ALGAL BIOFUELS

Roman[1)] M., Adriana Gog[1)], Lacrimioara Senila[1)], E. Luca[2)], A. Naghiu[2)] D.-F. Irimie[3)], Cecilia Roman[1)]

[1)]INCDO-INOE 2000, Research Institute for Analytical Instrumentation, 67 Donath, 400293-Cluj-Napoca, marius.roman@icia.ro
[2)]University of Agricultural Sciences and Veterinary Medicines, Manastur, str. nr 3-5, Cluj-Napoca, Romania
[3)]BABES-BLOYAI University, Mihail Kogalniceanu nr. 1, 400084 Cluj-Napoca, Romania

Abstract. *The paper presents an overview of the biofuels obtained from algae. Algae-based biofuel definitely has the potential to revolutionize the energy industry and will play a leading role in fight against greenhouse gas emissions, and climate change. Biofuels production from algae definitely deserves more attention in years to come due its potential: do not transform food into fuel like with corn or soy, fewer emissions involved when compared to fossil fuels. Biofuel production from algae could be one of the surprising competitors on alternative energy market in not so long future, especially if oil's price continues to grow.*

Keywords: biofuels, algae, renewable energy, renewable resources

INTRODUCTION

The world's dependence on the non-renewable energy sources (fossil fuels) generated a global effort to cut down the dependence on fossil fuels and develop economically viable and scalable alternative fuel sources that will significantly reduce massive emissions of CO_2 in the atmosphere (1, 2). One of the most attractive responses regarding the alternative sources is biofuels. Biofuels are quite adequate to provide an alternative to fossil fuels and can also reduce total CO_2 emissions because they are more ecologically acceptable energy source compared to fossil fuels (3). For photosynthetic organisms (rape, corn or soybeans), the plants use the energy of sunlight to convert available CO_2 into hydrocarbons, storing chemical energy. This represents a double benefit because not only fuel is produced but also CO_2 is consumed having positive effect on both energy demand and the climate change (4, 5). Fewer CO_2 emissions from biofuels are result of closed carbon circle – plants and algae use CO_2 to grow, and when biofuel is used this CO_2 gets back into atmosphere. Fossil fuel carbon footprint is one way only – from ground into atmosphere.

Biofuels can be produced from any biological carbon source; crops as corn with sugars (sugar beet, sugar cane) is typically used for ethanol production while soy, canola, and palm with oils are typically used for biodiesel production (1, 6, 7) so called 1st generation biofuels. But 1st generation biofuels are not seen as a sustainable biofuel solution because these crops requires good quality agricultural land, which increases the overall demand for cropland, and using food for fuel production definitely is not a logical choice, regardless of biofuel potential (6, 8). The focus is switching to 2nd or even 3rd generation biofuels (6). 2nd generation biofuels need only marginal land and no fertilizer application. However, for a commercial production of 2nd generation biofuels still vast areas of land are needed.

3rd generation biofuels are a promising alternatives to other biofuels. Algae is considered a prime candidate to serve as feedstock for 3rd generation biofuels. The important fuels synthesized from algae are vegetable oil, biogas, biodiesel, biomethanol, bioethanol, biobutanol and dry fuel (similar to coal) (9-11).

MATERIAL AND METHOD

Algae-based biofuels, or algal biofuels, refers to biodiesel, bioethanol and other biofuels derived from simple organisms such as algae and phytoplankton. While a number of bio-feedstock are currently being experimented for biodiesel production, algae have emerged as one of the most promising sources for biodiesel production (12)

Algae are a large group of primitive, mostly aquatic, chlorophyll-bearing plants, lacking specialize tissues and organs namely roots, stems, leaves, flowers etc (13, 14). Algae are usually found in damp places or bodies of water and thus are common in terrestrial as well as aquatic environments. Form of algae ranges from giant seaweeds to single-celled diatoms and pond scum. Algae require primarily three components to grow: sunlight, carbon-dioxide and water. Photosynthesis is an important bio-chemical process in which plants, algae, and some bacteria convert the energy of sunlight to chemical energy. Different types of algae grow in different environments having different nutritional requirements as well (15).

Algae can be cultivated in two ways – in an open pond system (either naturally occurring or engineered) or in an engineered closed system. Without controlled conditions, it can be difficult to sustain desired species of algae or grow them at optimal rates for biomass or fuel production. The closed growth systems prevent contamination of the algal culture with bacteria and viruses, which could potential damage the biofuel production. Closed growth systems have several advantages; not only do they support the cultivation of specific target cultures but also a closed growth system can feed CO_2 from industrial processes directly to the algae at high concentrations, which maximizes the amount of captured CO_2 (16-18).

Algae present several advantages over other biofuels.

