

# Contents

|  |    |
|--|----|
| <b>Chapter 1</b> Overview.....                                       | 1  |
| I. Introduction.....   | 1  |
| II. What Are Mushrooms? .....  | 1  |
| A. Definition.....   | 2  |
| B. Characteristics of Mushrooms.....                                 | 3  |
| C. Categories of Mushrooms.....                                      | 4  |
| D. Poisonous Mushrooms.....  | 5  |
| 1. Amanita-Type Poisoning.....                                       | 5  |
| 2. Muscarine-Type Poisoning .....                                    | 5  |
| 3. Psychotropic or Hallucinogenic Poisoning .....                    | 6  |
| 4. Coprinus Poisoning.....   | 6  |
| 5. Poisoning from External Sources .....                             | 6  |
| III. Magnitude of Mushroom Species .....                             | 6  |
| IV. Ecological Importance of Mushrooms and Fungi in General .....    | 6  |
| V. Collection and Classification of Mushrooms.....                   | 8  |
| A. Field Collection .....  | 9  |
| B. Preserving the Collection .....                                   | 9  |
| C. Precautions in the Use of Keys .....                              | 9  |
| VI. Justification for the Term Mushroom Biology .....                | 10 |
| VII. Impact of Mushroom Biology on Human Welfare.....                | 11 |
| VIII. Mushroom Science.....  | 12 |
| A. Definition.....   | 12 |
| B. Contributing Fields .....   | 12 |
| I. Microbiology.....   | 12 |
| 2. Fermentation .....  | 14 |
| 3. Environmental Engineering .....                                   | 15 |
| C. Mushroom Cultivation Technology .....                             | 17 |
| 1. Concept .....   | 17 |
| 2. Phases of Mushroom Technology .....                               | 17 |
| IX. Development of Mushroom Science.....                             | 21 |
| X. Mushroom Biotechnology.....                                       | 22 |
| XI. Nongreen Revolution.....   | 23 |
| References .....   | 24 |
| <b>Chapter 2</b> The Nutritional Attributes of Edible Mushrooms..... | 27 |
| I. Introduction.....   | 27 |
| II. Nutritional Attributes.....                                      | 27 |
| A. Protein.....  | 28 |
| B. Essential Amino Acids.....  | 30 |
| C. Fat .....   | 31 |
| D. Vitamins .....  | 31 |
| E. Carbohydrate and Fiber .....                                      | 34 |
| F. Minerals .....  | 34 |

|                  |  |           |
|------------------|--|-----------|
| G.               | Nucleic Acids.....                           | 34        |
| H.               | General Considerations.....                  | 35        |
| References ..... |  | 36..      |
| <b>Chapter 3</b> | <b>Medicinal Value.....</b>                  | <b>39</b> |
| I.               | Introduction.....                            | 39        |
| II.              | Medicinal Mushrooms.....                     | 39        |
| III.             | Effects of Medicinal Mushrooms.....          | 42        |
| A.               | Hematological Effects .....                  | 42        |
| B.               | Antiviral Effects.....                       | 43        |
| C.               | Antitumor Effects .....                      | 44        |
| D.               | Antioxidant Activity .....                   | 45        |
| E.               | Cardiovascular and Renal Effects .....       | 45        |
| F.               | Carcinogenicity of Mushrooms .....           | 46        |
| G.               | Allergic Reaction to Spores.....             | 46        |
| IV.              | General Considerations .....                 | 46        |
| References ..... |  | 47..      |
| <b>Chapter 4</b> | <b>Overview of the Biology of Fungi.....</b> | <b>53</b> |
| I.               | Introduction.....                            | 53        |
| II.              | The Fungi .....                              | 53        |
| A.               | Distinguishing Characteristics.....          | 53        |
| B.               | Habitats .....                               | 54        |
| C.               | Role in Nature .....                         | 54        |
| D.               | Classification .....                         | 54        |
| III.             | Vegetative Structure of Fungi.....           | 55        |
| A.               | Hyphae.....                                  | 55        |
| 1.               | Coenocytic Hyphae.....                       | 56        |
| 2.               | Septate Hyphae .....                         | 56        |
| B.               | Organelles .....                             | 56        |
| C.               | Septal Structures .....                      | 57        |
| D.               | Secondary Mycelium of Basidiomycetes .....   | 58        |
| E.               | Cell Walls.....                              | 59        |
| F.               | Unicellular Fungi.....                       | 60        |
| IV.              | Growth .....                                 | 60        |
| A.               | Growth Kinetics of Unicellular Fungi .....   | 60        |
| B.               | Filamentous Fungi .....                      | 60        |
| 1.               | Measurement of Growth .....                  | 61        |
| V.               | Specialized Vegetative Structures.....       | 62        |
| VI.              | Specialized Reproductive Structures.....     | 62        |
| A.               | Sexual .....                                 | 62        |
| B.               | Nonsexual .....                              | 64        |
| VII.             | Requirements for Growth.....                 | 64        |
| A.               | Nutritional Requirements .....               | 64        |
| 1.               | Carbon .....                                 | 64        |
| 2.               | Nitrogen .....                               | 65        |
| 3.               | Minerals .....                               | 66        |
| 4.               | Vitamins .....                               | 67        |

