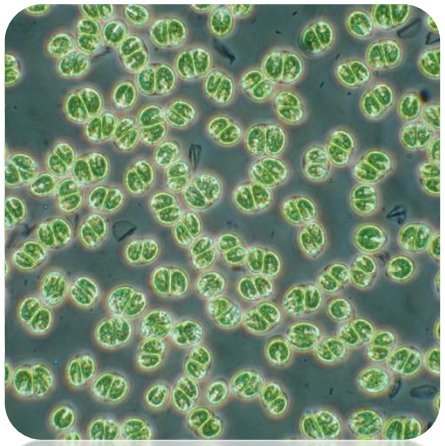
Microalgae cultivation in liquid foam-beds

Agnes Janoska, Marcel Janssen, René H. Wijffels

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This project has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement no 613588

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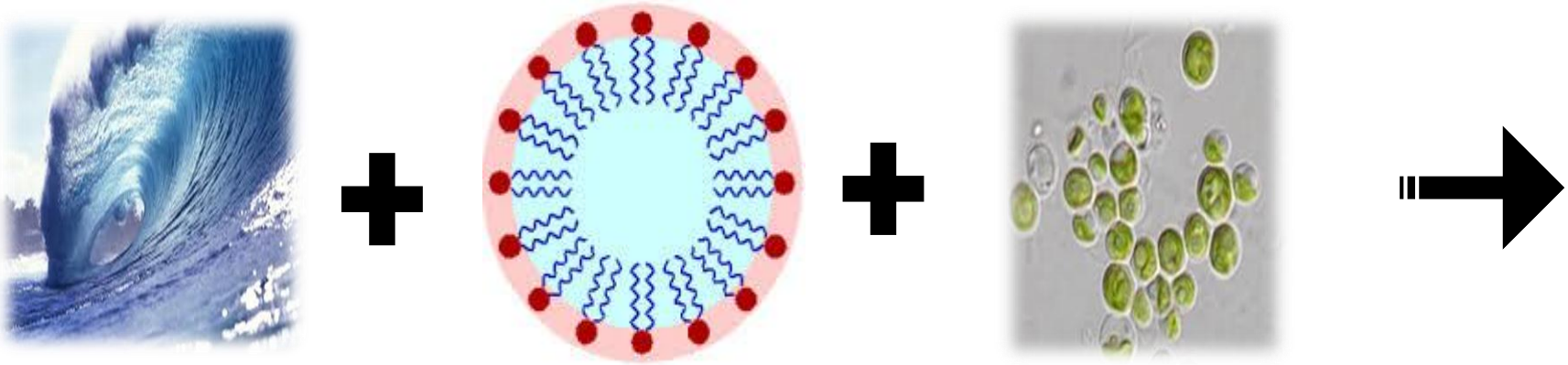
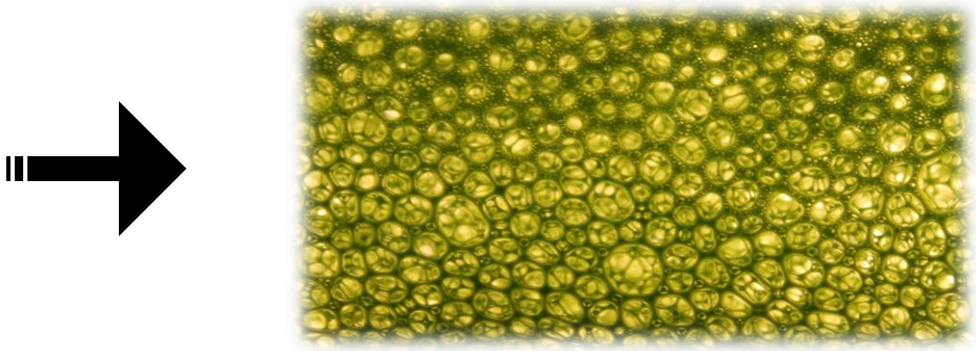
Concept





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Advantages

Feature	Consequence
Big interfacial surface area	➢ Increased mass transfer ➢ Increased CO_2 removal efficiency
Increased residence time	➢ Reduction in energy costs of aeration
Reduced pressure drop	➢ Reduced material requirement
Short light path	➢ Increased biomass density ➢ Reduced harvesting and processing costs

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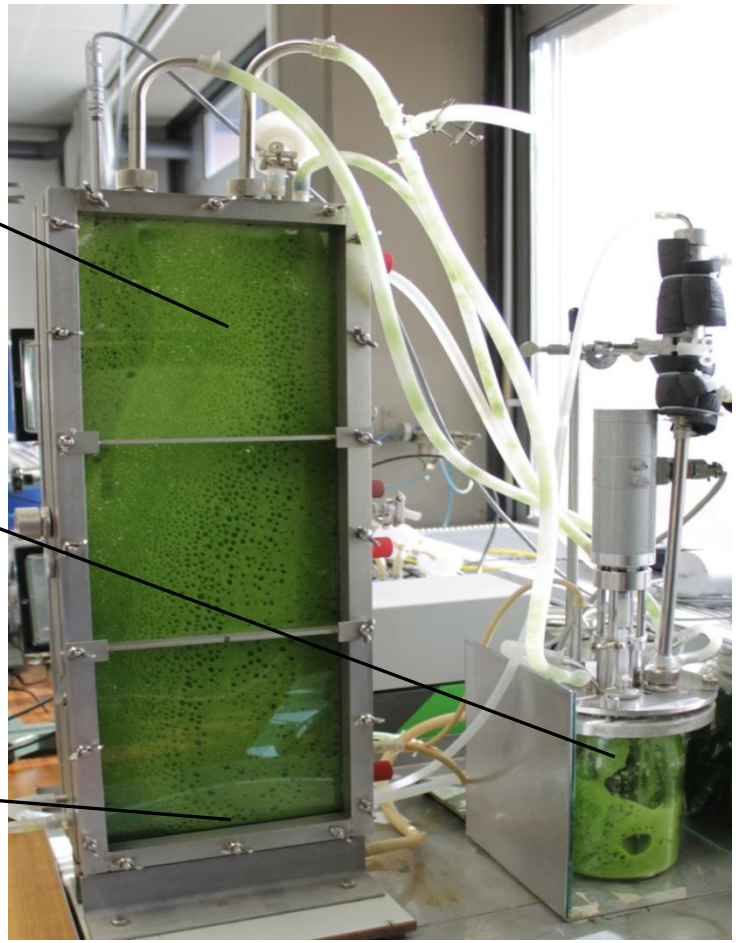
The foam-bed photobioreactor

Flat panel photobioreactor
In order to create short light path

Foam breaking device
gaseous phase is separated from the liquid phase.

Bubble formation due to gas sparging



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Main objective

Development of a bench-scale liquid foam-bed photobioreactor for microalgae cultivation.