- Traditional crops are more prone to disease and drought, requiring more energy-intensive treatments such as insecticides and herbicides to combat attacks (18, 19)
- Their energy output per land unit is at least 30 times higher than for 2nd generation biofuels (20, 21). Other studies speak about more than 102 – 103 times the productivity of land crops (21).
- One of the major benefits of algae as biofuel is that many algal species, particularly the small species (microalgae) can be used for extraction of biofuel (22, 23).
- The yield of vegetable oil from algae is comparatively much higher (about 30 times) than land crops (table 1). The rapid growth of algae is a contributing factor for mass cultivation without spending extra resources.

Marine water as well as wastewater can be used for mass cultivation of algae (24, 25).

- Unlike fossil fuels, biofuel produced from algae are biodegradable, thus reducing the chances of environmental pollution i.e. in case there is spillage of algal-based biofuel in water sources, there are no significant adverse effects on the ecosystem.

Table 1

Estimation of oil productivity from different crops

Crop	Oil content per tonne of biomass (WT% dry mass)	Oil production (t/ha/y)	Biodiesel yield (L/ha/y)
Oilseed rape	40–44% (of seed)	1.4	1560
Soya	20% (of seed)	0.48	544
Jatropha	30% (of seed)	2.4	2700
Chlorella vulgaris	Up to 46%	7.2	8200
Nannochloropsis	Up to 50%	20–30	23 000–34 000

RESULTS AND DISCUSSION

Algae are considered a promising potential feedstock for the 3rd generation biofuels, as certain species of algae contain high amounts of oil. This oil from algae can be extracted, processed and refined for various uses. This biofuel can also be used as transportation fuels. Other benefits of algae as a potential feedstock are their availabilities. They are found in abundance and their growth rates are fast as well. The major technical challenges for algae based biofuel include identifying the proper strains with the highest oil content with higher growth rates. Developing cost-effective growing and harvesting methods is the key to success for algae based biofuel.

The main branches/lines of algae are (26) :

- Chromista - this line includes the brown algae, golden brown algae, and diatoms. The plastids in these algae contain *Chlorophylls A* and *C*. (27)
- The Red Line – this is an early branch of marine algae containing just *Chlorophyll A*. Red algae can often be seen coating wave washed rocks. A characteristic of red algae is that their plastids contain only one type of chlorophyll - *Chlorophyll A*. This is different from green algae and plants which have both *Chlorophyll A* and *B*. (28)
- Dinoflagellates – these evolved on a separate line that includes, surprisingly, the ciliated protists. (29-31)
- The Euglenids – this independent line of single celled organisms that include both photosynthetic and non-photosynthetic species (32)
- The Green Line is related to plants. Plants and green algae have *Chlorophyll A* and *B*. (33)

Algae will present immediate advantages over other biofuels. It can be grown nearly anywhere and without the need for large tracts of land. It would also not be competing with food staples for space. Algal biofuels are a very promising alternative though.

Algae biodiesel has virtually no sulphur content. Biodiesel has superior lubricating properties, reducing fuel system wear and increases the life of fuel injection equipment. Algae biodiesel has more aggressive solvent properties than petrodiesel and will dissolve leftover varnish residue. Fuel filters should be changed shortly after introducing biodiesel into systems formerly running on petrodiesel to avoid clogging. Biodiesel has about 5% to 8% less energy density than petrodiesel, but with its higher combustion efficiency and better lubricity to partially compensate, its overall fuel efficiency decrease is only about 2%. Biodiesel reduces particulate matter by about 47% compared to petroleum diesel. Biodiesel has less dangerous particulate matter because it reduces the solid carbon fraction on the particulate matter while increasing the amount of oxygen (14)

CONCLUSIONS

Biofuel production from algae is very interesting topic of research. Algae are single celled or multicellular, chiefly aquatic, plantlike organisms. Algae are photosynthetic: like plants, they are nourished by carbon dioxide and nitrogen and release large amounts of oxygen into the atmosphere. There are over 65,000 known species of algae including many different varieties such as red, green, brown, yellow and black.

Algae have many reasons why they could be consider as one of the most perfect choices for biofuel production: are renewable non-food sources of feedstock for biofuels; can be grown in inexpensive culture systems on non-arable lands, nonproductive or water sources. (it need not displace land used for growing food sources; do not require freshwater resources or soil for growth, which makes things lot easier). The algae have the potential to yield at least 30 times more energy than land crops currently used in the production of biofuels, and in addition the remaining biomass residue can be used in value added byproducts like animal feed, as a fermentation feedstock, or combusted to generate heat.

The ability for algae to be cultivated on marginal (non-arable) land, using saltwater, greatly reduces its impact on the environment relative to other biofuels and fossil fuels. Moreover, algae's cultivation does not require that it compete with food crops, a social benefit that may be underestimated by many lawmakers. Algae's high-yield and reduced greenhouse gas emissions make it a good candidate for reducing transportation related pollution.

REFERENCES

1. Hanjalic, K. Van de Krol, R. Lekic, (2008), Sustainable Energy Technologies: Options and Prospects, Springer.

2. IEA, (2008), International Energy Agency. World Energy Outlook 2008, Paris. Available at: http://www.iea.org/weo/2008.asp [Accessed: 15th October 2009].

