NUTRICEUTICALS FROM MUSHROOMS

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Contents

Summary

The perception of mushrooms as a highly nutritional foodstuff is well founded. Compositional analyses of the main cultivated varieties have revealed that, on a dry weight basis, mushrooms normally contain between 19 and 35 percent protein. The low total fat content, and the high proportion of polyunsaturated fatty acids (72 to 85 percent) relative to total fatty acids, is considered a significant contributor to the health value of mushrooms. The recent application of modern analytical techniques has provided a scientific basis for their medicinal properties. The multi-functional effects of mushroom nutriceuticals/dietary supplements are based on the enhancement of the host's immune system and hold considerable potential benefit to health care because of the absence of major side effects.

There is no doubt that mushroom-based products, mushroom nutriceuticals, can serve as superior dietary supplements to improve biological functions and contribute to human fitness and health. Commercialisation of these products is a rapidly expanding industry

with the current market value of medicinal mushroom/ dietary supplement products worldwide estimated to be in excess of US$12 billion per year. Precisely how mushroom nutriceuticals exert their effects is still a matter of conjecture, but numerous laboratory and human trials have shown many of them to function mainly through their immunomodulating properties. However, mushroom-based dietary supplements are highly diverse, and a major problem faced by the industry is the current lack of standard production protocols and critical testing procedures for guaranteeing product quality and safety. The establishment of standard production protocols, strict adherence to these protocols, and appropriate monitoring and control is essential both to increase and maintain consumer confidence, and to meet the current and future standards set by the regulatory authorities.

1. Introduction

Humankind has constantly searched for new substances that can improve biological functions and thereby make people fitter and healthier. Recently, Western society has placed greater emphasis on plants, herbs and foods as sources of these enhancers. About 3.5 billion people worldwide rely on plant-based medicines/dietary supplements for their primary health care. These products have variously been called: vitamins, dietary supplements, functional foods, phytochemicals, nutraceuticals and nutriceuticals. Dietary supplements are ingredients extracted from foods, herbs and plants that are taken without further modification outside of foods for their presumed health-enhancing benefits. During the past decade, there has been a major expansion in the industries involved in providing these substances, especially in the United States. In 1990, US diet-supplement sales were valued at US$3.3 billion; in 1992, US$3.7 billion; in 1994, US$5.0 billion; in 1996, US$6.5 billion; in 1998, US$12.0 billion; and in the year 2000, it was estimated to have reached US$14.0 billion.

In 1994, worldwide sales of medicinal mushrooms, mushroom extracts and various derived products were estimated at US$3.8 billion. By 1999, this figure had risen to US$6.0 billion. In regional terms, Asia and Europe accounted for approximately 99% of this market with North America contributing less than 0.1% to the overall total. In 2002, mushroom products (mushroom derivatives from medicinal, edible and wild mushrooms) used mainly for dietary supplements (mushroom nutriceuticals) was assessed to have generated about US$11 billion. In 1994, the US market for mushroom-based dietary supplements had an estimated value of US$35 million. However, since that time, demand in North America for medicinal mushrooms and derived products has increased by between 20-40% annually depending upon the species.

Mushrooms have long been appreciated for their flavour and texture, and some for medicinal and tonic attributes. However, recognition that they represent a nutritious food and an important source of biologically active compounds of medicinal value has been much more recent. Mushrooms are now known to be rich in high quality protein, to contain a high proportion of unsaturated fatty acids, and to have nucleic acid contents low enough to allow them to be eaten on a regular basis as a form of vegetable. Moreover, the latter-day application of modern analytical techniques has, in a number of cases, provided a scientific basis for assigning medicinal value through the

identification of various mushroom-derived compounds, eg., polysaccharides, triterpenoids, lectins, steroids, proteins and protein-bound-polysaccharides, which may constitute anti-cancer, anti-viral, immunomodulatory, hypocholesterolaemic and hepatoprotective agents. These compounds, which can be consumed daily as a form of dietary supplement, are called mushroom nutriceuticals. For the last two decades, derivatives from *Ganoderma lucidum* (Cur.:Fr.) Karst., *Coriolus versicolor* (L.:Fr.) Pat. and *Lentinula edodes* (Berk.) Pegler, perhaps the best-known and most extensively studied medicinal mushrooms, have received intense scrutiny in terms of their ability to improve biological functions and thereby make people fitter and healthier. In some cases, these dietary supplements have been used for the prevention and treatment of various human diseases, and are without the troublesome side effects that frequently accompany treatments involving synthetic drugs. As an example, the severe pain that may often experienced by cancer patients following radiotherapy or chemotherapy can be reduced or eliminated by the regular intake of good quality mushrooms. Furthermore, the reported enhancement of the immune system (eg. increases in macrophage and killer T-cell activity) by mushroom nutriceuticals may help reduce the likelihood of contracting infectious diseases.

