

Can food save the fuel?:

Impact of protein co-production on microalgal biofuels

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Motivation and Approach:

- Improve techno-economic feasibility
- Develop integrated biorefinery
- Multitude of alternatives and decisions
- Use of model based optimization
- Flowsheet and design optimization

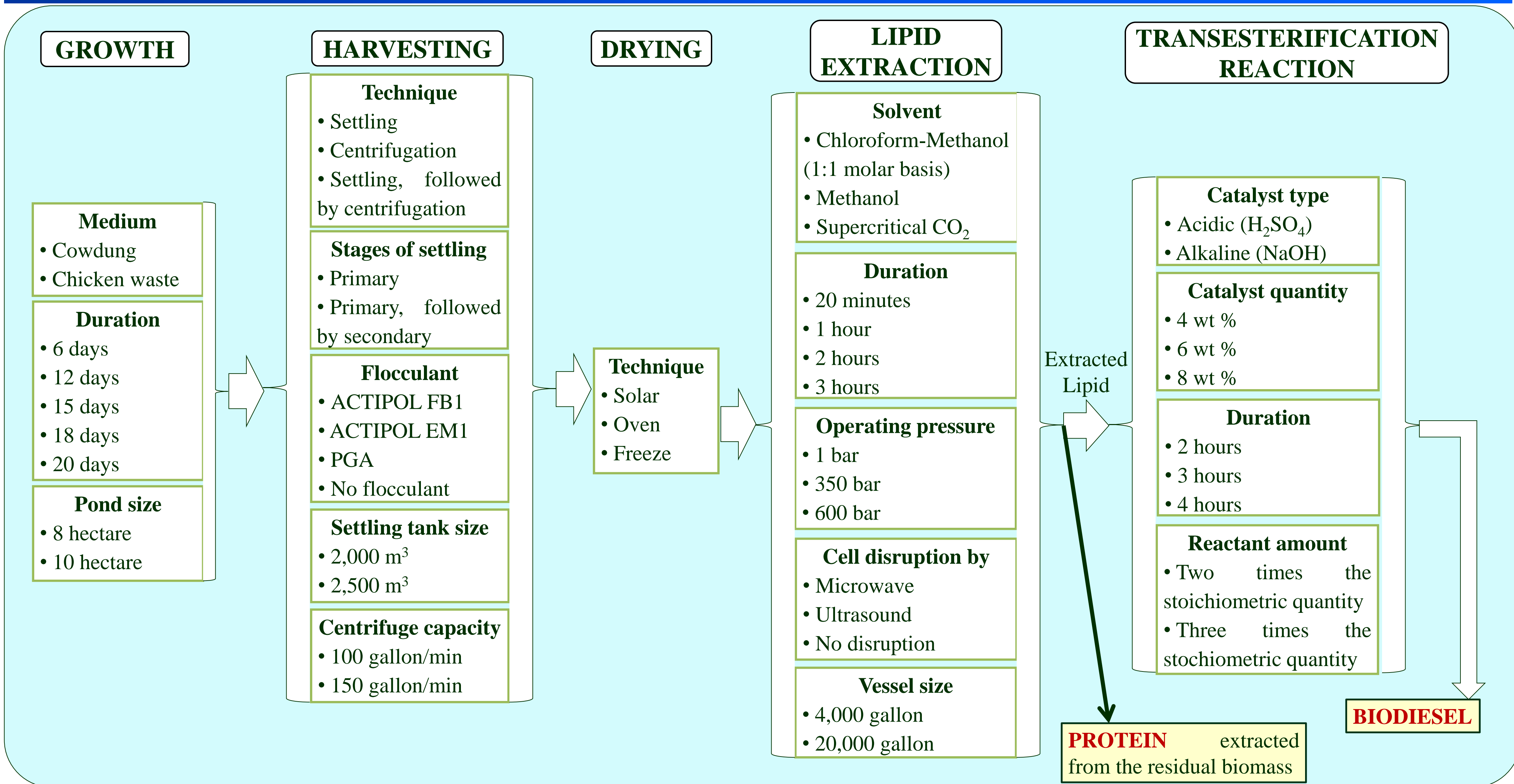
Model features:

- Mass balance across the processes
- Cost expressions for equipments
- Objective: Minimize Net ALCC
- Scheduling based on batch time
- Scale-up for a realistic scenario

Conclusions:

- Only biodiesel production cost = US \$16.3/L
- 16% reduction in cost due to protein co-production
- Cost distribution depends on desired product-mix

Biodiesel and Protein from microalgae: Processes and the superstructure



Results and Discussion

Biodiesel as the only product

Demand: 30 Mg/d from *Chlorella sp.*

Net ALCC based cost: US \$ 16.262/L

Steps of the process	Net cost (US \$/L)	Optimized model decisions
Growth of microalgae	2.776	• Duration: 16 days • Number of ponds: 720 (10 ha each)
Harvesting of cultivated solution	0.397	• Technique: Settling with ACTIPOL FB1 • Flocculant amount: 2,643.7 kg/batch • Number of settling tanks: 353 (2,500 m ³ each)
Drying of harvested microalgae paste	0.001	• Solar drying
Lipid extraction from dried biomass powder	12.455	• Solvent: Supercritical CO ₂ at 600 bar; 5.9x10 ⁶ kg/batch • Duration: 3 h • Number of extraction tanks: 72 (4,000 gallon each)
Transesterification reaction of extracted lipid	0.633	• Reactant alcohol amount: 7,446.4 kg/batch • Catalyst: Sodium Hydroxide; 6 wt % of reactant lipids • Duration: 4 h; Number of reactors: 4

Co-production of biodiesel and protein

Biodiesel demand: 30 Mg/d; Protein demand (maximum): 2,000 Mg/y from *Chlorella sp.*

Net ALCC based cost: US \$ 13.726/L

Steps of the process	Net cost (US \$/L)	Optimized model decisions
Growth of microalgae	6.663	• Duration: 18 days • Number of ponds: 1,728 (10 ha each)
Harvesting of cultivated solution	1.241	• Technique: Settling with ACTIPOL EM1 • Flocculant amount: 5,098.8 kg/batch • Number of settling tanks: 255 (2,500 m ³ each)
Drying of harvested microalgae paste	5.665	• Oven drying
Lipid extraction from dried biomass powder	2.756	• Solvent: Chloroform and methanol (1:1 molar basis) • Solvent amount: 4,980 L/batch • Duration: 20 minutes • Cell disruption technique: Microwave • Number of extraction tanks: 3 (20,000 gallon each)
Transesterification reaction of extracted lipid	0.629	• Reactant alcohol amount: 2,482.1 kg/batch • Catalyst: Sodium Hydroxide; 6 wt % of reactant lipids • Duration: 4 h ; Number of reactors: 2
Extraction of protein	4.239	• Solvent requirement: 525.8 m ³ /batch • Extraction vessel: 7 in number
• The value obtained from the extracted protein was US \$ 7.467/L		