia fuscosuccinea brown	Jin ear	4.02	9.87	61.32	11.69	73.01	82.88	4.48	8.62	114.28	15
Auricularia fuscosuccinea white	Snow ear	5.54	10.90	57.98	8.51	66.49	77.39	4.54	12.53	134.58	15
Auricularia mesenterica	Black ear	3.29	17.81	58.72	3.92	62.64	80.45	0.80	15.46	140.28	15
Auricularia polytricha	Red ear	2.05	17.62	70.52	3.63	74.15	91.77	0.48	5.70	97.60	15
Boletus edulis	King bolete	5.84	8.31	47.85	13.70	61.55	69.86	5.76	18.54	159.24	13
Clitocybe maxima cap	Big cup mushroom	5.28	22.21	21.44	26.78	48.22	70.43	2.70	21.59	199.50	16
Clitocybe maxima stipe	Big cup mushroom	3.67	31.47	19.45	31.76	51.21	82.68	1.24	12.41	186.68	16
Coprinus comatus	Shaggy ink cap	8.44	15.91	42.46	12.48	54.94	70.85	3.11	17.60	162.03	17
Cordyceps militaris	Northern *Cordyceps*	5.94	14.03	14.01	19.57	33.58	47.61	10.09	36.36	292.37	18
Trametes (=*Coriolus*) *versicolor*	Yun chih	6.37	28.27	36.82	23.24	60.06	88.33	1.10	4.20	139.78	19
Dictyophora indusiata	Basket stinkhorn	6.25	20.11	46.91	9.16	56.07	76.18	2.98	14.59	165.62	20
Flammulina velutipes white	Winter mushroom	6.93	13.88	34.31	15.99	50.30	64.18	8.89	20.00	215.53	21
Flammulina velutipes yellow	Winter mushroom	7.51	12.03	27.60	16.98	44.58	56.61	9.23	26.65	237.79	21
Ganoderma lucidum	Ling chih	1.77	15.12	10.90	59.16	70.06	85.18	5.13	7.92	138.33	19
Ganoderma lucidum antler	Ling chih	1.70	15.56	12.22	59.49	71.71	87.27	3.85	7.18	125.61	19
Ganoderma tsugae	Song shan ling chih	1.69	5.35	5.06	73.37	78.43	83.78	5.72	8.81	108.12	22
Ganoderma tsugae baby	Song shan ling chih	2.62	5.86	11.31	59.93	71.24	77.10	6.50	13.78	137.06	22
Grifola frondosa	Maitake	6.99	10.71	48.07	10.05	58.12	68.83	3.10	21.08	155.06	20
Hericium erinaceus	Lion's mane	9.35	17.39	39.63	7.81	47.44	64.83	3.52	22.30	190.44	20
Hypsizygus marmoreus	Hon-shimeji	7.75	15.69	24.78	28.09	52.87	68.56	4.09	19.60	177.97	23
Hypsizygus marmoreus white	Hon-shimeji	8.26	15.70	23.94	25.42	49.36	65.06	5.62	21.06	197.62	23
Inonotus obliquus	Chaga	8.36	4.92	48.27	34.58	82.85	87.77	2.36	1.51	46.96	24
Lentinus edodes 271	Shiitake	5.27	25.81	36.49	5.63	42.12	67.93	6.34	20.46	242.14	21
Lentinus edodes stipe	Shiitake	3.78	19.68	17.97	46.99	64.96	84.64	1.32	10.26	131.64	25
Lentinus edodes Tainung 1	Shiitake	5.85	21.91	41.99	4.88	46.87	68.78	5.71	19.66	217.67	21
Pleurotus citrinopileatus	Golden oyster	6.72	17.90	27.92	18.03	45.95	63.85	3.44	25.99	206.52	26
Pleurotus cystidiosus	Abalone mushroom	9.62	21.00	42.13	8.74	50.87	71.87	3.10	15.41	173.54	21
Pleurotus eryngii	King oyster mushroom	5.76	23.05	41.50	5.97	47.47	70.52	1.57	22.15	194.93	27
Pleurotus ferulae	Ferulae mushroom	6.60	30.46	30.67	12.98	43.65	74.11	3.01	16.28	214.05	16
Pleurotus ostreatus	Oyster mushroom	7.59	19.65	41.42	5.33	46.75	66.40	2.16	23.85	193.44	21
Pleurotus ostreatus gray	Oyster mushroom	5.90	23.21	40.99	9.82	50.81	74.02	3.76	16.32	191.96	16
Tremella fuciformis	Silver ear	6.14	31.64	50.08	2.91	52.99	84.63	0.93	8.30	168.13	15
Tricholoma giganteum	Giant mushroom	5.03	37.95	32.12	4.50	36.62	74.57	4.28	16.12	254.80	20

