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Microfluidics for Bioengineering of Phytoplankton

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Editorial

Microalgae's position as a renewable and sustainable feedstock for biofuel, smart nutrition, biopharmaceutical, cosmeceutical, biosensing, and space technologies has expanded. They gather useful biological substances, such as pigments and carotenoids, from protein, carbohydrate, and lipid groups. Microalgal biomass, which can be used for multivalorization in biorefineries, can be used to make a variety of biofuels as well as other high-value biotechnological products. To optimise yield, quality, and the economic aspects of both upstream and downstream operations, state-of-the-art technologies are necessary. Because of their microscale sizes and dilute cultures, microalgae require microfluidic-based devices for both fundamental research and industrial applications.

Microfluidics-based devices outperform their competitors because they can sort and analyse small amounts of samples (nanoliter to picoliter) with higher sensitivity. We look at how microfluidic technology are being used in microalgal processes like cell sorting, cultivation, and harvesting, as well as biofuels, biosensing, medicine delivery, and nutrition. Microalgae have shown to be capable of producing high-quality renewable biofuel feedstocks and other high-value compounds. However, major advancements in microalgal biology and strain development, as well as downstream processing, are necessary to make microalgae-derived biofuels and bioproducts economically viable. The majority of microalgal research methodologies are based on traditional cell culture and cell handling equipment, which are bulky, labor-intensive, time-consuming, and throughput-limited. Microfluidic lab-on-a-chip devices can help enhance microalgal biofuel and bioproduction research by providing high accuracy and high efficiency cell/reagent handling capabilities, allowing for high-throughput experiments in a cost-effective and time-efficient manner.

Recent advances in the development and application of microfluidic lab-on-a-chip systems for microalgal biotechnology, particularly microalgae-based biofuels, are discussed here, including microsystems for single-cell resolution high-throughput cell identification and separation, highly efficient cell transformation, high-throughput parallel cell cultivation, cell harvesting, and cell analysis applications. At the conclusion, several microfluidic applications such as microalgae-based fuel cells and microalgae-based biosensing platforms are discussed. Finally, we discuss potential approaches for using microfluidic lab-on-a-chip devices to solve present hurdles and improve the current state of microalgal biotechnology.

In a bio-based industry that is concerned about high productivity in a certain high-value product, the most prolific microalgae species and suited conditions should be chosen to maximise the production of specified chemicals. The earliest investigations of microfluidic techniques for microalgae intended to investigate the properties of different strains and create microscale bioreactors in order to obtain the best strains and conditions. To produce microalgae and analyse their growth at the microscale, a variety of microfluidic screening platforms have been developed.

Microalgae, unlike other commonly studied biological cells like mammalian and bacterial cells, are usually planktonic rather than attached unless an appropriate habitat is given. Because microalgae are non-adhesive cells that are driven by streams, it is important to trap them in microdevices in order to investigate them at the cell level or to follow the same population during a continuous media flow. Mechanical traps, droplets, and microchambers are the three types of microscale or microfluidic bioreactors that can be categorised depending on their architecture. Microstructures constructed in flow channels to keep cells are called mechanical traps; droplet systems trap cells in water droplets surrounded by hydrophobic solvents are called droplet systems; and microchambers are microreactors in which cells are free in an enclosed environment.

Microfluidic droplets

The use of microfluidic droplets allows single or many cells to be enclosed in their own environment, simulating batch culture conditions. Droplets also make cell sorting simple and enable for high throughput. Microfluidic droplets have been used in a variety of studies, including microbial and mammalian cell culture, chemical processes, and protein crystallisation.

Microchamber

Microchambers are miniaturised photobioreactors that are used to develop a cell population. Culture scale is often bigger than earlier microfluidic devices, allowing for biomass-based analysis and results that are closer to bulk culture conditions.

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