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14. Algal biomass – a viable source for biogas and biodiesel

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ABSTRACT. Algal biomass has been found to contain high levels of lipids and high quality polyunsaturated fatty acids, as well as many other organic compounds, that made this wide spread natural resource to be of great interest in the production of valuable biofuels, such as biogas and biodiesel. Paper aims to point out some socio-economical advantages that algal biomass could bring to small and large communities, if such organic materials are collected to be used for production of biofuels such as biogas and biodiesel. There are also mentioned the environmental benefits of algae-based technologies and the role of algal biomass in sequester CO_2 emitted from conventional fuel fired power plants, thus reducing the emission of greenhouse gases into the atmosphere. One innovative technical solution for producing biogas using a wide range of wet biomass generated in small farms, as well as algae and aquatic waste have been shown. Some benefits of biogas technology both for energy sector and environment protection, but also for supplying alternative fuel to be used for domestic applications in isolated communities have been shown. Main direct applications of this biogas technology which use algae and other organic substrates, to produce biogas and ecological soil fertilizers, but also their contribution to improve life quality of people living in isolated villages in delta area, have also been presented. Besides biogas applications, some technical solutions for harvesting and extraction of oils from freshwater and marine algae to produce biodiesel and other useful materials have been briefly mentioned.

Key words: algae, biogas, fertilizers, environment, biofuels

INTRODUCTION

The biodegradable aquatic wastes, such as algal biomass, represent a valuable renewable energy source that can be used to produce biogas but also a wide variety of bio-fuels due to the high level of lipids and polyunsaturated fatty acids [***7***]. In addition, the digested residue is rich in basic nutrients for agriculture and can be used as an ecological fertilizer, thus reducing the need for synthetic fertilizers and pesticides.

Algal biomass is wide spread everywhere where there is fresh and salt water but also in the soil. Unfortunately, algaculture or the production of algae to harvest oil for biofuels has not yet been undertaken on a commercial scale but naturally grown algae could be recovered al local level to produce alternative fuel in isolated communities. Recovery of algal biomass at regional level can provide economic and social benefits to rural communities and improve the living standards of the local population, simultaneously with cleaning the environment [***11***].

Presently, at world level there are developed various biogas technologies tailored for this purpose, namely biogas for household needs, technologies for land sanitation with reducing diseases risks or even advanced technologies for making profits by producing and selling electricity and heat. Technologies for energy recovery of algae and other aquatic biodegradable waste support production of biogas locally, as a valuable source of renewable energy. Biogas can replace successfully natural gas in the same household or industrial applications. In addition, this technology solves the problem of methane emissions to the atmosphere, but also of unpleasant odor produced by the decomposing biomass in areas with high tourism potential.

Methane is the major constituent of biogas and the second most important gas after carbon dioxide in terms of greenhouse effect. Moreover, methane has a global warming potential 25 times more harmful than CO_2, calculated on a time horizon of 100 years [***8***].

The economical feasibility of biofuels production from algal biomass can be increased if coproduce some high value products such as pigments, cosmetics, provitamins, food additives along with the biofuel [***5***].

MATERIAL AND METHODS

The algal biomass became excessively spread on the surface of lakes due to rising levels of nutrients resulting from organic synthetic fertilizers applied to the soil but also from some industrial processes. Such biomass could create real environmental problems by increasing oxygen consumption in lakes. Consequently, anaerobic conditions in waters have arisen, simultaneously with formation of hydrogen sulphide, ammonia, carbon dioxide and other compounds in waters, resulting in an unpleasant smell and taste of water. Therefore, collecting algal biomass and aquatic residuals to use them accordingly, could be an effective way of rendering the natural cycle of lakes and recreational areas, by recovery of water quality in ecosystems and also creating good conditions for growing of valuable fish species [***10***].

Currently, in coastal areas, algae and other vegetal and animal wastes collected from the beach are discarded at municipal dumps or on improper lands, where undergoes a natural process of decomposition, resulting air pollution by greenhouse gas emissions.

