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Algal Biofuel: A boon for society in future to solve Energy crisis

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ABSTRACT

Fossil fuel based energy resources (petroleum, coal and natural gas) are vanishing at a very faster rate to fulfill the demand of energy for growing population worldwide. So depletion of these resources will lead us to the chains of problems which may occur due to fuel shortage. It has been estimated that as per present uses, our coal reserves will be exhausted in 200 years and if we increase the use by 2%, then it will be vanished in 165 years. Therefore in such a condition sustainable and renewable energy resources are beneficial to solve the problem of energy crisis. Fortunately, our scientists have developed different categories of biodiesel as an alternative fuel to meet growing energy demands. In recent scenario, they are focused on the algae as a raw material for biodiesel and which may be proved as a boon for the society in future. Biofuels play a vital role in mitigating CO_2 emission, reducing global warming and bringing down the hike in oil prices. The biodegradable, renewable and non toxic nature of biodiesel has made it a recent attraction. The objective of the paper is to study the potential of microalgae as an alternative raw material for biodiesel generation that can be converted into fuel. Its easy availability, high mass productivity and faster lipid production have made it prior to all other alternatives for the raw material of biodiesel. Production of biodiesel from microalgae would be a greater alternative to oil crops due to economical instability, jeopardizing agricultural lands and insufficient oil crops. This article provide holistic review to enhance the production and commercialization of biodiesel by improving cultivation of different microalgal species, lipid content in various algal species, modes and efficiency of harvesting and trans-esterification methods.

Keywords: Renewable fuel, algae, Biodiesel

INTRODUCTION

The serious problems of energy requirements have been created by burgeoning population and uncontrolled urbanization.[1] The world's oil production is expected to decline in near future. These impending energy crisis have forced both governments and private industries to examine alternative sources of energy. Government organizations and major corporations are beginning to seriously invest in the biofuels market, in both research and commercial production; however, the many existing alternatives such as ethanol, hydrogen, and conventional biodiesel fail to be cost competitive with petroleum.[2]

"The global biodiesel industry is among the fastest-growing markets the chemical industry has ever seen world capacity, production, and consumption of biodiesel grew on average by 32%/year during 2000-05, and the industry looks set for even faster growth rates".[2]

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According to an investigation, possible results of policy support in developed and developing economies for developing algal biodiesel through to 2040. This investigation adopts the Taiwan General Equilibrium Model-Energy for Bio-fuels (TAIGEM-EB) to predict competition among the development of algal biodiesel, bioethanol and conventional crop-based biodiesel. Analytical results show that algal biodiesel will not be the major energy source in 2040 without strong support in developed economies. In contrast, bioethanol enjoys a development advantage relative to both forms of biodiesel. Finally, algal biodiesel will almost completely replace conventional biodiesel. CO_2 reduction benefits the development of the bio-fuels industry[3]. Other non-renewable sources of energy exist, such as coal and uranium; however, these sources are limited and will also inevitably decline in availability. The major disadvantages of using petroleum based fuel is atmospheric pollution by releasing greenhouse gases (GHG), other air contaminants including NOx, SOx,COs, volatile organic compounds, CO_2, etc which are adversely affecting the environment.[4] So, in order to solve these problems our scientists have discovered algae as a raw material for biodiesel. Biodiesel can also be produced from edible sources, non-edible sources and waste oil apart from algae.

PRODUCTION OF BIODIESEL FROM ALGAE

Algae have been proved as a root element of biodiesel as algal biomass is one of the emerging sources of sustainable energy. According to the US Department of Energy report, the biodiesel produced from algae could see yields greater than oilseed crops. Oil produced from microalgae is clearly superior to that of terrestrial plants such as palm, rapeseed, soybean or jatropha as microalgae is capable to double their biomass within 24hrs.[4] (Table 1)

Table 1. Comparison of some sources of biodiesel

Crop	Oil yield (L/ha)	Land area needed (M ha)	% of existing US cropping area
Corn	172	1540	846
Soybean	446	594	326
Canola	1190	223	122
Jatropha	1892	140	77
Coconut	2689	99	54
Oil palm	5950	45	24
Microalgae	136900	2	1.1

