ANNALS OF PLANT SCIENCES
ISSN: 2287-688X
OPEN ACCESS
www.annalsofplantsciences.com

Review Article

Algal biofuel: A promising perspective

Aishwarya N. Naik[1], Mrinalini J Singh[2], YasribQurishi[3]*
[1]MSc Biotechnology student from Garden City College, Bangalore, India
[2]Intellect Associate in Health Dynamics, Mumbai, India.
[3]Associate Professor, Department of Life Sciences, Garden City University, Bengaluru., India.

Received: 4/13/2018; **Revised:** 4/23/2018; **Accepted:** 4/29/2018

Abstract: The depleting energy resources and rising environmental issues have led to significant research in the field of producing fuel using alternative means. Biofuel can serve as better means to cope up with the depleting fossil and petroleum fuels. The novel properties of algae have set them as the best among all other biomasses and as a better alternative to the energy crisis. Algal biofuels are grouped under "Third generation biofuels" which has gained significant attention recently. Combustion of fossil and petroleum fuel releases sulphur dioxide in the air causing air pollution and acid rain. Most of the research on algal biofuel is done using microalgae which have high oil content along with faster growth rate. The potential of algae for producing biofuel can be improved by obtaining more efficient methods and by overcoming its certain limitations. The present review highlights the advantages, various types and production of algal biofuel.

Keywords: Algal Biofuel, Third generation biofuels, microalgae

Introduction

With an increasing population and an increasing demand for the conventional sources of energy such as fuel, it has become necessary to search for an alternative means of energy which should be renewable as well as non-conventional. Algae with the high biomass, oil and starch content have captured the world wide attention towards the production of fuel from them termed as algal biofuel. Biofuels are fuels derived from dead or living plant or animal waste matter or any other biological source through any contemporary biological processes; but the most promising one with least environmental effects is algal biofuel which is categorized as third generation biofuel [1]. A major concern with the biofuels is their sustainability in an environment along with economic viability and cost effectiveness [16] Algal biofuel being an important need of the hour; its types, production and usage needs to be investigated.

Moreover, industrialized environment has led to extensive environmental pollution with the release of a considerable amount of potentially toxic compounds in high proportion; thereby causing considerable deterioration of the available natural resources such as fossil fuels. Though petroleum products are the major source of energy in today's world; the release of hydrocarbons and toxic sulphur compounds from them has led to significant deterioration in the quality of soil, water and air [1]. It is estimated that the demand for petroleum fuel will rise to 45% by 2025 thus limiting the availability and supply of energy with the considerable increase in its prices. [3]

***Corresponding Author:**
Dr. Yasrib Qurishi,
Associate Professor,
Department of Life Sciences,
Garden City University, Bengaluru., India.
E-mail: yasrib.qurishi@gardencitycollege.edu

The high prices and less availability of petroleum fuel can be overcome by using alternative means of fuel such as biofuels. Biofuels derived from biological resources such as dead plants or animals or microorganisms, serve as an alternative means of energy; with the most popular being bio methanol and bioethanol [2] These biological factors can play an important role in substituting the chemical methods by adopting methods such as bio absorption, biofuel production, bioremediation, biodegradation, phytoremediation which will subside the effects of the pollutants in an environment. A variety of aliphatic and aromatic chemical compounds can be readily metabolized by microorganisms [1] Microalgae, macroalgae, seaweeds, cyanobacteria and yeasts are recognized as potential microorganisms for the production of biofuel[4] The concept of preparing algae based biofuel have gained significant publicity recently due to cost effectiveness in their production parameters [6].

Advantages of using algae for biofuel production;

(a)Algal oil productivity is higher than any other as it grows throughout the year.
(b) Ability to tolerate high carbon dioxide content.
(c)Algal cultivation requires less amount of water for growth.
(d) Herbicides or pesticides are not required during algal cultivation.
(e) The growth potential of algae is relatively very high.

