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Algal Bio-fuel: A sustainable source of energy

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Abstract

Bio oil obtained from algae can be used as a sustainable and unconventional source of biofuels as well as different crops such as *Jatropha*, rapeseed etc which contain high lipid content and can be used as a resource for production of biofuels. Algae, however contain the highest amount of bio oil as compared to other energy crops. They are present in wide range of environmental condition serving us wide variety of strains and lipid component. Biofuels obtained from algae in higher amount can be used as a substitute for petrofuels and thus it need production of biofuels at commercial level which demands proper industrial setup. In order to obtain high lipid content, different algal content can be genetically engineered and modified strains which can help in parallel in production of biofuels at scale. There are various high lipid containing species such as *Spirogyra, Chlorella, Spirulina, Porphyra*, are already used for the production of biofuel at commercial scale. Although there is a huge difference between the demand and supply of the biofuels. The only way to meet out the demands is to explore more Algae having feature of high amount biofuel production, reduce the cultivation cost, and improved the scale up methods.

Keywords: Biofuel, Algae, Bioengineering, Biodiversity, Renewable resources, Sustainability.

Introduction

The increasing demand of fuels leads to the limitation of non-renewable sources of energy. It is a global issue and in order to tackle this problem, there is a need of some sustainable form of energy source to meet the future demand of fuels. There is also a major negative impact of petro fuels on the present environment as it leads to the production of many harmful gases like SO_2, CO_2, CO, NO_X etc., emitting from vehicles or industries which causes many problems such as global warming, acid rain, etc. Not only the environmental imbalance is a result of increased use of petroleum fuel, it is also an economic and political issue, as the scarcity of non-renewable sources of energy led the increase in prices of petro-fuels which also affect the economy of countries and is also a cause of dispute.

Rather than production of fuels by geological process resulting in formation of fossil fuels such as petrol, coals, natural gases etc; there is a biological resource known as biodiesel or biofuel which involves the usage of different life forms such as plants or microalgae for its production; or indirectly from agricultural wastes, industrial or commercial wastes as a source of nutrition. Production of bio fuels such as bioethanol or biodiesel from different forms of algae as a source is an easy and fast step towards it. Algae is a diverse life form on the Earth and a source of various anthropological products and their applications Algal culture is not much challenging and easy to harvest with a low cost production and it could be available throughout the year. The range of diversity in the Algae extremely high from fresh water to marine water and from freezing temperate to high temperature even at various pH. Biofuels from plant sources take time as they take months to grow whereas algae just start growing within a week or two and oil content could also be extracted from them in a very short period of time and it can also be grown easily on lands which are not suitable for agricultural use [Hazar H *et al.,* 2010; Huang G *et al.,* 2010; Thamsiriroj, 2009].

Bio-fuel

The term biofuel refers to the fuel as an energy source which is obtained from different bio renewable food or energy crops. On the basis of technology used in production, biofuels are classified into different generations;

First generation biofuels: These are advanced biofuels mainly obtained from non-food crops. Biogas, bio-hydrogen, biomass-based biodiesel are obtained from non-food crops or cellulosic biomass whereas bioethanol is obtained from sugar, starch, hemicelluloses and other cellulosic materials [Altun S., 2011; Ertas M *et al.,* 2015].

Second generation biofuels: This generation biofuel is also obtained from non-food crops such as wood, wheat straw, corn etc. by using highly developed technologies [Demirbas M., 2011].

Third generation biofuels: This is also known as 'oilgae', bio oil obtained from algae [Demirbas M., 2011].

Fourth generation biofuels: Genetically modified strains of algae come under fourth generation which are modified in the sense to consume more CO_2 from the atmosphere than they produce during combustion of biofuel. Different technologies are being used for fourth generation biofuel processing such as gasification, pyrolysis, manipulation of algae at gene level to secrete hydrocarbons by using bioengineering and genetic engineering. Much advanced technology is being used for this generation crops for converting biodiesel or vegetable oil into biogasoline [Demirbas M., 2011].

DIFFERENT BIOLOGICAL SOURCES USED FOR THE PRODUCTION OF BIOFUELS

In the very near future, due to increasing population, there is also a high demand of fuels which is readily available in the form of petroleum, coals; which are non-renewable sources of energy. The solution of this problem is the production of some renewable sources of energy. There are number of plants (energy crops) such as *Jatropha*, rapeseed, etc. which can be used in the generation of biofuels. There are many characteristics which make microalgae a better source of biofuels than crop plants. It has been observed that the production of bio fuel from algae is 2000-5000 gallons per acre [Williams *et al.,* 2015]. It contains 30% oil content by weight which can be a good source of bio fuel production compared to other sources [Williams *et al.,* 2015].