|                  |  |           |
|------------------|--|-----------|
| B.               | Physical Requirements.....   | 68        |
| 1.               | Temperature.....   | 68        |
| 2.               | Light .....  | 68        |
| 3.               | Moisture .....   | 69        |
| 4.               | Aeration.....  | 69        |
| 5.               | Gravity.....   | 69        |
| C.               | Transport and Translocation .....  | 70        |
| 1.               | Bamers to Transport.....   | 70        |
| 2.               | Passive and Active Transport.....  | 71        |
| 3.               | Translocation.....   | 1         |
| VIII.            | Metabolism .....   | 73        |
| A.               | Carbon.....  | 73..      |
| 1.               | Respiration .....  | 73        |
| B.               | Nitrogen .....   | 77        |
| C.               | Lipids .....   | 78        |
| IX.              | Reproduction.....  | 78        |
| A.               | Introduction.....  | 78..      |
| B.               | Sexual.....  | 79        |
| 1.               | Homothallism.....  | 80        |
| 2.               | Heterothallism.....  | 80        |
| 3.               | Hormonal (Pheromonal) Control.....   | 82        |
| C.               | Nonsexual .....  | 83        |
| 1.               | Types of Reproductive Units .....  | 84        |
| D.               | Spore Germination.....   | 86        |
| 1.               | Factors Affecting Germination .....  | 86        |
| 2.               | Measurement .....  | 87        |
| X.               | Relationship of Fungi with Other Organisms — Symbiosis.....  | 87        |
| A.               | Parasitism.....  | 88        |
| B.               | Mutualism .....  | 88        |
| 1.               | Lichens .....  | 88        |
| 2.               | Mycorrhiza .....   | 88        |
| C.               | Saprophytism .....   | 89        |
| XI.              | Chemical Composition of Fungi .....  | 89        |
| A.               | Proximate Composition of Fungal Cells.....   | 90        |
| B.               | Edible Mushrooms .....   | 91        |
| References ..... |  | 91..      |
| <b>Chapter 5</b> | <b>Substrate and Mycelial Growth .....</b>   | <b>93</b> |
| I.               | Introduction.....  | 93        |
| II.              | General Nutritional Requirements for Mushroom Growth .....   | 94        |
| III.             | Preparation of Substrate .....   | 95        |
| A.               | Composting .....   | 95        |
| 1.               | Phase I Composting (Compost Preparation).....  | 96        |
| 2.               | Phase II Composting (Compost Conditioning).....  | 97        |
| B.               | Microorganisms Involved during Composting .....  | 98        |
| IV.              | Breakdown of Substrates by Extracellular Enzymes of Mushroom Mycelium.....   | 99        |
| V.               | Genetic Improvement of Mushroom Culture in Regard to Substrate Utilization by Increased Production of Extracellular Enzymes..... | 100       |
| References ..... |  | 101       |

|                  |  |            |
|------------------|--|------------|
| <b>Chapter 6</b> | <b>Sexuality and the Genetics of Basidiomycetes .....</b>  | <b>105</b> |
| I.               | Discovery of Sexuality by Kniep and Bensaude .....   | 105        |
| A.               | Tetrapolarity .....  | 105        |
| B.               | Clamp Connection Formation .....   | 106        |
| II.              | Other Early Findings in Sexuality in Basidiomycetes .....  | 108        |
| A.               | Results of Tetrad Analysis.....  | 108        |
| B.               | Geographical Races .....   | 111        |
| C.               | Bipolarity .....   | 111        |
| D.               | Illegitimate Matings.....  | 111        |
| E.               | Buller Phenomenon (= Di-Mon Mating) .....  | 112        |
| III.             | Reactions Other Than Those Forming Dikaryons .....   | 112        |
| IV.              | Genetics of the Mating Type Loci and Sexual Morphogenesis in<br><i>Schizophyllum commune</i> ..... | 113        |
| A.               | <i>Schizophyllum commune</i> .....   | 113        |
| B.               | The A Locus of <i>Schizophyllum commune</i> .....  | 114        |
| C.               | The Two-Locus Mating Type Factor Occurs Elsewhere .....  | 116        |
| D.               | Findings from Molecular Genetic Studies .....  | 116        |
| E.               | Sexual Morphogenesis .....   | 116        |
| V.               | Genetics of Fungi .....  | 117        |
| A.               | Induction of Mutants .....   | 117        |
| 1.               | Spontaneous Mutation Rates .....   | 118        |
| 2.               | Mutagenic Treatment: X Rays.....   | 118        |
| 3.               | Mutagenic Treatment: Ultraviolet.....  | 118        |
| 4.               | Mutagenic Treatment: Chemical .....  | 119        |
| B.               | Isolation of Mutants.....  | 119        |
| 1.               | Total Isolation .....  | 119        |
| 2.               | Filtration Enrichment Method .....   | 120        |
| 3.               | Starvation Selection Method.....   | 120        |
| 4.               | Rescue Method .....  | 121        |
| 5.               | Selective Elimination of Prototrophs by Use of Chemical Method.....                                | 121        |
| C.               | Characterization of Mutants .....  | 121        |
| 1.               | Auxotrophic Mutants .....  | 121        |
| 2.               | Morphological Mutants.....   | 122        |
| 3.               | Developmental Mutants .....  | 123        |
| 4.               | Fruiting Mutants .....   | 123        |
| D.               | Utilization of Methods of Molecular Biology in Genetic Studies of Fungi .....                      | 123        |
| 1.               | Taxonomic Studies & Distinguishing Species and Strains .....                                       | 123        |
| 2.               | Demonstration of Genetic Variation in Natural Populations .....                                    | 124        |
| 3.               | Demonstration of Genetic Variation in Germplasm Collections .....                                  | 125        |
| 4.               | Linkage Studies.....   | 125        |
| 5.               | Confirmation of Crosses.....   | 126        |
| 6.               | Patent Labeling .....  | 126        |
|                  | References .....   | 126        |

