LATEST ADVANCES IN USING ALGAE FOR PRODUCING BIODIESEL

Introduction

Biofuels make up around 10% of energy consumption. Biofuels are the environmentally friendly alternative to the use of petroleum fossil fuel. A type of biofuel that can provide fuel for diesel transportation is methyl esters and it can be produced from lipids or fatty acids that can be found in algae [1]. Algae is formed when autotrophs evolve by absorbing oxygen and light. Algae is usually found in the ocean due to its dependency on the water to survive. Algae can be categorized into four kingdoms: the Bacteria kingdom, the Plantae kingdom, the Chromista kingdom, and the Protozoa kingdom [2]. The Bacteria kingdom allows for the bacteria to live off the algae by degrading methylamine to form ammonia which allows the bacteria to grow [3]. The Plantae kingdom consists of green algae and this type of algae can make its own food through a process called photosynthesis [4]. The Chromista kingdom consists of chromites that can survive in most environments. Additionally, some species in this kingdom can form pigments and enzymes that cause organic materials to deteriorate [5]. The species in the Protozoa kingdom feed on the nutrients in their environment and can be parasitic [6]. Among these different kingdoms of algae, the one most used to make ethanol is brown algae, which is a part of the Chromista kingdom [7].

How can products for the ocean help us make better biofuels?

Algae can be used to make biofuels like ethanol. Algae can undergo processes like gasification, liquefaction, pyrolysis, fermentation, etc. [8]. Algae produce oils that contain a triacylglycerol structure and have lipids, which are fatty acids that are used to produce biodiesel [8]. These fatty acids allow algae to produce biofuels like ethanol. Although ethanol is widely used as a biofuel, ethanol is not a preferred biofuel because it reacts with water which may lead to damage to the engines. Therefore, biofuels that are hydrophobic are more preferred [1]. However, due to its cheap cost, ethanol is widely used as a biofuel.

Ways to convert algae to biodiesel

Transesterification

This triacylglycerol structure causes higher viscosity than that of petroleum. To reduce this viscosity level, the algae biomass undergoes a process called transesterification. Transesterification introduces a functional group to the algae and a catalyst, like an enzyme, is used in the reaction to form glycerol and methyl esters which are a preferred biofuel because they do not react with water [7]. There are two types of transesterification processes: direct and conventional transesterification. Direct transesterification involves removing the lipid content and does not require any additional pretreatment. However, conventional transesterification requires pretreatment where the lipids are extracted before a functional group is introduced to the algae [7]. Direct transesterification is preferred because it requires fewer steps and costs less than conventional transesterification.

Anaerobic Digestion

Anaerobic digestion can be used on algae to produce CH4 and CO2. This process contains four steps. The first step is hydrolysis where the organic matter of the algae is broken down into amino acids and sugars through the use of bacteria. The next step is fermentation where acidogenic bacteria is used to convert these sugars and amino acids into products like hydrogen and CO2. In the next stage, acetogenesis, hydrogen, and carbon dioxide are oxidized by removing hydrogen and increasing oxygen. The final step is methanogenesis where CH4 and CO2 are produced using bacteria as shown in figure 1 [7].

Gasification and Liquefaction

In liquefaction, pretreatment may be needed as it degrades the algae into smaller pieces, allowing for a quicker and more efficient conversion reaction. This pretreatment involves physical pretreatment like increasing the surface area, chemical pretreatment like destroying the structure of algae, or biological pretreatment where the polymerization of algae is reduced. The types of liquefaction are direct liquefaction and indirect liquefaction. Direct liquefaction allows the solvent to affect the biomass directly while indirect liquefaction uses catalysts to affect the biomass [10]. Gasification is a type of indirect liquefaction. Gasification transforms algae into CO, H, CO2, CH4, and tar by using catalysts and controlling the temperature and pressure [11]. Thermochemical liquefaction is a type of direct liquefaction. Thermochemical liquefaction converts algae into biofuel by using a catalyst and undergoing the process at high pressures and high temperatures [12].

