Dynamic flux balance analysis for the maximal valorisation of Dunaliella salina

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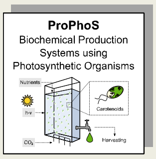
MOTIVATION



Natural β-carotene from the photosynthetic organism *Dunaliella salina* is considered as a high-value microalgal product. The design of an economically feasible and robust β-carotene process is challenging due to the high number of unknown model parameters and biological variability. We aim to provide qualitative and quantitative metabolic data on carotene accumulation and the underlying stress response. In combination with a robust modeling framework consisting of dynamic-kinetic reactor models and genome-scale dynamic flux balance analysis (DFBA) the potential of microalgal processes can be fully exploited.

MULTISCALE SYSTEM FOR ALGAE PRODUCTION

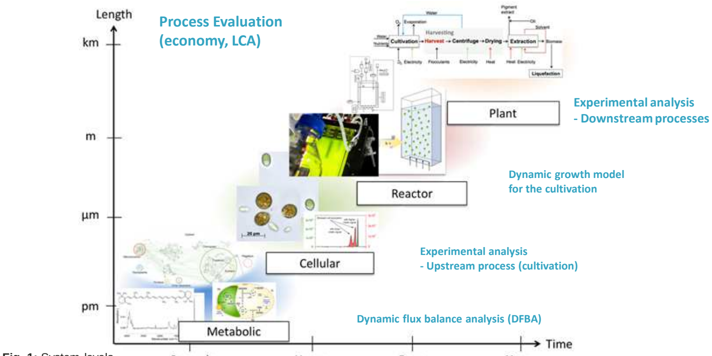


Fig. 1: System levels

GENOME-SCALE METABOLIC MODEL

- **Model characteristics:**
  - Multiscale model: extracellular dynamics combined with intracellular metabolism
  - 10 dynamic states (reactor dynamics, components of biomass)
  - Genome-scale metabolic network reconstruction from *Chlamydomonas reinhardtii*
  - ≈ 1700 metabolites, 4000 reactions

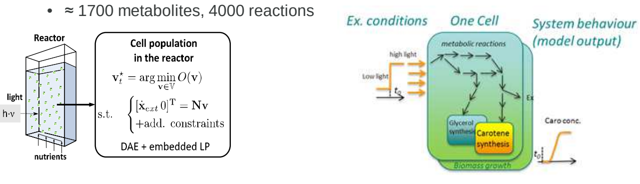


Fig. 2: Simplified representations of the multi-scale structure of the DFBA model for *D.salina*.

EXPERIMENTAL PLATFORM

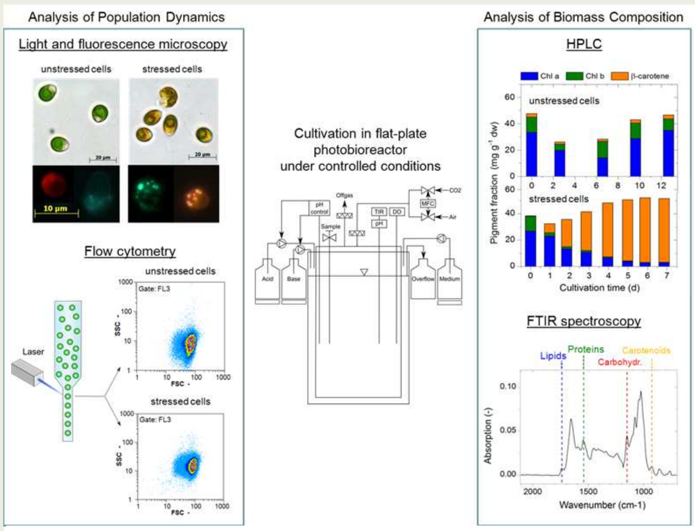


Fig. 3: Experimental techniques used to investigate population dynamics and changes of algae biomass composition upon exposure to abiotic stress [1].

PROCESS DESIGN: OPTIMIZED FED-BATCH PROCESS

- **Problem formulation:**
  - Fixed batch time (7 days)
  - Constant light stress per cell
  - Goal: Maximization of the β-carotene concentration by optimizing the nitrogen feeding
- **Experimental validation:**

Optimized fed-batch design outperforms the batch:

Output improvement:

- 2.46-fold biomass density
- 2.07-fold β-carotene density
- 1.52-fold β-carotene productivity

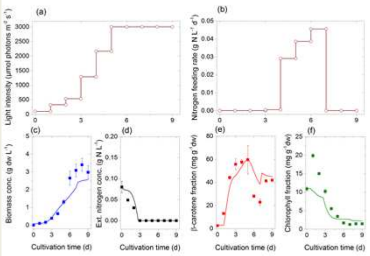


Fig. 5: Experimental validation of the optimized conditions.

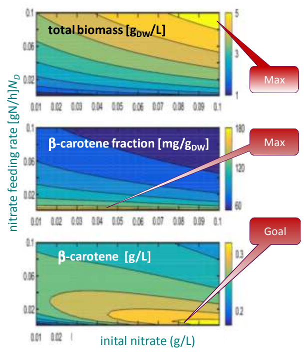
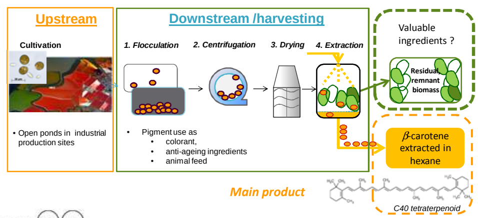


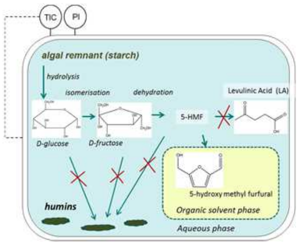
Fig. 6: Criterion over design space [3].

VALORISATION OF THE *DUNALIELLA* REMNANT



- **Use of remnant**
  - Source of renewable chemicals
  - Carbon source for the cultivation of
    - Bacteria
    - Algae
    - Yeast

Fig. 8: Process scheme for the production of 5-HMF and LA from *Dunaliella* algal remnant in biphasic reaction conditions.



$$C\ Yield[\%] = 100 \times \frac{moles\ of\ C\ in\ product\ i}{Initial\ moles\ of\ C\ (in\ remnant\ biomass)}$$

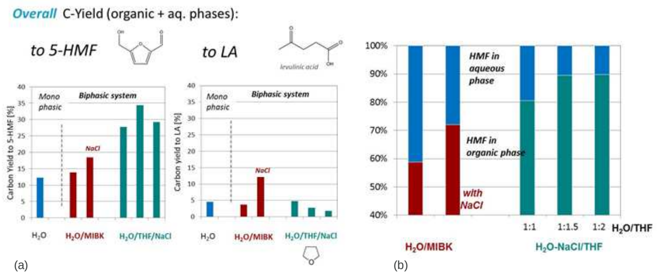


Fig. 9: (a) The overall C-Yield to 5-HMF and LA (b) Partition of 5-HMF between the aqeous and organic phases [5].

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