Moreover, this disposal practice is encouraging the breeding of insects or other pests. The energy value of such biomass is very high due to the high content of volatile organic compounds, which is the main chemical parameter responsible for production of biogas.

It is well known that algal biomass is very valuable to produce a large variety of bio-fuels by its content of oils and other organic compounds [***9***]. It can be used to produce biogas, vegetable oil, bio-diesel, bio-ethanol, methanol or buthanol, but the great advantage of this resource is that the algae and aquatic biomass does not require land, as well as many other energy crops need and does not entail a decrease in food production, since it requires neither farmland nor fresh water [***1***].

Algae to biogas and biofuel technologies can effectively contribute to reducing the amount of methane released directly into the atmosphere by capturing it and using it as an alternative fuel. Furthermore, these technologies allow production of valuable secondary materials (fermented slurry, process water) that can be successfully used in agriculture for soil conditioning.

Researchers from the National Institute for Research and Development in Electrical Engineering (ICPE-CA) Bucharest, have designed and built a biogas unit addressed to small communities, to be used in recovery of various organic domestic waste.

This biogas unit is very adequate for treating of algal waste in isolated villages in delta and coastal zones, with indisputable economical and environmental advantages in small comunities but in touristic sites as well. The frequency which algal growth phenomenon has occurred in recent years, adversely affect tourism and ecosystems of coastal zones and delta. Each year, local authorities and voluntary organizations collect tons of algae, which end to be disposed afterwards to municipal waste dumps and landfills.

Recovery of the algal waste in the proposed biogas unit is of highest interest in areas where clusters of algae and residual biomass are available. This treatment option has been proved an effective and profitable disposal solution in economic terms, but also for environmental considerations, compared to the storage for natural decay of the algal biomass on landfills. Besides biogas, the facility designed by researchers from ICPE-CA produces ecological fertilizers to be applied on the soil.

The biogas unit has many novelty and originality elements [***6***]. The plant consists of an underground spherical masonry fermenter having a typical inner configuration (as seen in **Fig. 1** and **Fig. 2**), where the waste biomass can be efficiently digested and converted into energy, a floating gas-holder which floats in a water jacket, two storage tanks for waste biomass and respectively digested slurry, located at the same side of the digester and two pipelines for inlet, respectively outlet of the row or fermented slurry.

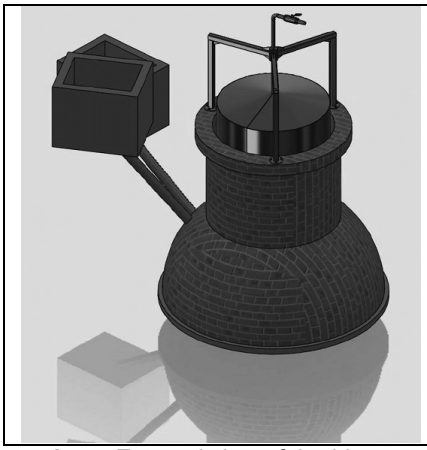

Fig. 1. External view of the biogas unit to treat algae and other organic waste.
Note. drawing by Ionel CHIRITA.

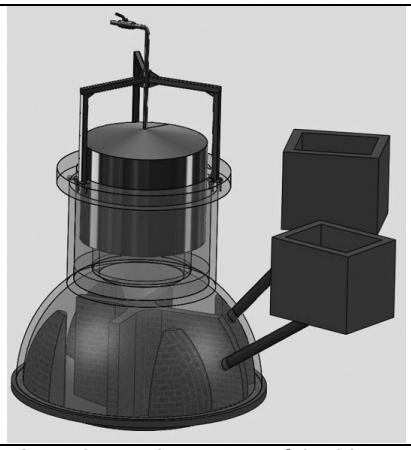

Fig. 2. Internal structure of the biogas unit to treat algae and other organic waste.
Note. drawing by Ionel CHIRITA.

