

Fungal Biology

Series Editors

Vijai Kumar Gupta
ERA Chair of Green Chemistry
Department of Chemistry and Biotechnology
School of Science
Tallinn University of Technology
Tallinn
Estonia

Maria G. Tuohy
Head of the Molecular Glycobiotechnology Group
Biochemistry, School of Natural Sciences
National University of Ireland Galway
Galway
Ireland

About the Series

Fungal biology has an integral role to play in the development of the biotechnology and biomedical sectors. It has become a subject of increasing importance as new fungi and their associated biomolecules are identified. The interaction between fungi and their environment is central to many natural processes that occur in the biosphere. The hosts and habitats of these eukaryotic microorganisms are very diverse; fungi are present in every ecosystem on Earth. The fungal kingdom is equally diverse, consisting of seven different known phyla. Yet detailed knowledge is limited to relatively few species. The relationship between fungi and humans has been characterized by the juxtaposed viewpoints of fungi as infectious agents of much dread and their exploitation as highly versatile systems for a range of economically important biotechnological applications. Understanding the biology of different fungi in diverse ecosystems as well as their interactions with living and non-living is essential to underpin effective and innovative technological developments. This series will provide a detailed compendium of methods and information used to investigate different aspects of mycology, including fungal biology and biochemistry, genetics, phylogenetics, genomics, proteomics, molecular enzymology, and biotechnological applications in a manner that reflects the many recent developments of relevance to researchers and scientists investigating the Kingdom Fungi. Rapid screening techniques based on screening specific regions in the DNA of fungi have been used in species comparison and identification, and are now being extended across fungal phyla. The majorities of fungi are multicellular eukaryotic systems and therefore may be excellent model systems by which to answer fundamental biological questions. A greater understanding of the cell biology of these versatile eukaryotes will underpin efforts to engineer certain fungal species to provide novel cell factories for production of proteins for pharmaceutical applications. Renewed interest in all aspects of the biology and biotechnology of fungi may also enable the development of “one pot” microbial cell factories to meet consumer energy needs in the 21st century. To realize this potential and to truly understand the diversity and biology of these eukaryotes, continued development of scientific tools and techniques is essential. As a professional reference, this series will be very helpful to all people who work with fungi and should be useful both to academic institutions and research teams, as well as to teachers, and graduate and postgraduate students with its information on the continuous developments in fungal biology with the publication of each volume.

More information about this series at <http://www.springer.com/series/11224>

Bhim Pratap Singh • Lallawmsanga
Ajit Kumar Passari
Editors

Biology of Macrofungi

 Springer

Editors

Bhim Pratap Singh
Molecular Microbiology and Systematics
Laboratory
Department of Biotechnology
Mizoram University
Aizawl, Mizoram, India

Lallawmsanga
Molecular Microbiology and Systematics
Laboratory
Department of Biotechnology
Mizoram University
Aizawl, Mizoram, India

Ajit Kumar Passari
Molecular Microbiology and Systematics
Laboratory
Department of Biotechnology
Mizoram University
Aizawl, Mizoram, India

ISSN 2198-7777

ISSN 2198-7785 (electronic)

Fungal Biology

ISBN 978-3-030-02621-9

ISBN 978-3-030-02622-6 (eBook)

<https://doi.org/10.1007/978-3-030-02622-6>

Library of Congress Control Number: 2018965199

© Springer Nature Switzerland AG 2018

This work is subject to copyright. All rights are reserved by the Publisher, whether the whole or part of the material is concerned, specifically the rights of translation, reprinting, reuse of illustrations, recitation, broadcasting, reproduction on microfilms or in any other physical way, and transmission or information storage and retrieval, electronic adaptation, computer software, or by similar or dissimilar methodology now known or hereafter developed.

The use of general descriptive names, registered names, trademarks, service marks, etc. in this publication does not imply, even in the absence of a specific statement, that such names are exempt from the relevant protective laws and regulations and therefore free for general use.