(f) Any source of waste water containing nitrogen or phosphorus can be used for algal cultivation without any additional nutrients.
(g) Tolerance against harsh conditions like coastal seawater, brackish water [1].
(h) Algae can be easily grown and harvested in the large outdoors. [18].

Types of biofuels
Bio alcohols produced through fermentation of starch, cellulose, sugars, vegetable oil or animal fats [1]; mainly bioethanol derived from sugarcanes or corns are considered as first-generation fuels [2]

Biodiesel: produced by Tran's esterification process is similar in composition to fossil/mineral diesel [1]

Green diesel is produced from renewable feedstock rather than fossils or minerals and used in most diesel or fuels [1]

Vegetable oil; usually non-edible and low-quality vegetable oil is preferred for preparing fuel [1]

Bio ethers are also known as fuel ethers or oxygenated ethers are cost-effective compounds that enhance the octane rating [1]

Biogas is methane produced through anaerobic digestion of an organic matter [1]Microalgae, macroalgae, seaweeds, cyanobacteria and yeasts are recognized as potential microorganisms for the production of biofuel [4] The concept of preparing algae-based biofuel have gained significant publicity recently due to cost effectiveness in their production parameters [6]

There are several advantages of using algae for biofuel production;
(a)Algal oil productivity is higher than any other as it grows throughout the year.
(b) Ability to tolerate high carbon dioxide content.
(c)Algal cultivation requires less amount of water for growth.
(d) Herbicides or pesticides are not required during algal cultivation.
(e) The growth potential of algae is relatively very high.
(f) Any source of waste water containing nitrogen or phosphorus can be used for algal cultivation without any additional nutrients.
(g) Tolerance against harsh conditions like coastal seawater, brackish water [1].
(h) Algae can be easily grown and harvested in the large outdoors. [18].

Syngas is the mixture of gases such as hydrogen, carbon monoxide and other hydrocarbons produced on incomplete combustion of biomass with the release of low amount oxygen which is not sufficient to convert biomass to carbon dioxide and water [1]

Solid biofuels such as charcoal, wood shavings, dried manure, grass cuttings, etc. [1]

Third generation Biofuels includes Cellulosic ethanol, bio hydrogen, wood diesel, Algal fuel, DMF, etc. [1].

Algal biofuel
Algal biofuel is recognized as a clean and an alternative energy source with high biomass and lipid yield [9] Among all other algae; microalgae are evolving to be the only source of renewable biofuel that can make up to the worldwide demand of fuel requirement [3] earth; however some microalgae can undergo mix trophic process wherein they combine process of photosynthesis and assimilation of organic compounds. Microalgae has rapid rate of growth, high lipid producing capacity and high capacity for fixing greenhouse gases, which makes it an alternative feedstock of biofuel [8]

Macroalgae or sea weeds;
•Macroalgae is not involved in lipid production.
•They produce sugars and carbohydrates which can be further fermented to biogas or fuel [5].
•Among macroalgae species, Laminaria and Ulva are most important ones for energy production. Macroalgae being an important part of the marine ecosystem plays an important role in controlling Eutrophication and water pollution [17]

Microalgae;
•These are generally cultivated for extraction of proteins and pigments.
•Some of these are used for aquaculture and fish feeding.
•These have high photosynthetic efficiency.
•High lipid production capacity which make them efficient biodiesel feedstock.
•Biodiesel production using microalgae gives polyunsaturated fatty acids as the co product [5]

Production of Algae
The technologies and methods adopted for production of biofuel through industrial and agricultural means are different.

Agricultural production; for the photosynthetic growth of the microalgae, photo bioreactor is used where an algae grows in the presence of sunlight. This method involves the use of non-arable land with the constant supply of carbon dioxide as the carbon source during biomass production phase [10]

Algae culture systems
- Land based culture system; involves simple open air cultivation system for algae wherein shallow unstirred ponds with the supply of carbon dioxide as a carbon source and agitation for mechanical stirring in circular ponds called Centre-Pivot ponds or raceway ponds.

