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A fighting chance

As Europe gets ready to implement a 7% cap on first generation biofuels, their second generation counterparts are tipped to be the real winners

Ready for the spotlight

Cellulosic ethanol is ready for prime time use by billions of consumers around the world

Policy uncertainty slows US biodiesel trade

Regulatory setbacks have prompted producers to scale back their output

Special focus: first generation production

How a photo bioreactor is helping to solve many challenges in the development of algal biofuels

Solving algae's problems

Biodiesel fuel is based on long-chain mono-alkyl (methyl, ethyl, or propyl) esters derived from plant oil or animal fat. These fatty acid esters are usually formed by reacting alcohol with the lipids extracted from the oil or fat.

The world's petroleum oil reserves are finite, but global consumption continues to increase even as prices have risen sharply. Accordingly, renewable sources of fuel, such as biodiesel, are required to support and expand the global economy. Moreover, they must also compete on a cost-basis with fossil fuels in order to gain market acceptance.

There are many sources of plant oils that have been used to create biodiesel, including soyabean and rapeseed, but these often compete with food crops for desirable farmland and other resources, driving up the price for both the food and biofuel. In addition, the growth cycle for many plant crops is relatively long, usually lasting several months.

What is needed is a renewable, inexpensive and quickly regenerated source of lipids, which will ensure the production of inexpensive and readily-available biodiesel on an essentially unlimited basis. Enter microalgae.

The potential of microalgae

Algae are classified as either macroalgae (such as seaweed), or microalgae, which are generally single-celled photosynthetic organisms (i.e. single-celled plants). Certain strains of microalgae can contain lipids of up to 70% or more, greatly exceeding the oil productivity of the best producing terrestrial plants.

These lipids are readily harvested by squeezing in a large press, often followed by extraction with hexanes. Pressing alone can extract up to 75% of the available oil in the algae; the hexanes-extraction method raises that to as high as 95%. For the purposes of this paper, all further discussion of algae will refer to microalgae.

Thus, algae has a lot of potential as a feedstock for biodiesel production. It is completely renewable and grows much faster than other plant sources of lipids, producing high-volume, high-lipid-density material; with many harvests (crops) per year per acre (doubling time can be as fast as 3.5 hours). It grows and produces the desired by-product (analogous to fruit of the corn plant) without need for additional complex or expensive nutrients or amendments. It is easily managed in bioreactors and raceway ponds, and is also harvested quite easily.

Algae also grows in extreme conditions, such as arid, hot climates not otherwise suitable for plant crops. Although it does require water as a growth medium, this water can be conserved and reused through careful design and engineering of the production facility (again, raceway ponds or fully contained bioreactors). Finally, as previously noted, algae does not compete with food crops for land and other resources, such as corn, sugarcane, or other cellulosic ethanol crops.

Getting started

With over 70,000 known species of algae (and some estimates are much higher), it is important to select the best one(s) for a desired given product (e.g. lipid for conversion to biodiesel), reactor type (raceway pond or closed system bioreactor) and production conditions (local climate and sunlight, for the case of an outdoor raceway). Further, it is important to determine the conditions necessary to optimise production. This often involves feeding trace nutrients, adequate delivery of carbon dioxide (e.g. proper aeration and mixing), pH, temperature, and more. Thus, there are several challenges involved in culturing algae for producing feedstock for biodiesel.

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There are really two types of approaches that can be followed. Fortunately, many strains of algae which produce lipids in high concentration are already known. One approach is to simply choose the one (or several) that perform best in a specific climate (if using a raceway) or a known prolific producer and design a closed system reactor for that strain.

In either case, the best strain and production conditions cannot be known without preliminary testing under conditions that mimic those of the production system (including climate for outdoor raceways), something that is not generally easy to do with a high level of predictability. In essence, preliminary testing under conditions that accurately mimic production conditions and predicted yields allow optimisation of the system design and infrastructure before building the facility and incurring significant capital expenditure (CAPEX).

Alternately, another approach is to select indigenous, perhaps previously unknown species of algae for production at a specific site, under local conditions, to produce algae with high lipid concentrations. New species of algae with unique characteristics and commercial potential are being discovered every day.

But how can the production system then be prepared to efficiently produce the most algae possible in the most cost-effective manner? Unfortunately, it is not as

easy as conducting some experiments with Erlenmeyer flasks or aquariums to get an idea of the process. This is because these crude types of experiments just do not provide the levels of controls and metrics needed to scale-up to commercial reactors.

For example, a hard learned lesson from the industrial fermentation industry is the general lack of scalability of fermentation processes. What that means is that small-scale discovery-sized culture conditions do not scale accurately to intermediate and production scale. You simply cannot extrapolate from an Erlenmeyer flask, Petri dish, or even an aquarium to yields in a production scale reactor. Doing so often leads to the requirement for post-build design changes, thus significantly decreasing efficiency and increasing CAPEX and time.

With that, sub-optimal or less-than-desirable strains might be incorrectly used for production, and/or production facilities designed around this sub-optimal strain, because a rapid and reliable tool for discovering and characterizing indigenous strains and optimal growth conditions was not available – until now.

