

# Contents

<b>Chapter 1</b>	<b>Introduction</b>	<b>1</b>
	<i>Abbas Kazmi, Birgit Kamm, Sören Henke, Ludwig Theuvsen and Rainer Höfer</i>	
1.1	Green Chemistry and the Biorefinery	1
1.2	The Biorefinery Concept	4
1.2.1	Introduction	4
1.2.2	Principles of Biorefineries	6
1.2.3	Building Blocks, Chemicals and Potential Screening	8
1.2.4	Biorefinery Systems	11
1.2.5	Two-platform Concept	19
1.2.6	Advanced Oil Crops Biorefineries	20
1.3	The Potential of Oil Crops in Europe	23
1.3.1	Introduction	23
1.3.2	Vegetable Oil Production in the European Community (EU-27)	24
1.3.3	Commodity Oils	26
1.3.4	Speciality Vegetable Oils	36
1.3.5	Crop Growing Potential for Non-European Oils	36
1.4	Summary and Conclusions	39
	Acknowledgement	39
	References	40

<b>Chapter 2</b>	<b>Farming and Harvesting</b>	<b>48</b>
	<i>Katerina Stamatelatou, David Turley, Ruth Laybourn, Francis Flénet, Alain Quinsac, Ray Marriott, Georgia Antonopoulou, Gerasimos Lyberatos, Antoine Rouilly and Carlos Vaca-Garcia</i>	
2.1	Introduction	48
2.2	Increasing Oil Yield	49
2.2.1	The Production of Oilseed Rape	49
2.2.2	Sunflower	56
2.3	Valorisation of Straw and Leaves through Green Technologies	67
2.3.1	Chemicals from Supercritical CO <sub>2</sub> Extraction	68
2.3.2	Biomethane	80
2.3.3	Biomaterials from Thermocoupling	85
	References	97
	Website Sources	101
<b>Chapter 3</b>	<b>Primary Processing</b>	<b>102</b>
	<i>Wim Mulder, Paulien Harmsen, Johan Sanders, Patrick Carre, Birgit Kamm, Petra Schönicke and Geertje Dautzenberg</i>	
3.1	Introduction	102
3.2	Pre-treatment Processes	103
3.2.1	Dehulling	103
3.2.2	Thermal Pre-treatment	115
3.2.3	Microwave and Radio Frequency	117
3.2.4	Pulsed Electric Field	118
3.2.5	Enzymatic Pre-treatment	118
3.3	Novel Oil Recovery Processes and Valorisation of Waste Streams	119
3.3.1	Introduction	119
3.3.2	Oil Extraction from Olives	121
3.3.3	Oil Extraction from Rapeseed	124
3.3.4	Oil Extraction from Sunflower Seeds	125
3.3.5	Pressing and Pressing-related Processes	127
3.3.6	Solvent Extraction	130
3.3.7	Residual Oil Recovery	132
3.3.8	Conclusions	132
3.4	Protein and Amino Acid Isolation	133
3.4.1	Protein Hydrolysis	134
3.4.2	Extraction Process of Peptides and Amino Acids	135
3.4.3	Conclusions	141

3.5	Production of Levulinic Acid from Straw	141
3.5.1	Introduction	141
3.5.2	A Short Survey on the Development of Levulinic Acid Chemistry	142
3.5.3	Levulinic Acid Production	143
3.5.4	Levulinic Acid from Hexoses <i>via</i> Formation of Fructose and 5-BHF	144
3.5.5	The Bofine Demonstration Plants and Outlook on Future Industrial Scale Facilities	148
3.5.6	Technology Draft for a Low-temperature Conversion Process of LCF to Levulinic Acid	149
3.5.7	Outlook	150
3.6	Integrated Biorefinery	151
3.6.1	Dehulling	151
3.6.2	Cold Pressing	154
3.6.3	Improvement of Meal Quality by Significant Reduction of Hexane Retention in Marcs	154
3.6.4	Supercritical CO <sub>2</sub> Extraction	155
3.6.5	Gas-assisted Oil Pressing	156
3.6.6	Use of Alcohols as an Alternative for Hexane	156
3.6.7	Simultaneous Extraction and Transesterification	157
3.6.8	Isolation of Oil Bodies (Oleosomes) Table 3.19	158
3.6.9	Water Extraction	159
3.6.10	Anaerobic Digestion of Residues	159
3.6.11	Recovery of Gums from Water Degumming	160
3.6.12	Integrated Scheme Biorefinery	160
	References	161

## **Chapter 4 Secondary Processing of Plant Oils** **166**

*Zsanett Herseczki, Abbas Kazmi, Rafael Luque and Diego Luna*

4.1	Applications of Glycerol	166
4.1.1	Existing and Novel Glycerol Purification Technologies	167
4.1.2	Transformation of Glycerol into High-quality Products through Green Chemistry and Biotechnology	174
4.2	Novel Routes to Biodiesel Incorporating Glycerol into Their Composition	187
4.2.1	Novel Biofuels Integrating Glycerol into Their Composition	189
4.2.2	Processing of Oils and Fats in the Actual Oil Refining Plants	192

4.2.3	Second-generation Technologies for the Production of Biodiesel-like Fuels	193
	References	197
<b>Chapter 5</b>	<b>Assessment of Economic and Environmental Cost-benefits of Developed Biorefinery Schemes</b>	<b>203</b>
	<i>Michael Binns, Anestis Vlysidis and Constantinos Theodoropoulos</i>	
5.1	Introduction	203
5.2	Methodology	205
5.2.1	Simulation Software	205
5.2.2	Optimisation Methods	205
5.2.3	Life Cycle Analysis	207
5.2.4	Multi-objective Optimisation	208
5.2.5	Biorefinery Schemes	209
5.3	Results and Discussion	223
5.3.1	Economic Optimisation	223
5.3.2	Environmental and Multi-objective Optimisation	240
5.3.3	Holistic Comparisons of Process Options	263
5.4	Conclusions	276
	References	277
<b>Chapter 6</b>	<b>Modelling Stakeholders' Interplay and Policy Scenarios for Biorefinery Implementation</b>	<b>280</b>
	<i>Piergussepe Morone, Caterina De Lucia, Antonio Lopolito and Maurizio Prosperi</i>	
6.1	Introduction	280
6.2	The Micro-economic Approach to Policy Modelling for Biorefineries	281
6.2.1	The Theoretical Framework	281
6.2.2	A Three-steps Methodology	285
6.2.3	Wrapping-Up – an Application of the Proposed Protocol of Analysis	297
6.3	The Macro-economic Approach: a CGE Model with the Inclusion of Biorefineries in the Production Process	299
6.3.1	Application of CGE Models to Biofuels	299
6.3.2	A Theoretical CGE Model for a Bio-based Economy	300
6.3.3	Summing Up	307
6.4	Conclusions	307
	References	308
	<b>Subject Index</b>	<b>311</b>