3. IPPC 2007. Intergovernmental Panel on Climate Change. Fourth Assessment Report. Climate Change 2007 Available at:http://www1.ipcc.ch/ipccreports/assessments-reports.htm [Accessed: 26th Oct. 2009].

4. EPA. 2010. Regulation of Fuels and Fuel Additives: Modifications to Renewable Fuel Standard Program. Pages 26026-26048. Federal Register: National Archives and Records Administration.

5. http://www.guardian.co.uk/environment/2008/oct/23/biofuels-energy

6. http;//www.biofuels.eu/info.html

7. CARBON TRUST, (2009), Welcome to carbon trust international. About. Available at:http ://www.carbontrust. com [Accessed: 28 November 2009].

8. Solomon Bd, Barnes Jr, Halvorsen KE. (2007), Grain and cellulosic ethanol: history, economics, and energy policy. Biomass Bioenergy 31: 416.

9. USDA. 2010. Grazing Systems and Alternative Livestock Breeds. http://afsic.nal.usda.gov/nal_display/index.php?info_center=2&tax_level=2&tax_subject=295&level3_id=0&level4_id=0&level5_id=0&topic_id=1410&&placement_default=0

10. Helena, P. (2009), Genetic Engineering, Agriculture and Climate Change. Bonn Climate Change Discussions, June 2009. Helena Paul of EcoNexus.Available at:http :// unfccc2 . meta-fusion.com/kongresse/090601_SB30_Bonn/downl/20090601_sb_1930_helena.pdf [Accessed: 25 November 2009].

11. Haye, S. Hardtke, C. S. (2008), The Roundtable on Sustainable Biofuels: plant scientist input needed. Forum Science & Society, Cell Press.

12. EurActiv. 2007. EU Renewable Energy Policy.

13. Scharlemann J, Laurance J. 2008. How Green Are Biofuels? Science 319. 30

14. Tilman D, et al. (2009), Beneficial Biofuels-The Food, Energy, and Environment Trilemma. Science 325: 270-271

15. http://www.oilgae.com/

16. Amin, S. (2009) Review on biofuel oil and gas production processes from microalgae. Energy Conversation and Management 50, pp. 1834-1840.

17. Beer, L. Eric, B. Peters J. Posewitz, M. (2009). Engineering algae for biohydrogen and biofuel production. Current Opinion in Biotechnology 20. pp. 254-271.

18. Chisti, Y. (2007), Biodiesel from microalgae. Biotechnology Advances 25. 294-306 pp.EIA, 2009. International Energy Outlook 2009. Energy Information Administration. Washington. Available at: http://www.eia.doe.gov/oiaf/ieo/index.html [Accessed: 15 October 2009].

19. FBAE, (2009), Foundation for Biotechnology, Awareness and Education. Science for Environmental Policy. Genetic Engineering could cut the cost of biofuels. Available at: http://fbae.org/2009/FBAE/website/images/pdf/imporatant-publication/Genetic_engineering_can_cut_the_costs_of_biofuels.pdf [Accessed: 28 October 2009].

20. Fortman, J.L., Chhabra S., Mukhopadhyay, A. Chou, H. Lee, T.S., Stehen, E., Keasing, J.D. (2009) Biofuel alternatives to ethanol: pumping the microbial well. Trends in Biotechnology 26 (7). pp.375- 381.

21. Gressel, J. (2008), Transgenics are imperative for biofuel crops. Plant Science 174, pp. 246–263.

22. Mata, T. Martins A. Caetano N. S. (2009), Microalgae for biodiesel production and other applications: A review. Renewable and Sustainable Energy Reviews 14, pp. 217–232

23. Posten, C., Schaub, G. (2009), Microalgae and terrestrial biomass as source for fuels – A process view. Journal of Biotechnology 142. pp. 64-69.

24. Schenk P, Thomas-Hall S, Stephens E, Marx U, Mussgnug J, Posten C, Kruse O, Hankamer B. (2008), Second Generation Biofuels: High-Efficiency Microalgae for Biodiesel Production. BioEnergy Research 1: 20-43

25. http://gigaom.com/cleantech/15-algae-startups-bringing-pond-scum-to-fuel-tanks/
26. http://cleantech.com/news/2961/algal-biofuels-algenol-ethanol-solazyme-sonora-mexico
27. http://www.castoroil.in
28. http://en.wikipedia.org/wiki/Brown_alga
29. http://www.ucmp.berkeley.edu/protista/rhodophyta.html
30. http://www.ucmp.berkeley.edu/protista/dinoflagellata.html
31. http://www.mbari.org/staff/conn/botany/dinos/info.htm
32. http://en.wikipedia.org/wiki/Dinoflagellate
33. http://en.wikipedia.org/wiki/Euglenid
34. http://www.ucmp.berkeley.edu/greenalgae/greenalgae.html
35. http://www.powerplantccs.com/ccs/cap/fut/alg/alg.html)