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ALGAE CULTIVATION FOR ENERGETIC PURPOSES, RESEARCH ON ALGAE TECHNOLGY AT THE UNIVERSITY OF PANNONIA

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Biotechnology and renewable materials are very popular research projects nowadays. The increasing attendance of industrial participants enhances the significance of these projects. We started cultivating microalgae a few years ago. Under the supervision of our biologist partner and based on the literature, we built our photobioreactor system on a laboratory scale. Our first objectives were algae cultivation for energetic purposes in addition to carbon-dioxide capture. It is reasonable to conclude that the extraction of bioactive compounds is worth consideration.

Keywords: alga technology, cultivation, lipid

Introduction

Driven by the rising need for biofuels and the necessity to capture carbon dioxide, autotrophic organisms got into the spotlight of energetic research. With the cultivation of these organisms we can feed back the carbon content of CO_2 into biological systems and we are able to get a number of valuable organic compounds – among other biofuels – to reach ecological and economical benefits. [1]

Algae production is the most promising solution amongst the alternatives due to its low specific needs of land use and high reproduction rate. Additional benefits are that there is no need to use agricultural land and some wastewater may be used for nutrient supplementation.

We have studied the technology of algae cultivation and processing at the Department of Chemical Engineering at the University of Pannonia. The utilization of algae cultures in experimental photo-bioreactors was examined together with the optimization of the operational conditions with both artificial and natural light and different fertilizers. Several densification processes of algae have been studied and numerous extraction experiments were carried out, where dried algae were made.

This article is a cross-sectional review presented about this diversified work.

Determining the key points of the technology

In order to examine this technology operated under the local climatic circumstances, we had to construct it all the way from the cultivation of algae to the preparation of the end product. Investigating the whole process is important because the composition of the algae suspension, as a raw material, affects the parameters of the technologies to be used in the later phases.

The laboratory and outdoor conditions of the cultivating algae were determined by the algae breeding examinations. A subsystem was created to provide raw material for further examinations.

Adaptations of existing analytic methods, as well as development of new ones, were necessary in order to determine the quality of the algae suspension. Therefore, development of the analytical instrumentation had top priority.

Algae suspension of acceptable quality has to be produced in order to gain the required product.

Processing has been concentrated on three critical operations. These were: densification, extraction, and processing of the residues.

The next goal was to automate the technological process, such as temperature control in the reactor, controlling the gas supplementation, etc.

The project outlined above is illustrated in *Figure 1*.