- Offshore culture system; involves shallow protected areas such as coastal areas that are easily accessible and allows better immobilization process. Generally by this method only seaweeds are cultivated and not microalgae for renewable energy source production. It involves a use of an underwater rope used for attachment of seaweeds with the slow release of fertilizers. Turbines are used for anchoring purpose and a grid connection for electricity need.

Industrial production; the process of industrial production is similar to microbial fermentation in industries. Production of algae involves sunlight in a photo bioreactor or reduced carbon sources such as sugar in a fermentation reactor [7]

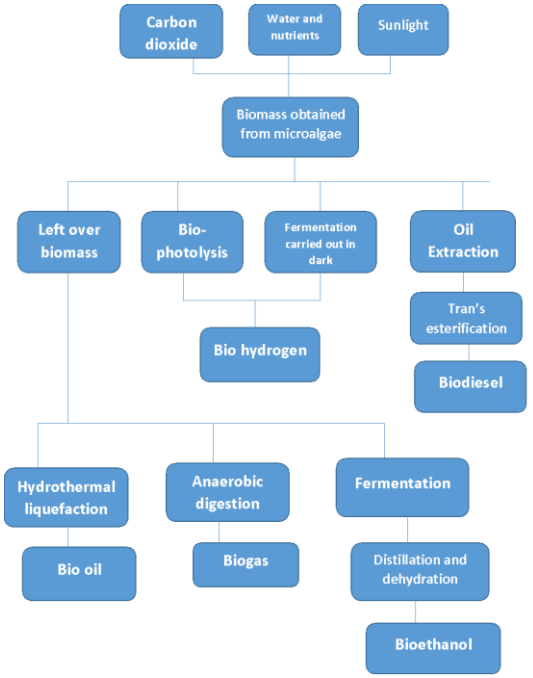

Figure 1. Biofuel production from algae:Detailed Process involved in production of biofuel from algae.

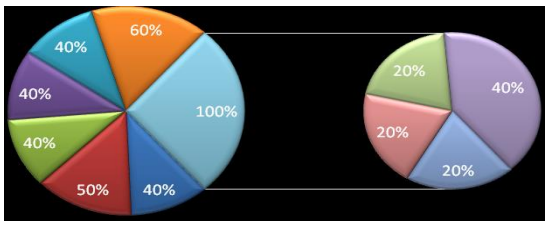

Figure2. Percentage of oil obtained from different sources:Detail about the percentage of oil obtained from variety of sources.

Table 1. Algae used in biofuel production includes;

Algae	Usage
Microalgae	These are aquatically grown microscopic species. These are basically plant species which produce algal oils having a potential to be converted as fuel.
Macro algae	These are multicellular non-microscopic species having high carbohydrate content. They are not rich in lipid content but high amount carbohydrate content can be converted to different types of fuels.

Table 2. Comparison of potential oil yields of algae and other oil seeds.

Crop	Oil yield gallon/acre	Product
Corn	18	bio alcohol
Cotton	35	biodiesel
Soybean	48	biodiesel
Mustard seed	61	biodiesel
Sunflower	102	biodiesel
Rapeseed/Canola	127	biodiesel
Jatropha	202	biodiesel
Oil palm	635	biodiesel
Microalgae	5000-15000	biofuel
10g/m²/day at 15% Triglycerides	1,200	
50g/m²/day at 50% Triglycerides	10,000	

Table 3. Oil content of few micro algal species[19]

