

# Subject Index

References to figures are given in *italic* type. References to tables are given in **bold** type.

- abrasive dehullers, 103
- acidity of rapeseed oil, 106
- acrolein production from
  - glycerol, 178, 181
- activated carbon, purifying glycerol
  - with, 173–4
- acylglycerols, 182
- adaptations to existing mills, 151–61
  - alcohols as hexane
    - alternative, 156–7
  - anaerobic digestion, 159–60
  - cold pressing, 154
  - dehulling, 151–4
  - gas-assisted oil pressing, 156
  - gum recovery, 160
  - integrated scheme, 160–1
  - marc hexane retention
    - reduction, 154–5
  - oleosome isolation, 158–9
  - supercritical CO<sub>2</sub>
    - extraction, 155–6
  - transesterification and
    - extraction, 157–8
  - water extraction, 159
- adjacency matrices, 291
- advanced oil crops
  - biorefineries, 20–3. *see also* biorefineries
- agent-based model (ABM)
  - design, 292–5
- alcohols as hexane alternative, 156–7, **157**
- alkanes
  - production of, 192–3
  - in straw waxes, 79
  - straw yields, 78
- alkyd resin production, 1, 2–3
- alkyl benzene sulfonate
  - alternatives, 2
- almond oil, 36
- alperujo (olive waste)
  - valorisation, 123–4
- Alternaria* spp., 58
- Amberlite, purifying glycerol
  - with, 170
- amino acids. *see also* protein and amino acid isolation
  - chemicals derived from, 139–41, **140**
  - extraction process, 135–41, 136–7
  - fractionation of, 139
- anaerobic digestion. *see also* biogas
  - biogas production with, 81–4
  - integrating into existing
    - plant, 159–60
  - SWOT analysis, **160**
  - wet vs. dry, 82
- annealing algorithm, 206–7
- aqueous extraction, 131–2, 137–9
  - advantages of, 137
  - of sunflower oil, 90–3, 126–7

- Argan oil, 39  
 aspartic acid, 9  
 Aspen Plus, 205
- barley straw, 77  
 beeswax, 78  
 Berber's gold (Argan oil), 39  
 biodiesel manufacturing
  - byproducts, utilising, 3
  - capital costs for, **212**
  - in conventional refineries, 192–3
  - cost analysis model, 210–4
  - economic optimisation, 223–7, **242**
  - environmental
    - optimisation, 240–9, **242**
  - enzyme catalysis for, 187–8
  - Fischer-Tropsch synthesis (FTS), 176, 194–6
  - flowsheet for, 28, 210
  - glycerol incorporation, 187–97
  - green methods, 2
  - holistic assessment of process
    - options, 263–7
  - Hydro Thermal Upgrading (HTU), 196
  - input and output flowrates, **224**
  - materials and utility prices, 212–3
  - multi-objective optimisation, **249**
  - oils commonly used for, 28
  - production process, 28
  - purified glycerol co-production
    - optimisation, 227–9, 249–55
  - pyrolysis for, 193–4
  - rapeseed oil for, 29
  - recycled greases for, 28
  - second-generation
    - technologies, 193–7
  - succinic acid co-production
    - vs. crude glycerol
      - production, 266–7
      - optimisation of, 213–4, 229–32
  - sunflower oil for, 31
- biodiesels
  - distilling, modelling for cost analysis, 212–3
  - glycerol in, 188–9
  - low-temperature behaviour, 29
  - lubricity of, 187, 189, 190
- Biofine process, 147–9  
 biofuels
  - glycerol incorporation, 189–92
  - legislation promoting, 29
  - lipase production, 189–92
  - producing *via* microbial
    - biotechnology, 193
- biogas. *see also* anaerobic digestion
  - anaerobic digestion production
    - of, 81–4
  - applications for, 83
  - benefits of, 84
  - combustion reaction, 256
  - composition of, 216–7
  - cost analysis model, 215–8
  - definition of, 81
  - digestate split, **233**
  - economic considerations, 84
  - economic optimisation, 232–4, **256**
  - emissions, 256–7
  - environmental
    - optimisation, 255–7
  - input and output flowrates, **233**
  - multi-objective optimisation, 257, **258**
  - parameter ranges for production, **216**
  - plants for, 81–2
  - process flowsheet for, 215, 232, 256
  - purification of, 83
  - rapeseed hull production of, 109
  - vs. supercritical CO<sub>2</sub>
    - production, 270–3, **271**
    - sustainability of, 83
- biolubricants, 2  
 biomass
  - CO<sub>2</sub> extraction of, 71–2
  - component extraction, economic considerations of, 3
  - composition of, 7, 139
  - cost considerations, 12, 17
  - economic dependence on, 4
  - efficient utilisation of, 6