|                  |  |            |
|------------------|--|------------|
| <b>Chapter 7</b> | <b>Mushroom Formation: Effects of Environmental, Nutritional, and<br/>Chemical Factors .....</b> | <b>129</b> |
| I.               | Introduction.....  | 129        |
| II.              | Development of Fruiting Bodies .....   | 129        |
| A.               | Role of Fruiting Bodies.....   | 129        |

|      |  |     |
|------|--|-----|
| B.   | Variation in Fruiting Body Structure.....  | 130 |
| 1.   | Mushroom with Cap. Gills. Stipe. and Volva .....                                       | 130 |
| 2.   | Fruiting Bodies with No Stipe .....  | 131 |
| 3.   | Spore-Bearing Layer (Hymenium) Not in Gills. But in Pores.....                         | 131 |
| 4.   | Funnel-Shaped Fruiting Body with Hymenial Layer in Folds on Underside<br>of Body ..... | 131 |
| C.   | Primordium Formation .....   | 132 |
| D.   | Primordium Development.....  | 132 |
| E.   | Types of Hyphae in Fruiting Bodies .....   | 133 |
| F.   | Growth of <i>Agaricus</i> .....  | 133 |
| III. | Environmental Factors and Fruiting.....  | 133 |
| A.   | Hydrogen Ion Concentration (pH) .....  | 134 |
| B.   | Temperature .....  | 134 |
| C.   | Aeration.....  | 135 |
| D.   | Light.....   | 136 |
| E.   | Gravity .....  | 137 |
| IV.  | Nutritional Factors and Fruiting.....  | 138 |
| A.   | Concentration of Nutrients .....   | 138 |
| B.   | Nature of Carbohydrate .....   | 139 |
| C.   | Nitrogen .....   | 139 |
| D.   | Mineral Nutrition .....  | 140 |
| E.   | Vitamins .....   | 140 |
| V.   | Chemical Factors and Fruiting.....   | 140 |
| A.   | Melanin Production and Perithecial Development in <i>Podospora</i> .....               | 141 |
| B.   | Morphogenesis in <i>Schizophyllum commune</i> .....                                    | 141 |
| C.   | Effect of Cyclic AMP.....  | 142 |
| VI.  | Summary.....   | 143 |
|      | References .....   | 143 |

|      |   |     |
|------|---|-----|
|      | <b>Chapter 8</b> Mushroom Formation: Effects of Genetic Factors; Breeding ..... | 145 |
| I.   | Introduction.....   | 145 |
| II.  | Genetic Factors for Fruiting Imposed on the Mating Type Requirements .....      | 145 |
| A.   | <i>Schizophyllum commune</i> .....  | 145 |
| 1.   | Multigenic Fruiting Factors .....   | 146 |
| 2.   | Morphological Fruiting Mutants .....  | 146 |
| B.   | <i>Lentinula</i> .....  | 147 |
| 1.   | Various Stocks Display Fruiting Differences.....                                | 147 |
| III. | Genetics of Fruiting of <i>Polyporus ciliatus</i> .....                         | 148 |
| A.   | No Subunits of Incompatibility Factors .....                                    | 148 |
| B.   | Genetic Control of Monokaryotic Fruiting .....                                  | 148 |
| IV.  | Monokaryotic Fruiting.....  | 149 |
| A.   | Species in Which Monokaryotic Fruiting Has Been Reported .....                  | 149 |
| B.   | Induction .....   | 149 |
| C.   | Relationship with Dikaryotic Fruiting .....                                     | 150 |
| D.   | Potential in Mushroom Cultivation .....   | 150 |
| V.   | Breeding for Desired Mushroom Features .....                                    | 151 |
| A.   | Extension of Temperature Range .....  | 151 |
| B.   | Utilization of Substrates .....   | 152 |
| 1.   | Use of Waste Substrates .....   | 152 |
| 2.   | Increased Yield.....  | 152 |