Fig. 3. Household biogas unit of 4 m^3 built in Boteni (Argeș county).
Note. photo credit: Nicolae ȘTANCIU.

The anaerobic chamber has an inovative shape which ensures a proper flowing and homogenization of the organic mass. The specific route followed by the biomass provides a slight hydrodynamics within the digester. The biogas unit is the subject of a RO Patent No. A/00616/2010 [***6***].

A prototype with a digester volume of 4 m^3 (**Fig. 3**) was built in Boteni (Argeș county). This unit uses mainly farm waste slurries but also green waste and other organic residuals generated in domestic activities.

This biogas unit presents various economical and energetical advantages such as:

- Simplicity in building and operation;
- Better yields in degradation of the organic compounds due to the longer mass flow;
- Profitable materials consumption and easy availability;
- Economical location on the site;
- Possibility to build the unit for larger size up to 16 m^3, function of the substrate availability and the family energy demand;
- Ensuring the sustainable fuel for domestic usage;
- Providing of a clean and healthy environment at local level.

The following daily performances can be reached: treating of ca. 50 kg organic slurry (25 kg organic waste, algae and 25 kg dilution water); producing ca. 1-2 m^3 biogas and ca. 20 kg fertilizer. It has a positive impact on the environment by facilitating of land and waters sanitation, households and annexes, reducing greenhouse gas emissions, improving the quality of agricultural land fertilized with digested sludge which is rich in nutrients [***10***].

RECOVERY OF ALGAL BIOMASS TO OILS AND BIODIESEL

Oils and biodiesel produced from algae represents other interesting valuable materials which can be obtained by algal biomass to energy applications. Besides proteins, carbohydrates and nucleic acids, all algae contain fats in various percent function of the type of algae. This fact makes algae get an important economical value by extraction and conversion of fatty acids to biofuels [***3***]. In **Fig. 4** – **Fig. 7** there are presented most useful algae strains currently used to produce biofuels.

Much research has focused on the lipid (specifically the fatty acid) composition from either a taxonomic or a nutritional perspective. Cultured microalgae are commonly used as feed for aquaculture applications because of the desirable fatty acid content of the algae, in particular servicing the need for essential polyunsaturated fatty acids as dietary supplements. The renewed interest in the use of algal lipid-derived biofuels, biodiesel in particular, has refocused research on algal lipids and lipid metabolism [***3***].

The types of lipids that algae can produce are very different and they include neutral lipids, polar lipids, esters, sterols, even hydrocarbons but also prenyl derivates such as tocopherols, carotinoids, terpens, quinones and chlorophylls [***4***].

Fig. 4. *Scenedesmus dimorphus*.
Note. source: http://www.plingfactory.de

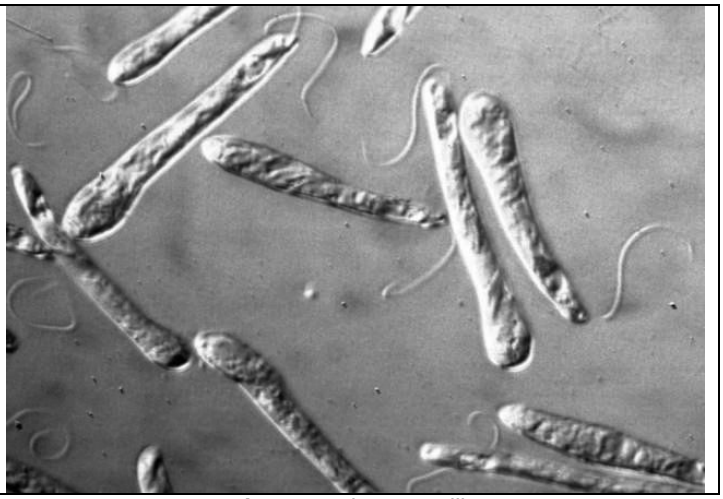

Fig. 5. *Euglena gracilis*.
Note. source: http://www.globalspecies.org/ecosystems

