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Performance Evaluation of Algal Photobioreactors using CFD and Growth Modelling

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Motivation

- Biodiesel production from microalgae economically infeasible
- Microalgae cultivation the most expensive step
- Higher culture densities and faster growth rates desired
- Photobioreactors (PBR): Potential but expensive solutions

Objective

- Develop better photobioreactor designs for improved performance
- Evaluate PBR designs using CFD modeling of hydrodynamics
- Integrate microalgae growth kinetics with CFD modeling
- Compare performance of novel design with conventional design

PBR Modeling

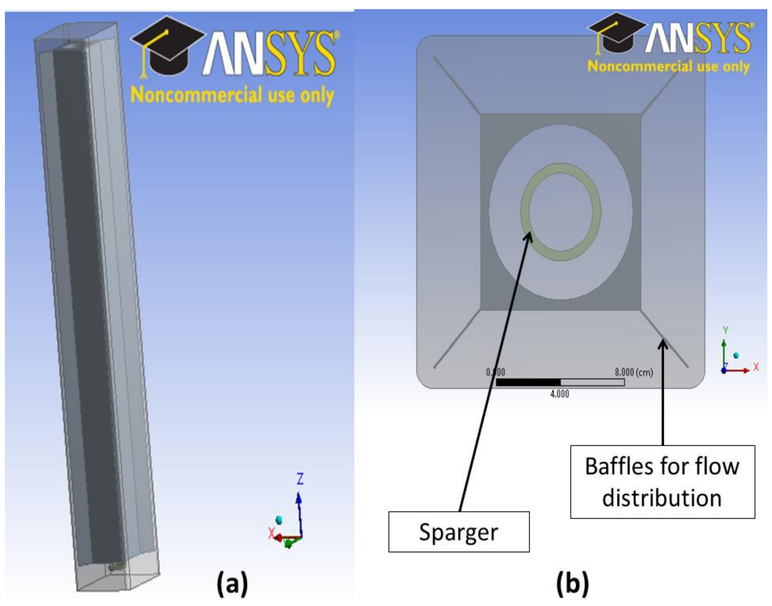
- PBR I: Standard air-lift reactor (Lou & Al-Dahhan, 2010)
- PBR II: Novel integration air-lift and flat plate (Soman & Shastri, 2014)
- CFD: Eulerian-Eulerian approach with k-ε turbulence modeling
- Light attenuation: Beer-Lambert model

Microalgae growth model: ODE model

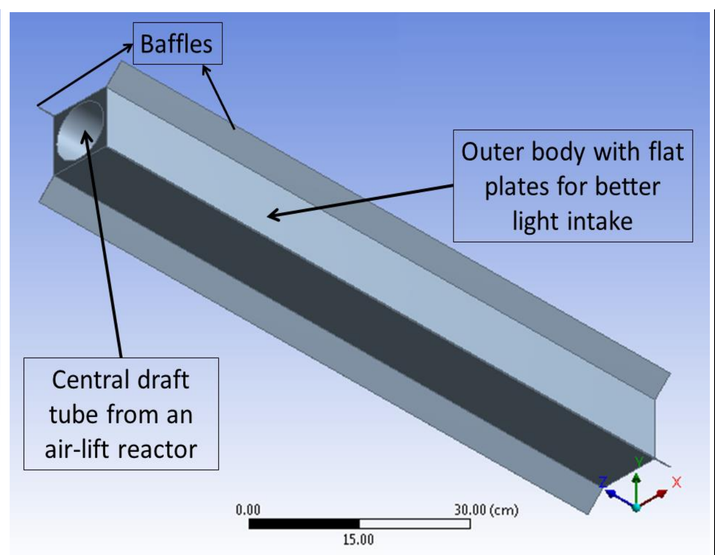
- Functional biomass
- Storage molecule
- Photosynthesis rate
- Extracellular nitrogen and carbon
- Intracellular nitrogen and carbon

Each computational cell modeled as a CSTR

Novel Photobioreactor Design and Simulation Approach



- 7% higher area to volume ratio
- Improved flashing light effect



- Possible higher capital costs
- Possible circulation dead zones

CFD simulation: Steady state hydrodynamics (FLUENT)

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Steady state particle trajectories, irradiance, and residence time

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Dynamic microalgae biomass growth simulation (MATLAB)

