Novel vacuum air-lift photo-bioreactor for microalgae production.

Alberto Brucato, Giuseppe Caputo, Franco Grisafi, Gaspare Marotta, Francesca Scargiali

Dipartimento dell'Innovazione Industriale e Digitale (DIID), Università degli Studi di Palermo

An innovative low-cost technology for microalgae production, currently under development at Palermo University, is described. The main ways through which the goal of costs containment is pursued are (i) the adoption of thin walled transparent tubing for the photobioreactor, and (ii) an evacuated-head air-lift system.

When compared to typical microalgae cultivation plants, in the present case there are two significant innovations: the top-evacuated Air-Lift system and the CO2 recovery/recycle section through mono-ethanolamine (MEA) absorption/desorption. Plant sections may be summarized as follows:

-Photobioreactor section: photobioreactor pipes are made of horizontal transparent pipes exposed to sunlight (outdoor system). The pipe construction material should be low-cost, characterized by high solar radiation transparency and sufficient UV resistance and, depending on their thickness and rigidity, may be either laid down on the ground (simply flattened and covered by a low-cost plastic protection cloth), or suspended on suitable pipe-racks.

-External loop Air-Lift section: the main components are the riser, the downcomer and the degaser. In the riser section, the medium coming from the photobioreactor ascends together with a CO2 gas stream injected through a suitable sparger. The separation between gas and liquid phase takes place in the degaser section. The gas-freed liquid phase descends via the downcomer and feeds the photobioreactor tubes.

-Withdrawal/Make-Up section: at the downcomer bottom a portion of the circulating microalgae suspension is withdrawn as a product stream, while fresh medium is fed to replace the liquid phase withdrawn.

-CO2 recovery/recycle section: this section comprises a chemical absorption column, a solar heater and a desorption flash separator. The low pressure gas phase coming from the air-lift degaser is fed at the bottom of the absorption packed tower, in which a mono-ethanolamine (MEA) water solution is also fed at the top. During the countercurrent contact with the liquid phase, the gas stream is freed from CO2 and from part of the water vapour, which are absorbed by the cold liquid phase. Oxygen reaches the tower top, where it is extracted by a vacuum pump. The spent liquid solution is sent to solar thermal panels, where it is heated to about 100°C: at this temperature the absorbed CO2 is released at a pressure sufficient for recycling it to the airlift, after cooling. The hot regenerated MEA-H2O solution is cooled-down and sent to the CO2 absorption tower.

-O2 rich stream: the almost pure oxygen stream obtained at the exit of the vacuum pump may be used as it is, for processes requiring O2 rich streams (e.g. oxy-gasification processes, incineration of toxic wastes, fish farming etc.), or further purified and compressed for medical applications. It is to be regarded in all respects as a microalgae co-product, being in the range of 1 kg of O2 / kg of algae biomass produced.

To the aim of providing a proof-of-concept of these ideas, a 500-liter pilot plant was built. This is presently being operated in semi-continuous mode under solar irradiation and external climatic conditions.