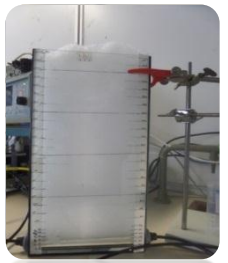
Steps done:

1. Pre-selection of surfactants/foam stabilising agents for further experimental testing

2. Development of a strategy for foam break-up

3. Compare and characterize foams – liquid holdup, foam stability

4. Set up a lab-scale foam-bed photobioreactor



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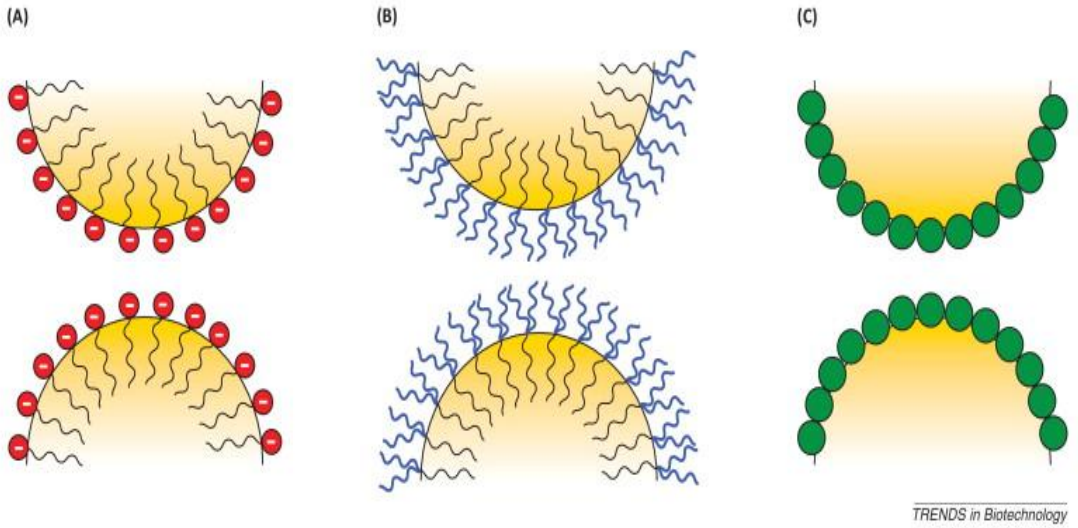
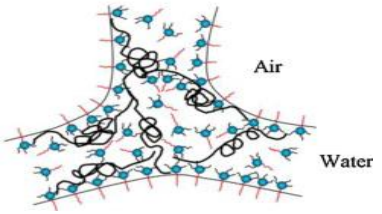
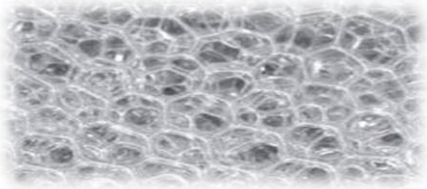
1. Possibilities: surfactants/foam stabilising agents

Criteria:

- Foaming properties
- Toxicity
- Algae hold-up
- Biodegradability







Heeres, A.S., et al., *Microbial advanced biofuels production: overcoming emulsification challenges for large-scale operation.* Trends in Biotechnology, 2014. **32**(4): p. 221-229.

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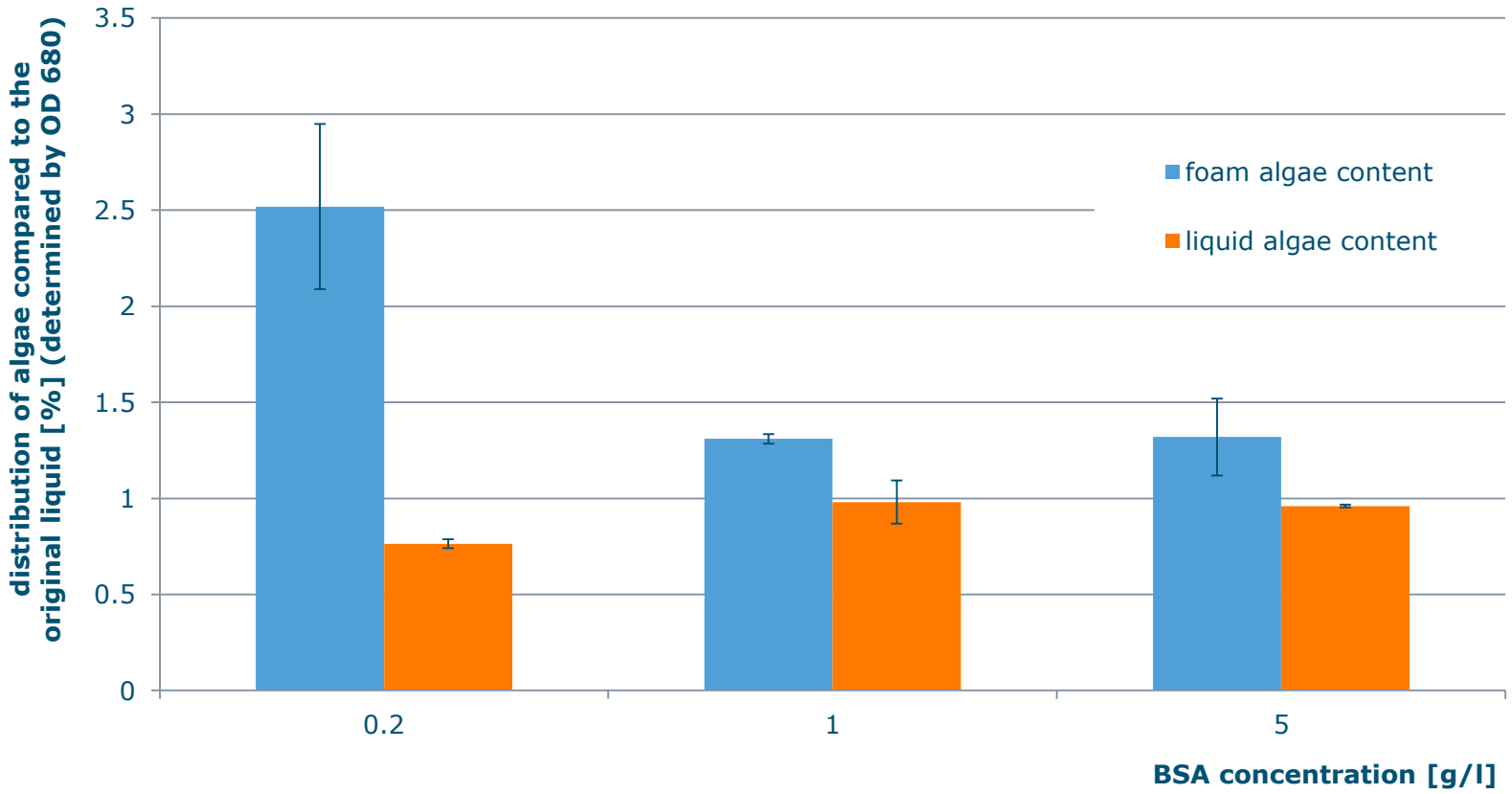
1. Quick choice surfactant BSA – algae hold-up

BSA: Non toxic, good foaming, however too easily biodegradable.