- as feedstock, 139–41
  - green, 17
  - hydrothermal conversion of, 197
  - pelletising, 73–5
  - photosynthetic reaction, 5
  - preservation methods, 17
  - product flowchart, 10
  - production of, 5
  - products based on, 5
  - pyrolysis, 193–4
  - separation of, 11
  - similarity to petroleum, 6–7
  - types of, 5
  - waste of, 4, 5
- biomethane. *see* biogas
- BIOPOL, 6
- biopol production, 15
- biorefineries. *see also* advanced oil crops biorefineries
- compared to petroleum-refineries, 6–7
  - design of, 11
  - efficiency improvements with, 2
  - integrated process for, 160–1
- biorefinery systems
- green biorefineries, 17–9
  - Lignocellulosic Feedstock (LCF), 11–4, 12
  - two-platform concept, 19–20
  - Whole Crop Biorefinery, 14–7
- biosorption, 88–90
- broomrape, 58, 65–6
- building blocks, 9
- cake meal, 93–6
- canola oil. *see also* rapeseed oil
- area harvested, 35
  - definition of, 27
  - glucosinolate levels, 49
  - origin of term, 49
- capital costs for equipment, **212**, 216, 224
- carbon sequestration via straw
- incorporation, 75
- carnauba palm, 78–9
- castor oil, 37–8
- cellulose
- hydrolysis of, 8
  - plant fibre composition of, 86
  - as precursor, 12
  - uses for, 3
- centrifugal propellers for
- dehulling, 103
- centrifugation systems, 120–1, 123–4
- cereal fractionation, 14–5. *see also* Whole Crop Biorefinery
- CGE (Computable General Equilibrium) models, 299–307
- applying to biofuels, 299–300
  - for bio-based economy, 300–7
  - commodity market block, 306–7
  - consumer structure, 304
  - environment block, 306
  - government module, 306
  - hybrid nature of, 300
  - model main closure rules, 307
  - production structure, 301–4
  - trade structure, 304–6
- charcoal rot, 58–9
- chromatography, purifying glycerol with, 173–4
- citric acid, producing with glycerol, 182–3
- CLEARFIELD sunflowers, 63
- CO<sub>2</sub>
- as extraction solvent, 68–70. *see also* supercritical CO<sub>2</sub> extraction phase diagram, 69
- cognitive maps, 290. *see also* fuzzy cognitive maps (FCMs)
- cold pressing
- cost analysis model, 220
  - vs.* hexane extraction, 269–70
  - integrating into existing plant, 154
  - rapeseed, 106
  - SWOT analysis for, **154**
- combined heat and power (CHP) engines
- biogas conversion, 83
  - modelling for cost analysis, 217
- commodity market block of CGE models, 306–7

- commodity oils. *see also specific oils*
  - cottonseed oil, 31–2
  - groundnut oil, 32
  - linseed oil, 34
  - olive oil, 32–4
  - rapeseed oil, 26–8
  - sesame oil, 32
  - soybean oil, 29–30
  - sunflower oil, 30–1
  - tall oil, 34–6
- Common Agricultural Policy (CAP), 23
- communication relations, 287–8
- composting sunflower hulls, 114
- coniferous trees, producing tall oil
  - from, 34–6
- consumer structure of CGE
  - model, 304
- corn
  - as feedstock, 6
  - products yielded from, 16
  - stalk composition, 86
  - wet-milling, 16–7
- cost analysis of biorefineries, 203–77
  - biorefinery schemes analyzed
    - in, 209–23
    - biodiesel production, 210–4
    - biogas production, 215–8
    - levulinic acid production, 222–3
    - oil extraction, 220–1
    - protein extraction, 219
    - supercritical CO<sub>2</sub>
      - extraction, 218–9
    - thermomoulding, 221
  - conclusions of, 276–7
  - economic optimisation, 223–39
    - of biodiesel and purified glycerol production, 227–9
    - of biodiesel and succinic acid production, 229–32
    - of biodiesel production, 223–7
    - of biogas production, 232–4
    - of supercritical CO<sub>2</sub>
      - extraction, 234–9
  - environmental and multi-objective optimisation, 240–63
    - of biodiesel and purified glycerol production, 249–55
    - of biodiesel production, 240–9
    - of biogas production, 255–7
    - of supercritical CO<sub>2</sub>
      - extraction, 257–63
    - holistic assessment of process
      - options, 263–76
      - of biodiesel production, 263–7
      - economic comparison, 274–5
      - environmental impact, 275–6
      - of oil extraction, 267–70
      - small-scale, 274
      - of straw consumption, 270–3
    - methodology for, 205–23
      - life cycle analysis, 207–8
      - multi-objective
        - optimisation, 208–9
      - optimisation methods, 205–7
      - simulation software, 205
    - overview of, 203–5
- cottonseed oil
  - area harvested, 35
  - demand for, 32
  - world production of, 31
- crambe oil, 38
- crop rotation
  - of rapeseed, 52–3
  - of sunflowers, 61
- Crude Sulfate Turpentine (CST)
  - distillation, 35
- crude tall oil (CTO), 34–6
- Data Envelopment Analysis (DEA), 296–7
- degumming, 160
- dehulling, 103–15
- economic evaluation of, **107**
  - equipment for, 103–4
  - hull separation after, 105
  - integrating into existing plant, 151–4
  - rapeseed, 103–10
  - sunflower seeds, 104, 110–4
  - SWOT analysis for, 151–4
- dehydrations of glycerol, 178

