Microalgae – the factories of the future

September 9 2014

Biology professor Ralf Kaldenhoff is making microalgae fit for industry. The microorganisms could produce a variety of products from carbon dioxide and light.

The brilliant green broth with the equally green cubes of jelly looks like a food from the future. Ralf Kaldenhoff, Professor for Applied Plant Science at TU Darmstadt, stirs the concoction and says: "You could theoretically eat this." But the soup and its content have a higher goal: it contains microalgae that could stop global warming. But why are they cube-shaped? This makes laboratory work easier, explains the scientist, because the cubes can be easily picked out when the nutrient medium needs to be changed.

Kaldenhoff has been working with microalgae for 1½ years. But he has already been studying photosynthesis, the basis of their metabolism, for two decades. "Photosynthesis is the only biochemical process that removes large quantities of carbon dioxide from the atmosphere and transforms them first into sugar and then into many other substances", he says; he also believes that industry should follow this example – in this way, industry would bind the greenhouse gas carbon dioxide during the manufacture of many products instead of releasing it. Therefore, his vision is to produce pharmaceutical ingredients, basic chemicals and other substances using microalgae in the future.

These potential saviors of the world's climate are just a few micrometers in size and should not be confused with their larger cousins, the macroalgae, which we find in our sushi. Microalgae can be found nearly everywhere, explains Kaldenhoff: "From the North Pole to the South Pole, and even in deserts." According to estimates, there are over 100,000 species, but not even a hundred have been studied in detail.

The TU laboratory contains, for example, the spherical unicellular alga Chlorella and the especially small Nannochloropsis, which makes itself at home in saline brackish water. The Darmstadt scientists also work with the easily cultivatable blue-green Spirulina – even if it isn't an alga, but rather a cyanobacterium formerly known as blue-green alga. Haematococcus is another exception: if there is a lack of food or too much sunlight, it switches its photosynthesis off, goes into a type of hibernation and produces red dyes, including the strong antioxidant astaxanthin. This not only protects the stressed-out alga from too much UV light, but has also proven to be healthy for people.

Antioxidants, vitamins, all essential amino acids – algae naturally produce many substances that are of use for people. And they can do even more: Kaldenhoff and his team genetically modify the green microorganisms in such a way that they synthesize substances that they cannot naturally produce. The researchers have already injected human gene sequences that control insulin production into the genomes of algae – in this way, the diabetes drug can be obtained from algal cultures. The procedure is also useful for producing vaccines. To do this, the scientists place virus genes in algae, such as the gene sequences that contain the blueprint for proteins in the virus envelope.

The genetic engineering of algae is not as well established as that in bacteria or yeast cells. This is what makes it exciting, finds Kaldenhoff. Although he and his team are still working on the basics, they already have an eye on future applications. Another goal of their research is to find out under which conditions a certain alga grows best. Some can tolerate a lot of light while others can't. Some need only a little iron while others need more. Temperature and water quality can also influence growth.

In order to cultivate particularly large algae, Kaldenhoff uses the knowledge he has gained in researching higher plants. For example, he works with so-called aquaporines, pore-forming proteins in the cell membrane that – according to established professional thinking – regulate the entry and exit of water. But Kaldenhoff is convinced that "some aquaporines control the permeability of carbon dioxide, not the water balance. This is a very exciting field that is still controversial." The Darmstadt-based researchers have already shown that genetically modified tomato and tobacco plants that form more aquaporines grow better. They can now see the same effect in chlorella algae. While their normal diameter is three to five micrometers, they were four to five times as large after genetic engineering had stimulated aquaporine production.

Kaldenhoff and his team are working not only on the performance of the algae, but also on facilities for their cultivation. In Asia and South America, open ponds are quite common for the commercial cultivation of algae, such as for the production of food supplements. Kaldenhoff is critical of this concept: "Reliable production can be achieved only with defined cultures in closed liquid circuits." Tanks, tubes or flatbed systems – when Kaldenhoff is studying which systems are best-suited, he starts acting like a designer. He has just attached spiral acrylic tubes to a wooden frame. Are the flow conditions correct? Are the algae in the tubes getting enough light? The team will now test this and more.

The biology professor is planning larger scale facilities together with partners. He recently co-founded the company ALYONIQ (see below). Furthermore, the first joint projects at the TU are getting started. "The nice thing is that colleagues from other disciplines are interested in our algae projects" enthuses Kaldenhoff. His vision: an algae facility that is connected directly to the TU's combined heat and power plant so that its carbon dioxide emissions can be reduced even further. For this undertaking, algae scientists, system constructors, professionals for light and control technology as well as experts for flow behavior and climatization have to work together. With its expertise in these areas, the TU Darmstadt offers the best conditions so that the small algae can make a big splash.

LEDs instead of sunlight

In nature, microalgae grow with sunlight. In industrial facilities, they can also be artificially illuminated. Algae researcher Ralf Kaldenhoff is working together with his colleague Tran Quoc Khanh, Head of Lighting Technology, on LEDs for algae facilities. The goal is optimum photosynthesis performance with minimum power consumption; in addition to other parameters, the efficiency of algae cultivation depends primarily on the power requirements of the lighting.

Furthermore, Kaldenhoff has founded ALYONIQ AG together with partners from the private sector; this company is currently focused on the development of algae cultivation facilities. ALYONIQ is planning to build a pilot plant in Griesheim. The space for this has already been found; now the spin-off from the TU Darmstadt is looking for investors.

Provided by Technische Universitat Darmstadt