Alge hold-up to be determined:



2. Possibilities: foam break-up

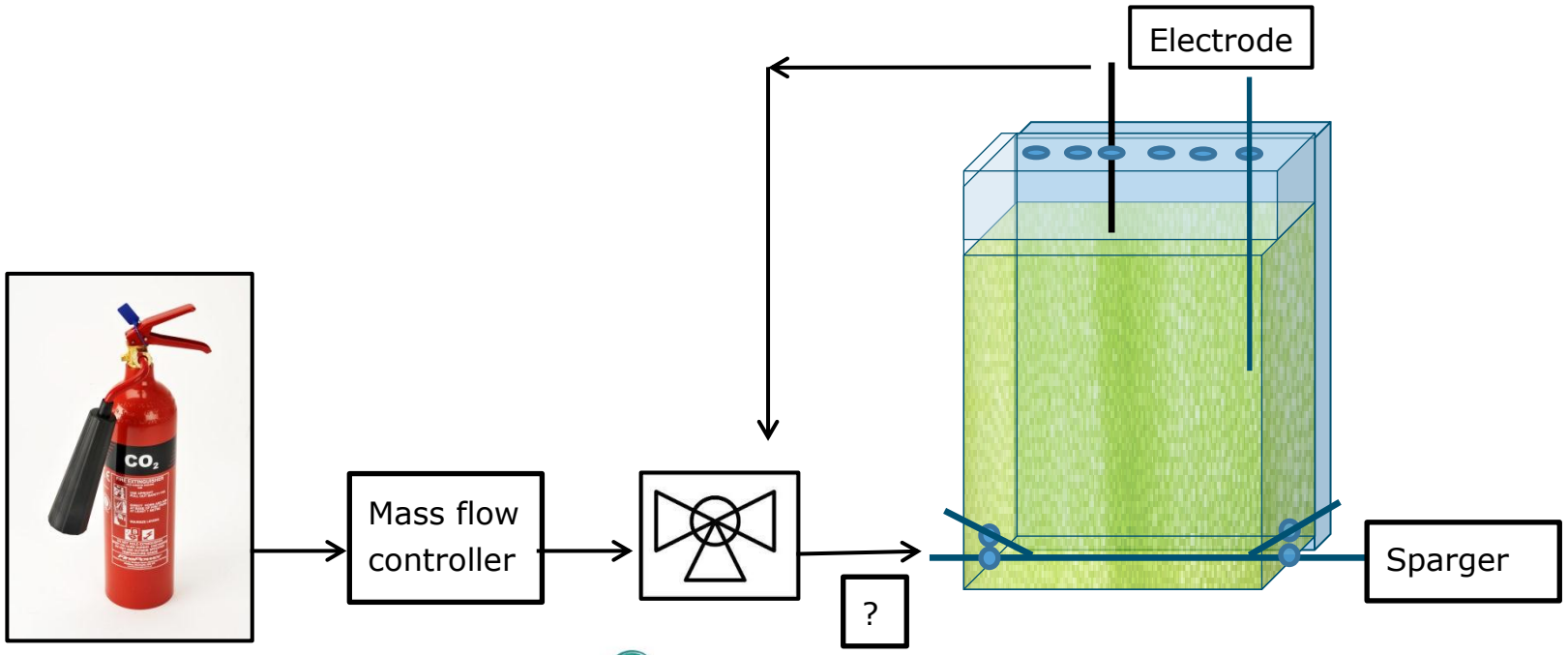
⇨ A method based on mechanical foam break-up was tested, by using a CSTR as a foam breaker.....

... However, small bubbles were formed instead of real gas-liquid separation.

2. Possibilities: foam break-up

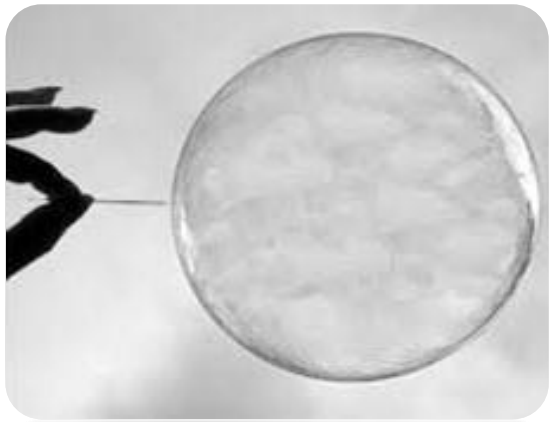
⇨ A method based on self break-up was tested, with electrodes regulating foam height...

....However, bubbles dried out and coalescence occured.



2. Possibilities: foam break-up

- Chemical foam breaker ideas
  - alcohols, oils, hydrophobic materials, etc.
- Mechanical foam breaker ideas
  - rotating disk foam breaker (or a stirrer)
  - expanded surface area
  - spraying liquid on the foam
- Size exclusion
  - sieve plate
  - packed bed with beads



3. Foam characterization

Background: Foams can be characterized and compared by foam volume halftime and foam liquid content.