|                  |   |            |
|------------------|---|------------|
| C.               | Sporeless Fruiting Bodies.....  | 152        |
| 1.               | Why Desirable?.....   | 152        |
| 2.               | Methods Used to Obtain.....   | 153        |
| D.               | General Techniques of Breeding for Strain Improvement.....                            | 154        |
| 1.               | Establishment of Cultures.....  | 155        |
| 2.               | Maintenance of Cultures.....  | 155        |
| 3.               | Characterization of Monosporous Mycelia.....  | 155        |
| 4.               | Selection of Recombinants .....   | 156        |
|                  | References.....   | 156        |
| <b>Chapter 9</b> | <b>Mushroom Formation: Effect of Pests and Diseases in Mushroom Cultivation,.....</b> | <b>159</b> |
| I.               | Introduction.....   | 159        |
| A.               | History of Mushroom Cultivation and Diseases.....                                     | 159        |
| 1.               | Outdoor Cultivation .....   | 159        |
| 2.               | Indoor Cultivation with Pure Culture Spawn.....                                       | 159        |
| II.              | Viral Diseases.....   | 160        |
| A.               | History.....  | 160        |
| B.               | Symptoms .....  | 160        |
| C.               | Diagnosis.....  | 161        |
| D.               | Virus Morphology.....   | 162        |
| E.               | Epidemiology.....   | 162        |
| F.               | Patch Disease .....   | 163        |
| III.             | Bacterial Diseases.....   | 164        |
| A.               | Various Mushroom Diseases .....   | 164        |
| 1.               | Blotch Disease .....  | 164        |
| 2.               | Mummy Disease .....   | 164        |
| 3.               | Drippy Gill Disease .....   | 164        |
| 4.               | Brown Center Rot Disease of Shiitake .....  | 165        |
| 5.               | Mushroom Soft Rots.....   | 165        |
| B.               | Management for Control of <i>Burkholderia gladioli</i> pv. <i>agricola</i> .....      | 166        |
| IV.              | Fungal Diseases.....  | 167        |
| A.               | Introduction.....   | 167        |
| B.               | Mycoparasites.....  | 167        |
| 1.               | Necrotrophic Parasitism.....  | 167        |
| 2.               | Economic Importance.....  | 168        |
| C.               | Competitor Weed Fungi.....  | 169        |
| 1.               | False Truffle Disease Caused by <i>Diehlomyces microsporus</i> .....                  | 169        |
| 2.               | Cobweb Disease Caused by <i>Dactylium</i> .....                                       | 170        |
| 3.               | Mushroom Green Mold .....   | 171        |
| V.               | Nematode Diseases.....  | 177        |
| A.               | Types of Nematodes.....   | 177        |
| 1.               | Saprophagous Nematodes.....   | 177        |
| 2.               | Mycophagous Nematodes.....  | 178        |
| 3.               | Entopathogenic Nematodes .....  | 178        |
| VI.              | Insect Diseases.....  | 179        |
| A.               | Introduction.....   | 179        |
| B.               | Insects That Serve as Agents of Disease in Mushroom Houses .....                      | 179        |
| 1.               | Family Phoridae.....  | 179        |

|  |            |
|--|------------|
| 2. Family Sciaridae .....  | 180        |
| 3. Family Cecidomyiidae.....   | 184        |
| VII. Activity of Mites in Mushroom Cultivation .....                       | 184        |
| A. Genera Found during Mushroom Cultivation.....                           | 184        |
| B. Economic Importance.....  | 185        |
| References .....   | 185        |
| <b>Chapter 10 Culture Preservation.....</b>                                | <b>189</b> |
| I. Introduction.....   | 1 8 9      |
| II. Objectives .....   | 190        |
| III. Methods .....   | 190        |
| A. Short-Term Storage.....   | 190        |
| 1. Culture Practices.....  | 191        |
| 2. Substratum .....  | 191        |
| 3. Small Flat-Sided Culture Bottles.....                                   | 191        |
| 4. Temperature.....  | 193        |
| B. Long-Term Storage.....  | 193        |
| 1. Starvation of Nutrients.....  | 193        |
| 2. Limitation of Oxygen .....  | 194        |
| 3. Lyophilization .....  | 194        |
| 4. Freezing.....   | 194        |
| C. A Useful Technique in Genetic Studies.....                              | 199        |
| IV. Conclusions.....   | 199        |
| References.....  | 201        |
| <b>Chapter 11 World Production of Edible Mushrooms.....</b>                | <b>203</b> |
| I. Introduction.....   | 203        |
| II. Species Cultivated Commercially .....                                  | 205        |
| A. <i>Agaricus bisporus</i> .....  | 205        |
| B. <i>Lentinula edodes</i> .....   | 205        |
| C. <i>Volvariella volvacea</i> .....                                       | 206        |
| D. <i>Flammulina velutipes</i> .....                                       | 206        |
| E. <i>Auricularia</i> spp. ....  | 206        |
| F. <i>Pleurotus</i> spp. .....   | 206        |
| G. <i>Pholiota nameko</i> .....  | 207        |
| H. <i>Tremella fuciformis</i> .....  | 207        |
| I. Mushroom Species Commercially Cultivated Recently .....                 | 207        |
| J. Mycorrhizal Fungi: <i>Tuber</i> ; <i>Tricholoma</i> .....               | 207        |
| K. <i>Termitomyces</i> .....   | 208        |
| III. General Information for Mushroom Growers.....                         | 209        |
| IV. Trends .....   | 210        |
| A. Production Methods Breaking the Barriers of Climate and Geography ..... | 210        |
| 1. <i>Agaricus</i> .....   | 210        |
| 2. <i>Lentinula</i> .....  | 211        |
| B. World Production of Mushrooms.....                                      | 211        |
| C. Utilization of Various Wastes as Substrates.....                        | 216        |
| V. Conclusion .....  | 1 8        |
| References .....   | 1 8        |

