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Fungi for Human Health

Current Knowledge and Future Perspectives

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This book is dedicated to our parents and siblings

Preface

This book spotlights macrofungi with health-promising properties, which mainly belong to Basidiomycota (Agaricomycotina) and Ascomycota (Pezizomycotina). Macrofungi or higher fungi are ascomycetous and basidiomycetous mushrooms forming conspicuous, epigeous, or hypogeous sporocarps and are large enough to be seen by the naked eye. The consumption of wild macrofungi by man goes back 13,000 years. Macrofungi vary in structure and reproduction and occur in a wide range of habitats in different ecogeographic zones of the world. Ethnomycological surveys across the globe reveal the food value and therapeutic significance of wild species in diet and folk medicine. Scientific research proves the nutritional and pharmacological properties of these macrofungi. The latter are consecrated with a wealth of nutrients such as carbohydrates, proteins, fats, fatty acids, amino acids, minerals, and vitamins contributing to their food value. The sporocarps/cultured mycelia or cultured broths of these fungi are rich in numerous high and low molecular weight bioactive constituents. These bioactive components include polysaccharides, proteins, fatty acids, proteoglycans, terpenoids, and phenolics, accounting for a broad spectrum of pharmacological activities such as antioxidant, antitumor, antidiabetic, antibacterial, antifungal, immunomodulatory, antimalarial, and antiviral. Several health-promoting products of macrofungal origin are available in market in the form of tablets, capsules, syrups, pastes, and powders. In spite of huge benefits of macrofungi, these are often overlooked as far as conservation efforts are concerned. Many macrofungal species are red listed by IUCN and need immediate attention to conserve and ensure sustainable use of this inexpensive natural treasure with huge health benefits. In this book, we endeavored to highlight the future prospects of macrofungi and tried to shed light on the taxonomy, ecology, ethnomycology, nutraceutical composition, bioactive active and pharmacological activities, commercialization, and conservation. Some information on cultivation and toxigenic macrofungi is also provided. Hopefully, the information cited within this

book will prove beneficial to the mycophiles, amateur naturalists, the general public, researchers, and industrialists interested in the consumption, research, and marketing of macrofungi.

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About the Authors

Uzma Azeem, Ph.D., is a postgraduate, M.Phil. and doctorate from Punjabi University, Patiala, Punjab, India. She spent more than a decade there from 2006 to 2018. Dr. Azeem completed her Doctorate in Botany with specialization in Mycology and Plant Pathology from Punjabi University, Patiala, Punjab, India, in 2018. She worked at Sri Guru Granth Sahib World University, Fatehgarh Sahib, Punjab, India, as an Assistant Professor in the Department of Botany from August 1, 2018, to January 21, 2019. Dr. Azeem joined Sanmati Government College of Science Education and Research, Jagraon, Ludhiana, Punjab, India, on January 21, 2019, and worked there for a short period. She has been awarded with the Maulana Azad National Fellowship for Minority Students by the University Grants Commission, New Delhi, India, in 2011. So far, she has authored nine papers (eight research papers plus one review paper) in peer-reviewed national and international journals. Dr. Azeem has participated and presented her research work at various conferences/symposia across India winning appreciation and awards. This is her first endeavor in book publication.

Khalid Rehman Hakeem, Ph.D., is Professor at King Abdulaziz University, Jeddah, Saudi Arabia. After completing his doctorate (Botany, specialization in Plant Eco-physiology and Molecular Biology) from Jamia Hamdard, New Delhi, India, in 2011, he worked as a Lecturer at the University of Kashmir, Srinagar, for a short period. Later, he joined Universiti Putra Malaysia, Selangor, Malaysia, and worked there as Postdoctoral Fellow in 2012 and Fellow Researcher (Associate Prof.) from 2013 to 2016. Dr. Hakeem has more than 10 years of teaching and research experience in plant eco-physiology, biotechnology and molecular biology, medicinal plant research, plant-microbe-soil interactions, as well as environmental studies. He is the recipient of several fellowships at both national and international levels; he has also served as Visiting Scientist at Jinan University, Guangzhou, China. Currently, he is involved in a number of international research projects with different government organizations.