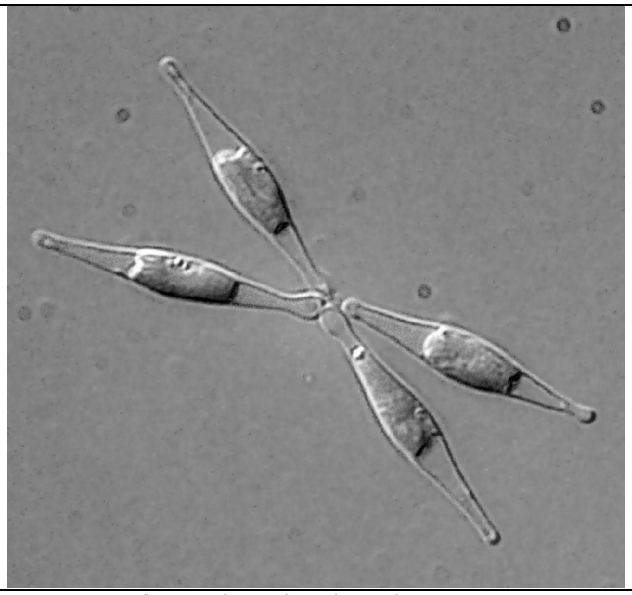

Fig. 6. *Phaeodactylum tricornutum*.
Note. source: http://en.wikipedia.org

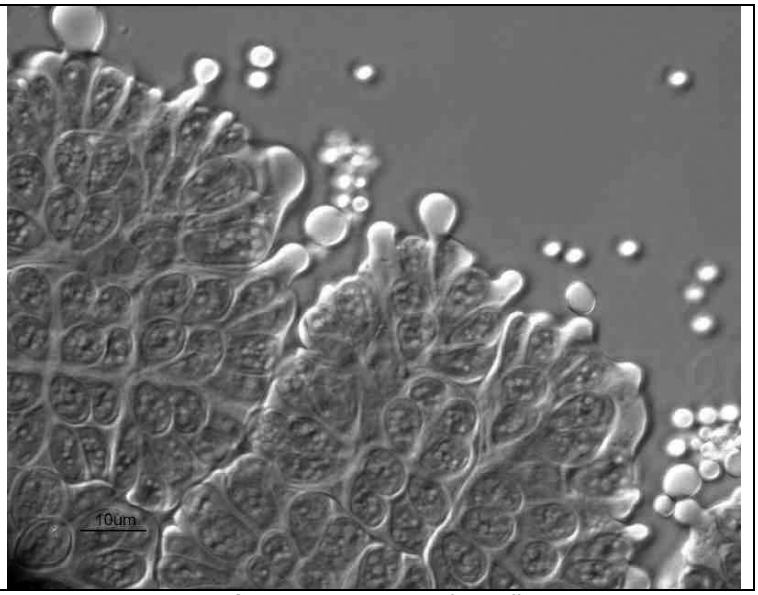

Fig. 7. *Botryococcus braunii*.
Note. source: http://newenergyandfuel.com

Synthesis of fatty acids by algae depends on the growth conditions. Thus, in optimal conditions, algae produces mainly fatty acids but when there are unfavorable environment or stress conditions for growths, many algae change their lipid biosynthetic pathways towards the formation and accumulation of neutral lipids [***7***].

Given these facts, it can be underlined that algae could be employed as cells factories to produce oils and other lipids for biofuels but also some useful materials like pigments, cosmetics, provitamins, food additives [***5***].

CONCLUSIONS

In the context of growing concern to improve the environment and given the current increase in energy costs while reducing fossil fuel resources, the identification and implementation of new technologies for energy recovery of various organic materials has become a global priority.

Algal biomass may replace a big part of fossil fuels since they are rich in organic materials which can be biochemically converted to biofuels and to other important byproducts like pigments, pharmaceutical components, vitamins etc. Methods to produce biogas and extract oils from algae to produce biodiesel have become actually viable.

