Microalgae for a bio-based economy

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Guido Breuer
Bioprocess Engineering & AlgaePARC, Wageningen University, The Netherlands
Bioprocess Engineering & AlgaePARC

- ± 20 Staff members
- ± 30 PhD students
- MSc & BSc students
- Different research topics of which algae are an important theme
Our algae research

- Various products
- In close collaboration with industry
- Lab-scale (indoor) and pilot-scale (outdoor)
- Fundamental research and applied research
- Multidisciplinary research
- Whole algae production chain (from strains to product)
Multidisciplinary algae production chain

Life cycle and techno-economic analysis, product characterization

- Strain selection and improvement
- Physiology
- Cultivation
- Harvesting
- Bio-refinery

- Strain selection (screening)
- Genetic engineering
- Photosynthetic efficiency
- Product accumulation
- Day-night cycles
- Photobioreactor design
- Process design
- Cultivation strategies
- Scale-up
- Optimization
- Flocculation
- Cell disruption
- Fractionation
- Cell wall characterization
AlgaePARC pilot facilities

- 4 reactor designs
- 25 m²
- Different cultivation modes
- Natural seawater
Production systems at AlgaePARC (1)

Raceway pond

Advantage
- Cheap to build and to operate
- Established technology

Disadvantages
- Prone to contamination
- Water evaporation
- Controllability
- Low biomass concentrations

Horizontal tubular reactor

Advantage
- High controllability
- Closed system
- High biomass concentrations

Disadvantages
- Photo inhibition
- Oxygen built up
Production systems at AlgaePARC (2)

Flat panels

**Advantage**
- Low material costs
- No need for external cooling
- High biomass concentrations

**Disadvantages**
- Prone to damage
- Energy costs of air sparging

Vertical stacked tubular reactor

**Advantage**
- High controllability
- Closed system
- Light dilution

**Disadvantages**
- Oxygen built up
- Costs/energy to built
Aims of AlgaePARC

- Comparison of photobioreactor designs
- Improve photosynthetic efficiency outdoors (>5%)
- Develop process & cultivation strategies
- Obtain knowledge and experience to scale-up
- Growth model development and validation
- Productivity projections
- LCA and techno-economic analysis

Biorefinery

- 10-80% Carbohydrates
- 0-50% Triacylglycerol (TAG)
- 10-20% Other lipids.
- 0-5% High value products
- 1-5% Pigments
- 10-60% Proteins
- Bioethanol, chemicals, feed
- Biodiesel, edible oil, feed
- Energy, chemicals
- Nutraceuticals, pharmaceuticals
- Food, chemicals
- Food, feed

Dependent on species and cultivation conditions

- Harvesting/Concentration
- Cell disruption
- Selective extraction
- Fractionation

- Flocculation
- Pulsed Electric Field
- Supersonic Fluid Flow
- Enzymatic
- Beadmilling
- Homogeneizer

- Aqueous two-phase
- Supercritical CO₂
- Ionic liquids
- Switchable solvents
- Surfactants
- Membrane separation


Strains selection and improvement

- Model species and industrially relevant species
- Photosynthesis and product formation
  - Antennae mutants
  - TAG production (starchless mutants)
  - Hydrocarbon production
- Mutagenesis and direct gene targeting approaches
- (Transcript)omics to obtain insight in regulation
Photobioreactor design
Thank you!
Biomass Production costs: Model

**Input**
- Location: Netherlands, Saudi Arabia, Canary Islands, Turkish Riviera, South Spain, Curacao
- Cultivation System
- Empirical data
- Specific parameters: Culture temperature, Daily Dilution, Mixing day/night, Operation days per year...

**Light Intensity**
- Electricity costs
- Taxes
- Labor

**Output**
- € / Kg biomass
- CAPEX & OPEX
- NER
- Sensitivity Analysis
- Areas to focus
Selection of oil producing species

- Nitrogen starvation to induce oil production
- Many oil producing species exist
- More than 40% of DW as oils

Strain improvement: starchless mutants

- Random UV-mutagenesis
- Screening using iodine staining

De Jaeger et al. 2014, Biotech. For Biofuels
Starchless mutants: biomass composition

Breuer & de Jaeger et. al. 2014, Biotech. For Biofuels
Day:night cycles

- Light intensity is variable during day:night cycle
- Use reactor design for light dilution

Not just light intensity changes during day:night cycles

Wijffels & Barbosa 2010, Science
Yield and biomass composition change during cell cycle

- Constant light intensity but cell-cycle-synchronized culture

De Winter et. al. 2013, Algal Res.
Starchless mutants: performance

- 50% higher yield

Breuer & de Jaeger et al. 2014, Biotech. For Biofuels