[a] RS, reducing sugar; SP, soluble polysaccharide; DF, dietary fiber = SP + fiber. [b] kcal/100 g = RS × 4 + fat × 9 + protein × 4.

TABLE 2. Proximate Composition of Mycelia of Studied Culinary-Medicinal Mushrooms

		Ash	Carbohydrate (%)						Protein	Energy [b]	
Species/Mycelia	**Common name**	**(%)**	**RS [a]**	**SP [a]**	**Fiber**	**DF [a]**	**Total**	**Fat (%)**	**(%)**	**(kcal/100 g)**	Ref.
Agaricus bisporus Tainung 3	Button mushroom	6.72	13.25	32.56	8.72	41.28	54.53	1.73	37.02	216.65	28
Agaricus brasiliensis	Brazilian mushroom	5.90	11.58	30.83	26.41	57.24	68.82	9.68	15.60	195.84	29
Agrocybe cylindracea brown	Willow-pine mushroom	5.12	17.48	13.17	28.96	42.13	59.61	17.32	17.95	297.60	14
Antrodia camphorata	Chang chih	3.92	25.39	31.27	20.14	51.41	76.80	9.79	9.49	227.63	29
Antrodia salmonea	Shiang shan chih	5.57	37.97	4.74	3.28	8.02	45.99	3.23	45.21	361.79	30
Coprinus comatus	Shaggy ink cap	5.26	36.45	12.33	20.38	32.71	69.16	2.96	22.62	262.92	17
Cordyceps militaris	Northern *Cordyceps*	6.97	12.97	24.57	19.17	43.74	56.71	7.20	29.12	233.16	29
Cordyceps sinensis	Caterpillar mushroom	3.59	29.26	21.80	10.18	31.98	61.24	11.76	23.41	316.52	30
Ganoderma tsugae	Song shan ling chih	5.18	15.42	11.56	19.39	30.95	46.37	21.86	26.59	364.78	22
Grifola frondosa	Maitake	3.95	10.19	23.11	11.70	34.81	45.00	24.65	26.40	368.21	31
Hericium erinaceus	Lion's mane	2.57	9.88	18.29	36.81	55.10	64.98	8.78	23.67	213.22	32
Hypsizygus marmoreus	Hon-shimeji	3.83	16.72	12.39	22.33	34.72	51.44	15.12	29.61	321.40	23
Hypsizygus marmoreus white	Hon-shimeji	3.69	19.10	6.40	22.40	28.80	47.90	20.62	27.79	373.14	23
Inonotus obliquus	Chaga	3.30	26.17	35.23	4.01	39.24	65.41	5.70	25.59	258.34	24
Morchella esculenta	Morel	5.03	12.21	22.72	6.30	29.02	41.23	12.03	41.71	323.95	31
Phellinus linteus	Sang hwang	1.91	19.04	35.02	11.57	46.59	65.63	4.04	28.42	226.20	33
Pleurotus citrinopileatus	Golden oyster	5.01	16.96	13.91	13.80	27.71	44.67	20.82	29.50	373.22	26
Sparassis crispa	Cauliflower mushroom	5.33	26.36	9.32	21.14	30.46	56.82	5.24	32.61	283.04	33
Termitomyces albuminosus	Termite mushroom	6.77	12.81	33.44	7.78	41.22	54.03	15.00	24.20	283.04	31

[a] RS, reducing sugar; SP, soluble polysaccharide; DF, dietary fiber = SP + fiber. [b] kcal/100 g = RS × 4 + fat × 9 + protein × 4.

fruiting bodies are low (<10.09%). However, the mineral composition in ash needs to be analyzed further.

