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Review Article

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Microalgae and Photo Bioreactors: the Future Linked to CO_2 Capture

Pasquale Gabriele*

University of Salerno - Engineering for the Environment and Territory: Environmental Remediation and Technologies for the Ecological Transition

*Corresponding Author
Pasquale Gabriele, University of Salerno - Engineering for the Environment and Territory: Environmental Remediation and Technologies for the Ecological Transition

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Abstract

Carbon dioxide (CO2) emissions are the main issue underlying climate change and are harmful to human health. To reduce this concentration, the use of microalgae has been experimented.

Microalgae are the most important microorganisms in aquatic ecosystems for the global carbon budget they are essential for the capture and bioconversion of carbon dioxide (CO_2) into energy. The microalgae come grown in photo bioreactors, closed and open systems that allow microalgae to grow and absorb CO_2.

Another widely used type of photo bioreactor is the membrane photo bioreactor (MPBR). An important future development related to photo bioreactors and microalgae could be to merge the two types of systems, open and closed, managing to minimize system costs and allow scale cultivation industrial.

1. Introduction

Carbon dioxide (also known as carbon dioxide: CO_2) is a climate-changing gas fundamental importance in the vital processes of plants and animals. From its anthropic production uncontrolled would in fact result in an increase in the greenhouse effect (GHG) [1]. The increase in greenhouse gases is mainly due to human activity: industrialization, deforestation and urbanization are the main anthropic phenomena that cause the increase of greenhouse gases, a phenomenon that is causing temperatures to rise excessively, putting life at risk life itself on Earth and causing global warming [2].

It has been predicted that by the end of this century there will be a rise of around 5°C [3].

Currently, many physicochemical carbon capture strategies exist [4]:

• CCS: Carbon Capture and Storage operating on 3 phases' main ones which are capture, transport and storage of CO_2.

• Where possible, CO_2 should not be stored but used as a chemical component mica to add value to the production of other products. This is capture technology and carbon use (CCU: Carbon Capture and Utilization). There is another technology logy related to CCU: biological CCU (BCCU), an emerging technology that can be used through forestation or reforestation, ocean fertilization, cultivation of microalgae [5].

2. Microalgae and Photo Bioreactors

Microalgae are microscopic algae found in freshwater and marine systems. Depending of the species, their size can vary from a few micrometers (ÿm) to a few hundred micrometri [6]. Microalgae do not have roots, stems or leaves; they are able to perform photosynthesis and simultaneously use the greenhouse gas carbon dioxide to grow photoautotrophic ally (use of light and carbon dioxide) [7].

Microalgae are the most important microorganisms in aquatic ecosystems for the global balance bale of carbon, playing fundamental roles in the fixation of CO_2 [8].

Microalgae are also researched for the production of renewable biofuels, foods, animal feed and aquaculture, and other products such as cosmetics, pharmaceuticals, biofer-using [9].

Recent technical-economic analyzes on microalgae have suggested that the only possible way le to realize the potential production and fully utilize the biomass in a plant of an integrated bio refinery in which each precious component is extracted, processed and valorized to [10]. The photoautotrophic growth of microalgae represents an ideal model for reuse of CO_2 coming from the combustion gases of power plants and industrial activities [11].

Photobioreactors represent microalgae cultivation systems and are essential for the effective bioconversion of CO_2 [12]. Conventionally, microalgae have been grown in open ponds or closed photo bioreactors, both of which require large volumes of water and a high amount of energy input for the cultivation, harvesting and drainage of microalgae [13].

The global seaweed economy has been estimated to have an annual turnover of between 7 and 8 percent
billions of dollars [14].

Among open systems, two types are most relevant: open ponds and raceways. The ponds open are very simple systems with a giant rotating mixer in the center of the pond [15].

Raceways, on the other hand, have the direction of the water flow channeled and controlled by the rotation speed of the paddle wheels. Closed systems are based on photo bioreactors in which the gas is fed through a gas filter to avoid contamination [16].

There are many types of closed photo bioreactors, some of which are: tubulars (horizontal, vertical, inclined), polyethylene bags (big bags), panel photo bioreactors, helical photo bioreactors in the shape of a truncated pyramidal cone [17]. There is further technology that has multiple advantages such as simple operation, easy scaling, low energy consumption and no use of chemicals: such technology and membrane technology [18]. Membranes are generally used in closed or semi-closed photo bioreactor systems: a combination of photo bioreactor (PBR) and membrane and generally called photo bioreactor a membrane (MPBR) [19]. The MPBR can be classified as a carbon membrane photo bioreactorbohydrates (C-MPBR) and biomass retention membrane photo bioreactor (BR-MPBR) [20].

In the C-MPBR system the membrane enhances the release of carbon dioxide (CO_2) into the medium of cultivation, while in BR-MPBR, the membrane exerts a barrier to separate the solids of biomass from the liquid [21].

