FROM MICRO-ALGAE TO BLUE OIL

Micro-algae are driving a small technological revolution. Their cultivation marks a new era in the production of biofuels, reinventing industrial processes as well as economic models. In the United States and Europe, several projects are now moving from an experimenting phase to actual operation.

Cultivation of phytoplankton and specifically of cyanobacteria may be in its infancy, yet it is one of the most promising areas of the biotechnology revolution. These single-celled microscopic organisms develop through a photosynthetic process similar to that of plants, which effectively makes them tiny biochemical factories; in nature, they actively participate in the regulation of CO2. Marine phytoplankton is responsible for more than half of the total CO2 fixation on our planet, and cyanobacteria, which are among the oldest living forms, were even the root of a phenomenon known as the Great Oxygenation Event (GOE) about 2.4 billion years ago: the opposite of the climate crisis threatening us today, with an imbalance of the atmosphere towards increases in oxygen.

Micro-algae develop at a pace that is significantly higher than that of most terrestrial plants: some of these unicellular organisms need as little as 24 hours to divide by mitosis, time and again. Being autotrophic (capable of producing organic matter by operating a reduction of inorganic matter), the sole contribution they require to multiply is that of light, water and CO2. In the process where they are operated industrially to produce biomass, their performance is well above that of terrestrial plants.

Even before taking into account any operations of genetic engineering, nature already has more than 30,000 known species to offer, some of which are both particularly rich in fat and particularly quick to grow.

Cleaning and production

Such remarkable diversity remains insufficiently explored, but we already know that the possibilities brought about by the cultivation of microalgae and algae in general are many. Cultivation can be carried out in a variety of environments, be they closed or open, natural or artificial, and with different purposes: cleansing the environment by benefiting from the capacity capturing carbon (algae and micro-algae) and elements such as nitrogen (algae), or otherwise producing biomass.

~~Patrick Kangas~~, professor in the Department of Agriculture and Technology of the University of Maryland, is the instigator of a project to clean up the Chesapeake Bay, while by the same token providing raw material for biofuels. In the fragile and polluted environment of this almost closed-up lagoon, algae proliferate and contribute in creating dead zones, which are oxygen-poor and harmful to aquatic life. However through the culture of seaweed in a controlled system, plants can cleanse the water of its contaminants. In this particular case, filamentous algae will be used.

More ambitious is project Salinalgue developed by the Competitiveness Cluster Mer – PACA, that regroups thirteen partners in a private-public consortium (among these is GDF Suez, one of ParisTech Review's sponsors). This project aims at producing microalgae grown in halophilic environment over vast lagoon expanses. Its first objectives are of an environmental nature, especially regarding bioremediation (natural sequestration) of industrial CO2 in an economic and legal context marked by the emergence of a carbon tax and the need for European companies to offset their carbon emissions. In this respect the culture of algae brings solutions.

The coastal wetlands of southern France constitute a particularly favorable environment for the development of seaweed farming. They are historically involved with salt production and are in search of conversion; they offer vast untapped expanses but also a large pool of production of industrial CO2 in the vicinity (Fos-sur-Mer). The natural occurrence of micro-algae (*Dunaliella salina*) allows for exploitation of this CO2 while also producing biomass. After a thorough study in an area of 1000 to 1500 m2, there are plans to exploit 20,000 hectares (50,000 acres) of saltworks.

What to do with the biomass thus produced? Among the possible outlets are sales for aquaculture (to feed fish and shellfish), but also substitutes for fish oils. Rich in fat, microalgae can also be used to produce vegetable oils, which can be transformed into vegetable oil methyl esters, or in layman’s terms, biodiesel. Such is the niche that Salinalgues has positioned itself into, especially because the nearby Fos-sur-Mer site is home to major refineries. Biorefining, which converts biomass into ethanol, requires treatment with CO2, and once more the presence of industrial CO2 constitutes a resource.

Industrialization could take place as soon as 2015. Other projects, involving the production of biofuels in Europe and the United States, are already in operational phase. And the most interesting one is, undoubtedly, the production of artificial petroleum.

Oil’s whole cycle recreated in just two days

The vast majority of the oil existing today actually comes from micro-algae and was formed from their decomposition.

Under certain conditions (deprivation and stress), some species may accumulate from 50 to 80% lipids. This raw material naturally turned into oil in a process that takes tens or hundreds of millions of years: a layer of organic material, covered with sediment, undergoes an increase in temperature and pressure until it eventually turns intokerogen. If certain conditions are met, including temperatures in excess of 50 °C (120 °F), the kerogen is pyrolysed, producing oil, natural gas, or coal.

The main factors of this transformation are pressure and temperature: high pressure and high temperature, applied to a paste made of microalgae biomass, can thus accelerate the cycle. At the initiative of a French engineer, Bernard Stroïazzo-Mougin, a Franco-Spanish team has successfully developed an experimental process and then an industrial one to reproduce the cycle of oil in just two days. Not only does this bio-oil have the ability to burn just like crude oil, but it also has the added advantage of not containing sulfur nor any heavy metal elements almost always present in natural deposits – which are highly polluting.