D. Total Carbohydrate

In Table 1, the total carbohydrate content is the sum of RS, SP, and fiber contents. It seems that total carbohydrate is the main component in mushroom fruiting bodies, and the contents range from 47.61% to 91.77%. Northern *Cordyceps* contains the highest amount of fat and protein and, conversely, contains the least amount of total carbohydrate. Besides, the total carbohydrate contents of most fruiting bodies are more than 56.61%.

Reducing sugars are the only component in carbohydrates producing energy in the human body. Thus, the content of RS also affects the glycemic index (GI), which is a measure of how fast a carbohydrate triggers a rise in blood sugar. The higher the GI value, the greater the blood sugar response that can be observed. However, the GI value of mushrooms is 32 as compared to the control, glucose, which is defined as a GI value of 100.[9]

The contents of RS in fruiting bodies range from 8.36% to 37.95%. In Table 1, only four fruiting bodies—*Tricholoma giganteum*, *Tremella fuciformis*, *Clitocybe maxima*, and *Pleurotus ferulae*, contain >30% RS; eight fruiting bodies contain 20%–30% RS; 18 fruiting bodies contain 10%–20% RS; and six fruiting bodies contain <10% RS. The information about RS in Table 1 is of great importance because the content of RS in each individual mushroom is directly related to its specific GI value and also the energy uptake.

Dietary fiber includes soluble (SP) and insoluble polysaccharides (fiber), and its content is calculated by subtracting the RS content from the total carbohydrate content. In Table 1, the contents of DP range from 33.58% to 82.85%, with Chaga being the highest and northern *Cordyceps* the lowest. This reveals that fruiting bodies are rich sources of DF, including SP and fiber. Dietary fiber promotes beneficial physiological effects, including relaxation, blood cholesterol attenuation, and blood glucose attenuation.[10] The crude fiber is acid-, alkali- and alcohol-insoluble polysaccharide and is ineffective in taste. The major component of crude fiber in mushrooms is chitin, which is an important structural polysaccharide found in the cell wall.[11] However, some medicinal mushrooms such as *Ganoderma lucidum* and *Inonotus obliquus* are not chewable due to their tough texture and woody structure. Thus, their crude fiber is not ingestible. On the other hand, SP is water soluble and can also be a biologically active component in human body.[5]

In Table 1, crude fiber contents range from 2.91% to 73.37%. *Ganoderma*, *Lentinus edodes* stipe, and *Inonotus obliquus* are high in crude fiber content (>34.58%) and are not readily edible. However, mushrooms with crude fiber contents of lower than 32% are acceptable for fresh consumption. In Table 1, contents of SP range from 5.06% to 70.52%. In addition to mushroom stipes, northern *Cordyceps*, and *Ganoderma*, most mushroom contain >21.44% of SP. Thus, fruiting bodies are rich sources of SP and eating them will be beneficial.

E. Energy

Carbohydrate, protein, and fat are three major energy-providing components. Only 100 g of pure fat provide energy of 900 kcal, whereas 100 g of pure carbohydrate and protein can produce energy of 400 kcal. Due to the high amount of DF present, the energy provided by 100 g of dry mushrooms will not be higher than 400 kcal. Thus, based on the energy provided, mushrooms can be classified into four levels: first level, >300 kcal/100 g; second level, 200–300 kcal/100 g; third level, 100–200 kcal/100 g; and fourth level, <100 kcal/100 g.

