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THE ENERGY BALANCE OF SEPARATION OPPORTUNITIES IN MICROALGAE TECHNOLOGIES

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Algae technology is at the focus of international research and development, since it is a green technology that reduces emissions of harmful chemicals and can be considered as a renewable energy source. Carbon dioxide from stack gases and the nitrogen content of wastewater can be considered as food sources for plants and algae. The utilisation of carbon dioxide by algae technologies depends on the technical environment and logistics of teamwork. This technology is a new opportunity in Hungary for decreasing emissions. We grew algae populations to utilise the carbon dioxide from a refinery's stack gas in the continental climate of Hungary. Critical parameters of the technology are the concentration of the algae suspension and extract, because of high investment and operating costs as well as the long operation time, which determines the feasibility of the algae technology. Our specific aim was to separate the algae mass faster and more efficiently from the starting solution. The optimisation of separation operations and technologies took into consideration environmental and economic aspects.

Keywords: microalgae technology, separation, filtration, renewable energy source

Introduction

The utilisation of microalgae carbon dioxide fixation is an important area of international research and development. The absorption of certain technological exhaust gases is possible on the basis of the photosynthesis of microalgae. The absorption of carbon dioxide can reach a magnitude of hundred ton per hectare. C_{16}-C_{22} esters are formed in certain algae cells that can be used for the production of biodiesels. This method is thus capable of producing fuels from renewable sources [1-4].

Algae production is a promising solution amongst the alternative fuel production processes, because it requires of low specific area for growth and high reproduction rate [5-8]. Algae are considered to be one of the most efficient organisms on Earth due to their outstanding reproduction rate, and generally high lipid content. For example, they can double their biomass in 24 hours [9-12]. Their lipid content on average is 20%, but it can be up to 60-80% for certain species [7, 9, 13, 14].

Research into oil production from algae is primarily based on microalgae. These are photosynthesising organisms with a cell size of no greater than 0.5 mm. They can be utilised for carbon dioxide and nitrogen oxide fixation, because they convert these compounds in a photosynthetic energy conversion [15]. The end product of these processes contains a significant amount of solar energy stored as chemical energy.

Furthermore, considerable amounts of biodiesel can be obtained [16-19]. The composition of a microalgae cell depends on cultivation parameters. We tested the available and applicable species under local climatic conditions. Afterwards microalgae that passed the local environmental tests can be considered useable for production.

Research is being carried out into carbon dioxide fixation from technological flows at our institute [15]. The absorption of carbon dioxide and reduction of the release of other pollutants in wastewater using microalgae are being studied. Algae technology utilises waste gases and some environmentally harmful components from wastewaters as nutrients, and thus purifies the growth media. These specific pollutants provide excessive amount of nutrients for the algae, which results in the algae's exponential growth. In addition to the above-mentioned method of energy extraction, a number of research efforts [4, 5, 8, 10-12, 18, 19 25] are currently dealing with the alternative use of biomass produced in this way, and biomass residue that remains after processing. In addition to the above-mentioned advantages, the operating costs can be a limiting factor.

The most critical steps in the production of algae-based biofuels are the harvesting of algae (harvesting, dewatering, and drying), and lipid extraction, because of the high level of investment and operating costs. The main challenge of the technology is to reduce costs, which by in large originate from the separation steps that need to be minimised.

Figure 1: Closed grower systems at the University of Pannonia

Figure 3: Open grower systems at a refinery

Results and Discussions

Our research focuses on carbon dioxide fixation from technological flows. We designed and built various grower systems at the Department of Chemical Engineering of the University of Pannonia (*Fig.1*), as well as at a refinery (*Figs.2* and *3*). By utilising these technological solutions we conducted research into the production of biomass and algae-based products as possible renewable fuels.

The propagation and environmental tolerance parameters were examined along with the possibilities of developing the technology. During the experiments, the whole technological chain was examined providing the possibility to optimise the entire chain of operational steps. The utilisation of algae cultures in experimental photobioreactors is examined, together with the optimisation of the operational conditions both for both artificial and natural light with different substrate solutions. The various parameters for algae processing are also determined.

The foci of our work were the processing and separation operations. Critical points of the technology are the processing steps, such as concentrating the algae suspension and extracting valuable components (lipids). The extraction technologies are of importance because of the high costs of investment and long operation periods. From the literature [5, 10, 12, 15, 17, 22, 23], biodiesel is not yet comparable to fuel produced from petroleum, however the cost of algae technology is dropping. Furthermore, algae technology could become viable if we consider the cost of wastewater purification and flue gas adsorption, and the price of products obtained from microalgae. We need to consider

Figure 2: Closed grower systems at a refinery

separating possibilities and beyond by analysing gains and losses simultaneously.

