MUSHROOM PRODUCTION

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Contents

Summary

Huge quantities of a wide variety of organic wastes are generated annually through the activities of the agricultural, forest, and food processing industries. These so called wastes constitute a negative factor both in the economic evaluation of existing industrial and agricultural operations and because of the adverse environmental effects resulting from their disposal. However, with the application of appropriate bioconversion technology, they constitute a potentially valuable resource. One particularly effective form of bioconversion technology is represented by mushroom production. Mushrooms are a source of high quality protein which can be produced with greater biological efficiency than animal protein. Moreover, mushrooms can be cultivated on a wide variety of organic wastes. Of further value is the spent substrate residue left after mushroom harvesting which can be used as an animal feedstock and /or a soil conditioner. There is also rapidly growing interest in mushroom products as a source of high-value dietary supplements (mushroom nutriceuticals), which have potential therapeutic applications. The introduction of technology to breed new strains, to

cultivate more new wild species which are adapted to greater climatic variation, and to maximize mushroom production from these lignocellulosic wastes at minimum cost for the purpose of providing both a cheap source of food protein and a source of health-promoting substances, is a continuing challenge. In 2002, world production of cultivated mushrooms was estimated to be 12,250.0 thousand tons and was valued about at US$32 billion, whereas mushroom products (mushroom derivatives from medicinal, edible and wild mushrooms) used mainly for dietary supplements (mushroom nutriceuticals) were assessed to have generated about US$11 billion and wild mushrooms collected mainly from the wild, was valued at US$3.5-4 billion. In addition, cultivation and development of mushrooms can positively generate equitable economic growth, reduce environmental pollution, and have an important social impact by increasing the possibilities of employment for women and youth, particularly in rural areas in less developed countries. Therefore, sustainable research and development of mushroom production can become a “non-green revolution”.

1. Introduction

The ultimate aim in the modern applied aspects of any scientific endeavour is to integrate, wherever possible, the various disciplines of science, as well as the associated technological processes, in order that maximum benefits may accrue from such efforts. Combined production of mushrooms for human food, health care, animal feed and soil conditioner/ fertiliser from rural and urban organic wastes should be one of the aims of such integrated schemes that can eventually be made into profitable operations. It is common knowledge that lignocellulosic wastes are available in abundance, in both rural and urban areas. These are usually by-products of agricultural-, forestry-, industrial- and household-based activities. They have insignificant or no commercial value, and certainly no food value, at least in their original form. When carelessly disposed of in the surrounding environment by dumping, or burning, these wastes lead to environmental pollution and may constitute a health hazard. However, with the application of appropriate bioconversion technology, they represent a potentially valuable resource for further economic growth.

One particularly effective form of bioconversion technology is represented by mushroom production. Even though wild edible mushrooms have been harvested by humans as food from times immemorial, their nutritive and medicinal values were not assessed, and their production under controlled conditions was not undertaken until recent times. Mushrooms are actually a source of high quality protein that can be produced with greater biological efficiency than animal protein. They also contain a great variety of substances that can improve human biological functions and make people fitter and healthier. Production is particularly applicable to situations where large-scale capital intensive operations are inappropriate, and where harvesting and post-harvest processing requirements are minimal. Moreover, mushrooms can be cultivated on a wide variety of lignocellulosic wastes and, by choosing the right species, can be cultivated under many different climate conditions. Mushrooms are made up of between 19 and 35 percent protein containing all the essential amino acids, and are especially rich in lysine and leucine, which are present in only low amounts in most staple cereal foods. 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. In addition, mushrooms are rich in fibre, minerals and vitamins. These properties are major contributing factors to the traditional recognition of mushrooms as "health" food. There is also a rapidly growing interest in mushrooms as a source of high-value metabolites, e.g. anti-tumour and immunopotentiating agents, hypocholesterolemic compounds, colourants and flavour compounds.

In 2002, world production of cultivated mushrooms was estimated to be 12,250.0 thousand tones (Chang 2006). Overall, world mushroom production has increased over 12.5 percent annually between 1981 and 2002. Latest figures have estimated the value of the mushrooms themselves to be woth US$32 billion and the market value of mushroom derivatives in the form of dietary supplements at about US$11 billion. However, in terms of percentage of total world production, *Agaricus* mushrooms decreased from 71.6 percent in 1981 to 31.8 percent in 1997 even though the actual production of the mushroom increased from 900 thousand tons in 1981 to 1,955.9 thousand tons in 1997, a 2.2-fold increase. This is the result of other alternative mushrooms gradually becoming more popular, in particular *Lentinula edodes* (Berk.) Sing., where output increased from 180 to 1,564.6 thousand tons, i.e. from 14.3 percent to 25.2 percent of total world production between 1981 and 1997, and *Pleurotus* mushrooms, where output increased from 35 thousand to 875.6 thousand tons, i.e. from 2.8 percent to 14.2 percent of total mushroom production. More than twenty new species of mushrooms have been cultivated on a small commercial scale in recent years and these have great potential for expansion. The successful cultivation of *Pleurotus sajor-caju* (Fr.) Sing., on water hyacinth and *L. edodes* on coffee wastes will, no doubt, enhance the production of these mushrooms in Africa and Latin America, where the two kinds of lignocellulosic wastes are available in large quantities.