- densification of straws, 73–5
- deterministic optimisation  
method, 206–7
- digestate recycling, modelling for cost analysis, 217–8
- dihydroxyacetone (DHA), 181
- direct thresh of rapeseed, 21
- diseases. *see also* pest and disease control  
of rapeseed, 51–2  
of sunflowers, 58–60
- DMC-Biod, 191
- downy mildew, 59
- dry-milling whole cereal crops, 14.  
*see also* Whole Crop Biorefinery
- Ecodiesel, 191
- economic analysis of biorefineries.  
*see* cost analysis of biorefineries
- economic optimisation, 223–39, **275**  
of biodiesel and purified glycerol production, 227–9  
of biodiesel and succinic acid production, 229–32  
of biodiesel production, 223–7, **242**  
of biogas production, 232–4, **256**  
of levulinic acid production, 274–5  
of protein extraction, 274–5  
of supercritical CO<sub>2</sub> extraction, 234–9, **259**  
of thermomoulding, 274–5
- electrostatic hull separation, 105
- emissions. *see also* environmental and multi-objective optimisation  
calculating, 207–8  
comparison of, **275**  
economic and environmental optimisation of, 241–9  
greenhouse gas, 75  
methanol feed and, 247, 264–6, 265  
vs. profits, 275–7  
recycle fraction effect on, 256–7  
from straw processing, 270–3  
from supercritical CO<sub>2</sub> extraction, 259–63  
energy costs, 208  
environment block of CGE models, 306  
environmental and multi-objective optimisation, **208**, 240–63, **275**.  
*see also* emissions  
of biodiesel and purified glycerol production, 249–55  
of biodiesel production, 240–9, **242**  
of biogas production, 255–7, **258**  
overview of, 275–6  
of supercritical CO<sub>2</sub> extraction, 257–63, **259**, **262**  
environmental impact, 207–8. *see also* emissions
- enzymatic pre-treatment, 118  
of rapeseed, 125  
of sunflower seeds, 127
- error function (EF) in simulations, 206
- erucamide production, 26
- esterifications of glycerol, 179
- ethanol  
glycerol production of, 177, 180–1  
uses for, 13  
via biomass-nylon-process, 13
- etherifications of glycerol, 179
- EU Biofuel Directive, 29, 299–300
- evening primrose oil, 37
- expeller presses, 127–8
- extraction, oil. *see* oil recovery  
extraction, straw. *see* supercritical CO<sub>2</sub> extraction
- extrusion extraction, 91, 126–7, 128–9
- falling film evaporators, 169, 171
- fats, historic importance of, 23.  
*see also* plant oils
- fatty acid methyl ester (FAME), 24

- fatty acids
  - in Argan oil, 39
  - effect on biodiesel at low temperature, 29
  - in jatropha oil, 38
  - in lallemantia oil, 37
  - in rapeseed oil, 27
  - in safflower oil, 37
  - in sunflower oil, 31
  - in tall oil, 35–6
- feed-in-tariff remuneration system, 84
- feedstocks
  - biogas production potential of, 81
  - biomass as, 139–41
  - carbohydrates as, 5–6
  - cost considerations, 12
  - flowchart for, 10
  - lignocellulosic. *see* lignocellulosic feedstock
- fertilisers, 60
- Fischer-Tropsch synthesis (FTS), 176, 194–6
- flaking seeds, 115
- flaxseed oil, 34
- flowrates
  - for biodiesel production, **224**
  - for biogas production, **233**
  - effect on profit, 231
  - for supercritical CO<sub>2</sub> extraction, **235**
- Fluid Catalytic Cracker (FCC), 24
- Foggia case study, 297–8
- food-feed-fuel conflicts, minimising, 6
- foodprocessing residues, 6
- fractionation
  - of amino acids, 139
  - of cereals, 14–5
  - of green biomass, 17–8
  - of oilseeds, 22
  - overview of process, 8
  - of sunflower plants, 92–6
- free fatty acids (FFA), removing from glycerol, 168–9
- Friolex process, 159
- fructose, 144–5
- Fuel Quality Directive, 29
- fumaric acid, 9
- fungicides
  - efficacy of, 52
  - for Phomopsis stem canker, 61
- 2,5-furan dicarboxylic acid, 9
- furfural, 13
- furfuryl alcohol, preparing levulinic acid via, 143–4
- fuzzy cognitive maps (FCMs), 290–1
- Gas Assisted Mechanical Expression (GAME), 129–30, 132
- gas-assisted oil pressing, 129–30
  - integrating into existing plant, 156
  - SWOT analysis for, **156**
- genetically modified (GM) crops
  - rapeseed, 54–5
  - sunflowers, 66–7
- Gliperol, 191
- glucaric acid, 9
- glucose
  - isomerisation into fructose, 144–5
  - products accessible by, 8
  - versatility of, 7
- glucosinolates
  - in canola oil, 49
  - extraction from rape meal, 3
- glutamic acid, 9
- glycerol
  - applications of, 166–87
  - aqueous phase reforming (APR), 176
  - in biodiesel
    - manufacturing, 187–97
  - biofuels incorporating, 189–92
  - biotransformations, 180
    - as building block, 9, 174–87
  - chemicals derived from, 180–5
  - commodity chemicals derived from, 176
  - composition of, **168**
  - continuous concentration of, 171
  - continuous distillation of, 172
  - co-production with biodiesel, 227–9

