

Contents

Contributors ix

Preface xi

1. An Open Pond System for Microalgal Cultivation

JORGE ALBERTO VIEIRA COSTA AND MICHELE GREQUE DE MORAIS

- 1.1 Introduction 1
- 1.2 Biotechnology and Microalgae 2
- 1.3 Open Pond Systems 3
- 1.4 Main Microalgae Cultivated in Open Pond Systems 6
- 1.5 Reactor Design 9
- 1.6 Light Regime 9
- 1.7 Hydrodynamics of the Reactor 10
- 1.8 Fixation of Carbon Dioxide (CO₂) 11
- 1.9 Temperature 11
- 1.10 pH 12
- 1.11 Sterility of Cultivation 13
- 1.12 Biomass Harvest 13
- 1.13 Drying of Biomass 15
- 1.14 Other Microalgal Culture Systems 16
- 1.15 Applications of Biomass 17
- 1.16 Conclusion 20

2. Design of Photobioreactors for Algal Cultivation

HONG-WEI YEN, I-CHEN HU, CHUN-YEN CHEN, AND JO-SHU CHANG

- 2.1 Introduction 23
- 2.2 Factors Affecting Microalgae Growth and Biofuels Production 24
- 2.3 Photobioreactor Design Principles 27
- 2.4 Microalgae Cultivation in Closed and Open PBRs for Biofuel Production 28
- 2.5 Commercial Microalgae Cultivation Systems for Biofuel Production 36
- 2.6 Conclusions 43

3. Metabolic Engineering and Molecular Biotechnology of Microalgae for Fuel Production

SU-CHIUNG FANG

- 3.1 Introduction 47
- 3.2 Biodiesel 48
- 3.3 Biohydrogen 52
- 3.4 Other Strategies 58
- 3.5 Challenges and Perspectives 59

4. Respirometric Balance and Carbon Fixation of Industrially Important Algae

EDUARDO BITTENCOURT SYDNEY, ALESSANDRA CRISTINE NOVAK, JULIO CESAR DE CARVALHO, AND CARLOS RICARDO SOCCOL

- 4.1 Introduction 67
- 4.2 Carbon Dioxide Fixation by Microalgae 73
- 4.3 Practical Aspects of Mass Cultivation for CO₂ Fixation 79
- 4.4 Carbon Market for Microalgal Technologies 81

5. Algal Biomass Harvesting

KUAN-YEOW SHOW AND DUU-JONG LEE

- 5.1 Introduction 85
- 5.2 Stability and Separability of Microalgae 86
- 5.3 Methods of Algae Harvesting 89
- 5.4 Challenges and Prospects 104
- 5.5 Conclusions 106

6. Heterotrophic Production of Algal Oils

JIN LIU, ZHENG SUN, AND FENG CHEN

- 6.1 Introduction 111
- 6.2 Heterotrophy of Microalgae 112
- 6.3 Potential of Heterotrophic Algal Oils 113

- 6.4 Factors Affecting Heterotrophic Production of Algal Oils 119
- 6.5 High Cell Density of Heterotrophic Algae 124
- 6.6 *Chlorella* as the Cell Factory for Heterotrophic Oils 129
- 6.7 Possible Improvements of Economics in Heterotrophic Algal Oils 133
- 6.8 Conclusions 135
- 7. Production of Biofuels from Algal Biomass by Fast Pyrolysis**
CARLOS JOSÉ DALMASNETO, EDUARDO BITTENCOURT SYDNEY, RICARDO ASSMANN, DOLIVAR CORAUCCI NETO, AND CARLOS RICARDO SOCCOL
- 7.1 Introduction 143
- 7.2 Fast Pyrolysis 147
- 7.3 Yields and Characteristics of Pyrolysis of Algal Biomass 150
- 7.4 Conclusions 152
- 8. Algae Oils as Fuels**
S. VENKATA MOHAN, M. PRATHIMA DEVI, G. VENKATA SUBHASH, AND RASHMI CHANDRA
- 8.1 Introduction 155
- 8.2 Cellular Biochemistry Toward Lipid Synthesis 157
- 8.3 Nutritional Mode of Microalgae 161
- 8.4 Substrates for Microalgae Growth and Lipid Production 166
- 8.5 Microalgae Cultivation 168
- 8.6 Preparation of Algal Fuel/Biodiesel 171
- 8.7 Transesterification 175
- 8.8 Algal Fuel Properties 177
- 8.9 Concluding Remarks 180
- 9. Production of Biohydrogen from Microalgae**
KUAN-YEOW SHOW AND DUU-JONG LEE
- 9.1 Introduction 189
- 9.2 Pathways of Hydrogen Production 190
- 9.3 Bioreactor Design and Operation 195
- 9.4 Economic Evaluation 198
- 9.5 Prospects and Challenges 199
- 9.6 Conclusions 201
- 10. Applications of Spent Biomass**
A. CATARINA GUEDES, HELENA M. AMARO, ISABEL SOUSA-PINTO, AND F. XAVIER MALCATA
- 10.1 Introduction 205
- 10.2 Spent Biomass for Biofuel Production 207
- 10.3 Spent Biomass for Fine Chemical Production 212
- 10.4 Bioremediation 224
- 10.5 Feed 225
- 10.6 Final Considerations 226
- 11. Hydrothermal Upgradation of Algae into Value-added Hydrocarbons**
RAWEL SINGH, THALLADA BHASKAR, AND BHAVYA BALAGURUMURTHY
- 11.1 Introduction 235
- 11.2 Algal Biomass 237
- 11.3 Macroalgae 239
- 11.4 Thermochemical Conversion 240
- 11.5 Hydrothermal Upgradation 241
- 11.6 Hydrothermal Processes for Upgradation of Algae 247
- 11.7 Opportunities and Challenges 255
- 12. Scale-Up and Commercialization of Algal Cultivation and Biofuel Production**
MAN KEE LAM AND KEAT TEONG LEE
- 12.1 Introduction 261
- 12.2 Life-Cycle Energy Balance of Algal Biofuels 262
- 12.3 Potential Biofuel Production from Algae 272
- 12.4 Techno-Economic Evaluation of Algal Biofuels 278
- 12.5 Conclusion 282

13. Life-Cycle Assessment of Microalgal-Based Biofuels

PIERRE COLLET, DANIELE SPINELLI, LAURENT LARDON,
ARNAUD HÉLIAS, JEAN-PHILIPPE STEYER, AND OLIVIER
BERNARD

- 13.1 Introduction 287
- 13.2 Assessed Functions, Associated Functional
Units, and Perimeters of Microalgae Production
LCAs 289
- 13.3 Modeling the Inventory Data 290
- 13.4 Microalgal Biomass Transformation into
Energy 300
- 13.5 Environmental Impact Assessment 303

- 13.6 Discussion and Guidelines 307
- 13.7 Conclusion 310

14. Economics of Microalgae Biomass Production

F.G. ACIÉN, J.M. FERNÁNDEZ, AND E. MOLINA-GRIMA

- 14.1 Introduction 313
- 14.2 Methodology for Cost Analysis of Microalgae
Production 314
- 14.3 Case Study 316

Index 327