Table 1. Oil Yield from different Biological Sources.

BIOLOGICAL SOURCES	OIL YIELD (L/ha)
Corn	172
Cottonseed	325
Soybean	446
Yellow grease	907
Sunflower seed	952
Peanut	1059
Rapeseed	1190
Oil palm	5950
Algae	95000

SOURCE: US Energy Information Administration.

It not just acts as a renewable source but it can also be harvested with the minimum requirement of water, with no use of fertilizers. It only requires sunlight, water in less amount and uptake of CO_2 for the production of bio oils or lipids. The production of high biomass content which contains lipid and bio oil can be processed in bio fuel. It is not that it just require low input but it also provides nutrients for aquaculture and fertilizers as a byproduct apart from production of bio fuels [Algae Biomass organization, 2015]. Not only as a source of renewable sustainable form of bio fuel, algae could also play an important role in maintaining the rate of CO_2 in the environment. The consumption of CO_2 during photosynthesis lower the concentration of CO_2 in the atmosphere or it can be said that more the production of algae, more the consumption of CO_2 from atmosphere. Hence, resulting in the maintenance of level of

CO_2 which acts as a helpful hand in controlling problem of global warming. It has been reported that bio fuels are carbon neutral energy source as the CO_2 released during combustion of bio fuel is equal to the consumption of CO_2 during photosynthesis [Biomass and the environment.]. Brazil and the United States produced around 70% of the global biofuel supply in 2015 which consists of mainly sugarcane-based and corn-based ethanol, respectively [Renewable Energy Network, 2016].

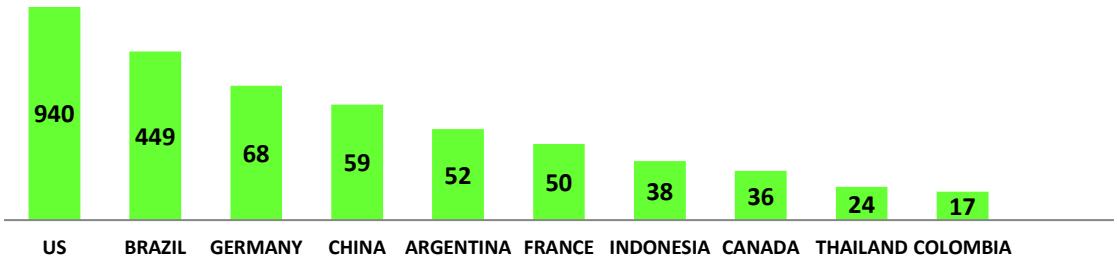


Figure 1: Graphical representation of Biofuel production in different countries(thousand barrels per day)

WHY ALGAE AS SOURCE OF BIOFUEL?

Algal biofuel is a better approach towards sustainability than any other sources. The amount of oil obtained from algae is much higher than other plant and in this way, conserving resources which are used as food and fodder for cattle. Some algae also grow very fast whereas, plants take much more time to grow. Hence it can be a quick source for biofuel production. In addition to all above, the most important feature is that it emits no pollutants or green house gases during its combustion except CO_2 which is a green house gas but is again consumed during its growth in compensatory manner i.e., the amount of CO_2 released is again utilized in biomass production.

ALGAL STRAINS USED IN BIOFUEL PRODUCTION

Algae are photosynthetic aquatic form of organisms, present in diverse habitat from marine to fresh water forms, from high range of temperature to low range of temperature and also present in different pH range. There are number of algal strains are found in nature but the choice of algae should depend on the production of high biomass and oil or lipid content for the production of algal bio fuel on commercial level. For example, *Dunaliella tertiolecta* is a fast growing alga with high CO_2 sequestration rate and contain lipid content of 37% dw [Minowa T *et al.,* 1995]. Then there come some algae such as *Chlamydomonas reinhardtii*, *Dunaliella salina*, *Botryococcus braunii* and also some *Chlorella* sps., which are slow growing in nature but can yield high lipid content which is up to 60 wt%[Metzger P *et al.,* 2005].

Table 2. Oil content in % dry weight (dw) from different sources [Chisti Y., 2007]

Strain	Oil content (% dw)
Chlorella sp.	29
Chlorella protothecoides	15-55
Scenedesmus TR-84	45
Porphyra	33
Diatoms	21-31
Botryococcus braunii	*29–75*

PRODUCTION OF BIOFUEL FROM ALGAL BIOMASS

This process involves different steps such as cultivation, harvesting and processing.

