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Letter to Editor Open Access

Microalgae Biotechnology in Integrated Processes

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The bio-based processes have been an essential support in the consolidation of new technologies in the industry. The current scenario for the use of more sustainable production methods, i.e., with a lower carbon and water footprint, dependence on fossil fuels and energy, more efficient and economical, further highlight the role that biological and chemical industries can play in this field [1].

Thus, microalgae have been considered as an alternative resource for the production of a wide range of bioproducts for the near future [2]. There are, potentially, several reasons for these microorganisms become largely employed by the industry: have high yields of lipids and carbohydrates, which can be used for biofuel production, overcoming the terrestrial energy crops; microalgae can thrive in different environments, using, for example, industrial effluents for growth; produce numerous high value-added compounds, which all can be used for various markets [3].

Typically, industrial facilities based on microalgae are usually composed of stand-alone or minimally integrated configurations, where raw materials, energy expenditure, and product delivery are used separately, increasing operational expenses considerably [4]. For this process to develop into reality and become competitive, is interesting to integrate the microalgae production with new or existing large-scale facilities, aiming to leverage the implementation of microalgae-based processes. Recently, the concept of process integration has started to be used for recovery of several compounds generated from biomass or using raw materials from adjacent industrial units [5,6]. This way, there is a need for research and technological development at the industrial level to optimize integrated production processes, since they seek to reduce the use of energy and materials in the total chain, from cultivation to end-use [7]. This is an appropriate and innovative technological route to complying with green engineering requirements) [8].

This letter summarizes new trends and perspectives in process integration in the microalgae systems. Through these possible approaches, it can be achieved greater profitability and environmental sustainability. The contributions of this summary highlighting the role that microalgae biotechnology can play in the production of a wide array of products and energy.

At a facility level, two possibilities are considered for reuse, recovery and possibly recycling of surpluses: (i) mass integration and (ii) energy integration. This methodology combines several parts of process or whole processes, with partial or total integration [9,10].

Mass integration is an approach that provides an understanding of the global flow of mass within the process, including effluent minimization and water consumption. Different strategies of mass integration can be implemented considering the possible effects on economic and environmental impacts [11].

This can be reflected by the use of gaseous effluent streams from industrial combustion processes, rich in CO_2 and NOx in algal growth, thus allowing the input of inorganic carbon and nitrogen in microalgae photosynthetic cultures. On the other hand, considering that the microalgae can also be grown heterotrophically, the wastewater integration allows the supply of essential nutrients, such as organic carbon, nitrogen, and phosphorus, being assimilated efficiently by these microorganisms [12]. These two bioprocesses offer, therefore, a pathway for production of biomass and other metabolites using low-cost substrates and reducing the emissions [7].

At the same time, it is also possible to integrate water through its reuse, either directly as partially treated for use in other processes. According to Dunn and El-Halwagi [13], wastewater reduction and water conservation are increasingly essential issues from the environmental point of view because it is a primary resource in manufacturing processes. Therefore, the microalgae can play a valuable role in the treatment of waste and contribute to the water reuse, as well as nutrients cycling [14]. Already the energy integration deals with all forms of heat recovery, such as heating, power generation/consumption, and fuels [15,16]. This type of integration is realized due to the increasing demand for expensive equipment within industries, aiming to minimize energy consumption and to maximize internal heat recovery. Thus, biomass can be converted to energy using thermochemical processes to obtain electric power, syngas or biofuels, aiming to increase energy-efficiency [17].

Finally, it is also possible to simultaneously integrate mass and energy. Mass integration, more specifically gaseous effluents, can be made by conversion of greenhouse gases, mainly CO_2 in photobioreactors. The VOCs, oxygen and CO_2 unconverted that are produced metabolically, can be reused in a bio-combustion process as biofuels, oxidizers and nitrogen diluent, through energy integration [18,19].

In this sense, the different approaches and potentialities of process integration, when associated with the concept of biorefinery, could meet the requirements of a sustainable and economic process. However, they still need optimization, efficient integration, scaling up, and optimal strategy analysis. These issues are identified as opportunities to overcome them in future developments [20].

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