

Contents

1	Biomass Conversion to Energy	1
1.1	Introduction	1
1.2	Biomass and Energy Generation	4
1.2.1	Methods of Biomass Conversion	7
1.2.2	Conversion of Biomass to Biofuels: The Biorefinery Concept	56
1.2.3	Biomass Conversion into Electricity	79
1.3	Economics and Modeling of Biomass Conversion Processes to Energy	84
1.4	Future of Biomass Conversion into Energy	87
	References	88
2	Biomass Energy	91
2.1	Introduction	91
2.2	Energy Plantation	93
2.3	Biomass Production Techniques	94
2.4	Biomass Conversion Processes	95
2.4.1	Direct Combustion Processes	96
2.4.2	Thermochemical Process	97
2.5	Types of Gasifiers	102
2.5.1	Updraught or Counter Current Gasifier	102
2.5.2	Downdraught or Co-Current Gasifiers	102
2.5.3	Cross-Draught Gasifier	103
2.5.4	Fluidized Bed Gasifier	103
2.5.5	Other Types of Gasifiers	104
2.6	Briquetting	104
2.6.1	Screw Press and Piston Press Technologies	104
2.6.2	Compaction Characteristics of Biomass and Their Significance	107

2.7	Anaerobic Digestion	109
2.7.1	Batch or Continuous	112
2.7.2	Temperature	113
2.7.3	Solids	113
2.7.4	Number of Stages	114
2.7.5	Residence	115
2.7.6	Feedstocks	115
2.8	Methane Production in Landfills	116
2.9	Ethanol Fermentation	117
2.10	Biodiesel	119
2.11	First-Generation Versus Second-Generation Technologies	120
2.12	Conclusion	121
	References	122
3	Lignocellulose Pretreatment by Ionic Liquids: A Promising Start Point for Bio-energy Production	123
3.1	Introduction	123
3.2	Ionic Liquids: Good Solvents for Biomass	124
3.2.1	Relationship Between Ionic Liquids' Structure and Solubility	125
3.2.2	Molecular Level Understanding of the Interaction of Ionic Liquids and Lignocellulose: The Key for Lignocellulose Pretreatment	126
3.3	Toward Better Understanding of the Wood Chemistry in Ionic Liquids	128
3.4	Ionic Liquids Pretreatment Technology for Enzymatic Production of Monosugars	130
3.5	Ionic Liquids Pretreatment Technology for Chemical Production of Monosugars	132
3.6	Enzymatic Compatible Ionic Liquids for Biomass Pretreatment	138
3.7	Conclusions and Prospects	140
	References	140
4	Application of Ionic Liquids in the Conversion of Native Lignocellulosic Biomass to Biofuels	145
4.1	Introduction	145
4.2	Pretreatment of Native Biomass	146
4.2.1	Cellulose and Lignin Composition in Biomass	146
4.2.2	Dissolution of Biomass in Ionic Liquids	147
4.2.3	Effect of Ionic Liquid Chemical Composition	149
4.2.4	Effect of Temperature	150
4.2.5	Effect of Density	151
4.2.6	Viscosity	151

4.2.7	Acid Hydrolysis	152
4.2.8	Catalysts	153
4.2.9	Pretreatment with Ammonia	153
4.2.10	Microwave Heating and Ultrasounds.	154
4.2.11	Biomass Size Reduction	154
4.2.12	Comparison with Other Pretreatments	155
4.2.13	Water Adsorption as an Issue.	155
4.2.14	Presence of Impurities.	156
4.3	Mechanism of Delignification and Cellulose Dissolution.	157
4.3.1	Analytical Techniques.	157
4.3.2	Purified Cellulose Substrates and Lignin Models	159
4.3.3	Swelling	160
4.3.4	Regeneration and Reduction of Cellulose Crystallinity	160
4.3.5	Hydrogen Bonding	161
4.3.6	Empirical Solvent Polarity Scales.	163
4.4	Compatibility with Cellulases.	165
4.4.1	General Toxicity of Ionic Liquids.	165
4.4.2	Deactivation of Cellulases in ILs	165
4.4.3	Temperature and pH Dependence of Cellulase Activity.	167
4.4.4	Effect of High Pressure	168
4.4.5	Identification of Cellulases Resistant to Ionic Liquids	169
4.4.6	Designing New Ionic Liquids Suitable for Cellulose Dissolution and Cellulase Activity	169
4.4.7	Stabilization of Cellulases in Microemulsions and by Immobilization	170
4.5	Recycling	171
4.5.1	How Green are ILs?	171
4.5.2	Recycling Attempts	171
4.5.3	Biodegradability	173
4.6	Applications.	173
4.6.1	Applications of Purified Cellulose Substrates.	173
4.6.2	Applications of Native Biomass	174
4.7	Conclusions	177
	References	177
5	Catalysts in Thermochemical Biomass Conversion	187
5.1	Thermochemical Biomass Conversion.	187
5.2	Types of Catalysts in the Thermochemical Biomass Conversion	188
5.2.1	Known Catalyst Types for Biomass Gasification	188
5.2.2	Catalyst Types for Biomass Pyrolysis	191