Microalgal species	Oil content (% dw)
Ankistrodesmus TR-87	28-40
Botryococcusbraunii	29-75
Chlorella sp.	29
Chlorella protothecoides (autotrophic/ heterothrophic)	15-55
Cyclotella DI- 35	42
Dunaliellatertiolecta	36-42
Hantzschia DI-160	66
Nannochloris	31(6-33)
Nannochloropsis	46(31-68)
Nitzschia TR-114	28-50
Phaeodactylumtricornutum	31
Scenedesmus TR-84	45
Stichococcus	33(9-59)
Tetraselmissuecica	15-32
Thalassiosira pseudonana	21-31
Crpthecodiniumcohnii	20
Neochlorisoleoabundans	35-54
Schiochytrium	50-77

Table 4. Percentage of oil obtained from different sources

Biodiesel	40%
Green	50%
Castor	40%
Fat	40%
Sunflower	40%
Biogas	60%
Manure	20%
Wood	20%
Methanol	20%
Algal	40%

Production of Algal biofuel

Algal biofuel is the fuel that is derived from algal biomass. Biofuel is a term used for bioethanol, biodiesel and biogas used in methane gas, diesel and petrol.

Biodiesel; its production is done through squeezing process wherein the oil content in microalgae is removed out biofuel production. The oil is collected, chemically changed and then used in biodiesel as an ingredient.

Bioethanol; plays an essential role in the production of petrol. Macroalgae with the high content of sugar are chosen for this fuel. These macroalgae are then cut, mashed and then treated appropriately to obtain a sludge called feedstock. At this stage yeast is added to the feedstock which utilizes it as a food and breaks it down into ethanol. This process is termed as Fermentation. Following this process is the separation of the ethanol from other components to be used in the petrol.

Biogas; Methane is the main component in biogas production. Macroalgae with the high sugar content must be used to produce the methane gas wherein they are cut, mashed and the sugars present in them are then fermented by microorganisms into glucose. At this stage a sludge is obtained called feedstock which then enters a big tank to which anaerobes (microorganisms that do not require oxygen to survive) are added. These microorganisms are special because they require an environment with the correct temperature and acidity to carry out certain reactions known as anaerobic digestion. Anaerobic digestion produces methane and other gases from which the methane gas is separated out to be used as biogas.[12]

Advantages of Biofuel

Produces high content of energy.

One of the biggest advantage of algal biofuel is that it can produce up to 30 times more energy than any other generation crops. According to the Department of Energy in US, algae may yield 100 times more oil per acre of field than any other terrestrial crops producing fuel.

Grows at a faster rate.

One of the best characteristic of algae is its fast growth. It requires only water, carbon dioxide and sunlight to grow without affecting freshwater sources. It can be grown using waste water or sea water and are biodegradable with almost no harmful environmental effect after biomass has been produced.

High consumption of carbon dioxide.

Cultivation of algae for biofuel requires large amount of carbon dioxide which ultimately lowers down the environmental carbon dioxide content.

Waste carbon dioxide.

Streams rich in carbon dioxide obtained from combustion of fossil fuels or any other industrial processes can be used as carbon source for algal cultivation. It also acts as food for algae along with remediation of fossil carbon dioxide [15]

Less requirement of space.

It is estimated that if algal biofuel replaces the petroleum fuel then it will require only 14% of the area which is less than the area required by the corn being harvested [13] Following table gives the comparison of different crops and algae for their oil yield per acre[14]

Conclusion

The need for a better alternative to replace the petroleum fuel and fossil fuel has led to significant research in the field of biofuel production. Biofuels have proven to be the better alternative to petroleum fuel but lack regarding energy and space. As described above, algae have the potential to emerge as a better biofuel than others because of its several advantages such as less space requirement for algal cultivation, high energy production, high yield of oil per acre and less resource requirement. Algae has achieved a great interest currently in the field of biofuel production, giving rise to better ideas and methods supporting its growth and fuel production. Certain improvements in the production procedure can replace the petroleum fuel with the cost effective algal biofuel in the future.

Acknowledgments

We express our sincere thanks to Dr. YasribQurishi (Associate professor, Department of Life Sciences, Garden City College) for helping and guiding us.