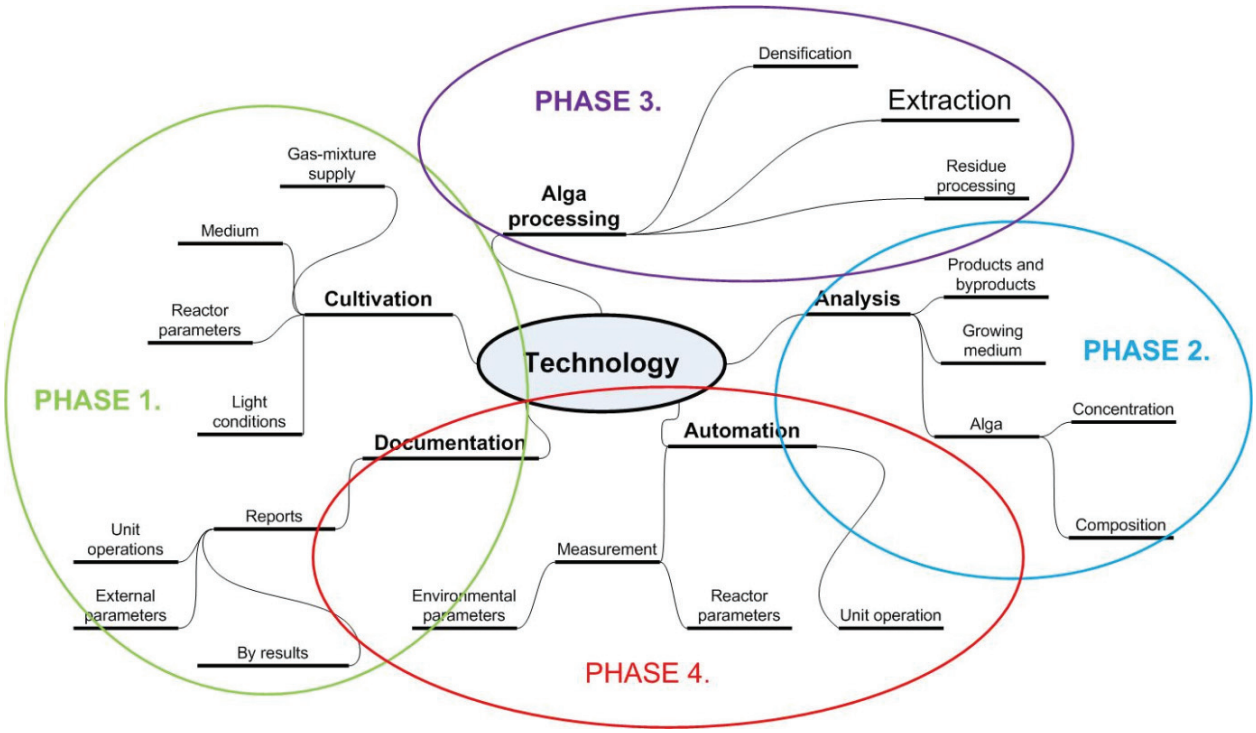

Figure 1: The four phases of technology setup and research subjects

Examinations of algae cultivation

The algae cultivation technology was investigated in a closed photobioreactor, according to the local microclimate.

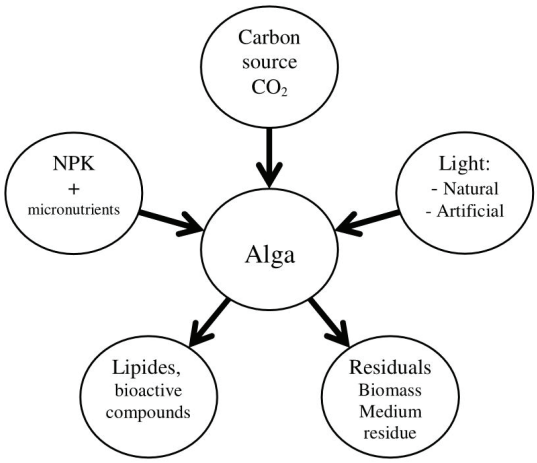

Figure 2: Algae requirements

For a successful breeding, the basic needs of algae have to be met. For optimal processing, a high density algae suspension is necessary, in which high lipid content algae exist.

The alga cultures were propagated in purpose-built flat panel photo-bioreactors. For the tests, closed photo-bioreactors were chosen since they allow fast and easy setting of the parameters [2].

Flat panel reactors were chosen because of the following advantages:

- the closed design minimizes the probability of infection
- light distribution is easily definable in the reactor
- high-area volume ratio
- the area/volume ratio can be modified by small changes of the construction

Flat panel reactors were also installed for the laboratory pre-experiments, the outdoor, scaled up laboratory reactor, and the pilot reactors.

Cultivation parameters

At first, a modified BG-11 nutrient solution formula was used, where a final algae concentration of 5–7 g/dm^3 could be reached. At the same time, the lipid concentration of the dried algae exceeded 20 (m/m%). These values are also true for the photo-bioreactors operating by natural light.

'Cool white' and other special-spectrum fluorescent lamps were used as light sources in the laboratory. Natural light was used for the open-air experiments exclusively.

Biomass output can be influenced by the amount of carbon dioxide inlet. Although experiments were carried out in the 0–100% (V/V%) range, most of the measurements used air with 6–15% CO_2 content.

A flat panel photo-bio reactor system was constructed which could be operated stably. This system proved capable of determining whether the algae species could be introduced to an open-air cultivation system.

Analytical methods

The applied analytical methods can be characterized on the basis of the following three aspects:

- algae cell content and concentration in the suspension
- characterization of the nutrient solution
- composition of the product and the by-products

Characterization of the algae

Almost continuous measurement is required to get information about the state of the algae cultivation. Short measurements are necessary because during the propagation experiments gaining more than 30 samples are performed occasionally. As a result of this, a *propagation index* was introduced, which is equal to the absorbance of the suspension at 681.5 nm. The pH of the suspension has to be measured too. If the propagation index of the suspension shows a decreasing trend, the system needs intervention.

At the initialization of the reactor and in the days before the harvest, determination of the exact algae concentration is usually followed by the dry matter content measurement.

The composition of the algae cells was determined after drying and extracting the samples taken from the algae suspension. This extract was analyzed according to the methods described in the section 'Analysis of the product contents'.

Parameters of the nutrient solution

The nutrient solution contains both micro and macro elements. There are at least 2 orders of magnitude difference in their concentrations. Nitrogen is an important macroelement which is advantageous mainly in the form of NO_3^-, but can also be present in the nutrient solution as ammonia or urea.

Another important ingredient is phosphate, the quantity of which also influences the final biomass concentration.

The presence of micro elements is significant for the biocatalysts needed for the algae to function. Their application involves a rather small concentration interval.

Nitrate and phosphate concentration have to be checked at constant intervals during the propagation cycle. This can be done by an appropriate photometric method. If the quantity of the nutrient solution components drops below a critical level, the propagation process stops and adequate measures have to be taken. These measures include the supplementation of missing components, harvest, or starvation. If the required biomass concentration has been reached, starvation can be useful. At this point, nitrogen-starvation causes the rise of lipid-concentration in the cells.

Analysis of the product contents

The primary product is the extract, the contents of which essentially affect the type of method we choose to produce biofuel. The samples were analyzed according to the EN 14105 standard and some individual components were determined by GC-MS.