So far, Dr. Hakeem has authored and edited more than 50 books with international publishers, including Springer Nature, Academic Press (Elsevier), and CRC

Press. He also has to his credit more than 110 research publications in peer-reviewed international journals and 60 book chapters in edited volumes with international publishers.

At present, Dr. Hakeem serves as an editorial board member and reviewer of several high-impact international scientific journals from Elsevier, Springer Nature, Taylor and Francis, Cambridge, and John Wiley Publishers. He is included in the advisory board of Cambridge Scholars Publishing, UK. Dr. Hakeem is also a fellow of Plantae group of the American Society of Plant Biologists; member of the World Academy of Sciences; member of the International Society for Development and Sustainability, Japan; and member of Asian Federation of Biotechnology, Korea. Dr. Hakeem has been listed in Marquis Who's Who in the World between 2014 and 2020. Currently, Dr. Hakeem is engaged in studying plant processes at eco-physiological as well as molecular levels.

M. Ali is currently working under the Ministry of Higher Education as a Lecturer of Pharmacognosy in the Department of Pharmacognosy, College of Pharmacy, Jazan University, Kingdom of Saudi Arabia (KSA). He received his Ph.D. from Jamia Hamdard University, New Delhi, India, in 2012 for "Phytochemical and Pharmacological Studies of an Anticancer Medicinal Plant and Its Authentication Using Molecular Biology Techniques." Dr. Ali is also recipient of Government of India's Junior Research Fellowship (JRF, GATE) for pursuing a master's degree in pharmacy (M. Pharm) for "Enhanced Production of Vasicine and Vasicinone from Callus Culture of Adhatoda vasica." He has published/presented about 25 research articles in national and international journals of repute. Dr. Ali has reviewed scientific papers in the field of pharmaceutical science.

Chapter 1
Introduction

Fungi constitute a group of eukaryotic, spore-bearing, achlorophyllous, saprotrophic or parasitic, sexually or asexually reproducing organisms with unicellular to filamentous (hyphal) forms, filaments, or hyphae branched or unbranched typically enclosed by cell wall made up of chitin or cellulose or both (Alexopoulos et al. 1996). In the sixteenth century, fungi were represented by two genera, *Fungus* and *Tuber* (De Lobel 1581). At the end of the seventeenth century and start of the eighteenth century, De Tournefort (1656–1708), father of modern generic concept, added five new genera including *Agaricus* (Bauhin 1623; De Tournefort 1694, 1700). Great mycologist Micheli, known as the father of mycology, proposed 30 new genera to fungi (Micheli 1729). This number is incessantly piling up with new reports. Approximately, 1200 new species are being reported per annum. Fungi are classified into six phyla: *Ascomycota*, *Basidiomycota*, *Chytridiomycota*, *Glomeromycota*, *Microsporidia*, and *Zygomycota* (Kirk et al. 2008). Based on morphology, ecology, phylogeny, and various other extrapolation techniques, fungal diversity is estimated to be approximately 3 to 5.1 million globally (Dai 2010; Blackwell 2011; Hawksworth 2012). However, 92% of these fungi are still undescribed (Hawksworth and Lücking 2017). Majority of all the described fungi belong to the subkingdom *Dikarya* including *Ascomycota* and *Basidiomycota*. *Ascomycota* represents the largest phylum of kingdom fungi and consists of nearly 90,000 described species of fungi belonging to *Taphrinomycotina* (yeast-like and some filamentous fungi), *Saccharomycotina* (the true yeasts), and *Pezizomycotina* (with majority of the filamentous and mushroom-forming ascomycetes). *Basidiomycota* follows *Ascomycota* and comprises of approximately 50,000 species of fungi divided into *Pucciniomycotina* (rust fungi: plant pathogens), *Ustilaginomycotina* (true smuts, some yeasts, and some filamentous fungi), and *Agaricomycotina* (most of the mushroom-producing fungi) (Cannon et al. 2018; Niskanen et al. 2018). The mushroom-forming fungi, macrofungi, constitute a phylogenetically heterogeneous fungal group with species forming epigeal/hypogeal, large spore-bearing structures called sporocarps. An estimated number of macrofungi in the world have risen from

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