The publisher, the authors, and the editors are safe to assume that the advice and information in this book are believed to be true and accurate at the date of publication. Neither the publisher nor the authors or the editors give a warranty, express or implied, with respect to the material contained herein or for any errors or omissions that may have been made. The publisher remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

This Springer imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

This volume is dedicated to
Late Shri Ram Prasad
father of Dr. Bhim Pratap Singh,
Senior Editor of this volume,
for his continuous motivation and
encouragement



Late Shri Ram Prasad (1938–2011)

Foreword

It is very important to estimate and document the mushroom (macrofungi) biodiversity as they are well known for the production of bioactive compounds having biotechnological applications and are recognized as supplementary foods due to high nutritional content and medicinal importance. Among the few important features of mushrooms, they can be used as a source of food and medicines besides their key ecological roles. They are also considered as the efficient food for the future as they have high amount of proteins and other nutrients, so they can be used to cope up with the nutrient malnutrition in developing countries. Mushrooms are the only edible source of Vitamin D and considered among the top foods to prevent osteoporosis.

The book volume published by Springer Nature on *Biology of Macrofungi* has received contributions from academicians and scientists from several countries throughout the world including the United Kingdom, the United States, Brazil, China, Serbia, etc. I believe the knowledge shared by the contributors will be very helpful for the readers working in the field of macrofungi. The book has descriptions about the methods used for the identification of macrofungi and how the macrofungi can be exploited for several applications for sustainable development. The book also describes how to cultivate the important types of mushrooms to generate self-employment.

I am sure that the contents given in this volume are a comprehensive coverage of various important aspects of exploitation of macrofungi and their applications in health and pharmaceutical industries. I congratulate the editors and contributors for bringing this volume on *Biology of Macrofungi*.

K. R. S. Sambasiva Rao
Vice-Chancellor
Mizoram University (A Central University)
Aizawl, Mizoram, India

Preface

Mushrooms are often been referred as functional food due to their high nutritional contents. They contain high amount of antioxidants, the chemicals that are required to get rid of free radicals. Free radicals are very dangerous for the body cells as they lead to several deadly diseases including cancer. Mushrooms have high content of selenium, a mineral which is not available by eating most of the fruits and vegetables, and help in detoxifying disease-causing compounds in the body and also play an important role in preventing inflammation. They are high in fiber, potassium, and Vitamin C content which play an important role in preventing cardiovascular health.

The present volume has 19 chapters contributed by the researchers and academicians from several countries including the United Kingdom, the United States, China, Malaysia, Poland, Serbia, Brazil, and India. The volume has covered most of the recent developments in macrofungal biology starting from the latest methods used for the identification of wild macrofungi and several applications of macrofungi for sustainable livelihood.

Editors of the volume express their gratitude to all the contributors for sharing their work in this volume. We are also thankful to Springer Nature publishers for giving us a chance to compile this important volume. We hope that the contents presented in this book will be useful for the readers involved in macrofungi research and all concern.

Mizoram, India

Bhim Pratap Singh
Lallawmsanga
Ajit Kumar Passari

Acknowledgments

My sincere thanks are extended to all the academicians and scientists who have contributed chapters and happily agreed to share their work on various aspects of macrofungi in this volume. At the same time, I also express my deepest gratitude to my family members, especially my wife (Dr. Garima Singh) and my daughter (Aadita Singh), for their kind support which has prompted me to complete the assignment on time. I am also thankful to the Department of Biotechnology (DBT), New Delhi, Government of India, for supporting us financially in the form of several externally funded projects from time to time and for the establishment of DBT Bioinformatics Centre at Mizoram University which was quite useful during the compilation of the book. I am equally thankful to the Springer Publishing for their full cooperation during the production of the volume. In particular, I am thankful to the series editors, Dr. Vijai Kumar Gupta and Prof. Maria G. Tuohy, for accepting our proposal and providing their full support and encouragements. I am also thankful to the production team of Springer Nature for all their efforts for publishing the volume on time. I admit that it is quite possible that some mistakes may have occurred in the text inadvertently, and I take responsibilities for the mistakes, and please feel free to inform me the same.