5.2.3	Nanocatalysts for Biomass Conversion	194
5.3	Conclusion.	196
	References	196
6	Fatty Acids-Derived Fuels from Biomass via Catalytic Deoxygenation	199
6.1	Introduction	199
6.2	Deoxygenation Processes.	201
6.2.1	Hydrodeoxygenation of Fatty Acids	201
6.2.2	Decarboxylation/Decarbonylation of Fatty Acids	207
6.2.3	Deoxygenation of Fatty Acids via Catalytic Cracking	214
6.2.4	Comparison of Deoxygenation Methods	215
6.3	Conclusions	217
	References	218
7	Biobutanol: The Future Biofuel.	221
7.1	Introduction	221
7.2	Microbiology of ABE Fermentation	223
7.3	Biomass as Feedstock	223
7.4	Improvements in Fermentation Processes.	225
7.4.1	Batch and Fed-Batch Fermentation Processes.	226
7.4.2	Continuous Fermentation Process	229
7.5	Recovery Techniques Integrated with Fermentation Process. . .	229
7.6	Economic Aspects	231
7.7	Prospective	232
	References	232
8	Molecular Genetic Strategies for Enhancing Plant Biomass for Cellulosic Ethanol Production.	237
8.1	Introduction	237
8.2	Strategies for Enhancement of Biomass.	239
8.2.1	Genetic Basis of Plant Architecture	239
8.2.2	Phytohormone-Related Genes and Developmental Regulation.	241
8.2.3	Functional Genomics Approaches for Identification of Useful Genes	244
8.2.4	Plant Breeding	244
8.2.5	Biotechnological Approaches to Further Improve Biofuel Crops.	245
8.3	Conclusions and Future Perspectives.	246
	References	247

9	Production of Bioethanol from Food Industry Waste:	
	Microbiology, Biochemistry and Technology	251
9.1	Introduction	251
9.2	Raw Materials	254
9.2.1	Wheat Straw	254
9.2.2	Sugarcane Bagasse	255
9.2.3	Rice Straw	256
9.2.4	Fruit and Vegetable Waste	256
9.2.5	Coffee Waste	259
9.2.6	Cheese Whey	259
9.2.7	Spent Sulfite Liquor	259
9.2.8	Bioethanol from Algae	260
9.3	Microorganisms for Bioethanol Production	260
9.3.1	Microorganisms and Their Characteristics	260
9.3.2	Substrate and Microorganisms	260
9.3.3	Lignocellulosic Material for Ethanol Fermentation	261
9.3.4	Fermentation of Syngas into Ethanol	263
9.4	Biochemistry of Fermentation	263
9.4.1	Fermentation of Carbohydrates	263
9.4.2	Efficiency of Ethanol Formation	271
9.4.3	Metabolic Engineering for the Production of Advanced Fuels	272
9.5	Genetically Modified Microorganisms for Bioethanol Production	275
9.5.1	<i>Escherichia coli</i>	276
9.5.2	<i>Zymomonas mobilis</i>	276
9.5.3	<i>Pichia stipitis</i>	277
9.5.4	<i>Kloeckera oxytoca</i>	277
9.5.5	<i>Saccharomyces cerevisiae</i>	278
9.6	Fermentation	279
9.6.1	Fermentation Kinetics	279
9.6.2	Fermentation Process for Bioethanol	283
9.7	Technology of Bioethanol Production	286
9.7.1	Sugar Molasses	286
9.7.2	Apple Pomace	287
9.7.3	Orange Waste	289
9.7.4	Banana Waste	290
9.7.5	Potato Waste	291
9.7.6	Wheat Straw	291
9.7.7	Rice Straw	291
9.7.8	Rice Husk	292
9.7.9	Barley	292
9.7.10	Whey	292