- crude, utilisation of, 186
- crude *vs.* purified economic
  - comparison, 264–6
- dehydrations, 178
- esterifications, 179
- ethanol production from, 177
- etherifications, 179
- Fischer-Tropsch synthesis (FTS), 176
- food applications, 175
- future market of, 186–7
- gel permeation, 174, 175
- generation of, 167
- global production of, 175
- as green solvent, 186
- halogenations, 177–8
- oxidations, 179
- price of, **189**
- purification technologies, 167–74, 213
  - catalyst removal, 240
  - chromatography and regenerative column adsorption, 173–4
  - conventional processes, 169–70
  - economic optimisation, **249**
  - environmental optimisation, 240–55
  - modelling for cost analysis, 212–3
  - recent developments in, 170–3
  - separation units, 241
  - soap splitting, 168–9
- pyrolysis of, 179–80
- selective reductions, 177
- succinic acid conversion, 213–4
- vs.* succinic acid, in biodiesel
  - production, 266–7
- transforming into
  - products, 174–87
- glycerol tertiary butyl ether (GTBE), 182
- GM crops
  - rapeseed, 54–5
  - sunflowers, 66–7
- government module of CGE
  - models, 306
- gravimetric hull separators, 105
- green biomass fractionation, 17–8
- green biorefineries, 17–9
- green certificate remuneration system, 84
- green chemistry, 1–4. *see also* emissions; environmental impact
- green juice production, 18
- green solvents, 186
- greenhouse gas (GHG) emissions, 75
- groundnut oil
  - area harvested, 35
  - uses for, 32
  - world production of, 32
- gum recovery, 160
- halogenations of glycerol, 177–8
- harvest index for sunflowers, 57–8, 65
- harvesting olives, 33–4
- hazelnut oil, 36
- health effects
  - of high oleic sunflower oil (HOSO), 31
  - of olive oil, 32–3
- HEAR (High Erucic Acid Rape), 26–7
- heating seeds as pre-treatment. *see* thermal pre-treatment of seeds
- hemicellulose/polyoses
  - plant fibre composition of, 86
  - as precursor, 12
- hemp oil, 37
- herbicides, 63. *see also* pest and disease control
- hexane extraction
  - vs.* cold pressing, 269–70
  - cost analysis model, 220–1
  - of rapeseed oil, 22
  - of sunflower oil, 126
- hexoses, producing levulinic acid from, 144–8
- high oleic sunflower oil (HOSO), 31
- HIPLEX system, 156

- hot-pressing sunflower cake meal, 93–6
- hulls, valorising. *see* dehulling
- hulls boiler, 112
- Hydro Thermal Upgrading (HTU), 196
- hydrogen, producing with glycerol, 180
- hydrolysis of proteins, 134–5
- 3-hydroxy propionic acid, 9
- 3-hydroxybutyrolactone, 9
- innovation niches, 282–4
  - assessing development status, 286–91
  - behavioural rules for, 293–5
  - questionnaire for investigating, **288**
- insecticides, 61. *see also* pest and disease control
- integrated scheme biorefinery, 160–1
- integrating biorefinery technology, 151–61
  - alcohols as hexane alternative, 156–7
  - anaerobic digestion, 159–60
  - cold pressing, 154
  - dehulling, 151–4
  - gas-assisted oil pressing, 156
  - gum recovery, 160
  - marc hexane retention reduction, 154–5
  - oleosome isolation, 158–9
  - supercritical CO<sub>2</sub> extraction, 155–6
  - water extraction, 159
- ion exclusion chromatography, 169
- irradiation as seed pre-treatment, 117–8, 125
- irrigation, 60, 63–4
- itaconic acid, 9
- jatropha oil, 38–9
- jojoba, 78–9
- Kraft pulping, 34–5
- lallemandia oil, 37
- landscape, in policy scenario modelling, 282
- LCF (lignocellulosic feedstock). *see* lignocellulosic feedstock
- LEAR (Low Erucic Acid Rape), 27
- levulinic acid
  - as building block, 9
  - formation of, from fructose, 144–5
  - history of development, 142–3
  - properties of, 141–2
  - uses for, 142
- levulinic acid production, 18, 21, 141–50, 142
  - Biofine process, 148–9
  - cost analysis model, 222–3
  - economic optimisation, 274–5
  - from hexoses, 144–8
    - at high temperature, 147–8
    - history of development, 142–3
  - from lignocellulosic feedstock, 149–50
    - at low temperature, 146–7
  - material prices, 222
  - preparation routes, 143–4
  - process flowsheet for, 222
  - from rapeseed, 21
  - reaction for, 223
- life cycle analysis (LCA), 207–8
- lignin
  - plant fibre composition of, 86
  - as precursor, 12
  - in sunflower seeds, 113
  - uses for, 3–4
- lignocellulosic feedstock, 9
  - biofuel production from, 196
  - levulinic acid production from, 149–50
  - treating for biogas production, 82
- Lignocellulosic Feedstock (LCF) biorefinery, 11–4, 12
- linoleic sunflower oil. *see* sunflower oil
- linseed oil
  - area harvested, 35
  - uses for, 34
  - world production of, 34