Cultivation: It can be done in two ways; in open pond and in photo bioreactors. Open pond system consists of direct supply of CO_2 and sunlight into water and contains a continuously moving blade like structure which helps in proper mixture of nutrients or broth. Photo bioreactor, on the other hand is somewhat advanced technique used in the cultivation of algae as the supply of light and CO_2 can be altered and optimized as required. This is one of the major concerns during cultivation, whether to go for open pond system or closed photo bioreactors. For growing biomass in open pond it requires large surface area than depth because light cannot penetrate beyond the limit when it contains sufficient thick layer of algae[Stuart A Scott *et al.,* 2010]. However, this method is very economical but the problem with open pond system is that it is nearly impractical to control the contamination and also to maintain the steady temperature and other environmental factors. Though contamination can be manipulated if required by preparing and operating the process in sterile condition but make up very high cost which again turns into high disbursement [Stuart A Scott *et al.,* 2010].

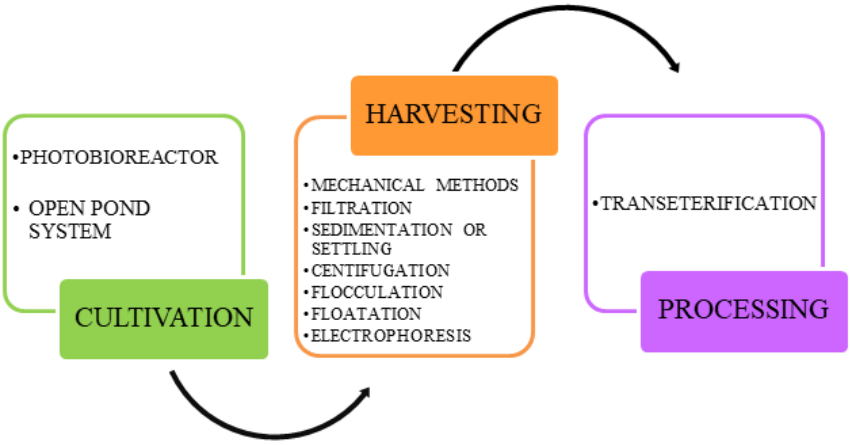
On the other hand, Chisti [Chisti Y., 2007] supported the use of photobioreactor suggesting that algae can be produced in higher density and its productivity per unit area is much higher than that cultivated in open pond with low energy input. In addition to this, nutrient supply and CO_2 supply can also be optimized and manipulated in photo bioreactor and the biomass obtained has high chances of being contamination free if processed properly.

Harvesting: Formation of biofilm takes place as the algal growth increases and it can be easily *harvested*. Algae of interest could be both phytoplanktonic and filamentous and they occur in both sessile and sedentary form. However, it has been reported that oil content is high in sedentary nature of algae. As the algae have been isolated from the growing site, excess amount of water should be removed from the algal content as it is grown in water so it contain high water content in its body. Harvesting methods also depend on the whether the desired algae is macroalgae or microalgae [Sustainable Development of Algal Biofuels]. Methods used are different for both of them. Mechanical methods are used for harvesting macroalgae which require low-energy input. [Roesijadi et al., 2010]. For harvesting microalgae, different methods are used which are mainly based on the density or size exclusion. The methods used are filtration, centrifugation, flocculation, sedimentation, floatation and other electrophoresis techniques [Uduman *et al.,* 2010]. Two of the mentioned methods are very similar in process; flocculation and sedimentation. Many agents are used in density dependent separation which causes aggregation of microalgae, resulting in settling or floating of algae. Flocculants used can be both organic and inorganic. Electrophoresis techniques are also used for the harvesting which includes electrolytic flocculation and electrolytic coagulation.

Centrifugation method concentrates the biomass hastily but is not much economic whereas filtration method is also used but it clogs the filter. But more innovations and improvements are being made in both of these methods for efficient harvesting of algal biomass [Sustainable Development of Algal Biofuels].

Extraction and Processing: For extraction, dry or wet algal biomass can be used which was previously harvested. Process of drying is highly energy demanding but material can be directly used for oil extraction [Viswanathan *et al.,* 2011]. For wet extraction, solvents are used which are insoluble in water in order to save the excess energy used in recovery of solvent. Characteristics of sought-after solvents are low toxicity, low heat of vaporization, low cost, low specific heat and high solvent power. For extraction of wet algal biomass most frequently used solvent is hexane [Sustainable Development of Algal Biofuels].

Processing mainly involves transesterification method, commonly used in biodiesel production, not only in algal feedstock but also in vegetative feedstock as well as in animals. In this process, oil is obtained by reacting methanol or ethanol with glycerides or Triacylglycerides (TAGs) obtained from microalgae in the presence of catalysts; Fatty acid methyl ester (FAME) is obtained by using methanol and Fatty acid ethyl ester (FAEE) by ethanol as alcohol [Abishek M.P. *et al.,* 2014].