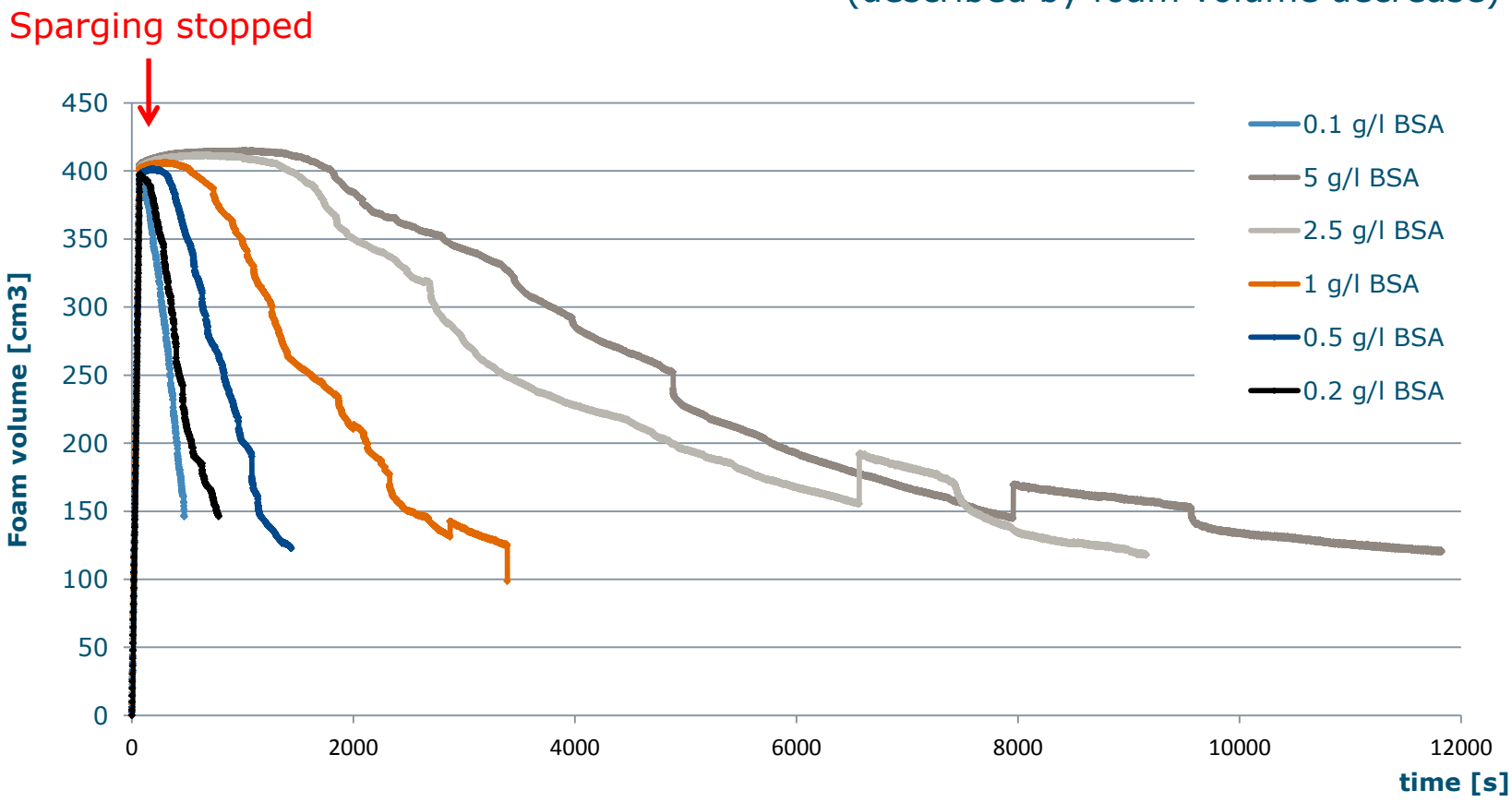
Objectives: Determine the effect of the following parameters on foam stability and on foam liquid content

- BSA concentrations
- gas flow rates
- Temperature
- pH
- Salinity

3. Foam characterization

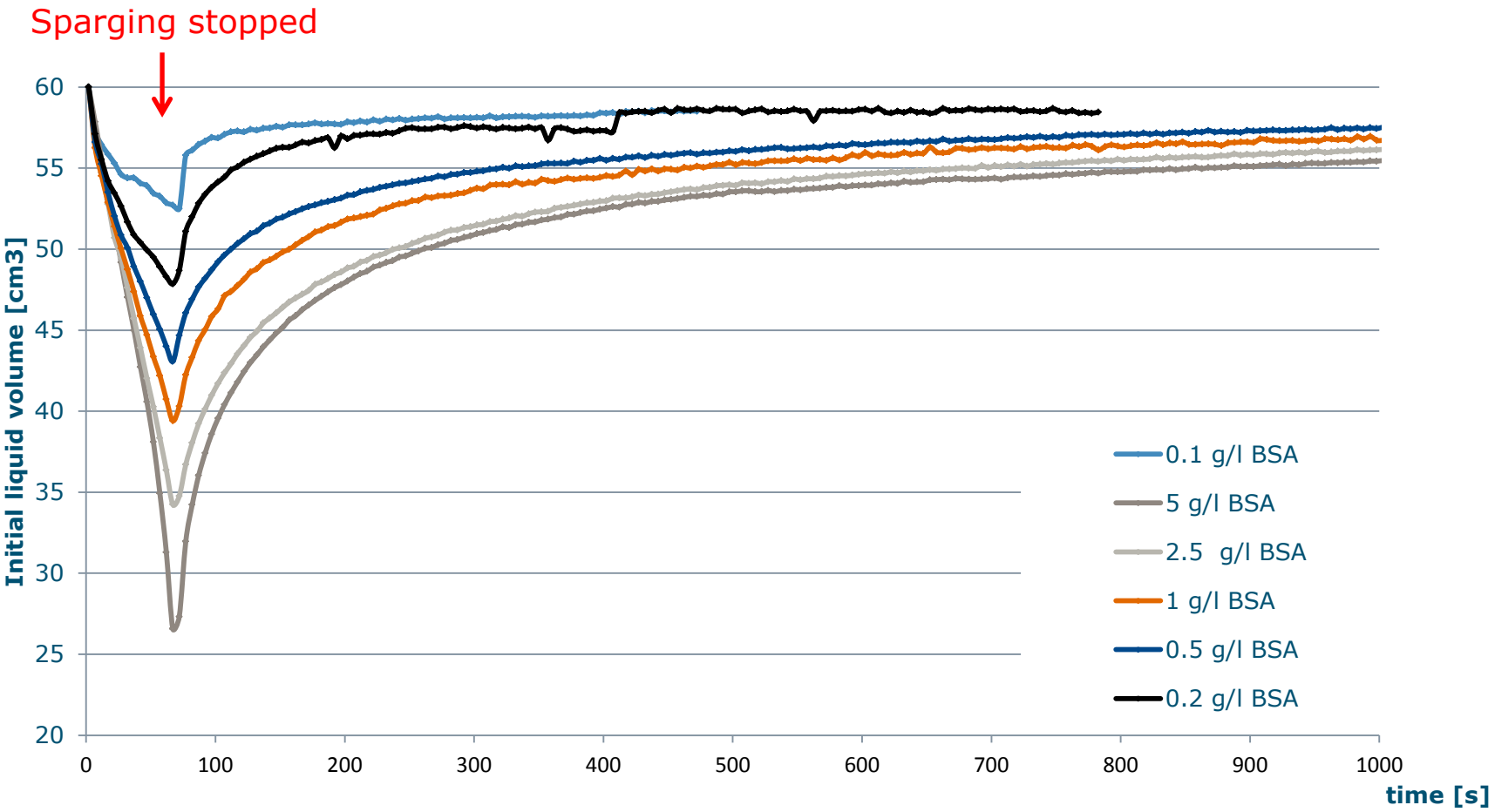
Effect of BSA concentration on foam stability

(described by foam volume decrease)



3. Foam characterization

Effect of BSA concentration on liquid hold-up (liquid volume change)