In Table 1, the energy provided by 100 g of dry fruiting bodies ranges from 46.96 to 292.37 kcal. No fruiting body is listed in the first level, eight in the second level, and two in the fourth level. Most fruiting bodies[27] are listed in the third level. It seems that fruiting bodies are not a good source of energy.

Based on the proximate composition and energy, most fruiting bodies are low in fat and calories and rich in protein and DF; some are rich in SP and others are rich in crude fiber.

IV. PROXIMATE COMPOSITION OF MYCELIA

The information about the proximate composition and energy of mushroom mycelia is limited because fruiting bodies are the main form of mushrooms consumed. Generally, mycelia are prepared after filtration as an air-dried or freeze-dried form.

The composition of mycelia is also presented on the dry basis for consistent comparison.

A. Protein

In Table 2, only three mycelia (*Antrodia camphorata*, *Agaricus brasiliensis*, and *Agrocybe cylindracea*) contain <20% protein. The protein contents of most mycelia are 22.62% to 45.21%, indicating that most mycelia are also good sources of protein. In addition, mycelia of *Antrodia salmonea* and *Morchella esculenta* are a better source of protein. Since no limiting amino acids are found in the protein of fruiting bodies, the profile of amino acids in mycelia must be analyzed further.

B. Fat

In Table 2, the fat contents of mycelia vary widely and range from 1.73% to 24.65%. Several mycelia, such as *Grifola frondosa*, *Ganoderma tsugae*, *Pleurotus citrinipiletus*, and *Hypsizygus marmoreus*, are a good source of fat, and thus a good source of energy. However, several mycelia contain less fat, such as *Agaricus bisporus* strain Tainung 3 (1.73%) and *Coprinus comatus* (2.96%). It seems that half of the mycelia in Table 2 contain higher amounts of fat than most fruiting bodies. Higher fat in mycelia may due to the ability of mycelia to synthesize more fat in submerged culture, and to the higher fat content of the medium.

C. Ash

In Table 2, the ash contents of all mycelia are below 7%, whereas those of mycelia of *Hericium erinaceus* and *Phellinus linteus* are below 3%. Obviously, the ash contents in mycelia are low. The mineral contents and composition in the medium affects the ash content and composition of mycelia. Thus, by manipulation of the medium composition, mycelia can contain certain amounts of minerals of interest.

D. Total Carbohydrate

In Table 2, total carbohydrate is the main component in mushroom mycelia and the contents range from 41.23% to 76.80%, except for that of *Morchella esculenta* mycelia, whose protein content is higher. The contents of RS in mycelia range from 9.88% to 37.97%. The mycelia of *Antrodia salmonea* and C*oprinus comatus* contain >30% of RS. The contents of DP in mycelia range from 27.71% to 57.24%, except for that of the mycelia of *Antrodia salmonea* (8.03%). Most mycelia are also rich sources of DF, including SP and fiber.

In Table 2, crude fiber contents range from 3.28% to 36.81%, with that of the mycelia of *Hericium erinaceus* being the highest. The contents of SP range from 4.74% to 35.23%. Only three mycelia (those of *Antrodia salmonea*, *Hypsizygus marmoreus*, and *Sparassis srispa*) contain <10% fiber. Obviously, most mycelia are also rich sources of SP and will be beneficial to eat.

E. Energy

In Table 2, the energy provided by 100 g of dry mycelia ranges from 195.84 to 373.22 kcal, much higher than that provided by the fruiting bodies. Nine mycelia are listed in the first level, ten in the second level, and only one in the third level.

Based on the proximate composition and energy, most mycelia are low in fat and calories, and rich in protein and DF; some are rich in SP and others are rich in crude fiber. When compared to the fruiting bodies, most mycelia are relatively high in energy.

V. CONCLUSIONS

Mushrooms, including fruiting bodies and mycelia, give food nutritional value. Based on the proximate composition and energy, most fruiting bodies and mycelia are low in fat and calories and rich in protein and DF. Overall, the information about the proximate composition and energy are of great interest for fruiting bodies and mycelia to be used as foods or food-flavoring materials or in the formulation of health foods.

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