- lipases, and biofuel
  - production, 189–92
- Low Erucic Acid Rape (LEAR), 27
- macadamia nut oil, 36
- macro-economic policy
  - modelling, 299–307
    - CGE model application, 299–300
    - CGE model for bio-based economy, 300–7
    - overview of, 307
- MacSharry reforms, 24
- malic acid, 9
- marc hexane retention
  - reduction, 154–5
- materials and utility prices, 212–3
- Mcgyan Process, 2
- methanation of biomass, 159–60
- methanol recovery, 169
  - crude glycerol *vs.* purified glycerol analysis, 264–6
  - distillation column for, **212**
  - emissions effect, 264–6, 265
  - energy requirements for, 243–4, 250–1
  - modelling for cost analysis, 225–6, 228
- methodology for cost
  - analysis, 205–23
  - life cycle analysis, 207–8
  - multi-objective
    - optimisation, 208–9
    - optimisation methods, 205–7
    - simulation software, 205
- microdiesel biosynthesis, 193
- micro-economic policy
  - modelling, 281–99
    - application of, 297–9
    - Data Envelopment Analysis (DEA), 296–7
    - theoretical framework, 281–5
    - three-steps methodology, 285–97
      - agent-based model (ABM) design, 292–5
        - assessing niche development status, 286–91
        - evaluating policy actions, 295–7
  - microwave and radio
    - pre-treatment, 117–8, 125
  - microwave pyrolysis, 4
  - Miscella* production, 22
  - modelling biorefinery schemes for
    - cost analysis, 209–23
      - biodiesel production, 210–4
      - biogas production, 215–8
      - levulinic acid production, 222–3
      - oil extraction, 220–1
      - protein extraction, 219
    - supercritical CO<sub>2</sub> extraction, 218–9
    - thermomoulding, 221
  - modelling policy scenarios. *see* policy scenario models
  - mono- (MAG) and di-acylglycerol (DAG), 182
  - multi-level approach (MLA) for micro-economic policy
    - modelling, 282
- network indices, 291
- niches, in policy scenario modelling. *see* innovation niches
- nitrogen fertiliser, 51
- NuSun sunflower oil, 31
- nylon production, 13
- oil bodies in seeds (oleosomes), 116, 158–9
- oil cake. *see* press cake
- oil crops. *see also specific oils*
  - area harvested, **35**
  - climatic requirements for, 25
  - economic potential of, 25–6
  - European cultivation of, 24–6
  - historic importance of, 23
  - world production of, 24
- oil of dragonhead (*lallelantia* oil), 37
- oil pressing processes. *see* pressing processes