Therefore, the cultivation and development of edible and medicinal mushrooms has already had a positive impact by generating equitable economic growth at both national and regional levels. This impact is expected to continue increasing and expanding into the twenty-first century because more than 70 percent of agricultural and forest-based materials are non-productive and are treated as processing wastes. By blending advances in basic biological knowledge with practical technology, a mushroom-related industry, that is, mushroom production (the mushroom themselves) through mushroom science technology and mushroom products (mushroom derivatives) through mushroom biotechnology, based on utilization of the lignocellulosic waste materials, can have a positive long-term global impact on human nutrition, health care, environmental conservation and regeneration, and economic and social change. Since mushrooms are non-green organisms, the impact of mushroom technology can represent a “non-green revolution”, which must be implemented vigorously according to locally available substrates, labour supply and climatic conditions.

2. What are Mushrooms?

The word mushroom means different things to different people living in different countries. In some Western countries, mushroom refers only to the "button" or "white" mushroom [*Agaricus bispours* (J. Lge) Sing. and *A. bitorquis* (Quel.) Sacc.], whereas all other cultivated species are referred to as “specialty", "exotic" or "alternative" mushrooms. According to the definition given by Chang and Miles in 1992, a mushroom is a "macrofungus with a distinctive fruiting body (Figure. 1) which can be either epigeous or hypogeous and large enough to be seen with the naked eye and to be picked by hand". Accordingly, mushrooms need not be Basidiomycetes, or aerial, neither fleshy nor edible. Mushrooms can be Ascomycetes, grow underground, have a non-fleshy texture and need not be edible. In other words, mushrooms can be roughly divided into four categories:

- those which are fleshy and edible fall into the edible mushroom category, e.g. *A. bisporus*;
- mushrooms which are considered to have medicinal applications are referred to as medicinal mushrooms, e.g. *Ganoderma lucidum* (Cur.:Fr.) Karst.*;*
- those which are proven to be, or suspected of being poisonous are called poisonous mushrooms, e.g. *Amanita phalloides* (Vaill.:Fr.) Secr.*;*
- a miscellaneous category which includes a large number of mushrooms whose properties remain less well-defined and which may tentatively be grouped together as "other mushrooms".

Figure 1. Distinctive fruiting bodies of *Volvariella volvacea* (Bull.:Fr.) Sing. Consisting of pileus (the cap), stipe (the stem or stalk) and a volva (the sack–like remnant of the universal veil). The majority of gilled mushrooms have pileus and stipe structures, but neither volva or annulus (ring), e.g. the common white mushroom [*Agaricus bisporus* (Lange) Sing] has an annulus but does not have a volva, *Lentinula edodes* (Berk) Pergler does not have both annulus and volva. However, the most complex members of the gilled mushrooms belong to the genus Amanita, eg *Amanita phalloides* (vaill.:Fr) Secr., which also has the four structures.

Certainly, this form of classifying mushrooms is not absolute. Many kinds of mushrooms are not only edible, but also possess tonic and medicinal qualities. It should be noted that there are no simple ways to distinguish between edible and poisonous mushrooms. Mushrooms should be eaten only if they have been identified with precision and the history of that species in terms of edibility is known. Therefore if you are not absolutely sure whether a given mushroom is edible or otherwise, don't touch, leave the strange mushroom alone!

It has been estimated that, in nature, there are approximately 1.5 million species of fungi. This figure has been reviewed after more than 10 years and is still retained as the current working hypothesis for the number of fungi on Earth while waiting for additional data to test its accuracy. Of the 1.5 million estimated fungi, Hawksworth (2001) has estimated that 140,000 species produce fruiting bodies of sufficient size and suitable structure to be considered macrofungi, which can be called mushrooms according to the definition given by Chang and Miles (1992). Currently, 14,000 mushroom species have been identified, which would account for 10% of the estimated mushroom species. Of these, over 3,000 species from more than 30 genera are regarded as prime edible mushrooms, but of these only about 100 species are grown experimentally, 60 cultivated economically, around 30 cultivated commercially, and only 15 are produced on an industrial scale. In general, oriental countries such as China, Japan and Korea grow and consume more varieties of mushrooms than do Western countries. However, in recent years, the production of what are referred to as "specialty" or "alternative mushrooms", mainly *L. edodes, Flammulina velutipes* (Curt.:Fr.) Sing., *Hypsizygus marmoreus* (Peck) Bigelow, *and Pleurotus spp*., has increased rapidly in Western countries.

3. Mushroom Cultivation

Mushroom cultivation is a complicated business. It involves a number of different operations including the selection of an acceptable fruiting culture of the mushroom, preparation of spawn and compost/substrate, inoculation of the compost/substrate, crop care, harvesting, preservation of the mushrooms and marketing.

Each of these operations consists of many sequential steps which are equally important if success is to be achieved in the mushroom business. Cultivation techniques vary for different mushroom species in different countries. More information can be found in the listed references (Chang and Miles, 2004; Quimio et al., 1990; Van Griensven, 1988).

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Biographical Sketch

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 B.Sc. degree from the

National Taiwan University in 1953 and earned M.Sc. and Ph.D. 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 Honors 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 185 articles in scientific journals and 16 books. Professor Chang and his family moved to Canberra (Australia) after his retirement in 1995.