|                   |   |     |
|-------------------|---|-----|
| <b>Chapter 12</b> | <b><i>Agaricus</i> — The Leader in Production and Technology.....</b> | 221 |
| I.                | Introduction.....   | 221 |
| II.               | Development in the Industry .....                                     | 223 |
| A.                | France.....   | 223 |
| B.                | Great Britain .....   | 223 |
| C.                | The Netherlands.....  | 224 |
| D.                | The United States .....   | 224 |
| E.                | Italy .....   | 224 |
| F.                | Ireland .....   | 225 |
| G.                | Taiwan.....   | 225 |
| H.                | South Korea .....   | 225 |
| I.                | China .....   | 225 |
| J.                | General Remarks .....   | 226 |
| III.              | Compost Materials and Composting.....                                 | 226 |
| A.                | Compost Materials.....  | 226 |
| B.                | Amount of Compost Material .....                                      | 228 |
| C.                | Composting .....  | 231 |
| IV.               | Spawn and Spawning .....  | 232 |
| A.                | Definition .....  | 232 |
| 1.                | Natural Virgin Spawn .....  | 232 |
| 2.                | Flake Spawn.....  | 232 |
| 3.                | Brick Spawn.....  | 233 |
| 4.                | Pure Culture Spawn.....   | 233 |
| 5.                | Liquid Spawn.....   | 233 |
| B.                | Preparation of Spawn .....  | 233 |
| 1.                | Pond Mud-Manure Spawn.....  | 233 |
| 2.                | Straw-Manure Spawn.....   | 234 |
| 3.                | Grain-Manure Spawn.....   | 234 |
| C.                | Spawning .....  | 234 |
| V.                | Casing .....  | 235 |
| VI.               | Harvesting.....   | 235 |
|                   | References .....  | 235 |

|                   |  |     |
|-------------------|--|-----|
| <b>Chapter 13</b> | <b><i>Lentinula</i> — A Mushrooming Mushroom .....</b> | 237 |
| I.                | Introduction .....                                     | 237 |
| II.               | Early History of Cultivation .....                     | 237 |
| III.              | Major Developmental Events of Cultivation .....        | 241 |
| IV.               | General Review of Production .....                     | 243 |
| V.                | Cultivation in Wood Logs .....                         | 246 |
| A.                | Preparation of Logs .....                              | 246 |
| 1.                | Felling of Logs.....                                   | 246 |
| 2.                | Moisture Content .....                                 | 247 |
| B.                | Preparation of Spawn .....                             | 248 |
| 1.                | Stock.....   | 248 |
| 2.                | Spawn.....   | 248 |
| C.                | Inoculation of Spawn into Logs .....                   | 249 |
| 1.                | Time of Spawning.....                                  | 249 |
| 2.                | Method of Spawning .....                               | 249 |
| D.                | Laying Logs for Mycelial Running.....                  | 250 |

|  |       |
|--|-------|
| E. Management of the Raising Yard for Fruiting .....               | 251   |
| F. Cropping .....  | 252   |
| VI. Cultivation in Polypropylene Bags ("Bag Log" Cultivation)..... | 253   |
| A. Materials .....   | 254   |
| 1. Sifting the Materials .....                                     | 254   |
| 2. Mixing the Materials .....                                      | 254   |
| B. Inoculation .....   | 254   |
| C. Incubation .....  | 255   |
| 1. Mycelial Running Stage .....                                    | 255   |
| 2. Established Mycelial Stage.....                                 | 255   |
| D. Fruiting.....   | 256   |
| E. Proper Care of the Bag Log .....                                | 258   |
| VII. Special Cultivation Practices.....                            | 259   |
| A. Taiwan .....  | 259   |
| B. China .....   | 259.  |
| 1. Seasonal Development.....                                       | 260   |
| 2. General Formulas for Substrate.....                             | 260   |
| 3. Method for Filling the Bags .....                               | 261   |
| 4. Sterilization .....   | 261   |
| 5. Inoculation .....   | 261   |
| 6. Indoor Mycelial Running.....                                    | 261   |
| 7. Shift to Outdoor Cultivation .....                              | 262   |
| 8. Formation of Mycelial Coats.....                                | 263   |
| 9. Stimulation of Fruiting by Temperature Fluctuation .....        | 263   |
| 10. Management of Fruiting .....                                   | 264   |
| 11. Reasons for Abnormal Mushrooms .....                           | 265   |
| 12. Case Studies: Qingyuan and Biyang .....                        | 266   |
| VIII. Fruiting in Liquid Media.....                                | 268   |
| A Experiments with <i>Lentinula</i> .....                          | 268   |
| B. Generalizations .....   | 271   |
| IX. Drying and Storage .....                                       | 273   |
| References .....   | 275.. |

