How microalgae bind carbon dioxide and how they are used as sources for material and energy production

In comparison to other plants, algae grow quickly and produce large quantities of biomass. They generate a much greater mass per square metre than other energy plants. In addition, almost all algal biomass can be used as raw material for the pharmaceutical industry, amongst others. Therefore, a technology that is able to effectively produce microalgae on an industrial scale could make a considerable contribution to the energy and material industry as well as to climate protection. A company called GICON uses a photobioreactor based on the “Christmas tree” principle to successfully minimise the formation of biofilm, which inhibits the productivity of the algae.

In addition to rapid growth, another positive point in algae’s favour is the ability to effectively bind carbon dioxide and use it as a carbon source. Carbon dioxide can thus be bound at the very site it is produced, which reduces the likelihood of damaging environmental effects. Algal biomass accrued in a photobioreactor can be used in a variety of ways, including recycling as a raw material in the pharmaceutical and cosmetic industries, as a nutritional supplement, and for the production of fuels and animal feed.

These days, it is possible to industrially produce algae in a number of different ways involving either closed or open production systems. “Natural lakes and artificial open ponds are examples of open systems; tubular photobioreactors are closed systems,” said Heribert Krämer, head of Wet Fermentation at GICON GmbH, going on to explain that the profitable, industrial use of algae is still hampered by the low productivity of existing systems. In addition, economic efficiency decreases as bioreactors get bigger and a great deal of energy is required to produce biomass at the quality required. “We are unable to produce biomass of a reliably high quality when we try to use less energy,” said Heribert Krämer. “In addition, the productivity of existing bioreactors is limited as we are unable to effectively control the temperature. However, the formation of biofilm is by far the greatest hurdle for the industrial application of microalgae.”

Maximum yield through “Christmas tree” principle

GICON hopes to solve the aforementioned problems by developing a photobioreactor based on the “Christmas tree” principle named after the outer shape of the photobioreactor. “We have come up with a completely new concept of photobioreactor based on a biogenically designed flexible, tubular system,” explains Heribert Krämer going on to add, “the three-dimensional structure of the “Christmas tree”-shaped system enables maximum light efficiency at the same time as...
reducing shade and it does not require a great deal of space.” The evolutionary success of the light-capturing structure of a fir tree gives a clue as to how the system works. “In general, algae do not need bright sunlight for optimal growth; light on a cloudy day is usually sufficient,” said Krämer who is nevertheless taking pains to limit the occurrence of shade from system components in order to prevent any loss in biomass production efficiency.

The way the production facility is built also prevents the immobilisation of algae, and hence the formation of biofilm at the site where the light enters the system, using as little energy as possible. “In order to prevent the formation of biofilm, we had to find new substances to coat the tubes of the “Christmas tree” photobioreactor. We found that newly developed plastics were excellent substances for this purpose. We also had to improve the circulation of the algae,” said Krämer. The new technique enables the temperature of the bioreactor to be controlled without external cooling. This also means that the company can use the photobioreactor in different climate zones, which is another critical hurdle on the path to the industrial production of microalgae. The photobioreactor based on the “Christmas tree” principle therefore reduces maintenance costs and increases the productivity of algal biomass production plants.

What does the new technology promise?

Being able to control the process temperature reduces the cost of large-scale production facilities by around 30 per cent. This is made possible, amongst other things, by the fact that no greenhouses are required. In addition, the new photobioreactor enables the production of biomass at different predetermined levels of quality. “As the production process can be implemented at a constant temperature, it is possible to predictively control the carbon dioxide and nutrition requirements in relation to the algal growth rate, which is an important prerequisite for being able to use large-scale industrial photobioreactors covering a growth area of several hundred hectares,” said Heribert Krämer.

Huge demand for fast-growing microalgae strains

The development of a closed-cycle algal bioreactor is the basis for the development of new technologies. “The objective is to use carbon dioxide from biogas and other industrial waste gases and couple this process with the production of material and energy from the algal biomass. The methane produced can also be used,” said Heribert Krämer summarising the advantages of the innovative photobioreactor. In future, Krämer and his team will investigate microalgae strains in greater detail in minireactors operated under laboratory conditions that will be used to identify rapidly growing strains that are suitable for industrial application. “The focus has now shifted from cultivating individual algae strains to the optimisation of production. However, one needs to differentiate between simple cell growth and the production of particularly high-quality products,” said Krämer. GICON is currently also focusing on methods to process algal biomass, including cell harvest, cell disruption, isolation and purification, and how these methods can be further optimised with the aim of increasing the concentration of algae in algae mixtures and developing process technologies to specifically interfere with the algal cell membrane. In addition, further research is being done on developing cost-efficient nutritional media, the use of wastewater for the cultivation of algae, which would further reduce costs, and the integration of waste heat from biogas and combined heating and power plants into the production of algae.

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