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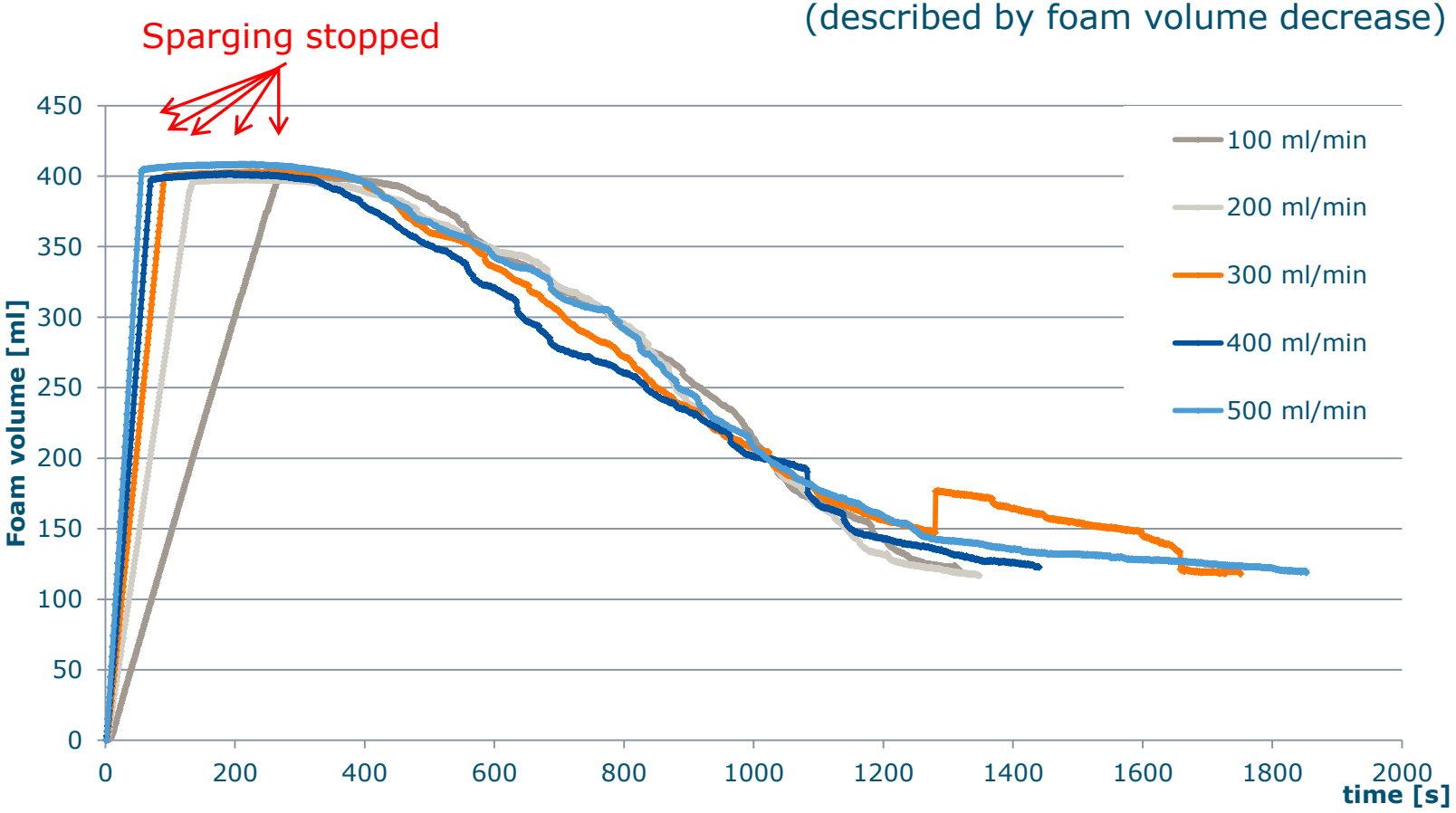

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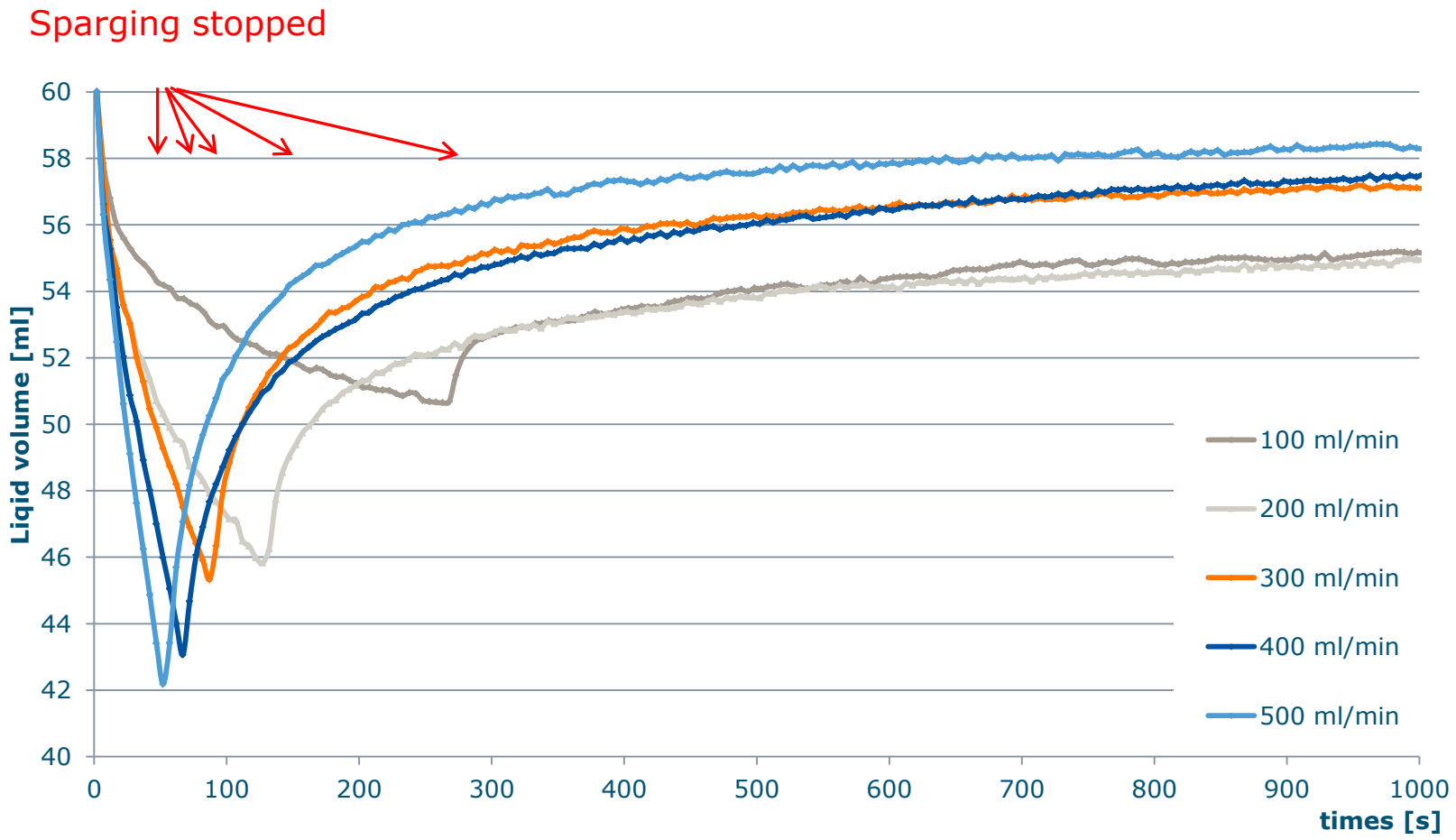