On the other hand, finding solutions to collect algal waste and clean environment represents a big concern of authorities in touristic sites. Furthermore, soil pollution due to chemical fertilizers has become a problem at global level, affecting ecosystems and human health. By recovery of algal biomass, biogas and ecological soil fertilizers can be produced at local level.

Algae and seaweeds are a very efficient feedstock for biogas reactors and biodiesel technologies but also raw materials for other industries. In this respect, algal biomass is very likely to become one of the most valuable energy sources to replace successfully and environmentally friendly the conventional energy sources [***2***]. It can be concluded that technologies for producing biogas and other biofuels using algae and seaweeds bring a significant contribution to current practices regarding the management of aquatic residual biomass and have got a high energy and economic potential.

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REFERENCES

[***1***]. BRIGGS (M.), 2004 – Widescale Biodiesel Production from Algae. Archived from the original on 24 March 2006. Publisher: University of New Hampshire - Biodiesel Group (available at http://www.resilience.org/stories/2004-10-03/widescale-biodiesel-production-algae - accessed on 12 December 2010)
[***2***]. CASSIDY (S.), 2010 – How can algae be converted to biofuels? (available on http://auto.howstuffworks.com/fuel-efficiency/biofuels/convert-algae-to-biofuel.htm - accessed on 30 June 2011)
[***3***]. GREENWELL (H. C.), LAURENS (L. M. L.), SHIELDS (R. J.), LOVITT (R. W.), FLYNN (K. J.), 2010 – Placing microalgae on the biofuels priority list: a review of the technological challenges. IN: *Journal of the Royal Society Interface*, vol. 7, No. 46, pp. 703 - 726. doi: 10.1098/rsif.2009.0322
[***4***]. HU (Q.), SOMMERFELD (M.), JARVIS (E.), GHIRADI (M.), POSEWITZ (M.), SEIBERT (M.), DARZINS (A.), 2008 – Microalgal Triacylglycerols as feedstock for Biofuels Production: Perspectives and Advances. IN: *The Plant Journal*, vol. 54, pp. 621 - 639.
[***5***]. LI (Y.), HORSMAN (M.), WU (N.), LAN (C. Q.), DUBOIS-CALERO (N.), 2008 - Biofuels from Microalgae. IN: *Biotechnology Progress*, vol. 24, No. 4, pp. 815 - 820. e-ISSN: 1520-6033; doi: 10.1021/bp070371k
[***6***]. MATEESCU (C.), CHIRITA (I.), BABUTANU (C. A.), STANCU (N.), 2010 - Household Biogas Unit for Rural Areas. RO Pattent Application No. A/00616/2010
[***7***]. MCMICHENS (R. B.), 2012 - Algae as a Source for Biofuel (pdf book). The University of Maryland.
[***8***]. PLATT (B.), CIPLET (D.), BAILEY (K. M.), LOMBARDI (E.), 2008 - Stop trashing the climate. 80 p. (available on http://www.ilsr.org/wp-content/uploads/2008/06/fullreport_stoptrashingtheclimate.pdf - accessed on 12 December 2010)
[***9***]. ***, 2008 – Technology: High Yield Carbon Recycling (http://www.greenfuelonline.com/technology.htm) - GreenFuel Technologies Corporation (available at http://www.greenfuelonline.com/technology.htm - accessed on 09 July 2008).
[***10***]. ***, 2009 – Creșterea eficienței echipamentelor și proceselor tehnologice pentru conversia energetică din resurse regenerabile. Project No. 0935/2009 - Program Nucleu, financed by National Authority for Scientific Research, Romania. [in Romanian]
[***11***]. ***, 2011 – Investigation on biogas producing microorganisms under high hydrostatic pressures and applied research on algae growth for CO2 recovery. Romania-China Bilateral Project No. 520/2011, financed by National Authority for Scientific Research, Romania.

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