MUSHROOMS AS FUNCTIONAL FOODS

Edited by

Peter C. K. Cheung
The Chinese University of Hong Kong

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This book is dedicated to my family members:
Carmen, Timothy, Rebekah, and Anthony Cheung

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FOREWORD

It has been over twenty years since the concept of "functional foods" was first introduced as a factor in the analysis of foods after nutrients. Consumers are now deeply interested in food bioactives that provide beneficial effects to humans in terms of health promotion and disease risk reduction. They also demand more detailed information about food factors in order to obtain appropriate functional food products.

In Asian countries, like China and Japan, mushrooms have been collected and cultivated for hundred of years. They have a long history of use for their health promotion benefits. In recent years reports on the chemistry, and the nutritional and functional properties of mushroom have been overwhelming. In the *Journal of Agricultural and Food Chemistry* alone there have been more than 300 articles related to mushrooms published since 1990. However, there is no in-depth comprehensive reference book of mushrooms as functional food available. The current book of Professor C. K. Cheung, *Mushrooms as Functional Foods*, is a timely and well welcomed book for scientists and students working in functional food research.

Besides covering the agricultural production, nutritional values, and health benefits of mushrooms, this book also introduces emerging molecular analysis and functional genomics to the study of mushroom. Health benefits of mushrooms, such as, antioxidative, hypocholesterolemic, and hypoglycemic effects are discussed in depth. Polysaccharides are the best known and potent mushroom-derived substances with immunomodulating and antitumor activities and this topic has been treated extensively in a separate chapter. Included also is a unique and useful chapter on regulatory issues of mushrooms as functional foods in different countries.

Scientists and students who research mushrooms will certainly benefit from reading this comprehensive monograph to gain in-depth knowledge for the development of mushrooms into functional foods.

CHI-TANG HO

Rutgers University

PREFACE

Mushrooms have been known for their nutritional and culinary values as well as viewed as tonics and used as medicines by humans for ages. In modern terms, they can be considered as functional foods which can provide health benefits beyond the traditional nutrients they contain. There are monographs that cover the medicinal and healing properties of some individual traditional mushrooms and fungi such as the *Ganoderma*, Shiitake mushroom, and *Cordyceps* for the general public. However, there are very few in-depth and up-to-date comprehensive reference books in the scientific literature of both the basic and applied aspects of mushrooms as functional foods.

This book is an integration of the recent research conducted on the biological and chemical aspects of mushrooms when being utilized as a functional food. Topics that are covered in this book range from the agricultural production of mushrooms to the use of molecular biological techniques like functional genomics, from nutritional values of newly cultivated mushroom species to the multifunctional effects of the unconventional form of the mushroom (sclerotium), and from the mechanistic actions of the physiological benefits and pharmacological properties of bioactive components in mushrooms to the regulations of their uses as functional foods and dietary supplements in different parts of the world.

This comprehensive book should serve as a reference for scientists; chemists; biologists; food manufacturers; students majoring in food science, nutrition, biology, and biochemistry, to name a few; and all those who are interested in obtaining a stronger background in the development of mushrooms and edible fungi into functional foods.

PETER C. K. CHEUNG

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CHAPTER 1

Overview of Mushroom Cultivation and Utilization as Functional Foods

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1.1 INTRODUCTION

In 1957, R. Gordon Wasson, a world known amateur mycologist, proposed the division of people into two classes for which he coined the following terms:

Mycophiles—Those who love and know their mushrooms intimately.
Mycophobes—Those who fear, dislike, and do not know their mushrooms.

I think all readers of this book belong to the former and not the latter.

Knowledge of numerous new mushroom species has accumulated through time. The number of recognized mushroom species has been reported to be 14,000, which is about 10% of the total estimated mushroom species on the earth (Hawksworth, 2001). China is estimated to have about 1500–2000 edible mushroom species with 981 species identified. By 2002, 92 species have been domesticated while 60 of these have been commercially cultivated (Mau et al.,

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2004). However, mushrooms have nearly always been around, with a very long and interesting history. Mushrooms have been found in fossilized wood that is estimated to be 300 million years old, and almost certainly prehistoric man used mushrooms collected in the wild as food. Recently, the importance of the role of mushrooms in history was evidenced by the fact that the desert truffle, *Terfezia arnenari*, was described in the Bible as "bread from heaven" and also "manna of the Israelites" (Pegler, 2002).

