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Growth impact of hydrodynamic dispersion in a Couette–Taylor bioreactor☆

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ABSTRACT

The development of a distributed parameter model of microalgae growth is presented. Two modelling frameworks for photo-bioreactor modelling, Eulerian and Lagrangian, are discussed and the complications residing in the multi-scale nature of transport and reaction phenomena are clarified. It is shown why is the mechanistic two time-scale model of photosynthetic factory the adequate model for biotechnological purposes. For a special laboratory Couette–Taylor bioreactor with cylindrical geometry, we reached reliable simulation results using a steady-state Eulerian approach and the finite difference scheme. Moreover, we prove numerically that the resulting photosynthetic production rate in this reactor goes, for growing inner cylinder angular velocity, to a certain limit value, which depends on the average irradiance only.

1. Introduction

Biotechnology with a microalgae and photo-bioreactor (PBR) design is regaining attention nowadays thanks to emerging projects of CO_2 sequestration and algae biofuels. Nevertheless, there neither exist reliable methods nor software for modelling, simulation and control of PBR [1]. Modelling in a predictive way the photosynthetic response in the three-dimensional flow field seems unrealistic today, because the global response depends on numerous interacting intracellular reactions, with various time-scales. In our previous works [2–5], we examined an adequate multi-scale lumped parameter model, describing well the principal physiological mechanisms in microalgae: photosynthetic light–dark reactions and photoinhibition. Now our main goal is the development and implementation of a mathematical model of microalgae growth in a general gas–liquid–solid PBR as a tool in PBR design and optimization of its performance. Afterwards, as a case study, we simulate the growth of microalgae in a Couette–Taylor bioreactor [6], in order to validate our results.

2. Development of a distributed parameter model of microalgae growth in a PBR

Leaving apart the inherently non-reliable scale-up methodology for PBR design [1], two main approaches for transport and bioreaction process modelling are usually chosen [7]: (i) Eulerian, and (ii) Lagrangian. While the Eulerian approach, resulting in partial differential equations, is the usual way to describe transport and reaction phenomena in bioreactors, the

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