Our specific aim was to devise densification and separation processes, which have low energy requirements and advantageous operation times. Furthermore, we defined useful components from algae and their optimised extraction, based on the optimisation of extraction techniques and other economical and environmental aspects.

Separation Opportunities

Harvesting can be carried out by microfiltration, ultra filtration, centrifugation, flocculation, sonochemical techniques, or some new techniques that are under development [21, 22]. In addition to chemical flocculation, clarification, and membrane separation procedures, special attention was paid to auto flocculation phenomena.

Forms of technology pay more and more attention to convert disposed waste into useful materials. The photosynthesising microorganisms, such as microalgae, utilise solar energy, rapidly reproduce, and do not require any soil to grow in. The biomass product contains solar energy stored in chemical bonds. To process the final product, the suspension, concentration, and extraction of the biomass are the most problematic parts of the methods of algae-based energy production. The main techniques for separation are mechanical operations (filtration, centrifugation, and settling), mechanical operations with admixture (flocculation and defecation), membrane operations (microfiltration and ultrafiltration), and other notable operations (sonochemical techniques, electroflocculation, and flotation). According to examples from the literature [9, 11, 15, 18], there are still only limited generally applicable and proven methods that can be used for biomass production with specific energetic goals.

Energetic Considerations

Increasingly diluted suspensions were examined during separation operations (*Fig.4*). Data from the literature [23-37] need to be brought to a common denominator for carrying out comparisons. For example, our results show that if we want to gradually treat more dilute suspensions using flotation, the energetic considerations can change by orders of magnitude.

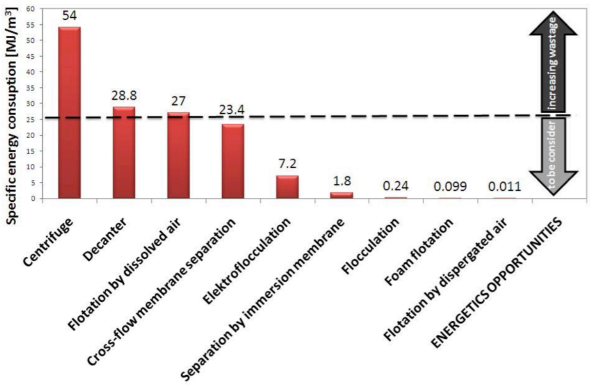

Figure 4: The energetic consideration of selected separation processes (the dashed line shows the energy content of algae suspensions on average of 25 MJ m^{-3})

According to *Fig.4*, cross-flow membrane separation, electroflocculation, centrifugation known as "spiral plate", immersion membrane separation, the flocculation, foam flotation and operation of the flotation by dispersed air are positioned favourably with respect to energetic rating (smaller demand of energy as the energy amount from the separated biomass).

The energy balances of chemical flocculation and electroflocculation do not include the costs of the procurement of chemicals and post-treatment, which would complicate the determination of its energy status. The amounts of chemicals used according to the quality of the suspension were between such wide intervals that they could not be considered using simple factors. By energetic rating, we should note the concentration of the kind of algae suspension in the chosen operation. The increase in volume and decrease in concentration of the suspension may require a review of the cost, materials and energy needs of the separation, and thus change its energetic status. For example, we can conduct a thought-experiment for flotation to see whether the treatment of a dilute suspension needs a device with a different energetic rating. Because of the fixed size of the flotation's device, we cannot decrease the amount of gas flow and the dilute suspension could start to foam, which may make it more difficult to handle than the stability and volume of the foam from a more concentrated suspension. Due to foaming, it will be more difficult for the algae layer to become thicker in the foam unless we use more chemicals and surface-active agents, which result in more parameters to consider. Apart from the above, an important question is how we consider the time domain of the technology (periodic, half-continuous, or continuous). The kind of growing system determines how to connect the separation operation. Half-continuous or continuous (or almost that) operation is beneficial for industrial biomass production to maximise the capacity of biomass. By running the reactor at the maximum rate of reproduction, we can maximise its capacity. According to the latter, the immersion membrane separation operation would be preferable.

Conclusions

According to our investigations, the usable operations for extraction and concentration in algae cultivation with regards to energetic causes vary greatly with respect to energy demands. For dilute suspensions, flotation and foam flotation are the most useful separation processes. We can use flocculation as well, but we have to consider the costs of and environmental damage caused by waste chemicals.

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