It may be interesting to have a charming mushroom poem as a beginning for this chapter: "Without leaves, without buds, without flowers, yet, they form fruit; as a food, as a tonic, as a medicine, the entire creation is precious" (Chang and Miles, 1989, p. 345). The first part describes the morphological and physiological characteristics of mushrooms while the second states the nutritional and medicinal properties of mushrooms.

Our attitudes to the phenomenon of nature are seldom based on simple observation. There are, however, examples throughout history where certain living things have inspired fear and loathing simply because they are regarded as ugly species with peculiar behavior and supposedly evil. For example, in some communities, bats, snakes, spiders, toads, and owls have all been associated with the devil or regarded as harbingers of illness and even of death. This is one of the reasons why some refer to the poisonous mushroom as a "toadstool." Actually, the name has no scientific basis at all and should not be used in any situations, although it is possible to find a toad sitting beside or even on top of a mushroom. Mushrooms attract toads, not due to the mushroom itself, but because of the various insects which are harbored in them. Insects certainly are interested in mushrooms as a source of food (Chang, 2005).

It cannot be denied that some mushrooms, even though they represent less than about 1% of the world's known mushrooms, are dangerous if eaten. Some are deadly poisonous. But perhaps a more likely explanation for the widespread abhorrence of wild mushrooms in communities is that they are by nature a rather strange and mysterious group of organisms, quite unlike the green plants. In some ancient communities, the seemingly miraculous manner of its growth without seed, without leaf, and without bud, its fruiting body's sudden appearance after rain, especially after lightning and thunderstorms, its equally rapid disappearance, and its curious umbrellalike shape gave rise to a wealth of illusions and mythologies.

Fungi are found just about everywhere. Mushrooms, a special group of macrofungi, are rather more selective than other fungi in that the size of the fruiting body requires the availability of more nutrients than are required for the production of asexual spores by microfungi. Nevertheless, in damp places, such as tree-fern gullies and areas of rain forest, plentiful moisture leads to mushroom formation and mushrooms can be collected during most of the year. There may be a particular flora of mushroom species associated with the seasons of autumn, summer, and spring. Relatively few mushrooms are produced during the cold winter months, although there are perennial fruiting bodies that persist during the winter. But in drier regions mushrooms occur only after seasonal rains. Formation of mushroom

fruiting bodies depends very much on the pattern of rain and, in some years, there may be virtually a complete lack of fruiting.

There has been a recent upsurge of interest in mushrooms not only as a health vegetable (food) which is rich in protein but also as a source of biologically active compounds of medicinal value. Uses include complementary medicine/dietary supplements for anticancer, antiviral, immunopotentiating, hypocholesterolemic, and hepatoprotective agents. This new class of compounds, termed *mushroom nutriceuticals* (Chang and Buswell, 1996), are extractable from either the mushroom mycelium or fruiting body and represent an important component of the expanding mushroom biotechnology industry. It has been shown that constant intake of either mushrooms or mushroom nutriceuticals (dietary supplements) can make people fitter and healthier. In addition, mushroom cultivation can also help to convert agricultural and forest wastes into useful matter and reduce pollution in the environment. Therefore, mushroom cultivation can make three important contributions: production of health food, manufacture of nutriceuticals, and reduction of environmental pollution.

1.2 WHAT ARE MUSHROOMS?

1.2.1 Definition of a Mushroom

Mushrooms along with other fungi are something special in the living world, being neither plant nor animal. They have been placed in a kingdom of their own, called Myceteae (Miles and Chang, 1997). But what are mushrooms? The word *mushroom* may mean different things to different people and countries. It was reported (Chang and Miles, 1992) that specialized studies and the economic value of mushrooms and their products had reached a point where a clear definition of the term mushroom was warranted. In a more broad sense "mushroom is a macrofungus with a distinctive fruiting body, which can be either epigeous or hypogeous and large enough to be seen with naked eye and to be picked by hand" (Chang and Miles, 1992). Thus, mushrooms need not be Basidiomycetes, or aerial, or fleshy, or edible. Mushrooms can be Ascomycetes, grow underground, have a nonfleshy texture, and need not be edible. This definition is not a perfect one but can be accepted as a workable term to estimate the number of mushrooms on the earth (Hawksworth, 2001). The most common type of mushrooms is umbrella shaped with a pileus (cap) and a stipe (stem), that is, *Lentinula edodes*. Other species additionally have a volva (cup), that is, *Volvariella volvacea*, or an annulus (ring), that is, *Agaricus campestris*, or both, that is, *Amanita muscaria*. Furthermore, some mushrooms are in the form of pliable cups; others are round like golf balls. Some are in the shape of small clubs; some resemble coral; others are yellow or orange jellylike globs; and some even very much resemble the human ear. In fact, there is a countless variety of forms.