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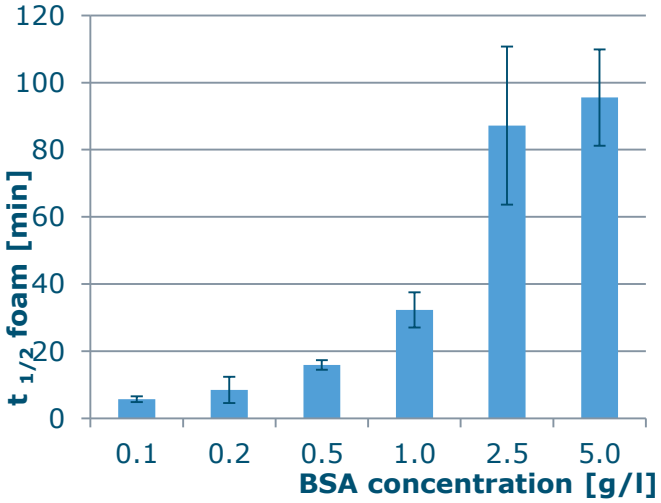
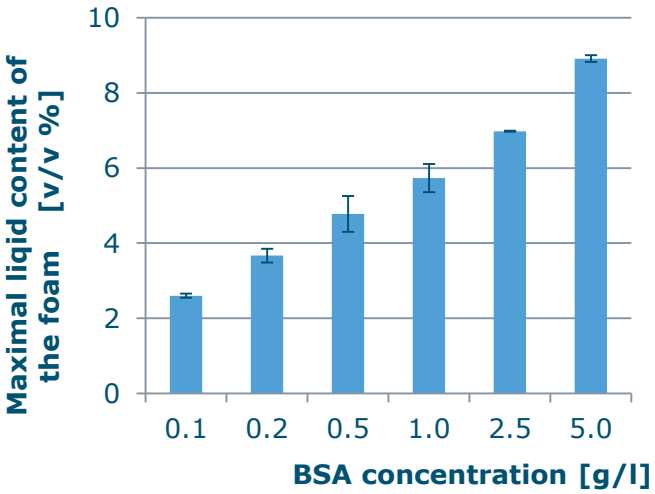
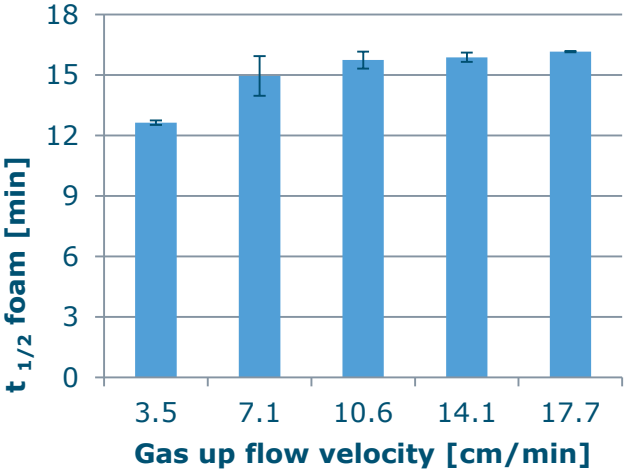
3. Foam characterization

