Algae Production And Research Center

AlgaePARC
Exploring scale-up challenges in microalgae mass production

Rouke Bosma
Dorinde Kleinegris

Maria Barbosa
René Wijffels

ALGAE WORKSHOP, 16-11-2012
Algae as a promising innovation

- **High productivity**
  - Oil content: 20-60%
  - 20,000-50,000 liter/ha/year oil
  - Palm oil: 6,000 liter/ha/year

- **No ‘competing claims’**
  - Grow on seawater
  - Use of residual nutrients (CO₂, N, P)
  - Co-products have value (e.g. lipids, proteins)
From a craft to an industrial process...

- Current worldwide microalgal manufacturing infrastructure
  ~5000 tons of dry algal biomass

- High value products such as carotenoids and ω-3 fatty acids
  used for food and feed ingredients.

- Total market volume is €1.25 billion
  (average market price of €250/kg dry biomass)

- World production of palm oil is nearly 40 million tons, with a
  market value of ~0.50 €/kg

How can we decrease production costs?

- Increasing photosynthetic efficiency
- Integrate processes (free nutrients)
- Decreasing mixing
- Developing cheaper and less energy consuming harvesting technologies
- Choosing locations with higher irradiations

At 1 ha scale today: 10 €/kg
At 100 ha scale today: 4 €/kg
What could be possible: 0.50 €/kg

Still too expensive for biodiesel alone

- Horizontal tubes
- Flat panels
- Raceway ponds

Biorefinery of microalgae: A need!

- 400 kg lipids
  - 100 kg as feedstock chemical industry (2 €/kg lipids)
  - 300 kg as transport fuel (0.50 €/kg lipids)
- 500 kg proteins
  - 100 kg for food (5 €/kg protein)
  - 400 kg for feed (0.75 €/kg protein)
- 100 kg polysaccharides
  - 1 €/kg polysaccharides
- 70 kg of N removed
  - 2 €/kg nitrogen
- 1,600 kg oxygen produced
  - 0.16 €/kg oxygen

Production costs: 0.50 €/kg biomass
Value: 1.65 €/kg biomass

Norsker et al. (2011) *Biotechnology Advances* 29: 24-27
Wageningen UR algae research

- Interaction between basic research and pilots
- Multidisciplinary approach
- Research topics
  - Efficient use of sunlight
  - Reduction of energy input
  - Use of residual nutrients
  - Lipid accumulation
  - Strain improvement
  - Scale-up
  - Biorefinery
  - Design scenarios/LCA’s
Develop this process is a sustainable and economical way within the next 10 - 15 years


To make the production economically feasible, it is essential to develop cultivation systems in which algae convert the light with a high photosynthetic efficiency

MANY SCATTERED ACTIVITIES

• Different locations
• Different designs
• Different measurements
• How to compare systems?
• How to learn from this process?
Example, photosynthetic efficiency

Theoretical maximum photosynthetic efficiency 9%
10% of light lost by transmission x 0.90
5% of biomass lost during the night x 0.95
10% of energy used for maintenance x 0.90
Maximum photosynthetic efficiency in photobioreactors: 7%

- At lab scale a photosynthetic efficiency of 6% seems to be within reach

- What about
  - Pilot scale 10 – 100 m²
  - Extended time > 1 yr

- How to design/operate even larger (1-100 ha plants)?

AlgaePARC
Algae Production And Research Center

Bridge the gap between fundamental research and scalable applications in industry
AlgaePARC objectives

- International center of applied research
- Bridge between basic research and applications
- Development of competitive technology-economics, sustainability
- Acquire information for full scale plants
- Algal biomass for food, feed, chemicals and fuels
Official opening of AlgaePARC 17 June 2011
Production systems at AlgaePARC

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
Principal of light dilution – go vertical!

$I_{\text{max}} : 1800 \, \mu\text{mol photons m}^{-2} \, \text{s}^{-1}$

Direct sunlight

$I_{\text{max}} : 400 \, \mu\text{mol photons m}^{-2} \, \text{s}^{-1}$

Dilution effect

Production systems at AlgaePARC

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
Main Features

*Uniqueness* - 4 different systems that can run in parallel under the same outdoor conditions

*Fundamental aspects* for successful operation and scale up of photobioreactors to commercial plants

*Control Units*: accurate online measurements and control of a wide range of metabolic and environmental parameters
R&D activities AlgaePARC

Comparison of large-scale photobioreactors, process analysis and optimisation
Deliverables: performance of different systems; optimised process control; Improved system

Screening, testing & optimising algal species on growth & product productivity using different nutrient feedstocks
Deliverables: Species; Cheap nutrient feedstock; High product productivity

Dynamic Process Control strategies
Deliverables: Dynamic process control strategies

Life Cycle Assessment
Deliverables: Sustainability analysis

Test business cases
Deliverables: Proof of concept
Comparison of large-scale photobioreactors, process analysis and optimisation

**Compare large systems on**
- Areal and volumetric biomass and lipid productivity
- Energy balance
- Nutrient requirements
- Carbon dioxide consumption and oxygen production
- Operational costs (including manpower)
- Cleanability
- Culture stability (assessment of infections and algae population)
- Robustness of the system

Information for improvement of operation strategies
Funding AlgaePARC 8M€

Facility financed by
- Ministry EL&I
- Province Gelderland
- Wageningen UR

Research program financed by
Future plans

**Technology platform**

- Production: AlgaePARC -> partnerships, new locations, different climates and conditions
- AlgaePARC Biorefinery: In development

**PPP Projects – Pre-competitive Research**

**Product platform**

- Production strategies for compounds of specific interest to individual companies
- Demo

**Bilateral projects**