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Short-term evaluation of the photosynthetic activity of an alkaliphilic microalgae consortium in a novel tubular closed photobioreactor

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Abstract A novel lab-scale tubular closed photobioreactor was developed and used for the assessment of the photosynthetic activity of an alkaliphilic microalgae mixed consortium under non-substrate limitation (i.e., bicarbonate excess), controlled irradiance, and mixing conditions. Two prominent haloalkaliphilic strains were identified as members of the consortium: *Halospirulina* sp. and *Picochlorum* sp. The photobioreactor (vol=0.5 L) consists of two interconnected U-shaped borosilicate glass tubes (internal diameter 2 cm) reaching a surface/volume ratio of 200 m^2 m^{-3}. This configuration specifically addressed the issue of the homogeneous light distribution among the microalgae suspended cells cultured by using fixed equidistant cool white light LEDs nearby the surface of the glass tubes. A soft homogeneous pneumatic mixing (i.e., airlift) was implemented in the culture fostering Reynolds numbers around 3000. The photosynthetic activity of the microalgae consortium was evaluated during different short-term kinetic assays by fitting the dynamics of the dissolved oxygen concentration to an oxygenic kinetic model. The photobioreactor operated in a closed loop allowed to control the produced oxygen by the extraction of the cumulated gas in the headspace. The use of this novel photobioreactor allowed the photosynthetic activity of microalgae suspended cells to be assessed, where the dissolved oxygen concentration and irradiance were the main parameters affecting the oxygenic rates under alkaline pH.

Keywords Tubular closed photobioreactor · Bicarbonate · Alkaliphilic microalgae · Oxygen production rate · Photosynthesis rate · Oxygen recovery

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Introduction

For millions of years, cyanobacteria and higher plants have performed the production of oxygen (O_2) and the fixation of inorganic carbon (CO_2) by photosynthesis (Campbell and Squire 2010), being the main organisms responsible for life support on Earth. Biotechnology has intensified this naturally occurring process by developing microalgae cultures under controlled conditions in artificial environments, known as photobioreactors. These systems can be operated indoor or outdoor and used for the production of biomolecules such as lipids, proteins, and carbohydrates, precursors of highly valuable products (Abomohra et al. 2013), and for the removal of nutrients and CO_2 from wastewater and biogas (Bahr et al. 2014). Equation 1 shows a brief summary of the relation between oxygen and biomass production when CO_2 assimilation is performed by a photosynthetic microalgae consortium that uses nitrate as a nitrogen source for growth (Bahr et al. 2014). The later stoichiometry is highly dependent on the metabolism of the microalgae strains and the culture conditions. Nevertheless, Eq. 1 can be used to obtain an approximation of the productivity of the microalgae based on the corresponding oxygenic rate.

$$10CO_2 + 2NO_3^- + 2H^+ + 7H_2O + \text{Light} \rightarrow 2C_5H_8O_2N + 14.5O_2 \quad (1)$$

The produced oxygen could be employed in any other oxygen-demanding process, from traditional aerobic processes to spacecraft (Muñoz and Guieysse 2006; Taub and McLaskey 2013; Bahr et al. 2014). Closed photobioreactors can be

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