MPBRs, compared to conventional membrane systems, have some different characteristics. including a not too high sludge retention time (below 20-30 days ni) [22]. Therefore, there is no doubt that membrane technology can play a vital role in the intensification of microalga bio refinery processes, including cultivation, harvesting culture and drainage of microalgae [14].

3. Modeling of the Pilot Plant

Modeling means, in technical language, representing a system, a machine, a phenomenon, etc., using a model. 3D modeling (three-dimensional modeling), in the computer 3D graphics, and the process of defining a three-dimensional shape in a general virtual space installment on computer; these objects, called 3D models, are created using details software programs, called 3D modelers, or more generally 3D software.

A pilot plant is a process plant, that is, it is a plant that belongs to processing cycles transformation of small-medium sized industrial products used to replicate the behavior management of large industrial plants. The scale (i.e. the size and capacity) of a facility pilot and intermediate between laboratory scale and industrial scale.

The pilot plant to be represented and designed in 3D is based on CO_2 capture and production of biomass for energy through the cultivation of microalgae in a closed system (photo bioreactor to membrane).

SolidWorks software was used for the three-dimensional modeling of the pilot plant, a three-dimensional parametric drawing and design software, produced and marketed from Assaults Systems. The software provides the creation of 2D and 3D drawings of solids and surfaces, through a parametric and fully customizable geometric system.

The elements of the pilot plant that have been modeled in detail are: the vertical column tidal, the photo bioreactor, the membrane module, the 4 LED lamps, the 1 liter container, one shelf on which to place the 2 pumps and the container, and the pipes with the fittings. The other elements which complete the pilot plant are the CO_2 cylinder, the air compressor, 2 periphery pumpstaltics and 2 flow meters.

The absorption column is 2.9 meters high, has a maximum capacity of 8 liters, and an external diameter of 7 centimeters and is made with Plexiglas (PMMA) in the transparent part and in polyvinyl chloride (PVC) in the connecting parts between the transparent parts. The membrane photo bioreactor has a height of 60 centimeters (overall of 110 centimeters also considering the bottom part), one capacity maximum capacity of 40 liters, an external diameter of 30 centimeters and is made of Plexiglas (PMMA).

The membrane inserted into the photo bioreactor is made up of various parts assembled and joined together via bolts. The membrane frame includes a transparent central support and 2 transparent side supports in PMMA. Between these 3 elements, 4 Dacron sheets and 2 PVC plastic holders. Subsequently, 2 sockets for the tubes, 2 diffusers and 2 suction cups to keep the membrane firmly in the photo bioreactor.

For the simulation of the pilot plant process, it was necessary to use an additional software: Blender. Blender is a modeling, animation, video editing, composing software section and rendering of three-dimensional and two-dimensional images. It has features for fluid simulation, particle coatings, other nonlinear simulations, and creating applications 3D tions/games. The Blender software is rich in features and potential typical of advanced systems modeling data. One of the most important features is support for a large variety of geometric primitives (polygonal meshes, Bezier curves, vector fonts), or other character-Unique features are related to the use of the right mouse button to select objects (contrary to other

programs), to keyboard shortcuts. Blender, in the specific case of the pilot plant considered, is used to simulate two distinct processes. In the first process considered simulated, the countercurrent fluid in the vertical column meets the mixed gas, which moves always from bottom to top in the column. With the process there will be more solubilization of the CO_2 in the liquid phase, a fundamental phenomenon because the microalgae are in the liquid phase here and use this dissolved CO_2. In the second process considered permeate, a liquid obtained thanks to the use of the membrane and clearer than that in the photo bioreactor, through a tube tied to the membrane exits the photo bioreactor and is conveyed towards the container of 1 liter.

In the end, you will have a virtual representation of the pilot plant very similar to the real one, which it will allow you to study and understand in detail the various parts of the system and the various processes, everything thanks to Solid Works 3D and Blender software.

4. Conclusions

In recent years, important progress has been made in the development of photo bioreactors for the production duction and cultivation of microalgae biomass through the capture and use of CO_2. Processes combined with microalgal biomass allow the production of bio products and biocar-buranti, which have among the many advantages that of drastically reducing CO_2 emissions, therefore to reduce pollution [18].

However, such progress still faces many different issues related to different issues types of photo bioreactors, further improvements are needed especially on cost reduction of bioreactor design. Many studies have focused on closed photo bioreactors because the quality of the algal biomass obtained from these systems is better than the obtained biomass from open photo bioreactors [10]. The main challenges are related to minimizing the costs of the plant and to allow cultivation on an industrial scale. A further challenge could be to merge the two types of systems, open and closed, allowing large-scale cultivation and quality of very good biomass obtained. Finally, it must be underlined that virtual modeling and simulations are fundamental for study of a system because they are able to make some people understand it in a precise and simplified way processes that are not easy to visualize with the naked eye or that require a lot of execution time [23-28].

Figure 1: Helical photobioreactor in the shape of a truncated pyramidal cone (source: gicon.de)

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