- oil recovery, 119–33. *see also*  
*specific oils*  
 cold pressing *vs.* hexane  
 extraction, 269–70  
 cost analysis model, 211, 220–1  
 flake water content, effect on, **117**  
 holistic assessment of process  
 options, 267–70  
 from olives, 121–4  
 pressing processes, 127–30  
 process overview, 119  
 from rapeseed, 124–5  
 residual, 132  
 simultaneous with protein  
 extraction, 137–9, **158**  
 solvent extraction, 130–2  
 from sunflower seed, 125–7
- oilseed rape. *see* rapeseed; rapeseed oil
- oleiferous crops. *see* oil crops
- oleochemical industry, 2
- oleosomes, 116, 158–9
- olive cake, 122–4
- olive leaves, 122
- olive oil  
 area harvested, 35  
 centrifugation process, 120–1  
 culinary uses for, 32–3  
 extraction process, 121–4  
 harvest of, 33–4  
 historic importance of, 23  
 quality definitions for, 33  
 subsidisation of, 34  
 uses for, 32–3  
 world production of, 32, 122
- olives  
 anatomical parts of, 121–2  
 byproducts of, 122–4  
 composition of, 133  
 mill wastewater, 123  
 oil content of, 121, **122**  
 waste valorisation, 123–4
- optimisation, economic. *see* economic  
 optimisation
- optimisation, environmental. *see*  
 environmental and multi-objective  
 optimisation
- optimisation methods in cost  
 analysis, 205–7  
 deterministic and  
 stochastic, 206–7  
 identifying parameters for, 205  
 multi-objective  
 optimisation, 208–9  
 objective function,  
 constructing, 205–6
- organic solvent extraction, 130
- organosolv process, 3–4
- Orobanche cumana*, 58
- oxidations of glycerol, 179
- palm oil production, 24
- peanut oil (groundnut oil)  
 area harvested, 35  
 uses for, 32  
 world production of, 32
- pectins, extracting from sunflower  
 stalks, 88
- pelletising straw, 73–5
- peptide bonds, 134
- peptide extraction process, 135–41
- pest and disease control. *see also*  
 diseases  
 birds and game animals, 62  
 fungicides, 61  
 GM modifications for, 54–5, 66  
 insecticides, 61  
 prophylactic methods, 65  
 with wheat wax extracts, 79
- petroleum-refineries, compared to  
 biorefineries, 6–7
- phenols, extracting from olive  
 waste, 124
- Phoma* black stem, 59
- Phomopsis stem canker, 59, 61
- phosphorus, cooking, 116
- pig pancreatic lipase (PPL), biofuel  
 production with, 190
- pith, sunflower, 87
- plant oils. *see also specific oils*  
 European production of,  
 24–6, **25**  
 historic importance of, 23

- polymer production with, 2–3
- uses for, 24
- plant waxes, 75–80
  - in sunflower oil, 110–1
  - supercritical CO<sub>2</sub> extraction
    - optimisation, 234–9
- platform chemicals, 16. *see also* levulinic acid
- policy scenario models, 280–308
  - macro-economic
    - approach, 299–307
    - CGE model application, 299–300
    - CGE model for bio-based economy, 300–7
    - overview of, 307
  - micro-economic approach, 281–99
    - application of, 297–9
    - theoretical framework, 281–5
    - three-steps methodology, 285–97
- poly-3-hydroxybutyric acid
  - production, 15
- polycosanols in straw waxes, 79
- polymers, green production of, 2–3
- polytrimethylenterephthalate (PTT), 13
- pomace olive oil, 33. *see also* olive oil
- precursors, 7, 9
- press cake
  - amino acid extraction from, 137
  - from aqueous extraction of sunflower oil, 93–6
  - fibre extraction from, 22–3
  - production of, 18
  - residual oil recovery from, 132
- pressing processes, 127–30
  - cold pressing. *see* cold pressing
  - extrusion, 128–9
  - gas-assisted oil pressing, 129–30
  - screw pressing, 127–8
- pre-treatment processes, 103–18
  - dehulling, 103–15
  - enzymatic, 118, 125, 127
  - microwave and radio
    - frequency, 117–8, 125
- pulsed electric field, 118
- thermal, 115–8, 124–5
- processing oil-bearing plants, 102–61
  - biorefinery integration in existing plants, 151–61
    - alcohols as hexane
      - alternative, 156–7
    - anaerobic digestion, 159–60
    - cold pressing, 154
    - dehulling, 151–4
    - gas-assisted oil pressing, 156
    - gum recovery, 160
    - integrated scheme, 160–1
    - marc hexane retention
      - reduction, 154–5
    - oleosome isolation, 158–9
    - supercritical CO<sub>2</sub>
      - extraction, 155–6
    - transesterification and
      - extraction, 157–8
    - water extraction, 159
  - levulinic acid production, 141–50
    - Biofine process, 148–9
    - from hexoses, 144–8
    - history of development, 142–3
    - LCF conversion
      - process, 149–50
  - oil recovery processes, 119–33
    - from olives, 121–4
    - pressing processes, 127–30
    - from rapeseed, 124–5
    - residual oil recovery, 132
    - solvent extraction, 130–2
    - from sunflower seeds, 125–7
  - pre-treatment processes, 103–18
    - dehulling, 103–15
    - enzymatic, 118, 125, 127
    - microwave and radio
      - frequency, 117–8
    - pulsed electric field, 118
    - thermal, 115–7
  - protein and amino acid
    - isolation, 133–41

