

Contents

Series Preface	ix
Preface	xi
List of Contributors	xv
1 The Biorefinery Concept—An Integrated Approach	1
<i>James H. Clark and Fabien E. I. Deswarte</i>	
1.1 The Challenge of Sustainable Development	1
1.2 Renewable Resources — Nature and Availability	3
1.3 Impact on Ecosystem Services	5
1.4 The Biorefinery Concept	6
1.4.1 Definition	6
1.4.2 Different Types of Biorefinery	6
1.4.3 Challenges and Opportunities	14
1.5 Conclusions	18
References	18
2 The Chemical Value of Biomass	21
<i>David B. Turley</i>	
2.1 Introduction	21
2.1.1 Key Routes of Plant Exploitation for Chemical Raw Materials	23
2.2 Plant Oils	25
2.2.1 Abundance and Sources	25
2.2.2 Oil Profiles of Major Oil Crops	26
2.2.3 Oils with Modified Fatty-Acid Content	29
2.2.4 High Erucic Acid Oils	29
2.2.5 Novel Fatty-Acid Derivatives found in Plants that have Industrial Uses	30
2.2.6 Industrial Uses for Glycerol	31

2.3	Carbohydrates	31
2.3.1	Starches and Sugars	32
2.3.2	Cellulose	34
2.3.3	Hemicellulose	35
2.4	Lignin	35
2.5	Proteins	36
2.5.1	Healthcare Proteins	36
2.6	Waxes	37
2.7	Secondary Metabolites	37
2.7.1	Glucosinolates	39
2.7.2	Other Industrial Uses for Secondary Metabolites	39
2.8	Prospects Arising from Developments in Plant Biotechnology and Biorefining	40
2.8.1	Protection of Conventional Food Crop Chains	42
2.8.2	Cell and Tissue Culture	42
2.8.3	Biorefining	43
2.8.4	Thermochemical Routes of Exploitation	43
2.9	Concluding Comments	44
	References	45
3	Green Chemical Technologies	47
	<i>Francesca M. Kerton</i>	
3.1	Introduction	47
3.2	What are Green Chemistry and Green Engineering?	48
3.3	Evaluating the Environmental Effects of Chemistry and Green Metrics	51
3.4	Alternative Solvents	52
3.4.1	Supercritical Fluids	53
3.4.2	Water	56
3.4.3	Ionic Liquids	58
3.4.4	Other Alternatives to VOCs: 'Solventless', Biphasic and Bio-Sourced Solvents	59
3.5	Energy Considerations: Microwaves, Ultrasound, Electricity and Light	61
3.5.1	Microwave-Assisted Chemistry	61
3.5.2	Sonochemistry	62
3.5.3	Electrochemistry	64
3.5.4	Photochemistry	64
3.6	Catalysts	66
3.6.1	Homogeneous Catalysts	66
3.6.2	Heterogeneous Catalysts	68
3.6.3	Biocatalysts	70
3.7	Conclusions	71
	References	72

4	Production of Chemicals from Biomass	77
	<i>Apostolis A. Koutinas, C. Du, R.H. Wang and Colin Webb</i>	
4.1	Introduction	77
4.2	Carbohydrates	79
4.2.1	Chemical Production from Saccharides	79
4.2.2	Chemical Production from Lignocellulosic Biomass	87
4.3	Vegetable Oils	90
4.4	Chemical Production from Proteins	92
4.5	Chemical Production through Green Chemical Extraction of Biomass	93
	References	94
5	Biomaterials	103
	<i>Carlos Vaca-Garcia</i>	
5.1	Introduction	103
5.2	Wood and Natural Fibres	104
5.2.1	Molecular Constitution	104
5.2.2	Wood and Timber	106
5.2.3	Plant Fibres	112
5.3	Isolated and Modified Biopolymers as Biomaterials	116
5.3.1	Cellulose	117
5.3.2	Cellulose Esters	119
5.3.3	Cellulose Ethers	123
5.3.4	Starch	125
5.3.5	Chitin and Chitosan	127
5.3.6	Zein	128
5.3.7	Lignin Derivatives	128
5.4	Agromaterials, Blends and Composites	129
5.4.1	Agromaterials	129
5.4.2	Blends of Synthetic Polymers and Starch	132
5.4.3	Wood Plastic Composites (WPC)	133
5.4.4	Wood-Based Boards	135
5.5	Biodegradable Plastics	136
5.5.1	Polyglycolic Acid (PGA)	136
5.5.2	Poly(lactic Acid) (PLA)	137
5.5.3	Polycaprolactone (PCL)	138
5.5.4	Poly(hydroxyalkanoates) (PHA)	138
5.5.5	Cellulose Graft-Polymers	139
5.6	Conclusion	140
	References	141
6	Production of Energy from Biomass	143
	<i>Mehrdad Arshadi and Anita Sellstedt</i>	
6.1	Introduction	143

6.2	Physical Upgrading Processes	144
6.2.1	Refinement of Solids to Biofuel	144
6.2.2	Wood Powder	145
6.2.3	Briquette Production	145
6.2.4	Pellet Production	146
6.2.5	Torrefaction	149
6.3	Microbiological Processes	149
6.3.1	Organisms and Processes	149
6.3.2	Microbiological Ethanol Production	150
6.3.3	Production of Butanol from Bacteria	153
6.3.4	Production of Biodiesel from Plants and Algae	153
6.3.5	Biogas Production	154
6.3.6	Hydrogen Production	156
6.3.7	Artificial Photosynthesis	158
6.4	Thermochemical Processes	159
6.4.1	Thermal Processing Equipment	159
6.4.2	Gasification	161
6.4.3	Pyrolysis	163
6.4.4	Liquefaction	164
6.4.5	Combustion	164
6.5	Chemical Processes	165
6.5.1	Dimethyl Ether (DME)	165
6.5.2	Biodiesel	166
6.5.3	Rapeseed Methyl Ester (RME)	166
6.5.4	Primary Alcohols	167
6.5.5	Ethanol from Sugar Feedstock	169
6.5.6	Ethanol from Starchy Feedstock	170
6.5.7	Ethanol from Cellulose Feedstock	171
6.6	Power Generation from Biomass	174
6.6.1	Fuel Cells	174
	References	176
	Index	179