|  |            |
|--|------------|
| <b>Chapter 14 Volvariella — A High-Temperature Cultivated Mushroom .....</b> | <b>277</b> |
| I. Introduction.....   | 277        |
| II. Biological Characteristics.....  | 278        |
| A. Morphological Characteristics.....  | 278        |
| 1. Mature Stage .....  | 279        |
| 2. Elongation Stage .....  | 281        |
| 3. Button and Egg Stages .....   | 282        |
| 4. Pinhead Stage.....  | 283        |
| 5. Germination and the Germling.....   | 283        |
| 6. Vegetative Hyphae .....   | 284        |
| 7. Chlamydospores .....  | 285        |
| B. Requirements for Mycelial Growth.....                                     | 285        |
| C. Requirements for Fruiting Body Formation .....                            | 285        |
| III. Cultivation Methods .....   | 286        |
| A. Production of Spawn .....   | 286        |
| 1. Starting Cultures .....   | 286        |
| 2. Culture Media .....   | 287        |

|  |     |
|--|-----|
| 3. Spawn Media .....   | 288 |
| B. Mushroom Production .....   | 289 |
| 1. Without Pasteurization (Indoor Cultivation) .....   | 291 |
| 2. Without Pasteurization (Outdoor Cultivation) .....  | 291 |
| 3. With Pasteurization .....   | 292 |
| IV. Harvesting and Processing .....  | 295 |
| A. Harvesting .....  | 295 |
| B. Processing .....  | 295 |
| V. Special Cultivation Practice .....  | 296 |
| A. Rural Spawn Station in Ping-Shan County, Hebei Province, China .....  | 296 |
| 1. Substrate .....   | 296 |
| 2. Bagging .....   | 296 |
| 3. Sterilization .....   | 297 |
| 4. Inoculation .....   | 297 |
| 5. Incubation .....  | 297 |
| 6. Comments on Management .....  | 297 |
| 7. Implications of This Experimental Project .....   | 297 |
| B. Technique of Cultivation of Straw Mushrooms in Green Poplar Village,<br>Ping-Shan County, Hebei Province, China ..... | 298 |
| 1. Preparation of Compost .....  | 298 |
| 2. Arrangement of Bed Blocks .....   | 298 |
| 3. Harvesting of Mushrooms .....   | 299 |
| 4. Spent Compost .....   | 299 |
| 5. Conclusion .....  | 299 |
| VI. Some Special Methods and Their Rationale .....   | 299 |
| A. Phenomenon of Early Fruiting .....  | 299 |
| B. Insect Enemy of Straw Mushrooms — Nematodes .....   | 300 |
| C. <i>Coprinus</i> — Fungal Competitor of <i>Volvariella</i> .....   | 301 |
| References .....   | 302 |

|  |     |
|--|-----|
| <b>Chapter 15</b> <i>Flammulina</i> and <i>Pholiota</i> — Low-Temperature Cultivated Mushrooms ..... | 305 |
| I. Introduction .....  | 305 |
| II. Biological Characteristics of <i>Flammulina</i> .....  | 305 |
| A. Morphology .....  | 306 |
| B. Natural History .....   | 306 |
| C. Requirements for Mycelial Growth .....  | 307 |
| D. Requirements for Fruiting Body Formation .....  | 308 |
| III. Biological Characteristics of <i>Pholiota</i> .....   | 308 |
| A. Morphology .....  | 308 |
| B. Natural History .....   | 309 |
| C. Requirements for Mycelial Growth .....  | 310 |
| D. Requirements for Fruiting Body Formation .....  | 310 |
| IV. Cultivation Methods .....  | 311 |
| A. <i>Flammulina</i> .....   | 311 |
| B. <i>Pholiota</i> .....   | 312 |
| References .....   | 313 |

|  |     |
|--|-----|
| <b>Chapter 16</b> <i>Pleurotus</i> — A Mushroom of Broad Adapability ..... | 315 |
| I. Introduction .....  | 315 |