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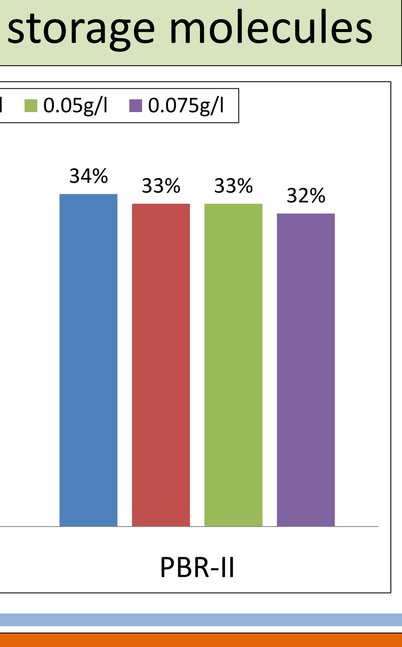
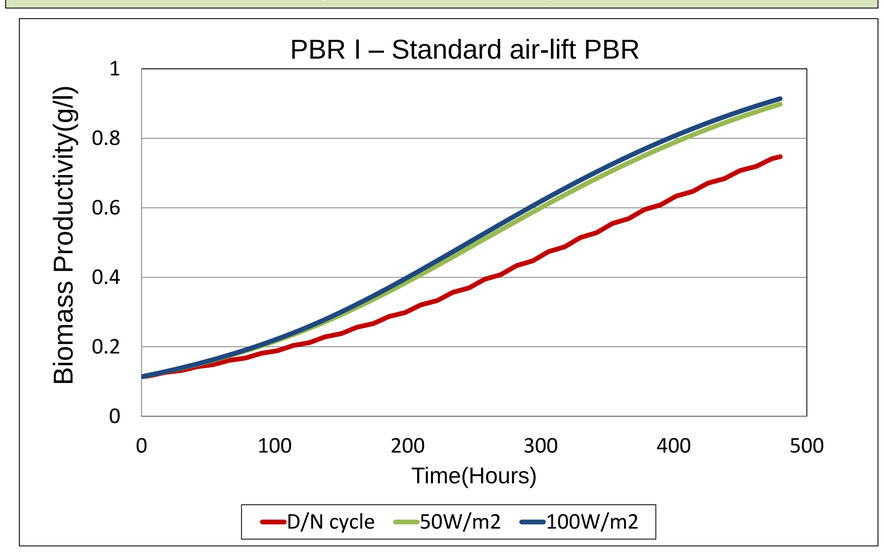
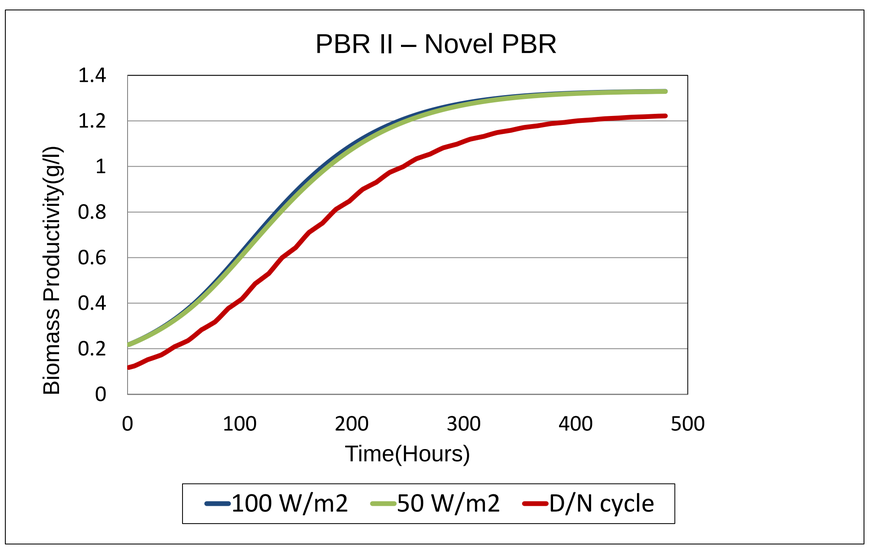


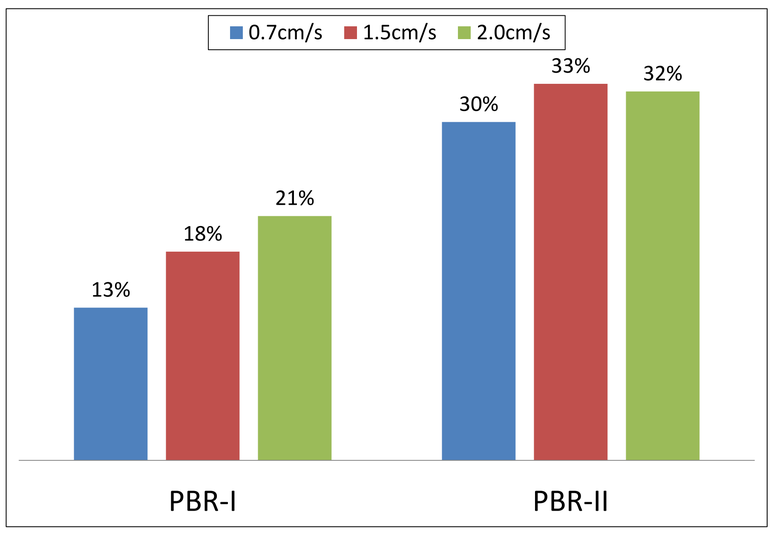
Results

Biomass productivity for PBRs





Effect of superficial air velocity and nitrogen content on storage molecules



Conclusions

- Computationally efficient simulation scheme to integrate CFD and microalgae growth model for PBRs
- Light attenuation comparable in both PBR designs
- Biomass productivity and lipid accumulation better in novel design
- Light saturation in the microalgae growth model needs to be addressed

Reference:

- A. Soman and Y. Shastri. *Applied Energy*, 140: 246-255, 2015
- H-P. Luo and M.H. Al-Dahhan. *Chemical Engineering Science*, 66(5): 907-923, 2011