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Research article

Development of a bench-scale photobioreactor with a novel recirculation system for continuous cultivation of microalgae

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A B S T R A C T

Microalgae cultivation can be used to increase the sustainability of carbon emitting processes, converting the CO_2 from exhaust gases into fuels, food and chemicals. Many of the carbon emitting industries operate in a continuous manner, for periods that can span days or months, resulting in a continuous stream of gas emissions. Biogenic CO_2 from industrial microbiological processes is one example, since in many cases it becomes unsustainable to stop these processes on a daily or weekly basis. To correctly sequester these emissions, microalgae systems must be operated under continuous constant conditions, requiring photobioreactors (PBRs) that can act as chemostats for long periods of time. However, in order to optimize culture parameters or study metabolic responses, bench-scale setups are necessary. Currently there is a lack of studies and design alternatives using chemostat, since most works focus on batch assays or semi-continuous cultures. Therefore, this work focused on the development of a continuous bench-scale PBR, which combines a retention vessel, a photocollector and a degasser, with an innovative recirculation system, that allows it to operate as an autotrophic chemostat, to study carbon sequestration from a biogenic CO_2-rich constant air stream. To assess its applicability, the PBR was used to cultivate the green microalga *Haematococcus pluvialis* using as sole carbon source the CO_2 produced by a coupled heterotrophic bacterial chemostat. An air stream containing ≈0.35 vol% of CO_2, was fed to the system, and it was evaluated in terms of stability, carbon fixation and biomass productivity, for dilution rates ranging from 0.1 to 0.5 d^{-1}. The PBR was able to operate under chemostat conditions for more than 100 days, producing a stable culture that generated proportional responses to the stimuli it was subjected to, attaining a maximum biomass productivity of 183 mg/L/d with a carbon fixation efficiency of ≈39% at 0.3 d^{-1}. These results reinforce the effectiveness of the developed PBR system, making it suitable for laboratory-scale studies of continuous photoautotrophic microalgae cultivation.

1. Introduction

Microalgae cultivation has been on the rise, due to their ability to fixate atmospheric CO_2 and produce a variety of valuable bioproducts, such as long-chain fatty acids, edible proteins, carbohydrates, pigments, antioxidants and specialized biopharmaceuticals (Jacob-Lopes and Franco, 2013; Singh et al., 2020; Kumar et al., 2020; Nie et al., 2020; Anerao et al., 2022). However, for some applications, especially when it involves human uses, the production of microalgae biomass demands especially controlled conditions to mitigate the presence of contaminants (both chemical and biological) and avoid endangering human health. This requires the use of closed photobioreactors (PBRs), as well as high purity CO_2, increasing costs and lowering sustainability, which has prompted continued interest in the development of new PBR designs for microalgae cultivation.

Over the years, different PBRs have been proposed and the design of these systems has been mostly shaped by their intended applications, type of analysis selected and type of microalgae cultivated (Fernández et al., 2013). Factors such as light efficiency, hydrodynamics, mass transfer and growth efficiency are the keys that drive both PBRs development and their operational strategy. Regardless, when concerning closed PBRs, three types are the most employed, namely tubular PBRs, flat-plate PBRs and bubble columns. These systems have a high surface to volume ratio, to facilitate light penetration and increase biomass productivity. However, they can also have limitations, such as improper mixing, resulting in mass transfer issues and cell sedimentation, and

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