|      |   |     |
|------|---|-----|
| II.  | Biological Characteristics.....                   | 316 |
| A.   | Morphology of Sporophores .....                   | 316 |
| B.   | Sexuality .....                                   | 316 |
| C.   | Requirements for Mycelial Growth.....             | 317 |
| D.   | Requirements for Fruiting Body Formation .....    | 317 |
| III. | Nutritional Values and Medicinal Properties ..... | 318 |
| A.   | Nutritional Values .....                          | 318 |
| B.   | Medicinal Properties.....                         | 318 |
| IV.  | Cultivation Methods .....                         | 1 8 |
| A.   | Production of Spawn .....                         | 318 |
| 1.   | Grain Spawn.....                                  | 319 |
| 2.   | Straw Spawn .....                                 | 319 |
| B.   | Production of Mushrooms .....                     | 319 |
| V.   | Harvesting and Processing .....                   | 320 |
| VI.  | Special Cultivation Practice .....                | 322 |
|      | References .....                                  | 324 |

|      |  |     |
|------|--|-----|
|      | <b>Chapter 17 <i>Tremella</i> — Increased Production by a Mixed Culture Technique.....</b> | 327 |
| I.   | Introduction.....  | 327 |
| II.  | Biological Characteristics.....  | 328 |
| A.   | Morphology.....  | 328 |
| B.   | Natural History .....  | 329 |
| C.   | Requirements for Mycelial Growth.....  | 330 |
| D.   | Requirements for Fruiting Body Formation .....   | 330 |
| III. | Cultivation Methods .....  | 330 |
| A.   | Wood Log Culture .....   | 3 1 |
| 1.   | Selection of Materials.....  | 331 |
| 2.   | Spawn.....   | 331 |
| 3.   | Inoculation .....  | 331 |
| 4.   | Mycelial Running .....   | 331 |
| 5.   | Management for Fruiting .....  | 331 |
| B.   | Plastic Bag Culture .....  | 332 |
| 1.   | Substrate .....  | 332 |
| 2.   | Spawn Production .....   | 332 |
| 3.   | Inoculation .....  | 335 |
| 4.   | Mycelial Running .....   | 335 |
| 5.   | Management for Fruiting .....  | 335 |
| IV.  | Special Cultivation Practices.....   | 335 |
| A.   | Cultivation on Cottonseed Hulls in Gutian County, Fujian Province, China .....             | 335 |
| 1.   | Formulas for Substrate.....  | 336 |
| 2.   | Preparation of Substrate.....  | 336 |
| 3.   | Filling the Bags.....  | 336 |
| 4.   | Sterilization .....  | 337 |
| 5.   | Inoculation .....  | 337 |
| 6.   | Mycelial Running .....   | 337 |
| 7.   | Management for Fruiting Body Formation .....   | 337 |
| 8.   | Harvesting .....   | 337 |
| 9.   | Processing .....   | 338 |
| B.   | Mixed Culture Cultivation of the Golden Ear Mushroom .....                                 | 339 |

|   |            |
|---|------------|
| V. Harvesting and Processing .....  | 340        |
| References .....  | 340        |
| <b>Chapter 18 <i>Dictyophora</i> — Formerly for the Few.....</b>                    | <b>343</b> |
| I. Introduction.....  | 343        |
| II. Biological Characteristics.....   | 344        |
| A. Morphology.....  | 344        |
| B. Natural History .....  | 346        |
| C. Requirements for Mycelial Growth.....  | 346        |
| D. Requirements for Fruiting Body Formation .....                                   | 347        |
| III. Cultivation Methods .....  | 348        |
| A. Cultivation in Forests.....  | 349        |
| 1. Selection of Place .....   | 349        |
| 2. Selection of Materials .....   | 349        |
| 3. Spawn.....   | 349        |
| 4. Inoculation .....  | 350        |
| 5. Covering the Substrate Materials .....   | 350        |
| 6. Management.....  | 351        |
| 7. Fruiting.....  | 352        |
| B. Indoor Cultivation.....  | 352        |
| 1. The Mushroom House .....   | 352        |
| 2. Containers for Cultivation .....   | 353        |
| 3. Cultivation.....   | 353        |
| 4. Management.....  | 353        |
| IV. Harvesting and Processing .....   | 353        |
| A. Harvest Time and Method .....  | 353        |
| B. Rapid Drying .....   | 354        |
| C. Grading and Packaging.....   | 354        |
| References .....  | 355        |
| <b>Chapter 19 <i>Ganoderrna lucidum</i> — A Leader of Medicinal Mushrooms .....</b> | <b>357</b> |
| I. Introduction.....  | 357        |
| II. Biological Characteristics.....   | 358        |
| A. Taxonomic Characteristics.....   | 358        |
| B. Morphological Characteristics.....   | 359        |
| C. Growth Parameters .....  | 359        |
| III. Cultivation of <i>Ganoderrna lucidum</i> .....                                 | 360        |
| IV. Traditional Uses.....   | 361        |
| V. Biological Compounds .....   | 362        |
| A. Triterpenes-Triterpenoids.....   | 362        |
| 1. Bitterness.....  | 362        |
| 2. Cytotoxicity.....  | 363        |
| 3. Platelet Aggregation Inhibition.....   | 363        |
| 4. Antihypertension.....  | 363        |
| 5. Hepatoprotective Activity .....  | 363        |
| 6. Anti-HIV .....   | 363        |
| 7. Hypoglycemic Effects.....  | 363        |
| B. Polysaccharide .....   | 363        |
| C. Fungal Immunomodulatory Protein .....  | 364        |

