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Experimental analysis and novel modeling of semi-batch photobioreactors operated with *Chlorella vulgaris* and fed with 100% (v/v) CO_2

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HIGHLIGHTS

- ▶ A novel mathematical model for the growth of *C. vulgaris* under high CO_2 concentration.
- ▶ The model is capable of simulating biomass concentration and pH evolution.
- ▶ The model is able to successfully describe and predict the experimental data.

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ABSTRACT

In order to viably scale up the microalgae based technology for CO_2 capture and biofuels production, suitable mathematical models should be developed. In particular, since the potential exploitation of flue gases as carbon source is one of the main targets of this technology, the effects resulting from such operating mode on microalgae growth, i.e. low pH values and high dissolved concentration of CO_2, should be properly simulated. Along these lines, this work addresses a novel mathematical model of the growth of *Chlorella vulgaris* in semi-batch photobioreactors fed with pure CO_2 (100% v/v). In particular, the proposed model simulates temporal evolution of cells, light intensity and nutrients concentration within the growth medium as well as carbon dioxide and oxygen concentration in the liquid and gas phase. Moreover, by taking advantage of comprehensive kinetics and considering the ion speciation phenomena taking place, the model is able to quantitatively describe the dynamics of pH evolution and its effect on microalgae growth. The adjustable parameters of the proposed model are fitted against experimental data obtained when starting from a specific set of initial concentration of nutrients in the growth medium. Then, the reliability of the mathematical model is successfully tested through the prediction of the temporal evolution of microalgae concentration and pH when using different initial concentrations of nutrients. Thus, the proposed model might represent a useful tool to develop suitable control and optimization strategies to improve microalgal cultures fed with high concentration of CO_2.

1. Introduction

The production of biofuels from renewable feedstocks is recognized to be critical to fulfill a sustainable economy and face global climate changes [1]. When compared to first-generation biofuel feedstocks, microalgae are characterized by higher growth rates and lipid content which result in larger bio-oil productivities. Moreover, cultivation of microalgae can be carried out in less- and lower-quality lands, thus avoiding the exploitation of arable ones [2]. In addition, cultivation of microalgae might be coupled with the direct bio-capture of CO_2 emitted by industrial activities that use fossil fuels for energy generation [3–6]. Ultimately, when compared to first generation biofuels, microalgae are characterized by a greater environmental sustainability and economic viability [7]. For these reasons, the potential exploitation of microalgae as renewable resource for the production of liquid biofuels is receiving a rising interest mostly driven by the global concerns related to the depletion of fossil fuels supplies and the increase of CO_2 levels in the atmosphere [8,9]. The high potential of algae based biofuels is confirmed by the number of recent papers available in the literature [10] on the subject. In spite of such interest, the existing microalgae-based technology for CO_2 sequestration and biofuels

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