Growth impact of hydrodynamic dispersion in a Couette–Taylor bioreactor

Štěpán Papáček a,*, Václav Štumbauer a, Dalibor Štys a, Karel Petera b, Ctirad Matonoha c

a Institute of Physical Biology, University of South Bohemia, 373 33 Nové Hrady, Czech Republic
b Czech Technical University in Prague, Faculty of Mechanical Engineering, Technická 4, 166 07 Praha 6, Czech Republic
c Institute of Computer Science, Academy of Sciences of the Czech Republic, Pod Vodarenskou vezi 2, 182 07 Prague 8, Czech Republic

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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.

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1. Introduction

Biotechnology with a microalgae and photo-bioreactor (PBR) design is regaining attention nowadays thanks to emerging projects of CO2 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