- processing oil-bearing plants  
(*continued*)
- peptide and amino acid extraction, 135–41
  - protein hydrolysis, 134–5
  - waste stream valorisation, 119–33
- product flowchart, 10
- production structure of CGE model, 301–4
- profit analysis. *see* cost analysis of biorefineries
- propan-1,2,3-triol. *see* glycerol
- 1,3-propanediol, 13, 81
- propylene glycol production, 13, 181
- proteases, protein hydrolysis with, 134
- protein and amino acid isolation, 133–41, 138
- after oil recovery, 136–7
  - cost analysis model, 219
  - economic optimisation, 274–5
  - peptide and amino acid extraction, 135–41
  - protein hydrolysis, 134–5
  - simultaneous with oil extraction, 137–9
- pulsed electric field pre-treatment, 118
- pumpkin seed oil, 36
- punctual indices, 291
- purification of glycerol, 167–74, 213
- with activated carbon, 173–4
  - adsorption techniques, 173–4
  - catalyst removal, 240
  - chromatography and regenerative column adsorption, 173–4
  - conventional processes, 169–70
  - vs.* crude glycerol, 264–6
  - economic optimisation, **249**
  - environmental optimisation, 240–9
  - modelling for cost analysis, 212–3
  - recent developments in, 170–3
  - separation units, 241
  - soap splitting, 168–9
- pyrolysis
- of biomass, 193–4
  - of glycerol, 179–80
  - microwave, 4
- quantitative trait locus (QTL), 66
- radiation interception of rapeseed, 53
- radio pre-treatment. *see* microwave and radio pre-treatment
- rape straw
- alkane yields from, 78
  - composition of, **51**, 215
  - yields, 51
- rapeseed
- aqueous extraction of, 138
  - biogas production with hulls, 109
  - climatic hardness of, 26, 50
  - cold pressing, 106
  - composition of, 105–6, 133, 210
  - cost analysis model for biogas production, 215–8
  - crude fibre extraction, 22–3
  - cultivars, breeding for yield, 53–4
  - cultivars of, 49
  - cultivation problems, 50
  - dehulling, 103–10
  - diseases affecting, 51–2
  - enzymatic pre-treatment, 125
  - European production of, 50
  - flaking, 115
  - GM cultivars of, 54–5
  - growing conditions for, 49
  - harvest of, 20–1
  - HEAR (High Erucic Acid Rape), 26–7
  - hull utilisation, 108–10
  - hybrids, yield from, 54
  - LEAR (Low Erucic Acid Rape), 27
  - microwave and radio pre-treatment, 125
  - oil content of, 121, **122**
  - oil recovery, temperature effect on, **116**
  - protein extraction, 219

- quantity of straw production, 20
- rotational breaks for, 52–3
- sulfur, effect on, 51
- SWOT analysis for
  - dehulling, 151–4, **152**
  - thermal pre-treatment, 124–5
  - world production of, 49
  - yields from, 22, 29, 50–6
- rapeseed oil
  - acidity of, 106
  - area harvested, 35
  - as biodiesel source, 29
  - decentralised production of, 22–3
  - extraction process, 124–5
  - fatty acid composition, 27
  - fractionation of, 22
  - levulinic acid production, 21
  - predicted consumption of, 29
  - uses for, 27–8
  - world production of, 24
- refining glycerol. *see* purification of glycerol
- Renewable Energy Directive, 29
- residual oil recovery, 132
- roll dehullers, 103–4
- safflower oil, 37
- sclerotinia, 65, 66
- screw pressing, 127–8
- Sequential Quadratic Programming (SQP), 206–7, 226, 230
- sesame oil
  - area harvested, 35
  - growing conditions for, 32
  - uses for, 32
  - world production of, 32
- simulated annealing (SA), 206–7, 226, 230
- simulation software for cost analysis, 205
- soap splitting, as glycerol pre-treatment, 168–9
- social circles, 287
- social network analysis (SNA), 286–9
- socio-technical regime (ST-regime), 282
- solid state fermentation of alperujo, 124
- solvent extraction of oils, 130–2
  - levulinic acid recovery with, 150
  - with organic solvents, 130
  - with supercritical fluids, 130–1
  - with water (aqueous extraction), 131–2
- sorbitol, 9
- sorghum composition, 86
- soybean oil
  - area harvested, 35
  - European production of, 30
  - uses for, 30
  - world production of, 24
  - yields from, 30
- speciality oils, 36
- sterols in straw waxes, 79
- stochastic optimisation method, 206–7
- straws. *see also specific straws*
  - component extraction, economic considerations of, 3
  - defined, 14
  - densification of, 73–5
  - holistic assessment of process options, 270–3
  - levulinic acid production from, 141–50
  - nutrient value, **75**
  - pelletising, 73–5
  - unutilised amount of, 75
  - waxes from, 75–80
- succinic acid
  - as building block, 9
  - vs.* crude glycerol in biodiesel production, 266–7
  - glycerol production of, 180, 214
  - glycerol production of, modelling for cost analysis, 213–4, 229–32
- sugar platform interaction with syngas platform, 19–20
- sulfur levels, effect on rapeseed yield, 51