|   |      |
|---|------|
| D. Steroids .....   | 365  |
| VI. Contemporary Uses .....                                   | 365  |
| VII. Products of <i>Ganoderma lucidum</i> .....               | 365  |
| VIII. Market Value of <i>Ganoderma lucidum</i> Products ..... | 367  |
| IX. A Protocol for Quality Mushroom Nutriceuticals .....      | 368  |
| X. Conclusion .....   | 369  |
| References .....  | 369. |

|   |      |
|---|------|
| <b>Chapter 20</b> <i>Agaricus blazei</i> and <i>Grifola frondosa</i> — Two Important Medicinal<br>Mushrooms ..... | 373  |
| I. Introduction.....  | 373  |
| II. Biological Characteristics of <i>Agaricus blazei</i> .....  | 373  |
| A. History.....   | 373  |
| B. Morphology.....  | 374  |
| C. Requirements for Growth .....  | 374  |
| III. Biological Characteristics of <i>Grifola frondosa</i> .....  | 375  |
| A. History.....   | 375  |
| B. Morphology.....  | 375  |
| C. Requirements for Growth .....  | 376  |
| IV. Cultivation Methods .....   | 377  |
| A. <i>Agaricus blazei</i> .....   | 377  |
| B. <i>Grifola frondosa</i> .....  | 377  |
| V. Nutritional Content and Medicinal Properties.....  | 378  |
| A. <i>Agaricus blazei</i> .....   | 378  |
| B. <i>Grifola frondosa</i> .....  | 379  |
| References .....  | 380. |

|  |     |
|--|-----|
| <b>Chapter 21</b> Other Cultivated Mushrooms — Their Number Grows..... | 383 |
| I. Introduction.....   | 383 |
| II. <i>Auricularia</i> .....   | 384 |
| III. <i>Hericium</i> .....   | 385 |
| IV. Other Types of Interest .....                                      | 387 |
| A. Mycorrhizal Mushrooms .....   | 387 |
| B. Species with Regional Appeal.....                                   | 388 |
| References .....   | 389 |

|   |     |
|---|-----|
| <b>Chapter 22</b> Technology and Mushrooms .....          | 391 |
| I. Introduction .....                                     | 391 |
| II. Microbial Biotechnology .....                         | 392 |
| A. What Is Biotechnology? .....                           | 392 |
| B. Lignocellulose Degradation and Utilization .....       | 392 |
| 1. Isolation of Actinomycete Strains .....                | 393 |
| 2. Selection of Suitable Species of White-Rot Fungi ..... | 393 |
| 3. Isolation of Hypercellulolytic Mutants.....            | 394 |
| 4. Cultivation of Mushrooms.....                          | 394 |
| 5. A New Cloning Strategy for Filamentous Fungi .....     | 397 |
| III. Biotechnology in the Mushroom Industry .....         | 397 |
| A. General Review of Mushroom Production .....            | 397 |

|                      |  |      |
|----------------------|--|------|
| <b>B.</b>            | <b>Major Steps of Mushroom Technology .....</b>                            | 397  |
| <b>IV.</b>           | <b>Some Fungal Genetic Techniques and Their Possible Applications.....</b> | 398  |
| A.                   | Protoplast Fusion for Genetic Manipulation.....                            | 399  |
| B.                   | Di-Mon Matings and Sporeless Mutants .....                                 | 400  |
| C.                   | Breeding for High-Temperature Strains.....                                 | 4 1  |
| D.                   | Conservation of Germplasm.....   | 403  |
| <b>V.</b>            | <b>Potential Use of Mushroom Mycelium.....</b>                             | 404  |
| <b>VI.</b>           | <b>Some Observations and Considerations.....</b>                           | 405  |
| A.                   | Mushroom Cultivation.....  | 405  |
| 1.                   | Microbiology.....  | 405  |
| 2.                   | Fermentation .....   | 405  |
| 3.                   | Environment.....   | 405  |
| 4.                   | Genetics.....  | 405  |
| 5.                   | Nutritional Requirements and Enzyme Activities.....                        | 406  |
| B.                   | Criteria for Study of Major Phases of Cultivation .....                    | 406  |
| C.                   | Problems in Cultivation in Developing Countries .....                      | 406  |
| 1.                   | Social Concept .....   | 407  |
| 2.                   | Lack of Support from Government and Industry .....                         | 407  |
| 3.                   | Lack of Interest of Academia.....  | 407  |
| 4.                   | Additional Concerns .....  | 407  |
| D.                   | Prospects for Mushroom Cultivation in Developing Countries .....           | 407  |
| References.....      |  | 409  |
| <b>Glossary.....</b> |  | 4.13 |
| <b>Index.....</b>    |  | 4 1  |