I am thankful to Prof. KRS Sambasiva Rao, Vice-Chancellor, Mizoram University, for his endeavor and motivations at all stages of the progress.

Mizoram, India

Bhim Pratap Singh

Contents

1	Exploration of Macrofungi in Sub-Tropical Semi-Evergreen Indian Forest Ecosystems	1
	Lallawmsanga, Ajit Kumar Passari, and Bhim Pratap Singh	
2	A Global Overview of Edible Mushrooms	15
	Malarvizhi Kaliyaperumal, Kezhocuyi Kezo, and Sugantha Gunaseelan	
3	Molecular Characterization of Wild Mushrooms: A Paradigm Shift from Morphotyping	57
	Madhusmita Borthakur and S. R. Joshi	
4	Antimicrobial and Hepatoprotective Activities of Edible Mushrooms	81
	Jasmina Glamočlija, Marina Kostić, and Marina Soković	
5	Mushroom-Mediated Protection from Oxidative Damage to DNA . . .	115
	John A. Buswell	
6	Chemical and Bioactive Profiling of Wild Edible Mushrooms	129
	Katarzyna Sułkowska-Ziaja, Katarzyna Kała, Jan Lazur, and Bożena Muszyńska	
7	Biotechnological Requirements for the Commercial Cultivation of Macrofungi: Substrate and Casing Layer	159
	Jaime Carrasco, Maria L. Tello, Margarita Perez, and Gail Preston	
8	Role of Mushroom Fungi in Decolourization of Industrial Dyes and Degradation of Agrochemicals	177
	Sachin Gupta, Sudheer K. Annepu, Baby Summuna, Moni Gupta, and Sunil A. Nair	
9	Mushrooms: Isolation and Purification of Exopolysaccharides	191
	Yuxiao Wang, Xiaojun Huang, and Shaoping Nie	

10	Novel Prospective of Wild Mushroom Polysaccharides as Potential Prebiotics	211
	Yuxiao Wang, Xiaojun Huang, and Shaoping Nie	
11	Pharmaceutic Prodigy of Ergosterol and Protein Profile of <i>Ganoderma lucidum</i>	227
	Anna Goyal and Anu Kalia	
12	Application of Wild Macrofungi as Anticancer Therapeutics	243
	Peter Chiew Hing Cheong, Chon Seng Tan, and Shin Yee Fung	
13	Recent Advances in Cultivation of Edible Mushrooms	275
	Meena Kapahi	
14	Medicinal Mushrooms: Cultivation and Pharmaceutical Impact	287
	Peter Chiew Hing Cheong, Chon Seng Tan, and Shin Yee Fung	
15	Biological Control of Microbial Pathogens in Edible Mushrooms	305
	Gail M. Preston, Jaime Carrasco, Francisco J. Gea, and María J. Navarro	
16	Cordycepin: A Biotherapeutic Molecule from Medicinal Mushroom	319
	Mohammad Soltani, Roslinda Abd Malek, Nagib A. Elmarzugi, Mohamad Fawzi Mahomoodally, Davin Uy, Ong Mei Leng, and Hesham A. El-Enshasy	
17	Biosynthesis of Nanoparticles Using Mushrooms	351
	Anu Kalia and Gagandeep Kaur	
18	Bioconversion and Biotransformation Efficiencies of Wild Macrofungi	361
	Aparecido Almeida Conceição, Joice Raisa Barbosa Cunha, Vandinelma Oliveira Vieira, Rubén Darío Romero Pelaéz, Simone Mendonça, João Ricardo Moreira Almeida, Eustáquio Souza Dias, Euziclei Gonzaga de Almeida, and Félix Gonçalves de Siqueira	
19	Wild Macro-Fungi from Northwest Himalayas: Future Prospects and Challenges	379
	Monika Thakur	
	Index	395

Contributors

João Ricardo Moreira Almeida Graduate Program Microbial Biology, University of Brasília, Distrito Federal, Brasília, Brazil

