Biodiesel from Algae as Green Alternative of Petrofuels

Indu Bala Sharma[1] and Shweta Sharma[2]

[1]Department of Chemistry Northern India Engineering College New Delhi, India
E-mail: [1]indu17_vivek@yahoo.co.in, [2]shweta.lav@gmail.com

Abstract—*The global fuel market is one of the fastest growing markets. Conventional energy resources are depleting very fast and cause pollution at alarming level. Therefore renewable biofuels are needed to displace petrofuels. Plant biomass is an abundant and renewable source of energy which can be converted by microbes in to biofuels. Biodiesel has emerged as one of the alternative fuel for the future to save the planet from catastrophe. Due to rapid growing demand of biofuel, biodiesel and bioethanol productions using algal lipids and carbohydrates respectively have received special attention. Biodiesel from microalgae seems to be the only renewable biofuel that has the potential to completely substitute petroleum-based transport fuels without adversely affecting the supply of food and other products. The productivity of these autotrophic microorganisms in converting carbondioxide into carbon rich lipids is a simple one or two stes away from biodiesel. Algal biofuels have many advantageous features that would have lower impacts on environmental degradation and also improves the well being of life. Although microalgae are not yet produced at large scale for bulk applications but advancement of technology, biology, genetic engineering and biorefining may act as keys to sustainable and economical option for future. This article provides an overview about few strains of algae for biodiesel production. A further work in this area needed global attention to save the global environment.*

Keywords*: biofuels, biodiesel, microalgae, biomass, petrofuel, renewable*

1. INTRODUCTION

To search a new, renewable, greener, sustainable alternative to fossil fuels various research groups and the private sectors have invested in the technology to grow algae and convert it to liquid biofuels over the last few years. Algae have a number of characteristics that allow for production concepts which are significantly more sustainable than their alternatives. These include high biomass productivity; an almost 100% fertilizers use efficiency, the possibility of utilizing marginal, infertile land, salt water, waste streams as nutrient supply and combustion gas as CO_2 source to generate a wide range of fuel and non-fuel products. Furthermore, another competitive advantage of algal biofuels is that their development can make use of current fossil fuel infrastructures. As more expensive sources of fossil fuels are starting to be exploited at the expense of the environment, [1, 2] the more rapidly algal biofuels can provide a viable alternative to petrofuels therefore rate of consumption of fossil fuel will be greatly reduced. Possible algal biofuels include[3, 4] biodiesel, bioethanol, bio-oils, biogas, biohydrogen and bioelectricity, while important non-fuel options include the protein part of algae as staple food, certain algal oils, pigments and other bioactive compounds as health foods, neutraceuticals or pharmaceuticals, or other renewable inputs for the food industry, including as feed for livestock and aquaculture. Other commercial applications [5] as non-food compounds can be extracted for use by the chemical industry, in cosmetics and skin care products, as organic fertilizers and as an alternative fiber source for the paper industry.

Advancement in research and technology of algal biofuels could eventually contribute to the alleviation of a number of energy and offer solution to environmental problems. The importance of investigating new options provided by algae cultivation is motivated by the fact that algae are very efficient at converting light, water and carbon dioxide (CO_2) into biomass in a system that does not necessarily require agricultural land. Depending on the concept, the water can be salty and the nutrients can come from waste streams. Depending on the species and cultivation conditions, algae can contain extremely high percentages of lipids or carbohydrates that are easily converted into a whole range of biofuels including biodiesel or bioethanol. Furthermore, the remaining biomass, mostly protein and carbohydrate, may be processed into many other products. Algae-based products can serve as an alternative to a wide range of products that are currently produced from fossil resources or land-based agriculture, but without requiring high quality land and in some cases without requiring fresh water, with CO_2 as the only carbon input. The real advantage of microalgae over plants lies in their metabolic flexibility, which offers the possibility of modification of their biochemical pathways (e.g. towards protein, carbohydrate or oil synthesis) and cellular composition. Algae-based biofuels have an enormous market potential, can displace imports of fossil fuels from other countries and hence reduce a country's dependency.

Algae are recognized as one of the oldest life-forms [6] and are present in all existing earth ecosystems, representing a big variety of species living in a wide range of environmental conditions [7]. They are primitive plants (thallophytes), i.e. lacking roots, stems and leaves, have no sterile covering of cells around the reproductive cells and have chlorophyll *a* as their primary photosynthetic pigment [8]. Under natural growth conditions phototrophic algae absorb sunlight, and assimilate carbon dioxide from the air and nutrients from the aquatic habitats [9]. Microalgae can produce lipids, proteins and carbohydrates in large amounts over short periods of time. These products can be processed into both biofuels and valuable co-products. High oil prices have ignited interest in algaculture (farming algae) for making vegetable oil, bio diesel, bio ethanol, bio gasoline, bio methanol, bio butanol and other biofuels, using land that is not suitable for agriculture.

Meeting the world's growing energy demands will require a multitude of sources. Algal biofuel could be a green, more efficient part of the solution in the future because of its potential as an economically viable, low emissions transportation fuel. In addition, algae have potential benefits and advantages for biofuel production.

2. ADVANTAGES OF ALGAE AS BIOFUEL RESOURCE

1. Algal cultivation can be carried out using non-arable land and non potable water.
2. Algae produce bio-oils through the natural process of photosynthesis-requiring only sunlight, water and carbon dioxide.
3. Growing algae consume carbon dioxide from the environment and hence reduce global warming.
4. Bio-oil produced by photosynthetic algae and the resultant biofuel will have molecular structures that are comparable to the petrofuels we are currently using.
5. Algae used to produce biofuels are highly productive. As a result, large quantities of algae can be grown quickly, and the process of testing different strains of algae for their fuel-making potential can proceed more rapidly than for other crops with longer life cycles.