9.7.11	Cassava Roots	293
9.7.12	Hydrolysed Cellulosic Biomass	293
9.7.13	Recent Advances in Bioethanol Production Process . . .	300
9.7.14	Boiethanol Refinery	300
9.8	Future Perspectives and Conclusions.	301
	References	302
10	Enhancement of Biohydrogen Production by Two-Stage Systems:	
	Dark and Photofermentation.	313
10.1	Introduction	313
10.2	Dark Fermentation	314
10.2.1	Dark Fermentation with Pure Cultures	317
10.2.2	Dark Fermentation with Mixed Cultures	318
10.2.3	Substrates for Dark Fermentation	320
10.2.4	Factors Influencing Dark Fermentation	321
10.2.5	Pre-treatment of Mixed Culture	322
10.2.6	pH and Temperature	322
10.2.7	Partial Pressure of Produced Hydrogen	323
10.2.8	Reactor Configuration.	323
10.3	Photofermentation.	324
10.3.1	Substrates for Photofermentation	326
10.3.2	Factors Influencing Photofermentation	327
10.3.3	C/N Ratio	327
10.3.4	Inoculum Age	328
10.3.5	Light Source and Light Intensity	328
10.3.6	pH and Temperature	329
10.3.7	Reactor Configuration.	329
10.4	Two-Stage Systems.	330
10.5	Conclusion.	332
	References	333
11	Organosolv Fractionation of Lignocelluloses for Fuels, Chemicals and Materials: A Biorefinery Processing Perspective	341
11.1	Introduction	341
11.2	Overview of Organosolv Fractionation	342
11.3	Ethanol Fractionation	343
11.3.1	Effect of Treatment on the Structure of Lignocellulosic Material	343
11.3.2	Process of Ethanol Fractionation and Lignin Recovery.	347
11.3.3	Applications of the Products	350
11.4	Organic Acid Fractionation	355

11.4.1	Effect of Treatment on the Structure of Lignocellulosic Material	355
11.4.2	Process of Organic Acid Fractionation and Lignin Recovery	358
11.4.3	Applications of the Products	360
11.5	Other Fractionation Processes Using Organic Solvents	364
11.5.1	Methanol	364
11.5.2	Ethylene Glycol	367
11.5.3	Ethanolamine	367
11.5.4	Acetone	368
11.5.5	Dimethyl Formamide	369
11.6	Concluding Remarks	370
	References	370

12	Lignin as Source of Fine Chemicals: Vanillin and Syringaldehyde	381
12.1	Lignin, a Fascinating Complex Polymer	381
12.2	Main Lignin Types: Origin, Producers, End Users and Characteristics	383
12.2.1	Kraft Lignins	384
12.2.2	Lignosulfonates	385
12.2.3	Organosolv Lignins	388
12.2.4	Other Lignins	390
12.3	Lignin as Source of Monomeric Compounds	390
12.3.1	General Overview	390
12.3.2	Industrial Vanillin Production	390
12.4	Production of Vanillin and Syringaldehyde by Lignin Oxidation	394
12.4.1	Reaction Conditions	394
12.4.2	Evolution of Products and Temperature During Lignin Oxidation	399
12.4.3	Influence of the Parameters in Lignin Oxidation and Vanillin Oxidation	400
12.4.4	Catalysts	405
12.4.5	The Continuous Process of Lignin Oxidation	406
12.4.6	Perspectives	408
12.5	Separation Processes for Oxidation Products of Lignin	408
12.5.1	Conventional Process of Extraction	409
12.5.2	Ion Exchange Processes	409
12.5.3	Membrane Processes	410
12.5.4	Supercritical Extraction and Crystallization	410
12.5.5	The Integrated Process for Vanillin Production	411
	References	413

13 Liquefaction of Softwoods and Hardwoods in Supercritical Methanol: A Novel Approach to Bio-Oil Production	421
13.1 Introduction	421
13.2 Materials and Methods	423
13.2.1 Supercritical Fluid Processing	423
13.2.2 Chemical Characterization	424
13.3 Results and Discussion	424
13.3.1 Biochar Characterization	425
13.3.2 Bio-Oil Characterization	427
13.4 Conclusion	431
References	432
14 Bioextraction: The Interface of Biotechnology and Green Chemistry	435
14.1 Disadvantages of Metal Extraction Process, its Environmental Concerns and Need of Bioextraction	436
14.2 Brief Description of Bioextraction Process	436
14.2.1 Phytoextraction	437
14.2.2 Biomining	441
14.3 Contribution of Microbes/Microorganisms in Bioextraction	444
14.3.1 Role of Microbes in Biomining	445
14.3.2 Role of Fungi in Biomining	446
14.4 Various Chemical Processes for Extraction of Heavy Metals	447
14.4.1 Concentration of the Ore (Removal of Unwanted Metals and Gangue to Purify the Ore)	447
14.4.2 Conversion into Metal Oxide	447
14.4.3 Reduction of Metal Oxide to Metal	448
14.4.4 Refining of Impure Metal into Pure Metals	449
14.5 Development of Metal Specific Chelating Resins to Extract Metal Ions	451
14.6 Applications of Bioextraction	451
14.7 Economization of Bioextraction	454
14.8 Flow Diagram to Summarize the Chapter and the Process of Bioextraction	455
14.9 Conclusion	456
References	456
About the Editors	459
Index	461