Embrapa Agroenergy, Brasília, Distrito Federal, Brazil

Sudheer K. Annepu ICAR-Directorate of Mushroom Research, Solan, India

Madhusmita Borthakur Microbiology Laboratory, Department of Biotechnology & Bioinformatics, North-Eastern Hill University, Shillong, Meghalaya, India

John A. Buswell Institute of Edible Fungi, Academy of Agricultural Sciences, Shanghai, China

Jaime Carrasco Department of Plant Sciences, University of Oxford, Oxford, UK

Peter Chiew Hing Cheong Medicinal Mushroom Research Group (MMRG), Department of Molecular Medicine, University of Malaya, Kuala Lumpur, Malaysia

Aparecido Almeida Conceição Graduate Program of Biosciences, Federal University of Bahia, Vitória da Conquista, Bahia, Brazil

Embrapa Agroenergy, Distrito Federal, Brasília, Brazil

Joice Raisa Barbosa Cunha Graduate Program Microbial Agricultural, Federal University of Lavras, Lavras, Minas Gerais, Brazil

Embrapa Agroenergy, Distrito Federal, Brasília, Brazil

Eustáquio Souza Dias Graduate Program Microbial Agricultural, Federal University of Lavras, Minas Gerais, Brazil

Euziclei Gonzaga de Almeida Graduate Program of Biotechnology and Biodiversity, Federal University of Mato Grosso, Mato Grosso, Grosso, Cuiabá, Brazil

Félix Gonçalves de Siqueira Graduate Program of Biosciences, Federal University of Bahia, Vitória da Conquista, Bahia, Distrito Federal, Brazil

Graduate Program of Biotechnology and Biodiversity, Federal University of Mato Grosso, Mato Grosso, Cuiabá, Brazil

Embrapa Agroenergy, Distrito Federal, Brasília, Brazil

Hesham A. El-Enshasy Institute of Bioproduct Development, Universiti Teknologi Malaysia, Johor Bahru, Johor, Malaysia

School of Chemical Engineering, Faculty of Engineering, Universiti Teknologi Malaysia, Johor Bahru, Johor, Malaysia

City of Scientific Research and Technology Application, New Burg Al Arab, Alexandria, Egypt

Nagib A. Elmarzugi Department of Industrial Pharmacy, Faculty of Pharmacy & Biotechnology Research Center, Tripoli, Libya

Shin Yee Fung Medicinal Mushroom Research Group (MMRG), Department of Molecular Medicine, University of Malaya, Kuala Lumpur, Malaysia

Centre for Natural Products Research and Drug Discovery (CENAR), University of Malaya, Kuala Lumpur, Malaysia

University of Malaya Centre for Proteomics Research (UMCPR), University of Malaya, Kuala Lumpur, Malaysia

Francisco J. Gea Centro de Investigación Experimentación y Servicios del Champiñón (CIES), Quintanar del Rey, Cuenca, Spain

Jasmina Glamočlija Department of Plant Physiology, Institute for Biological Research “Siniša Stanković”, University of Belgrade, Belgrade, Serbia

Anna Goyal Department of Microbiology, College of Basic Sciences and Humanities, Punjab Agricultural University, Ludhiana, Punjab, India

Moni Gupta Division of Biochemistry, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Jammu, India

Sachin Gupta Division of Plant Pathology, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Jammu, India

Xiaojun Huang State Key Laboratory of Food Science and Technology, Nanchang University, Nanchang, Jiangxi Province, China

S. R. Joshi Microbiology Laboratory, Department of Biotechnology & Bioinformatics, North-Eastern Hill University, Shillong, Meghalaya, India

Katarzyna Kala Department of Pharmaceutical Botany, Faculty of Pharmacy, Jagiellonian University Medical College, Kraków, Poland

Anu Kalia Electron Microscopy and Nanoscience Laboratory, Department of Soil Science, College of Agriculture, Punjab Agricultural University, Ludhiana, Punjab, India

Malarvizhi Kaliyaperumal Centre for Advanced Studies in Botany, Guindy Campus, University of Madras, Chennai, Tamil Nadu, India