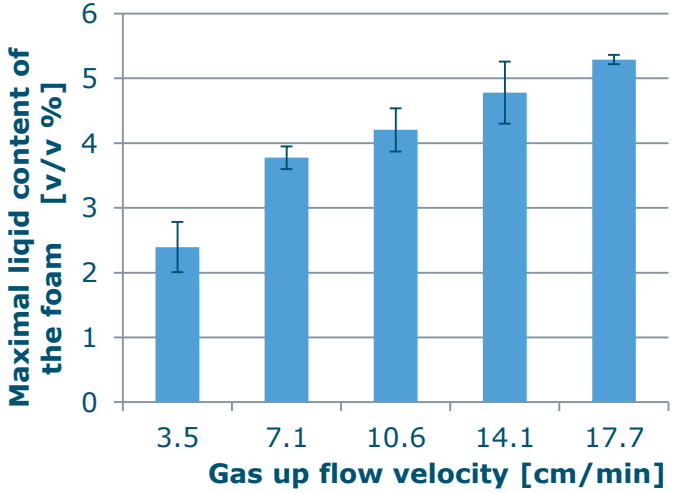
BSA concentration





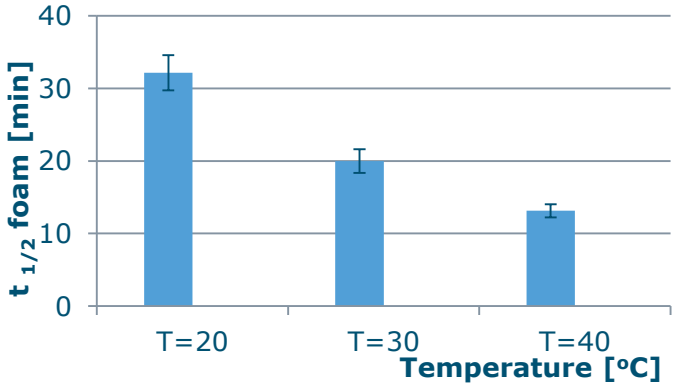
Gas flow rates

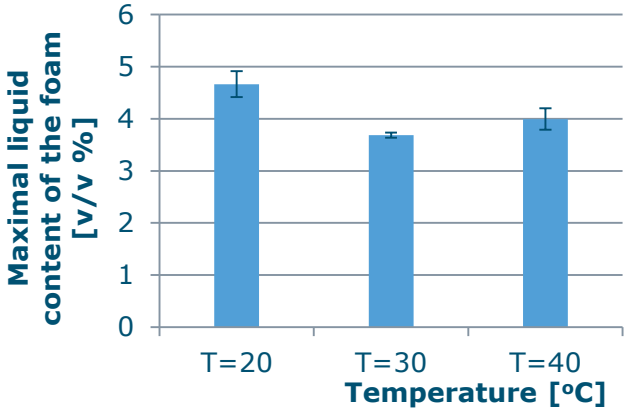




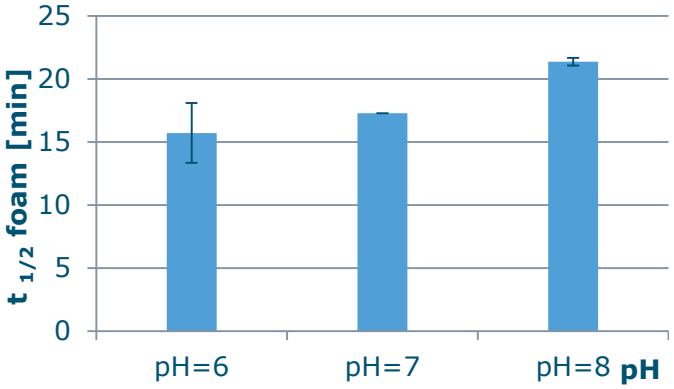
3. Foam characterization

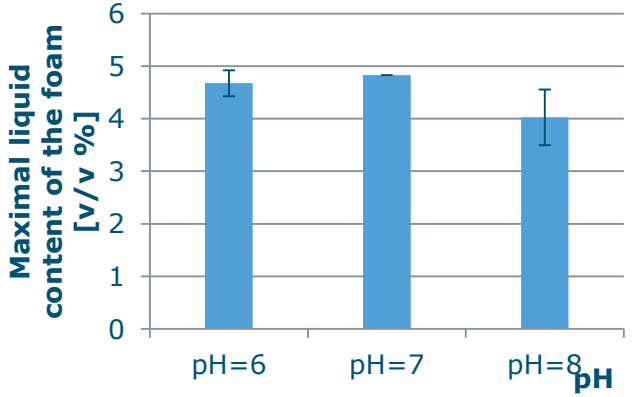
Temperature



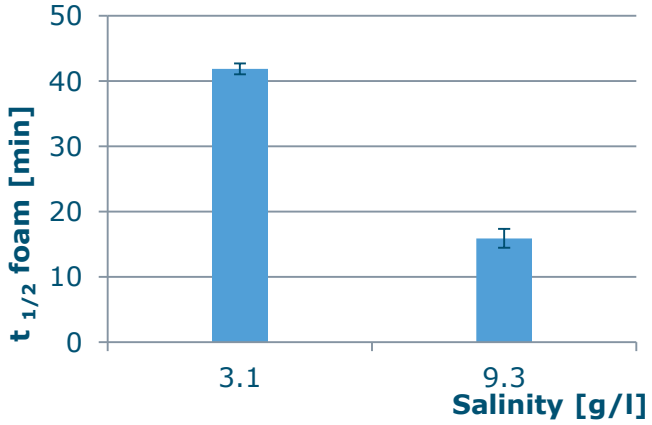


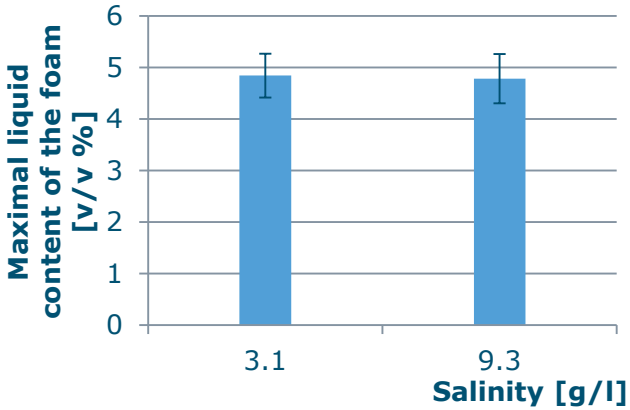
pH





Salinity





3. Foam characterization

Conclusions from foam characterization experiments

Higher BSA conc.
Higher gas flow rates

→ Higher liquid hold-up
→ More stable foam

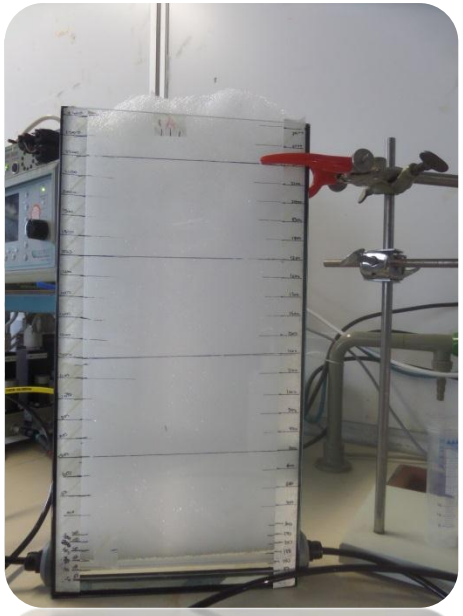
Temperature
pH
Salinity

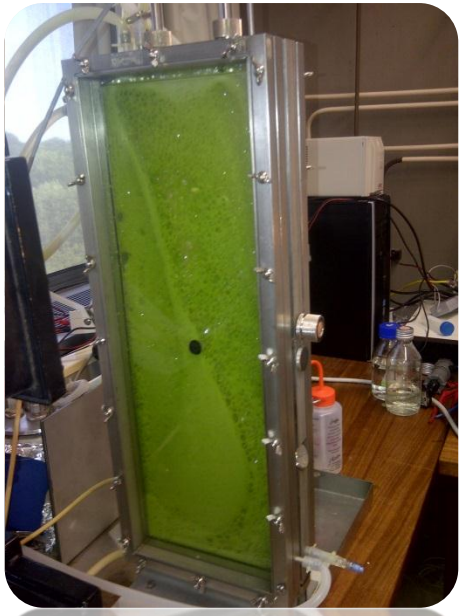
→ Little effect on liquid content,
Foam stability increse by