- SUNFLO model for sunflower
  - planting, 64–5
- sunflower oil
  - aqueous extraction, 90–3, 126–7
  - area harvested, 35
  - European production of, 30–1
  - extraction process, 125–7
  - extrusion extraction, 126–7
  - fatty acid composition, 31, 57
  - hexane extraction, 126
  - supercritical CO<sub>2</sub> extraction, 126
  - therm moulding, 221
  - uses for, 31
  - waxes in, 110–1
  - world production of, 24
- sunflower seeds
  - composition of, 110–1, 113, 133
  - crude fibre extraction, 23
  - dehulling, 104, 110–4
  - enzymatic pre-treatment, 127
  - hullability of, 111
  - oil content of, 121, **122**
  - SWOT analysis for
    - dehulling, 151–4
  - yield from, **64**
- sunflower stalks
  - applications for, 88–90
  - biosorption with, 88–90
  - composition of, 85–7, 88
  - pectin extraction, 88
  - pith/straw separation, 87–8
  - potential harvest size, 85
  - pulp production with, 90
  - structure of, 85–6
- sunflower straw
  - alkane yields from, 78
  - separation from pith, 87–8
- sunflowers
  - breeding for disease resistance, 66
  - cake meal composition, 94
  - composition of, **85, 94**
  - disease control, 61
  - diseases of, 58–60
  - European production of, **57**
  - farming practices *vs.*
    - recommendations, 62
    - fertiliser for, 60
    - fibre composition, **86**
    - GM and, 66–7
    - growing conditions for, 30–1, 58
    - harvest index, 57–8
    - historic cultivation of, 57
    - hulls, uses for, 113–4
    - irrigation of, 60, 63–4
    - physical characteristics of, 56–7
    - pith, application for, 88, **89**
    - pith composition, **87**
    - rotational breaks for, 61
    - water availability, adapting
      - practices to, 64–5
    - weed control, 61, 63
    - yield increase, 60–7
- supercritical CO<sub>2</sub> extraction
  - vs.* biogas production, 270–3, **271**
  - CO<sub>2</sub> density, 70
  - co-solvents, 70
  - cost analysis model, 218–9
  - economic considerations, 71–3
  - economic optimisation, 234–9, **259**
  - energy requirements for, 260
  - environmental
    - optimisation, 257–63, **259**
  - equipment components, 71
  - extraction time considerations, 69
  - extractor arrangements, 70–1
  - input and output flowrates, **235**
  - integrating into existing
    - plant, 155–6
  - multi-objective optimisation, **262**
  - operating costs, 73, **236**
  - process flowsheet for, 218, 235, 258
  - raw material costs, 75
  - as solvent, 130–1
  - straw densification for, 73–5
  - straw extractives from, 75–8
  - of sunflower oil, 126
  - SWOT analysis for, **155**
- surfactant production, 2
- surplus reduction, 24
- sustainability, and biomass
  - increase, 48

- SUSTOIL project policy  
 objectives, 281
- swath thresh of rapeseed, 21
- SWOT analysis  
 for alcohols as hexane alternatives, **157**  
 for anaerobic digestion, **160**  
 for cold pressing, **154**  
 for dehulling strategies, 151–4  
 for gas-assisted oil pressing, **156**  
 for marc hexane retention, **155**  
 for oleosome isolation, **158**  
 for simultaneous extraction and transesterification, **158**  
 for supercritical CO<sub>2</sub> extraction, **155**  
 for water extraction, **159**
- syngas  
 production of, 18, 20, 195–6  
 via pyrolysis, 14
- syngas platform, interaction with sugar platform, 19–20
- tail-end separation, for dehulling, 104
- tall oil, 34–6
- tall oil fatty acids (TOFA), 35–6
- thermal pre-treatment of seeds, 115–8, 124–5
- thermomoulding  
 cost analysis model, 221  
 economic optimisation, 274–5
- thermoplastic extrusion, 131–2
- thin film distillation, 170
- trade structure of CGE models, 304–6
- transesterification and extraction  
 integrating into existing plant, 157–8  
 modelling for cost analysis, 211–2
- triglycerides  
 as biofuels, 187  
 processing in oil-refining plants, 192–3  
 transesterification reaction, 167
- trombin, specificity of, 135
- trypsin, 134, 135
- twin-screw extruder, 91
- two-platform concept, 19–20
- vacuum flash evaporators, 170
- vegetable oils. *see* plant oils
- virgin olive oils, 33. *see also* olive oil
- viscosity, 188
- walnut oil, 36
- waste biomass, 4–6
- waste stream valorisation, 119–33
- wastewater from olive mills, 123
- water conservation, 63–4
- water extraction, 159
- waxes from plants, 75–80  
 in sunflower oil, 110–1  
 supercritical CO<sub>2</sub> extraction optimisation, 234–9
- weed control, in sunflower crops, 61, 63
- wet-milling whole cereal crops, 16–7. *see also* Whole Crop Biorefinery
- wheat straw  
 fibre composition, 86  
 wax composition, 77  
 wax extraction  
 economic optimisation of, 234–9  
 environmental optimisation of, 257–63  
 process flowsheet for, 258  
 wax extracts, pest reduction with, 79  
 wax fraction, 77  
 yields from, 55
- Whole Crop Biorefinery, 14–7
- xylitol/arabinitol, 9
- yield increase  
 average per annum, 55  
 for rapeseed, 50–6  
 for sunflowers, 57–8, 60–7