Meena Kapahi Department of Chemistry, Manav Rachna University (MRU), Faridabad, India

Gagandeep Kaur Punjab Agricultural University, Ludhiana, Punjab, India

Kezhocuyi Kezo Centre for Advanced Studies in Botany, Guindy Campus, University of Madras, Chennai, Tamil Nadu, India

Marina Kostić Department of Plant Physiology, Institute for Biological Research “Siniša Stanković”, University of Belgrade, Belgrade, Serbia

Lallawmsanga Molecular Microbiology and Systematics Laboratory, Department of Biotechnology, Mizoram University, Aizawl, Mizoram, India

Jan Lazur Department of Pharmaceutical Botany, Faculty of Pharmacy, Jagiellonian University Medical College, Kraków, Poland

Ong Mei Leng Harita Go Green Sdn Bhd, Johor Bahru, Johor, Malaysia

Mohamad Fawzi Mahomoodally Department of Health Sciences, Faculty of Science, University of Mauritius, Réduit, Mauritius

Roslinda Abd Malek Institute of Bioproduct Development (IBD), Universiti Teknologi Malaysia (UTM), Skudai, Malaysia

Margarita Department of Plant Sciences, University of Oxford, Oxford, UK

Simone Mendonça Embrapa Agroenergy, Distrito Federal, Brasília, Brazil

Bożena Muszyńska Department of Pharmaceutical Botany, Faculty of Pharmacy, Jagiellonian University Medical College, Kraków, Poland

Sunil A. Nair Dr. Y.S. Parmar University of Horticulture and Forestry, Solan, India

María J. Navarro Centro de Investigación Experimentación y Servicios del Champiñón (CIES), Quintanar del Rey, Cuenca, Spain

Shaoping Nie State Key Laboratory of Food Science and Technology, Nanchang University, Nanchang, Jiangxi Province, China

Ajit Kumar Passari Molecular Microbiology and Systematics Laboratory, Department of Biotechnology, Mizoram University, Aizawl, Mizoram, India

Rubén Darío Romero Pelaéz Graduate Program Microbial Biology, University of Brasilia, Distrito Federal, Brasília, Brazil

Embrapa Agroenergy, Distrito Federal, Brasília, Brazil

Margarita Perez Centro Tecnológico de Investigación del Champiñón de La Rioja (CTICH), Autol, Spain

Gail M. Preston Department of Plant Sciences, University of Oxford, Oxford, UK

Bhim Pratap Singh Molecular Microbiology and Systematics Laboratory, Department of Biotechnology, Mizoram University, Aizawl, Mizoram, India

Marina Soković Department of Plant Physiology, Institute for Biological Research “Siniša Stanković”, University of Belgrade, Belgrade, Serbia

Mohammad Soltani Institute of Bioproduct Development (IBD), Universiti Teknologi Malaysia (UTM), Skudai, Malaysia

Gunaseelan Sugantha Centre for Advanced Studies in Botany, Guindy Campus, University of Madras, Chennai, Tamil Nadu, India

Katarzyna Sulowska-Ziaja Department of Pharmaceutical Botany, Faculty of Pharmacy, Jagiellonian University Medical College, Kraków, Poland

Baby Summuna Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, Wadoora, India

Chon Seng Tan Ligno Research Foundation, Balakong Jaya, Selangor, Malaysia

Maria L. Tello Centro Tecnológico de Investigación del Champiñón de La Rioja (CTICH), Autol, Spain

Monika Thakur Amity Institute of Food Technology, Amity University Uttar Pradesh, Noida, India

Davin Uy Research and Innovation Center, Tumnuptek, Chamkarmorn, Phnom Penh, Cambodia

Vandelma Oliveira Vieira Graduate Program of Biotechnology and Biodiversity, Federal University of Mato Grosso, Cuiabá, Mato, Grosso, Brazil

Embrapa Agroenergy, Brasília, Distrito Federal, Brazil

Yuxiao Wang State Key Laboratory of Food Science and Technology, Nanchang University, Nanchang, Jiangxi Province, China