The current market value of mushroom nutriceuticals/dietary supplement products worldwide is estimated to be in excess of US$14 billion per year. In 1995, the market value of *Ganoderma*-based dietary supplements alone was estimated to be US$1,628.4 million, and the value of equivalent products derived from *L. edodes* was probably of the same order. More recently, *Hericium erinaceus* (Bull.:Fr.) Pers., *Agaricus blazei* Murr, *Cordyceps sinensis* (Berk.) Sacc., *Flammulina velutipes* (Curt.:Fr.) Sing., *Grifola frondosa (*Fr.) S. F. Gray, and *Tremella fuciformis* Berk. have been the subject of intensive research and development as potential sources of immunotherapeutic agents. It has been proposed that mushroom nutriceuticals should be regulated as a special intermediate class of compounds between pharmaceuticals and healthy foods. Furthermore, in view of the large expansion this sector is currently experiencing, there is a serious need to improve the quality control of these products. A trustworthy and good quality product is essential in order to protect public health, to maintain and increase consumer confidence, and to meet current and future standards set by the regulatory authorities.

2. Nutritional value of mushrooms

The source of energy food -- carbohydrates, -- accessory food factors, vitamins, and inorganic compounds, together with water, are indispensable to good health. However, the greatest difficulty in meeting human nutritional requirements is to supply a sufficient amount of the body-building material -- protein.

The moisture content of fresh mushrooms varies within the range 70- 95 percent, depending upon the time of harvest and the environmental conditions, and between 10-13 percent in dried mushrooms. The protein content of the major cultivated species ranges from 1.75 to 5.9 percent of their fresh weight although it has been estimated that an average value of 3.5 to 4.0 percent would be more representative. Therefore, the protein content of edible mushrooms is, in general, about twice that of onion (1.4 percent) and cabbage (1.4 percent), four times that of oranges, and 12 times higher than

apples (0.3 percent). In comparison, the protein contents of common meats are as follows: pork, 9-16 percent; beef, 12-20 percent; chicken, 18-20 percent; fish, 18-20 percent; and milk, 2.9-3.3 percent. On a dry weight basis, mushrooms normally contain 19-35 percent protein, as compared to 7.3 percent in rice, 12.7 percent in wheat, 38.1 percent in soybean, and 9.4 percent in corn. Consequently, in terms of crude protein content, mushrooms rank below animal meats, but well above most other foods, including milk. Furthermore, mushroom protein contains all nine essential amino acids required by humans.

Quantitative data relating to the nutritive value of mushrooms are sparse. In the absence of feeding trials, alternative methods have been used to determine or predict the nutritional value of foods based on their content of essential amino acids. The Essential Amino Acid Index (EAA Index) rates dietary protein in terms of an essential amino acid pattern based on known adult human dietary requirements. The Amino Acid Score (Chemical Score) is the amount of the most limiting amino acid in the food protein expressed as a percentage of the same amino acid present in the reference protein. In an attempt to resolve the difficulties inherent in comparisons between those mushrooms containing small amounts of high quality protein with those containing larger amounts of a protein of lesser nutritional quality, Crisan & Sands proposed in 1987 the use of a Nutritional Index calculated as follows:

$$Nutritional\ Index\ = \frac{(EAA\ Index\ \times\ percentage\ protein)}{100}$$

The EAA Indexes, Amino Acid Scores and Nutritional Indexes for various mushrooms and other foods are shown in Table 1. In terms of EAA Indexes and Amino Acid Scores, the most nutritive mushrooms (highest values) rank alongside meat and milk in potential nutritive value and considerably higher than most legumes and vegetables. The least nutritive mushrooms rank appreciably lower but are still comparable to some common vegetables.

In addition to their high quality protein, mushrooms are a relatively good source of the following individual nutrients: fat, phosphorus, iron, and vitamins including thiamine, riboflavin, ascorbic acid, ergosterol and niacin. Fruit bodies are low in calories, carbohydrates and calcium, and the commonly cultivated mushrooms are reported to have a total lipid content between 0.6 and 3.1 % on a dry weight basis. Unsaturated fatty acids, essential and significant to our diet and to our health, constitute at least 70 percent of the total fatty acid content.