Competing and Conflicting Interests:

The author has no relevant affiliations or financial involvement with any organization or entity with the financial interest or conflict with the subject matter discussed in the manuscript.

References

1. Sameera V, Sameera C, Ravi Teja Y. Current Strategies Involved in Biofuel Production from Plants and Algae. J Microbial Biochem Technol R1:002.2011. doi:10.4172/1948-5948.R1-002.

2. Paula Bianca MARICA, A Review of the Advances in Biofuels Production.

3. Kavita Tariyal1, Dhanesh M. Bartwal1, Seema Bartwal2, Algal biofuel: A symbol of sustainability in the developmental era, Scholars Academic Journal of Biosciences (SAJB) ISSN 2321-6883, Sch. Acad. J. Biosci., 2013; 1(5):192-197

4. Michael Thomas Ramsey, Microbes in Biofuel Production: A Review.

5. Tom Bruton (BioXL), Dr Henry Lyons (Shannon Applied Biotechnology Centre), Dr Yannick Lerat (European Research Centre for Algae, CEVA), Dr Michele Stanley (Scottish Association for Marine Science, SAMS), Michael Bo Rasmussen (National Environmental Research Institute, NERI), A Review of the Potential of Marine Algae as a Source of Biofuel in Ireland, February 2009.

6. Bhavish Patel, BojanTamburic, Fessehaye W. Zemichael, PongsathornDechatiwongse, and Klaus Hellgardt, Algal Biofuels: A Credible Prospective? Volume 2012 (2012).

7. Sjors van Iersel (Ecofys), ALGAE-BASED BIOFUELS: A Review of Challenges and Opportunities for Developing Countries, May 2009.

8. Roberto Parra-Saldivar1, Sara P Cuellar-Bermudez1, Miguel Angel Romero-Ogawa1 and Bruce E Rittmann2, Algae Biofuels Production Processes, Carbon Dioxide Fixation and Biorefinery Concept, August 25, 2014.

9. Ravindra Prasad, Biofuels from Algae: A Promising Future Fuel, 10 May 2016.

10. D. Ryan Georgianna1 & Stephen P. Mayfield, Exploiting diversity and synthetic biology for the production of algal biofuels, 16 AUGUST 2012 | VOL 488 | NATURE | 329.

11. Shuvashish Behera,1 Richa Singh,1 Richa Arora,1 Nilesh Kumar Sharma,1 Madhulika Shukla,1 and Sachin Kumar1, Scope of Algae as Third Generation Biofuels, 2015 Feb 11.

12. How Algae can be used to produce Biofuel, BioMara.

13. FutureofWorking.com | 7 Advantages and Disadvantages of Algae Biofuel; February 4, 2016.

14. Yebo Li, Assistant Professor and Extension Engineer, Caixia Wan, Graduate Student, Ohio State University Extension.

15. Philip T. Pienkos, Ph.D, The Potential for Biofuels from Algae.

16. Tanvi Taparia, Manjari MVSS, Rajesh Mehrotra, Paritosh Shukla, Sandhya Mehrotra, Developments and challenges in biodiesel production from microalgae: A review, 15 September 2015.

17. RenganathanRajkumar, ZahiraYakob and MohdSobriTakriff, Potential of the Micro and Macro Algae for Biofuel Production: A Brief Review.

18. Al Darzins (NREL), Philip Pienkos (NREL), Les Edye (BioIndustry Partners), Current Status and Potential for Algal Biofuels Production 6 August 2010. http://www.oilgae.com/algae/oil/yield/yield.html.

Cite this article as:
Aishwarya N. Naik, Mrinalini Singh, YasribQurishi. Algal biofuel: A promising perspective. *Annals of Plant Sciences 7.5 (2018) pp. 2262-2266*.
http://dx.doi.org/10.21746/aps.2018.7.5.10

Source of support: Nil.
Conflict of interest: Nil