The structure that we call a mushroom is in reality only the fruiting body of the fungus. The vegetative part of the fungus, called the mycelium, comprises a system of branching threads and cordlike strands that branch out through soil, compost,

wood log, or other lignocellulosic material on which the fungus may be growing. After a period of growth and under favorable conditions, the established (matured) mycelium could produce the fruit structure which we call the mushroom. Accordingly mushrooms can be grouped into four categories: (1) those which are fleshy and edible fall into the edible mushroom category (e.g., *Agaricus bisporus*); (2) mushrooms which are considered to have medicinal applications are referred to as medicinal mushrooms (e.g., *Ganoderma lucidum*); (3) those which are proven to be or suspected of being poisonous are named poisonous mushrooms (e.g., *Amanita phalloides*); and (4) a miscellaneous category, which includes a large number of mushrooms whose properties remain less well defined, may tentatively be grouped together as "other mushrooms." Certainly, this approach of classifying mushrooms is not absolute and not mutually exclusive. Many kinds of mushrooms are not only edible but also possess tonic and medicinal qualities.

1.2.2 Ecological Classification of Mushrooms

Mushrooms can be ecologically classified into three categories: saprophytes, parasites, and mycorrhiza.

There are only a few parasitic mushrooms. Most of the cultivated gourmet mushrooms are saprophytic fungi. Some are mycorrhizal mushrooms, for example, Perigold black truffle (*Tuber melanosporum*) and matsutake mushroom (*Tricholoma matsutake*). It is difficult to bring these pricey wild gourmet species into cultivation because they are mycorrhiza. These mushroom species have a symbiotic relationship with some vegetation, particularly trees, that is, there is a relationship of mutual need. Therefore, the substratum (host) should be carefully recorded, as this can be an important feature in identification and in classification, for example, whether the mushroom is growing on dung, wood, bark, living trees, litter, or soil. If the mushroom is growing on a living plant or on dead parts recognizable as belonging to a nearby plant, flowers, fruits, or other parts of the plant, these should be collected for identification of the host or substrate if its name is not known.

Saprophytes obtain nutrients from dead organic materials; parasites derive food substances from living plants and animals, causing harm to the hosts; and mycorrhiza live in a close physiological association with host plants and animals, thereby forming a special partnership where each partner enjoys some vital benefits from the other.

However, some mushrooms do not fall neatly within these man-made categories and can share two of these categories (Figure 1.1). For example, some *Ganoderma* spp., including *G. lucidum*, are common saprophytes but can be pathogenic too; also *T. matsutake*, while initially appearing to be mycorrhizal on young roots, soon becomes pathogenic and finally exhibits some saprophytic ability.

1.2.3 Identification of Mushrooms

Successful identification of wild mushrooms requires a basic knowledge of the structure of fungi and of the way in which they live. To identify a given mushroom,

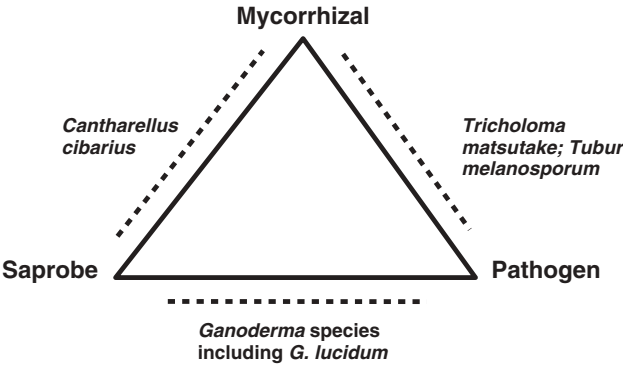

Figure 1.1 Modified triangular model for ecological classification of mushrooms (Hall et al., 2003b).

it is necessary to examine the fruiting bodies with the utmost care. A fresh fruiting body is much easier to identify than a pickled (preserved in formalin) or a dried one. A good reference material, usually a book with color, pictures of the different mushrooms known, is a basic requirement. A key is usually provided to simplify identification in most reference texts (Arora, 1986; Carlucccio, 2003; Chang and Mao, 1995; Fuhrer, 2005; Shepherd and Totterdell, 1988; van der Westhuizen and Eicker, 1994).