With the instrumentation available at the Clean World Laboratory of the University of Pannonia, we were able to gain a considerable amount of information about the individual algae species as well as the processes.

Processing the algae suspension

Since the algae are cultivated for energetic purposes, the energy balance has to be considered. The main objective for energy input is not to exceed the amount of maximally retrievable energy.

Processing can be divided into three important steps. In the first step, dry algae powder is to be made from a relatively dense aqueous suspension. Then the key components are extracted from the dry algae powder. At the end, the main task is to process the residue in the third step.

Densification

The main objective of the densification methods was to gain dry algae in the shortest time and at the lowest energy cost.

Experiments were carried out with chemical flocculation, which proved to be simple a method, but it was rather sensitive to the quality of the algae input.

The applicability of ultrafiltration was also examined. This process proved advantageous for being insensitive to the quality of the algae input. Its drawback is the relatively high investment cost.

Further combined methods were also examined (e. g. autoflocculation) which are useful due to their low energy needs. The possibility of scaling up these methods is being examined at the present.

Extraction

The other important step in processing dry algae is the extraction. The lipid components are extracted in this step. This is the raw material for biodiesel production [3, 4].

There are various ways of extracting lipids. The amount of neutral lipids is determined by extraction with *n*-hexane. The Bligh-Dyer method is a widely used method for determining the total lipid content. These techniques are used for both analytics and processing. In addition, a number of other industrial solvents and solvent mixtures have been tested. The highest extract yield can be reached with the Bligh-Dyer chloroform-methanol mixture. The drawback of the method is that additional components are extracted along with the non-polar lipids. Solvent mixtures consisting only paraffins give products of higher purity, but at the cost of a lower specific yield. It is worth to consider the

fractional distillation of the extract when choosing the appropriate extraction method.

In addition to simple solvent extraction, the applicability of supercritical carbon-dioxide extraction (SCF) was also examined. The main advantage is that we can control the composition of the extract with appropriately chosen operational parameters and co-solvent. Its drawback is the high investment cost and the need of high pressure (in order to reach the supercritical state of CO_2).

Residue processing

Residue processing is necessary because the liquid phase separated at the densification step can be either recycled or purified, depending on the processing steps. If membrane separation was used as the first step of densification, the permeate can be reused to make nutrient solution because of the remaining salt contents. Direct recycling is not always possible. In the case of chemical flocculation, a purification step is often necessary.

It is also reasonable to utilize the raffinate produced by the extraction, as it can contain sugar, starch, dyes, and other bioactive components.

A number of possibilities arise for secondary energy retrieval when processing the raffinate. On one hand, it can be used for the production of biogas, on the other hand, bioethanol can be produced from it by fermentation.

Experiments were carried out for biogas production, which prove that the raw algae mass and the raffinate can be used for the production of biogas within certain limitations.

Conclusions

A number of algae species were tested and processed as part of the algae cultivation experiments. Below is given the essence of our experience in the various examination phases.

PHASE 1.

Operation temperature is one of the most important parameters to control.

Application of artificial light was only considered in the laboratory scale reactors. Algae strain cultivation was observed to be better than the cultivation of special alga species.

PHASE 2.

Daily analysis of the algae suspension was sufficient by measuring the propagation index (enhanced optical density) and pH.

The recirculation of nutrient media residue is to be considered. The number of recirculation cycles depends on the densification processes.

PHASE 3.

Algae suspension is an expensive but valuable material. The processing of algae suspension needs energy and economic analysis in order to reach optimal processing.

PHASE 4.

Scale-up and automation need special considerations which are part of the current working phase.

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REFERENCES

1. L. BRENNAN, P. OWENDE: Biofuels from microalgae – A review of technologies for production, processing, and extractions of biofuels and co-products, Renewable and Sustainable Energy Reviews, 14 (2010) pp. 557–577, doi:10.1016/j.rser. 2009.10.009
2. R. LAU, X. CHEN, Q. YVONNE GOH, W. TAN, I. HOSSAIN, W. N. CHEN: Lumostatic strategy for microalgae cultivation utilizing image analysisand chlorophyll a content as design parameters, Bioresource Technology 102 (2011) pp. 6005–6012, doi:10.1016/j.biortech.2011.02.061
3. J. PRUVOST, G. VAN VOOREN, B. LE GOUIC, A. COUZINET-MOSSION, J. LEGRAND: Systematic investigation of biomass and lipid productivity by microalgae in photobioreactors for biodiesel application, Bioresource Technology 102 (2011) pp. 150–158, doi:10.1016/j.biortech.2010.06.153
4. L. C. SEEFELDT, B. D. WAHLEN, R. M. WILLIS: Biodiesel production by simultaneous extraction and conversion of total lipids from microalgae, cyanobacteria, and wild mixed-cultures, Bioresource Technology 102 (2011) pp. 2724–2730, doi:10.1016/j.biortech.2010.11.026