3. CULTIVATION SYSTEMS FOR ALGAE

Although not specific to biofuel production from algae, it is important to understand the basics of algae cultivation systems. Systems which use artificial light demand, per definition, more energy in lighting than what is gained as algal energy feedstock, hence only systems using natural light are considered. There are three main types to cultivate algae [10-12].

- Open cultivation systems
- Closed cultivation systems
- Sea-based cultivation systems

4. BIODIESEL FROM ALGAE

Biodiesel production from algal oils has received most attention since algae can contain potentially over 80% total lipids, (while rapeseed plants, for instance, contain about 6% lipids). Under normal growth conditions the lipid concentration is lower (<40%) and high oil content is always associated with very low yields. The various lipids production can be stimulated under stress conditions, e.g. insufficient nitrogen availability. Under such conditions, biomass production is not optimal though, reducing the non-lipid part of the biomass that can be further used as a source for co-products. Biodiesel refers to any diesel-equivalent biofuel made from renewable biological materials such as vegetable oils or animal fats consisting of long-chain saturated hydrocarbons. It can be used in pure form (B100) or may be blended with petro diesel at any concentration. The purpose of blending is to reduce viscosity of the fuel and making it thinner. Biodiesel made from crops such as corn and soybeans is one such alternative that most people are aware of. However, there are problems associated with biodiesel made from crops namely the displacement of food and the amount of crops it takes to produce a gallon of oil. Therefore algae to biodiesel have been widely discussed among experts in the petroleum industry and conservationist who are looking for a more reliable and safer source of energy that is both renewable and easy to attain.

5. PROCEDURE FOR MANUFACTURING OF BIODIESEL

Once the algae are grown and harvested by any means, there are a different ways of extracting the oil. Oil extraction by conventional methods using organic solvents like hexane, chloroform, methanol are associated with, high cost, health and safety issues. These techniques are also non-selective, time consuming [13-14]. An alternative method to extract green oil from algae has been developed by Santana et al using supercritical carbondioxide [15]. They have successfully extracted sensitive lipid fractions without degradation. Use of supercritical carbondioxide provides a safe, low toxic, less time consuming method to extract algal oils[16-17]. Whichever method is used for extraction, the resulting product is a vegetable oil called "green crude" which is similar to crude oil, and further transformed into biodiesel fuel through "transesterification" [18].

Triglyceride+3Methanol$\rightarrow$Glycerine+3Methyl esters(Biodiesel)

Gao C *et al* [19] have reported that Microalga *Chlorella protothecoides* can grow heterotrophically with glucose as the carbon source and accumulate high proportion of lipids. These microalgae lipids are suitable for biodiesel production. To further increase lipid yield and reduce biodiesel cost, they have used Sweet sorghum juice as an alternate to carbon source to glucose.

A comparative study of the two species of Algae *i.e, Oedogonium* & *Spirogyra* were reported for the amount of biodiesel production & it was observed that *Oedogonium* is better option than *Spirogyra* for production of biodiesel [20].

Currently, few private companies and some publically funded research groups are working on algae cultivation similar to those contained in Cargill ponds near the southern horn oh San Francisco Bay and working on the aspect of bringing the cost of algal oil manufacture down to levels of affordable gasoline prices. A Newzealand company Aquaflow binomics is working on the production of biofuels by harvesting wild algae from the polluted waterways. It was reported that productivity of algae was not enough to yield appreciable amounts of fuel, so heterotrophic species of algae was used which utilized carbon based compounds rather than passively fixing carbon dioxide from the atmosphere. The specific algal strains of *Chlamydomonas* can synthesize some hydrocarbons but they can produce triacyglycerides on large extent. The bio diesel is synthesized using the glyceride backbones from these triglycerides by adding methanol [21]. The potential of microalgae for production of biodiesel along with other biofuels has been reviewed by Mata *et.al.* [22] in 2010. Recently by using electrocoagulation for production of biodiesel from *Nannochloropsis* sp. Was reported by Matos *et al* [23]. Nakanishi et al [24] studied a recently isolated marine green alga *Chlamydomonas sp*. JSC4 and found that it would be a feasible oil producer due to its high biomass production and lipid productivity under marine salinity. It is also reported that CO_2 fixation and lipid productivity increased up to 10%-CO_2 supplementation in *Chlorella* and *Botryococcus* cultures [25]. Very recently thermal conversion of whole algal biomass, especially wet processing that can significantly cut the cost of production of biodiesel has been reviewed [26]. G. W. O. Neil *et al* have reported that decolorization improves the fuel properties of biodiesel obtained from *Isochrysis sp.* They found that after removal of pigments like chlorophylls and pheophytins using montmorillonite K10, fuel properties like cetane number, kinematic viscosity and lubricity are significantly improved [27].

6. CONCLUSION

While the technology for large scale algal biofuel production is not yet commercially viable, algal production systems may contribute to rural development, not only through their multiple environmental benefits but also through their contribution of diversification to integrated systems by efficiently co-producing energy with valuable nutrients, animal feed, fertilizers, biofuels and other products that can be customized on the basis of the local needs. Algae are economical choice for biodiesel and bioethanol production, because of its availability and low cost. In this way algae can be used as renewable and sustainable energy as plants can grow repeatedly. Further research should be done having macroalgae and microalgae to compare the ratio of biodiesel production, chemical analysis and statistical significance.

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