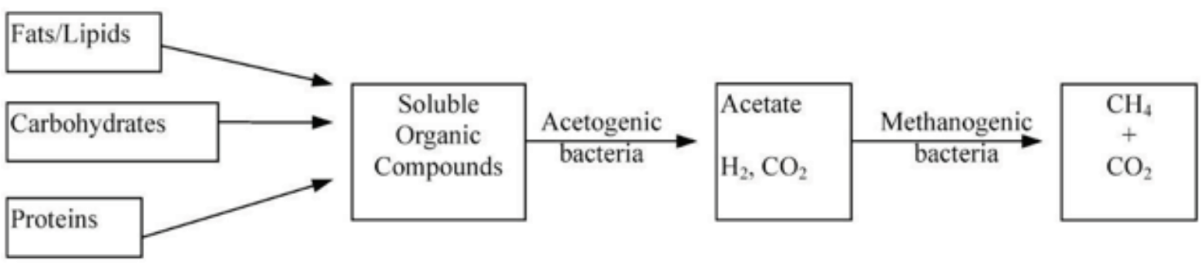


Figure 1. Process flow schematic of Anaerobic Digestion [9]

Authors

Dr. Raj Shah is a Director at Koehler Instrument Company in New York, where he has worked for the last 27 years. He is an elected Fellow by his peers at IChemE, CMI, STLE, AIC, NLGI, INSTMC, Institute of Physics, The Energy Institute and The Royal Society of Chemistry. An ASTM Eagle award recipient, Dr. Shah recently coedited the bestseller, "Fuels and Lubricants handbook", details of which are available at https://bit.ly/3u2e6GY

He earned his doctorate in Chemical Engineering from The Pennsylvania State University and is a Fellow from The Chartered Management Institute, London. Dr. Shah is also a Chartered Scientist with the Science Council, a Chartered Petroleum Engineer with the Energy Institute and a Chartered Engineer with the Engineering council, UK. Dr. Shah was recently granted the honorific of "Eminent engineer" with Tau beta Pi, the largest engineering society in the USA. He is on the Advisory board of directors at Farmingdale university (Mechanical Technology), Auburn Univ (Tribology) and Stony Brook University (Chemical engineering/ Material Science and engineering). An Adjunct Professor at the State University of New York, Stony Brook, in the Department of Material Science and Chemical engineering, Raj also has over 475 publications and has been active in the petroleum industry for over 3 decades.

More information on Raj can be found at https://bit.ly/3sayVgT

Ms. Sharon Lin and **Blerim Gashi** are Chemical Engineering students from SUNY, Stony Brook University, where Dr. Shah is the chair of the external advisory board of directors. They are also a part of a growing internship program at Koehler Instrument Company in Holtsville, NY that helps students explore opportunities in the field of Alternative energies.

Fermentation

Algae contain sugars that can be converted into bioethanol through a process called fermentation. In addition to the production of ethanol, this process can also produce acetone and butanol. This process requires pre-treatment to increase the number of products produced [7]. There are many different methods for pre-treatment such as physical, chemical, physicochemical, and biological. Physical treatment involves the fragmentation of algae, chemical treatment involves the use of oxidation and solvents to alternate the chemical structure of algae, and biological treatment involves the treatment of the bacteria and enzymes on the algae [13]. These pretreatment methods improve fermentation.

Pyrolysis

Pyrolysis is the process that breaks down algae without the involvement of oxygen in order to produce biofuels. Conventional pyrolysis slowly heats the algae to produce biochar whereas fast pyrolysis and flash pyrolysis quickly heats the algae to produce bio-oil and syngas [7].

Ways to Improve the Biofuel Made from Algae

The process to convert algae to biofuels is an expensive process that demands a large amount of energy. Research has been conducted to improve algae to make it preferable. To improve algae, many researchers have attempted to breed algae to improve their phenotypes by directly increasing the yield of lipids from algae [14].

Engineers have found techniques to alter the structure of algae DNA to allow for proliferated growth. However, this may be a problem if these genes placed in the algae cannot be controlled by the engineer which is why further research is needed on this topic [15].

Conclusion

Fossil fuels release greenhouse gases into our environment, contributing to climate change. To prevent this further damage to the environment, biofuels were found to be an efficient and environmentally friendly alternative. Biofuels can be produced from ocean waste, plastic, and algae. Algae can be converted into biofuels through a variety of processes including the enhancement of algae or the efficiency of biofuel production. These processes can be further researched to improve its overall yield in order to replace fossil fuels and petroleum.

