Mechanistic model for design, analysis, operation and control of microalgae cultures: calibration and application to tubular photobioreactors

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Microalgae biomass production is an industrial sector that continues growing each year. Products made from microalgae are nowadays presented by industry as a natural and green solution to the energy, food, economic and climate challenges facing the Earth [1, 2].

Another potential market application of microalgae is their use in the context of wastewater treatment. Although this is not a new application, the feasibility of microalgae cultures for wastewater treatment and at the same time encouraging resource recovery and feedstock production has revived the interest on this technology [3]. Microalgae treatment systems are currently viewed as a future alternative to conventional activated sludge treatment plants, where produced biomass can be valorised in the form of biofuels or bioproducts therefore optimising treatment costs [4, 5].

Closed photobioreactors (PBRs) are usually used for the production of high-value microalgae biomass at higher productivities than in open ponds. A large variety of different PBRs have been developed to optimize the biomass productivity and photosynthesis efficiency. At the same time mathematical models for PBRs are also increasing in popularity for design of new systems and for improving understanding of the complex processes occurring inside. The aim of the present study is therefore the calibration of the new mechanistic model of Solimeno et al. (2015) [5] using experimental data from two different tubular photobioreactors. Fluid flow, transport equations and light attenuation were included in the model described in our previous work and implemented in COMSOL Multiphysics^{TM} software. The results of calibration indicate that the mass transfer of gases and the maximum specific growth rate of microalgae fit well within literature ranges.

Furthermore, the potential of the model is demonstrated by means practical study cases in which we simulate oxygen concentrations (the most critical growth inhibition factor of closed photobioreactors) and predict microalgae production as a function of temperature and light intensity. The model proves to be an efficient tool for photobioreactor design and production optimization.

Simulations show the potentiality of photobioreactor configuration to optimize microalgae production. The overall objective of this model is to become a reference to simulate physical, chemical and biokinetic microalgae processes in different types of photobioreactors fed with different types of medium cultures.

References

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