ENVIRONMENTAL IMPACT OF ALGAL BIOFUEL

Algal biofuel have almost no negative impact on the atmosphere as its combustion emits carbon dioxide and water. The carbon dioxide emitted from biofuel goes to the environment and again utilized during the growth of algal biomass, hence acts as a carbon neutral source. Moreover, the production and cultivation of algal biomass adds oxygen content to the atmosphere.

Figure 2: STEPS INVOLVED IN ALGAL BIOFUEL PRODUCTION

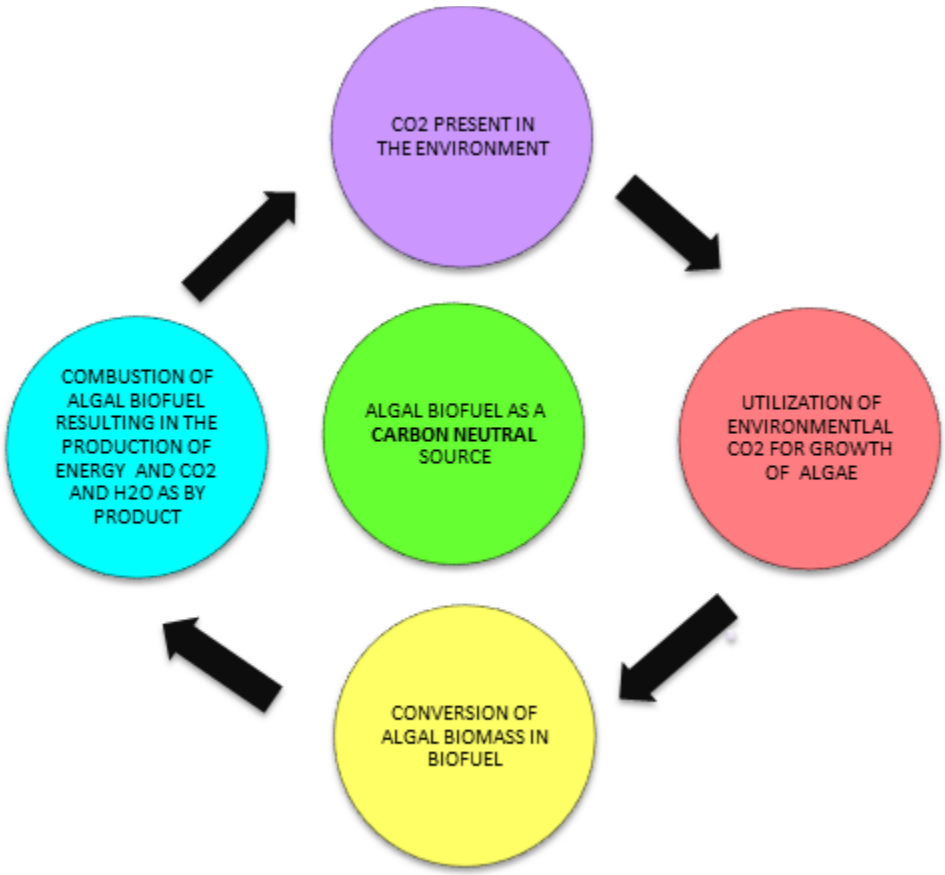


Figure 3: FLOW CHART SHOWING RECYCLING OF CO_2 IN THE ENVIRONMENT

ADVANTAGES AND DISADVANTAGES OF BIOFUELS

Advantages:

1. There are number of advantages of growing algae for biofuel production as it can be grown easily as compared to other feed stocks and it is somewhat grown 20-30 times faster than other sources [Demirbas A *et al.,* 2011].
2. One of major benefits of cultivating algae at large scale is that it will help in limiting CO_2 in environment [PROJECTS, 2015], whereas O_2 level will be increased by them.
3. The gases emitting from algal biofuels are not much harmful as compared to petro fuels.
4. Another positive point regarding the growth of algae is that they can be grown in waste water or water quality which is not suitable for the growth of other plants.
5. Compounds such as phosphates, nitrates are reason of declined water quality serve as nutrients for algae [Mata T.M. *et. al.,* 2010].

Disadvantages:

1. In order to replace petro fuels, biofuels should be produced in large scale and this needs organization of large industrial setup for commercial production which could be quite costly [Williams *et al.,* 2015].
2. There also should be manufacturing of machines or engines which should be favorable to the emitting gases such as nitrogen, phosphorus from algal biofuels, which is currently a problem which can effect [Algae Biomass Organization, 2015].

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