Technology

The PBR101 (Figure 1) from Phenometrics, was specifically designed to overcome the aforementioned limitations encountered with setting up large-scale mass production facilities. It provides step-by-step individual selection of algal strain and corresponding production parameters under highly-controlled experimental conditions, all monitored and recorded with an easy-to-use software package, Algal Command. This allows optimal determination of many key factors, including:

- Selection of the best producing strain for a given production facility and/or local environment
- Rapid exploration and optimisation production conditions
- Accurate prediction of scaled production at the lab bench
- Clear path to scale-up, significantly reducing CAPEX risk and time, while optimising growth, production and return on investment (ROI).

This is achieved by allowing for the selection of various experimental options and controls that accurately mimic production conditions, including:

- Programmable diurnal light cycles and light intensity
- Programmable temperature cycles
- Real time pH monitoring and control
- Programmable addition of gases (such as carbon dioxide)
- Variable mixing
- A custom-designed 2-channel pump for continuous-flow turbidistatic cultivation
- Real-time growth monitoring
- Algal Command software permits a wide variety of additional customisation by the user of Java scripting.

All of these may be performed using a single PBR101, or via a matrix of several systems for faster experimentation, concurrently comparing different conditions and/or algal species (Figure 2). Up to 256 individual PBR101 systems can be linked and controlled from one computer, providing independent yet simultaneous control and data collection for each. This highly controlled environment provides a detailed level of experimentation that is not possible with any other algae cultivation technologies.

And in order to help drive the realisation of algae-derived biofuels, the PBR101 has been designed to be affordable, and therefore widely available. Several hundred units are already in service worldwide today.

The Phenometrics PBR101 is a suitable tool in maximising by-product yield from algae and directly up-scaling to production, whether raceway or closed system bioreactor. It is also ideal for use in the discovery of novel species from a particular climate, but which are as-yet uncharacterised – and estimates suggest that up to millions may actually exist.

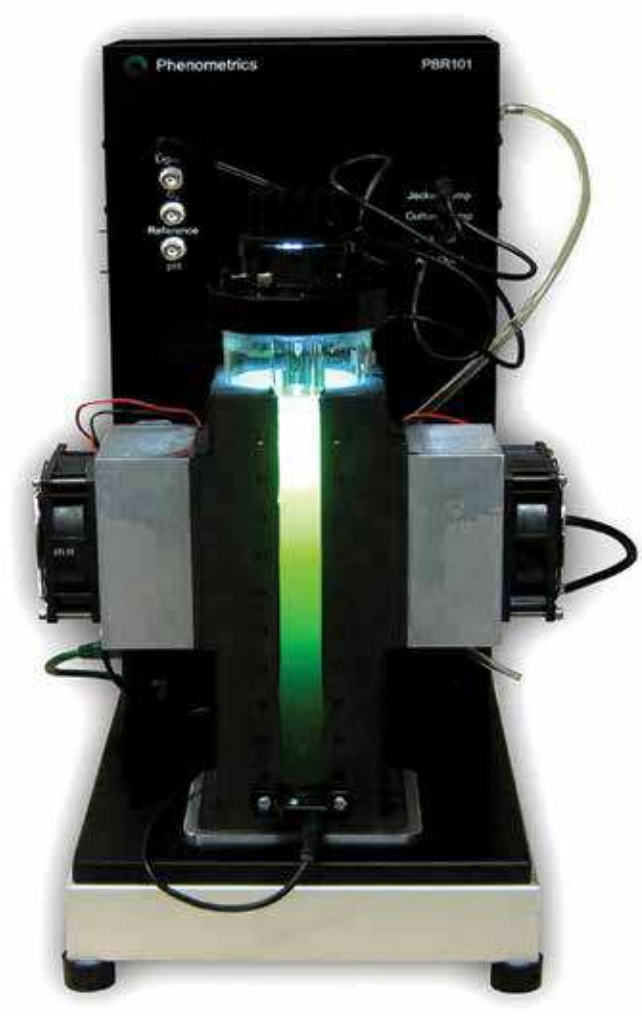

Figure 1: The PBR101 from Phenometrics

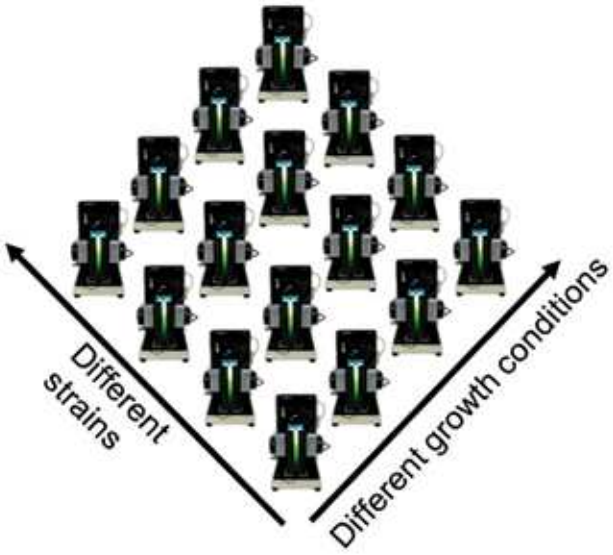

Figure 2: A matrix of several systems provides faster experimentation

For more information:
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