Essential amino acid indexes	**Amino acid scores**	**Nutritional indexes**
100 pork; chicken; beef	100 pork	59 chicken
99 milk	98 chicken; beef	43 beef
98 mushrooms (high)	91 milk	35 pork
96 *V. diplasia*	89 mushrooms (high)	31 pork
91 potatoes; kidney beans *P. ostreatus*	71 *V. diplasia*	28 mushroom (high)

88 corn	63 cabbage	27 *V. diplasia*
87 *A. bisporus*	59 potatoes *P. ostreatus*	26 spinach
86 cucumbers	53 peanuts	25 milk
79 peanuts	50 corn	22 *A. bisporus*
76 spinach; soybeans	46 kidney beans	21 kidney beans
74 *L. edodes*	42 cucumbers	20 peanuts
72 mushrooms	40 *L. edodes*	17 cabbage
69 turnips	33 turnips	15 *P. ostreatus*
53 carrots	32 mushrooms (low)	14 cucumbers
44 tomatoes	31 carrots	11 corn
	28 spinach	10 turnips
	23 soybeans	9 potatoes
	18 tomatoes	8 potatoes
		6 carrots
		5 mushrooms (low)

Ranking based on essential amino acid indexes, amino acid scores and nutritional indexes as calculated against the FAO reference protein pattern. Values for mushrooms represent the mean of the three highest values (high) and the three lowest values (low). Data from Crisan & Sands (1978).

Table 1: Comparison of nutritive value of mushrooms with various foods

The desirability of a food product is not necessarily correlated to its nutritional value. However, appearance, taste, and aroma are often important in stimulating the appetite. Thus, in addition to nutritional value, edible mushrooms possess unique characteristics in terms of colour, taste, aroma and texture that make them attractive for human consumption.

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Biographical Sketches

Professor Shu-Ting Chang, Emeritus Professor of Biology, The Chinese University of Hong Kong, is the Vice-President of the World Society for Mushroom Biology and Mushroom Science; and Director of Hong Kong MIRCEN for Mushroom Science, which is sponsored by Unesco. He is also the Director of the Centre for International Services to Mushroom Biotechnology under the aegis of UNIDO, and Editor of the International Journal of Medicinal Mushrooms.

Professor Chang received a BS degree from the Naitonal Taiwan University in 1953 and earned MS and PhD degrees in 1958 and 1960 respectively from the University of Wisconsin. He was awarded a post-doctoral fellow at Harvard University during 1966-67, a Visiting Fellow at the University of Tokyo in 1969 and at the same time a Visiting Fellow of the Australian National University (ANU) and the CSIRO during 1972-73 and 1978-79. Other Honours include:

-Elected Fellow of the World Academy of Art and Science (1989)

-Fellow of the International Institute of Biotechnology (1990)

-Fellow of the World Academy of Productivity Science (1992)

-International Cooperation Award for Light Industry, China (1990)

-Honorary Life Member of the British Mycological Society (1990)

-Honorary Life Member of the International Society for Mushroom Science (1993)

-An Officer of the Most Excellent Order of the British Empire (OBE) in 1994

Prof. Chang has authored or co-authored over 200 articles in scientific journals and 22 books.

Professor Chang and his family have moved to Canberra (Australia) after his retirement in 1995.

J.A. Buswell gained a BSc in Bacteriology at the University of Birmingham, England in 1963, followed by a PhD in 1966 on "Microbial degradation of methoxylatedphenolic compounds". He was the Rosalie B. Hite Postdoctoral Fellow at the Department of Microbiology, University of Texas, Austin, Texas from 1996-7.

Employment History:

1967-68	Research Scientist, University of Texas, USA.
1968-71	Assistant Professor, Department of Microbiology, University of Southwestern Louisiana,USA
1971-72	Science Research Council Postdoctoral Fellow, Biological Laboratories, University of Kent, UK
1972-89	Lecturer I, Lecturer II and Senior Lecturer (Microbiology), Department of Biology, Paisley College of Technology, Paisley, UK
1989-90	Associate Research Microbiologist, University of Georgia, Athens, Georgia, USA
1990-2003	Lecturer/Senior Lecturer/Reader, Department of Biology, The Chinese University of Hong Kong.
2003-present	Guest Professor, Institute of Edible Fungi, Shanghai Academy of Agricultural Sciences.
1978-80	Visiting Researcher, Swedish Forest Products Laboratory, Stockholm, Sweden.
1984-85	Visiting Researcher, Institut National Agronomique, Paris, France.

His major research interests are the fungal mediated biodegradation and bioconversion of lignocellulose, microbial degradation of xenobiotics, and mushroom nutriceuticals (i.e. mushroom–derived bioactive compounds). He has also been: Co–Director, Hong Kong MIRCEN (Microbial Resource Centre); Hong Kong Representative and General Secretary, International Mycological Association Committee for Asia; Deputy Director, UNIDO–Chinese University of Hong Kong Centre for International Services to Mushroom Biotechnology; Secretary/Treasurer, World Society for Mushroom Biology and Mushroom Products; and Committee and Founding Member of the Mycological Association of Hong Kong. He is a Past Member of the Editorial Board of the Journal of General Microbiology, and Past Member of the Editorial Boards of the World Journal of Microbiology and Biotechnology and Letters in Applied Microbiology. He has published 82 scientific papers and edited two books.