- Decreasing temperature
- Increasing pH
- Decreasing salinity

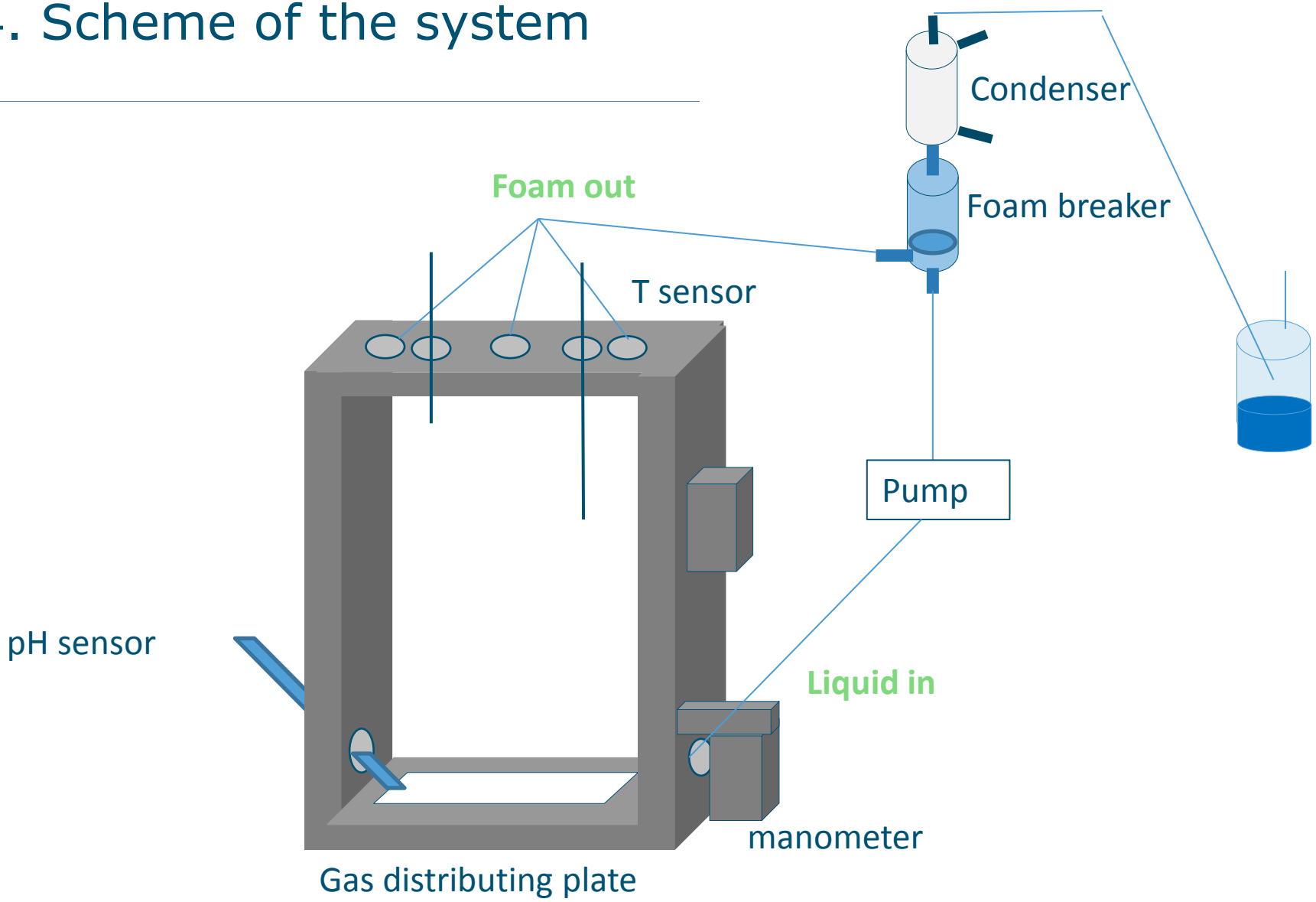
4. Design a lab-scale foam-bed photobioreactor

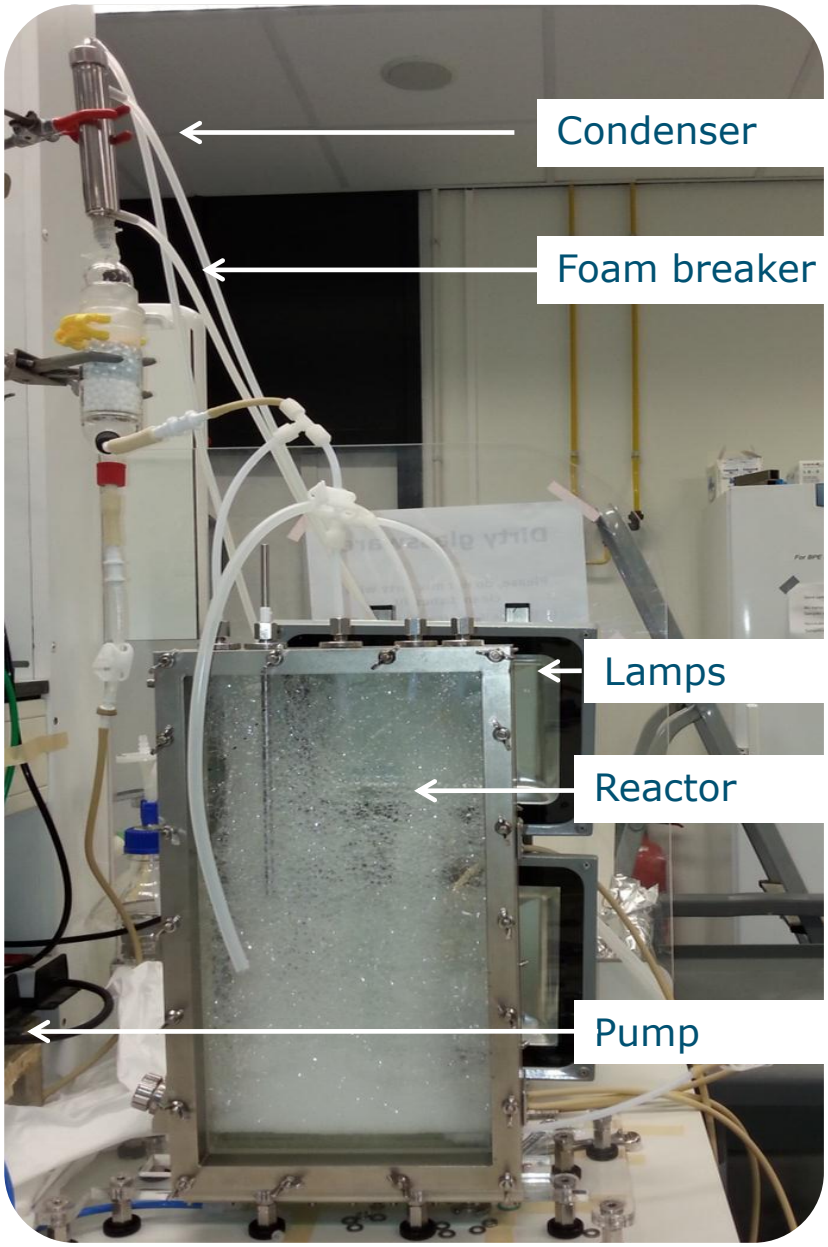
- Adopted flat-panel photobioreactor
- Closed system
- Improved sparging system- over the whole cross sectional area to avoid settling
- Integrated recirculation to/from the foam break-up system





4. Scheme of the system




Condenser
Foam breaker
Lamps
Reactor
Pump

Conclusions

- A bench-scale liquid foam-bed photobioreactor was developed
- BSA can be used as a surfactant for preliminary experiments to stabilise the foam, due to its non toxicity and high algae hold-up
- Foam stability and liquid hold-up depends on several factors, including surfactant concentration, gas flow rate, pH, T and salinity.
- For foam break-up, the two different methods tested, namely self drainage and mechanical stirring are not suitable for the foam-bed photobioreactor

Thank you!
Questions?

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