Process chain development of five algae-to-product value chains

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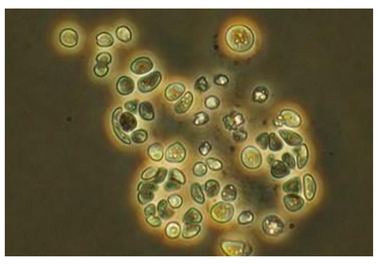
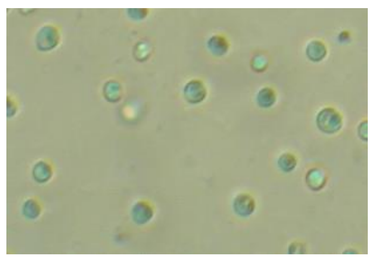
Background

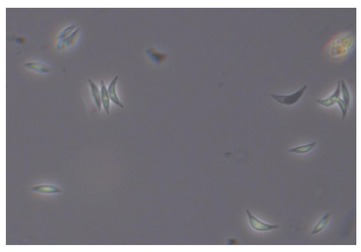
The EU-MIRACLES project aims at developing integrated, multiple-product biorefinery technologies for producing microalgal specialties for food, aquaculture and non-food products. This poster focusses on **quantifying the feasibility of 5 product value chains and addressing the effect of algal species on the economics of the complete processing chain.** The selected value chains are shown in Figure 1.