References

1. Somerville, C. (2007). Biofuels. Current Biology, 17(4). https://doi.org/10.1016/j.cub.2007.01.010
2. Guiry, M. D. (2012). How many species of algae are there? Journal of Phycology, 48(5), 1057–1063. https://doi.org/10.1111/j.1529-8817.2012.01222.x
3. Cirri, E., & Pohnert, G. (2019). Algae–bacteria interactions that balance the planktonic microbiome. New Phytologist, 223(1), 100–106. https://doi.org/10.1111/nph.15765
4. Plantae. Biology Articles, Tutorials & Dictionary Online. (2021, July 23). Retrieved February 3, 2022, from https://www.biologyonline.com/dictionary/plantae
5. Gordon, D. (2007). Kingdom Chromista in New Zealand. Marine Biodiversity, 15(4), 14–15. https://doi.org/https://niwa.co.nz/publications/wa/vol15-no4-december2007/kingdomchromista-in-new-zealand
6. Land, M. (2019, March 2). Characteristics of Protozoa & Algae. Sciencing. Retrieved February 3, 2022, from https://sciencing.com/characteristics-protozoa-algae-8124201.html
7. Adeniyi, O. M., Azimov, U., & Burluka, A. (2018). Algae biofuel: Current status and future applications. Renewable and Sustainable Energy Reviews, 90, 316–335. https://doi.org/10.1016/j.rser.2018.03.067
8. Borowitzka, M. A., & Moheimani, N. R. (2010). Sustainable Biofuels from algae. Mitigation and Adaptation Strategies for Global Change, 18(1), 13–25. https://doi.org/10.1007/s11027-0109271-9
9. Lyberatos, G., & Skiadas, I. V. (1999). Modelling of Anaerobic Digestion - A Review. Global Nest, 1(2), 63–76. https://doi.org/https://journal.gnest.org/sites/default/files/Journal%20Papers/Lyberatos.pdf
10. Song, C., Zhang, C., Zhang, S., Lin, H., Kim, Y., Ramakrishnan, M., Du, Y., Zhang, Y., Zheng, H., & Barceló, D. (2020). Thermochemical liquefaction of agricultural and forestry wastes into biofuels and chemicals from Circular Economy Perspectives. Science of The Total Environment, 749, 141972. https://doi.org/10.1016/j.scitotenv.2020.141972
11. Sikarwar, V. S., Zhao, M., Fennell, P. S., Shah, N., & Anthony, E. J. (2017). Progress in biofuel production from Gasification. Progress in Energy and Combustion Science, 61, 189–248. https://doi.org/10.1016/j.pecs.2017.04.001
12. Yang, Y. F., Feng, C. P., Inamori, Y., & Maekawa, T. (2004). Analysis of energy conversion characteristics in liquefaction of algae. Resources, Conservation and Recycling, 43(1), 21–33. https://doi.org/10.1016/j.resconrec.2004.03.003
13. Kucharska, K., Rybarczyk, P., Hołowacz, I., Łukajtis, R., Glinka, M., & Kamiński, M. (2018). Pretreatment of Lignocellulosic Materials as Substrates for Fermentation Processes. Molecules, 23(11), 2937. https://doi.org/10.3390/molecules23112937
14. Georgianna, D. R., & Mayfield, S. P. (2012). Exploiting diversity and synthetic biology for the production of algal biofuels. Nature, 488(7411), 329–335. https://doi.org/10.1038/nature11479
15. Purton, S., Szaub, J. B., Wannathong, T., Young, R., & Economou, C. K. (2013). Genetic engineering of algal chloroplasts: Progress and prospects. Russian Journal of Plant Physiology, 60(4), 491–499. https://doi.org/10.1134/s1021443713040146

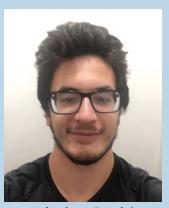
Author Contact Details

Dr. Raj Shah, Koehler Instrument Company • Holtsvile, NY 11742 USA • Email: rshah@koehlerinstrument.com • **Web: www.koehlerinstrument.com**

Sharon Lin, SUNY, Stony Brook University •

Blerim Gashi, SUNY, Stony Brook University •

Sharon Lin



Blerim Gashi

Raj Shah