In using the reference, it is essential that one knows some specific characteristics of the mushroom being identified. These characteristics are (1) size, color, and consistency of the cap and the stalk; (2) mode of attachment of the gills to the stalk; (3) spore color in mass; and (4) chemical tests or reactions.

Although the color of the gills is a good indication of the spore color, there are instances when the experienced mycologist will have to resort to what is called "spore print" examination to determine the real color of the spores. For specimens with a distinct cap and stem, the cap is removed and placed fertile-side down, preferably on a microscope slide, but in the absence of such, on white paper, black paper, or cellophane. Then it is covered with a bowl or similar object to prevent air currents. A thin spore print is often visible after as little as a half hour, but a useful deposit usually requires longer time (up to 2 hours or more). The print is necessary to determine overall spore color. It is also a source of mature spores for microscopic examination and measurements.

The mode of gill attachment to the stem indicates the genus of the mushroom and should be carefully noted. To determine the mode of attachment, the mushroom is cut longitudinally through the cap, exposing the point of attachment of the gills to the stem.

The environment in which the mushroom was picked should also be noted. It is important to know whether the mushroom grows directly on the ground, on decaying wood, on a living tree trunk, or on compost. One should not overlook the species of those on which the mushrooms are found growing or the type of grasses or moss present in the area where the mushrooms are collected.

There is no single reference work in which all mushrooms are illustrated or described. In most cases, mushroom species in publications are grouped by region or locality, for example, North American mushrooms, mushrooms of the Western Hemisphere, and mushrooms of South Africa. While certain mushrooms are easy to identify, many are not. In fact, there is a great number of look-alikes. To avoid any unpleasant experiences, especially when identifying mushrooms for the purpose of determining edibility, experts should always be consulted (Quimio et al., 1990).

Collectors should always remember when using keys that the mushroom they have in hand might not be included in the book they are consulting (or in any other book, for that matter). Once they have obtained a name with a key, they must read the detailed description provided for the mushroom and compare it with the one they are trying to identify. If the description does not fit the specimen, then they must go back to the key and try again, following a different route. If they exhaust all of the possible routes and still cannot find a description that fits, they should assume that the fungus in hand is not in the books being consulted. Using the information gained, they may then consult other appropriate references that may be available or they may seek the assistance of specialists working with the group in question. They should never attempt to force a specimen into a category where it does not fit.

Some mushrooms are very palatable due to their exotic taste, but some mushrooms are very poisonous. Unfortunately, there are no general guidelines for distinguishing between the poisonous and edible species. The only means by which a nonspecialist can determine the edibility or toxicity of a given mushroom is to carry out an accurate identification of the specimen. Such identification may be obtained by consulting the relevant literature, preferably with illustrations, or experts in the subject. Identification of a mushroom at the generic level is inadequate since, within a given genus (e.g., *Lepiota*) some species are edible while other species are highly poisonous.

Several species of *Amanita* are extremely poisonous, but obvious symptoms do not appear until 8–12 hours after ingestion. The poisonous compound, amatoxin, is not destroyed by boiling or processing. Some less poisonous mushrooms produce only nausea or gastric upset within 30–60 minutes of ingestion (Hall et al., 2003a; Quimio et al., 1990). Mushrooms partially eaten by animals or insects are not necessarily fit for human consumption. When the mushroom is in doubt, throw it out. *If you are not absolutely sure whether a given mushroom is edible or otherwise, do not touch it. Leave the strange mushroom alone*.

1.3 CONCEPT OF MUSHROOM BIOLOGY AND APPLIED MUSHROOM BIOLOGY

1.3.1 Mushroom Biology

The biological science that is concerned with fungi is called mycology. Mushroom biology is the branch of mycology that deals with mushrooms in many disciplines.