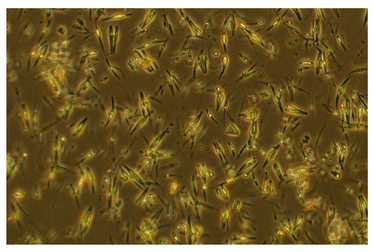
Isochrysis galbana



Nannochloropsis gaditana



Scenedesmus obliquus



Phaeodactylum tricornutum

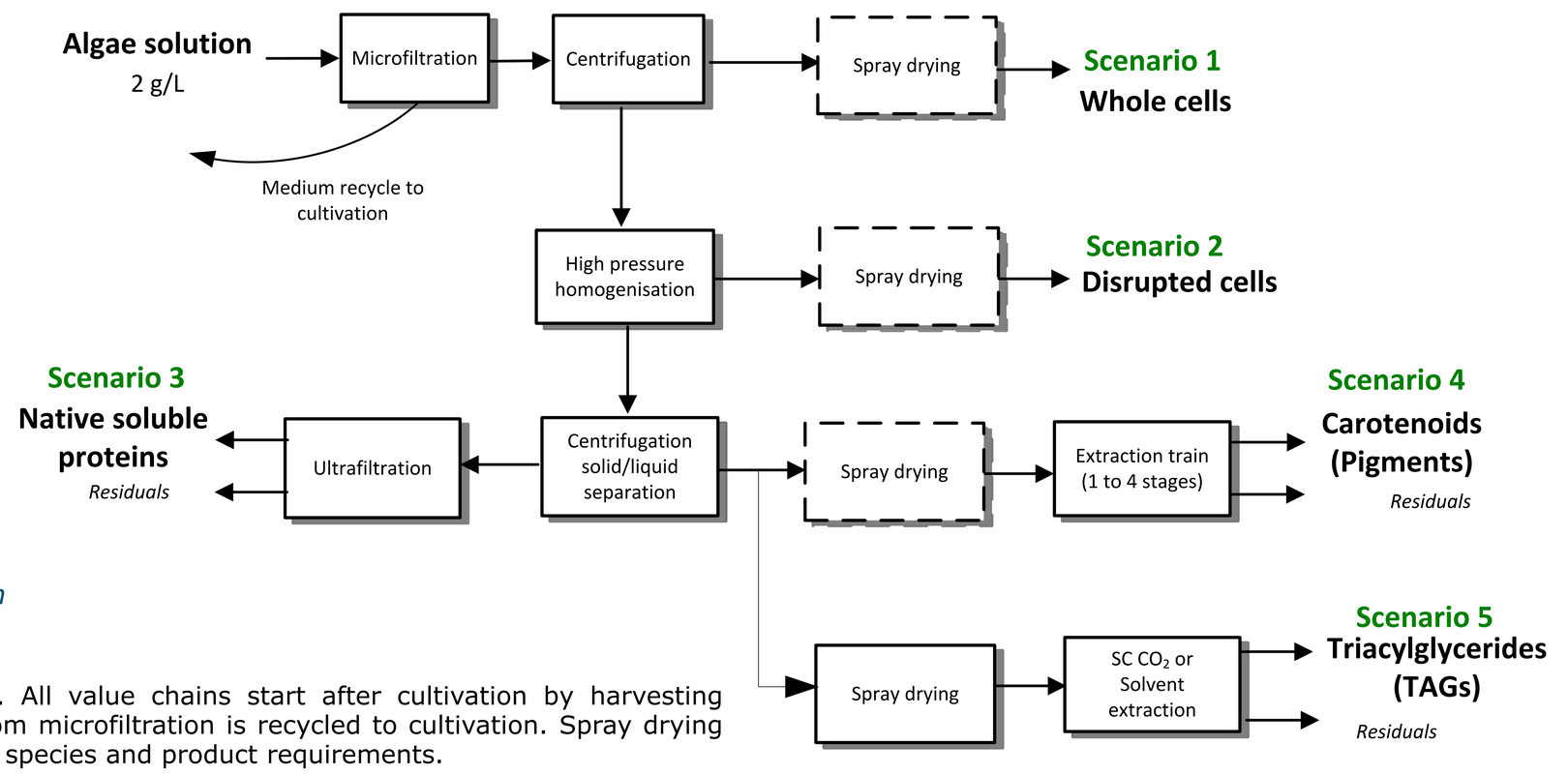


Figure 1. Overview of selected biorefinery value chains. All value chains start after cultivation by harvesting through microfiltration and centrifugation. The effluent from microfiltration is recycled to cultivation. Spray drying is optional in scenarios 1, 2 and 4, depending on the algae species and product requirements.

Approach

- Combine experimental data for the selected algae-to-product value chains (combination of 4 species, 5 product scenarios)
- Calculate mass and energy balances (flows, yield, purity)
- Project to large-scale conditions through process integration in SuperProDesigner® (processing 10,000 ton biomass / year)
- Determine size and number of equipment units. Define scheduling procedures for batch operations
- Determine optimal configurations and operating conditions
- Economic evaluation (CAPEX, OPEX, cost breakdown)

Results

Equipment sizes and demands for utilities, materials, labour and consumables were combined to estimate the capital (CAPEX) and operating (OPEX) expenditures for each combination of algae species and product. An example of the results is shown in Figure 2, for scenario 3 focussing on proteins. The economic results for the all value chain scenarios are summarised in Table 1.

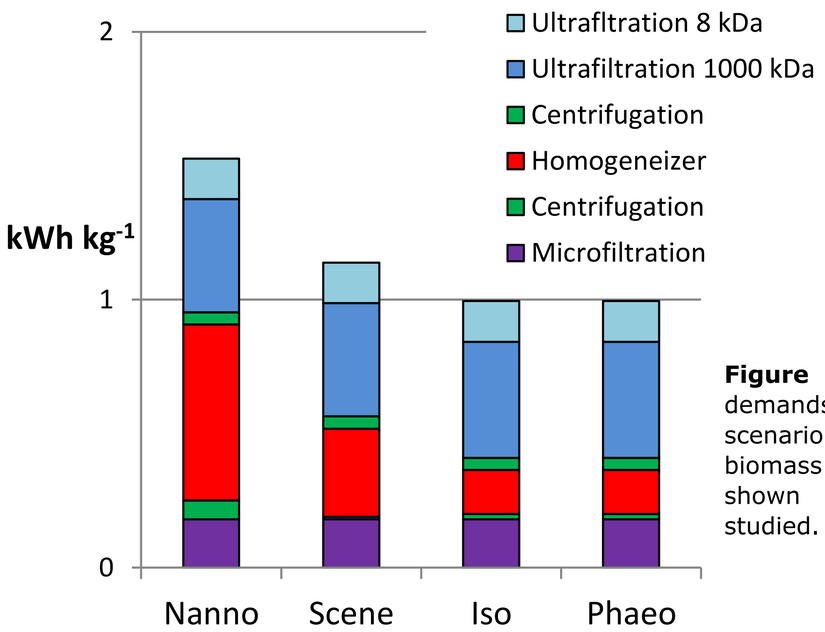


Figure 2. Calculated electricity demands for each process step in scenario 3 (kWh electricity per kg biomass processed). Results are shown for each algae species studied.

Table 1. Cost estimates in € per kg biomass processed for the 5 value chains

	CAPEX - € kg^{-1}	OPEX - € kg^{-1}	Most sensitive design parameter
Scenario 1	0.06-0.31	0.22-1.12	Permeate flux rate and energy consumption in microfiltration
Scenario 2	0.08-0.14	0.43-0.57	Flux rate and energy consumption in microfiltration, pressure and passes in the homogeniser, inlet concentration at homogeniser
Scenario 3	0.12-0.15	0.48-0.78	Ultrafiltration permeate flux rate at 300kDa membrane
Scenario 4	0.50-8.00	1.00-2.00	Biomass throughput in the extraction step
Scenario 5	1.00-3.00	0.50-0.70	Residual water content after drying

Conclusions and main future challenges

- Combined harvesting by micro-filtration and centrifugation reduces the CAPEX tremendously
- Centrifugation efficiency strongly depends on algae cell diameter
- Breakthrough in single step microfiltration requires flux of 100 L m^{-2} h^{-1}, power input of 0.01 kW m^{-2} and final biomass concentration >10% dw
- Homogenisation cost improve when operating at 15-20% dw and by applying lower pressure and less passes
- For ultrafiltration the pumping cost and membrane area reduce when membranes can deal with higher inlet concentrations
- The CAPEX of extraction (sc. 4 & 5) are a real bottleneck. Increased biomass throughput is the first step forward
- Avoid drying by choosing proper co-solvent for wet extraction of pigments and lipids

The next steps within EU-MIRACLES are assessing 1) environmental sustainability through LCA, 2) marketability of the selected value chains.

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