The very first artificial oil plant was launched in 2010 in Alicante, Spain, and the start-up Bio Fuel Systems (BFS) is producing oil since March 2011. The facility is located near a cement plant rejecting the CO2 indispensable for such an operation. Intensive cultivation of microalgae and the massive absorption of CO2 take place in closed loop environments and in vertical photobioreactors to optimize implant surfaces, to better control physical and chemical properties of the farming environment and to attain maximum profitability.

The goal of this plant is to eventually produce 230,000 barrels of oil per year over an area of 100 acres. A figure that is still small and which corresponds to the consumption of about 20,000 Europeans. Yet, the big oil companies are showing keen interest in the process and Exxon, the world's No. 1 in the industry, is said to be ready to invest heavily.

Do algae fuels have a future?

One of the advantages of these "third generation" biofuels is that compared to the first and second generations, derived from vegetable oil obtained from terrestrial plants, they do not compete with food crops and therefore do not consume arable land.

Microalgae are unrivaled in terms of biomass production capacity, both in terms of the high and steady pace of this production, but also regarding the specific quality of such biomass, which is free of lignocellulosic compounds (these provide the rigidity of terrestrial plants, from ear to tree). These characteristics make them especially suitable for industrial exploitation.

In addition, production can be carried out in natural settings but also in tanks or in cylinders, almost without contact with the environment, and with a vertical use of space limiting the footprint's surface. BFS' photobioreactors are eight meters tall (25 feet) and have been specifically designed to optimize the ground coverage and productivity per hectare.

There are limits, however, which are of several kinds.

The first is the dependence to the sun, which can incur variations in the production cycles. But solutions have already emerged: the company Fermentalg for instance, has recently developed a process to culture in the dark, with high yields.

The second is the rapid fouling of the tubes that happens in closed loop cultures. But again significant progress has been achieved and BFS' cylinders, for instance, are self-cleaning.

Biorefining is one of the areas where there is room for improvements, and they are necessary. In the case of Salinalgue this is also a major issue for R&D, which is conducted under the authority of the *Green* laboratory at the University of Avignon. The processes for liquid extraction and fractionation of algal oil are given special attention, with an imperative on the development of clean and energy-efficient processes.

More generally the question of production costs arises, especially when the competition from fossil fuels is taken in consideration. While the production of “blue oil” and algae fuels is now too marginal, too close to the experimental stage, for a comparison with conventional oil to be possible, it is still far from equivalent. Figures vary, but the most optimistic estimates indicate production costs that are two or three orders of magnitude higher on the side of algae fuels. Today, a barrel of blue oil today would thus amount to 30 euros.

Complex and integrated solutions

However Fermentalg and the Alicante plant have something in common: they don’t limit themselves to producing biomass or blue oil. Part of their revenue originates from the sale of beta-carotene and fatty acids like omega 3, which are extracted by pressing and filtering at the beginning of the process, and these are currently trading at around 100,000 euros per ton.

Here we approach what is perhaps the most interesting part in this story: the complexity of industrial models and beyond that, of the economic models implemented to develop this brand new activity.

The production of biofuels from microalgae is part of a multi-product and multi-input structure. The basic model is as follows: among the inputs is industrial CO2. Among the outputs of the biomass are products with high added value (omega 3, etc.) and the basis for biofuels.

And yet this model can be further refined. In Shenandoah (Iowa), Green Plains Renewable Energy and BioProcess Algae Project combines the production of microalgae with a pre-existing corn ethanol production. The microalgae are used to clean residue and to enrich the first-generation biofuels… all while benefitting from the heat produced by the very same refining of these fuels.

What is being invented here are complex uses, looped industrial processes where inputs are outputs and vice versa. Refining heat is reused to grow algae, which feed on waste from ethanol production, and which are then consumed as raw material by the same production. Therefore what we are beholding here is nothing short of a life cycle grafted onto an industrial process, a circularity whose motion brings an uncanny boost to the traditional input-ouput logic.

Similarly, the cost of the raw materials used in the production of microalgae can end up being negative. Indeed, within the framework of European carbon credits, which imposes quota management on industries, the company supplying CO2 may actually make a profit from the tons of carbon saved, and may be willing to pay for the consumption of this carbon. This, clearly, is one of the major stakes in the emerging industry of algae fuels production, which anticipates the future establishment of a carbon-economy by inventing a new value chain.

Paths to improvement

The economical and industrial inventiveness of this industry's stakeholders is really remarkable. But much remains to be done for the present experiments to give rise to real industrial lines.

There are at least two areas where substantial improvements are expected, which will not change the essence of the model but should allow it to function better.

The first area has to do with biology. There is much to be done on this point, first, regarding a deeper exploration of biodiversity and an improved selection of species best suited for different types of production. Second, regarding the control of their metabolism in order to obtain the best yields. Genetic improvement is obviously one of the most promising leads. As in the case of transgenic maize, the question of contamination risks for the environment and of potential harm to biodiversity will naturally arise. This is consequently a major research issue, beyond the sole expertise of genetic engineers.

A second area is the engineering of processes: be it in production or in extraction and refining, we are still in an era of experiments and vast progress is more than possible. On this point industrial companies are already very active, but they are still few. The expected growth of the sector and the arrival of investors are liable to stimulate this field, to increase competition and to allow for rapid and significant increases in productivity. This is not the last we'll hear of microalgae.

Source : http://www.paristechreview.com/2011/12/01/micro-algae-blue-oil/