Microalgae has very significant role in our environment or ecology as they are the food sources for many animals and also belongs to the bottom of the food chain. Moreover, they are the principal producers of oxygen on earth. The above mentioned data itself defines the importance of algae as a raw material for biodiesel. Its unicellular structure made it live and grow under harsh conditions rapidly. They are prokaryotic or eukaryotic photosynthetic microorganisms. Microalgae, also called ‘miniature sunlight-driven, biochemical factories, are capable of producing several different types of renewable biofuels and byproducts. These include renewable biofuel, bio hydrogen, hydrocarbon, methane, ethanol, carotenoids and phycocolloids, minerals, vitamins, polysaturated fatty acids (PUFAs), α-linolenic, eicosapentanoic and doco succinic acids, belong to ω-3 group, propylene glycol, acetol, butanol, biogas, neutral lipid, polar lipid, carbohydrates, sterols, tocopherols, carotenoids, terpenes, quinones and phytylatedpyrrole derivatives such as the chlorophylls, β carotene, antioxidants, antibiotics,astaxanthin and pigment.

Oil content is only one criterion for selecting the species for cultivation. Growth rate, density, and survivorship must also be considered.

Table 2. A comparison of the oil content found in greenalgae.

Species	**Oil Content (% based on dry weight)**
Chlorella sp	28-32
Nitzschia sp.	45-47
Nannochloropsis sp.	31-68
Schizochytriumsp	50-77

MICROALGAE CULTIVATION

Microalgae cultivation can be done in open culture systems such as lakes or ponds and in highly controlled, closed- culture systems called photobioreactors (PBRs).[5] The photosynthetic growth of microalgal biomass require light, CO_2, water, organic salts and temperature of 20-300 ^{0}C.[6] The microalgal biomass can be achieved by different cultivating methods like raceway ponds, photo bioreactors, etc. Microalgae cultivation can easily be done in urban wastewater as it provides nutrients to them. There is a block diagram through which the importance of waste ater treatment can easily be elaborated.

The following block diagram depicts the significance of wastewater treatment.[6]

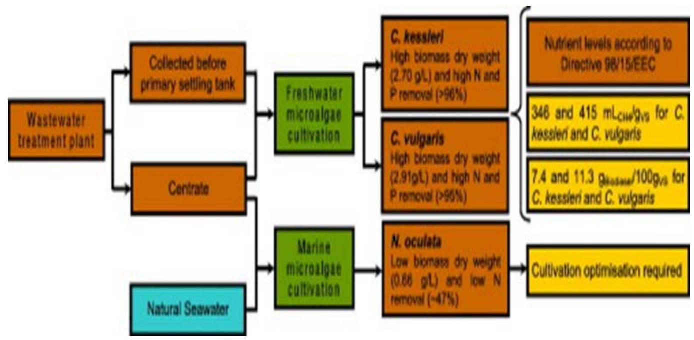

Figure 1. Waste water treatment.

There are some harvesting techniques for the microalgae cultivation. Harvesting biomass represents one of the significant cost factors in the production of biomass. Centrifugation, flocculation, filtration, screening, gravity sedimentation, immobilization, flotation and electrophoresis are some of the major techniques applied to the harvesting of microalgae.

Method of centrifugation itself signifies the production of microalgae from the liquid broth. A report was given that the laboratory centrifugation tests were conducted on pond effluent at 5001000g recovered about 80-90% microalgae within 2-5min. Exposure of microalgal cells to high gravitational and shear forces can damage cell structure. In addition this is not economically feasible for large scale harvesting because it is energy intensive and time consuming.[6] Flocculation is one of the another process in which dispersal particles are aggregated together to form large particles for setting. Autoflocculation is one of its kind where precipitation of carbonate salts with algal cells take place.[7] Gravity sedimentation can be effective for separating larger and smaller organisms. Enhanced microalgal harvesting by sedimentation can be achieved through lamella separators and sedimentation tanks.[7] Filtration is again another method commonly used for solid liquid separation. Vacuum filtration is effective in the recovery of larger algae (greater 70µm), when used with the aid of filters.[8] A further method of harvesting is floatation. Floatation is a gravity separation process in which air or gas bubbles attach to solid particles and then carry them to the liquid surface. Floatation is more beneficial and effective than sedimentation with regard to removing microalgae. Flotation can capture particle with a diameter of less than 500µm by collision between a bubble and a particle and the subsequent adhesion of the bubble and particle.[5] The electrolytic method is another potential approach to separate algae without the need to add any chemicals. In this method, an electric field drives changed algae to move out of the solution. Moreover algae cultivation can be improved by providing it with proper requirements: carbon, water, light, and space. By maximizing the quality and quantity of these requirements, it is possible to maximize the quantity of oil-rich biomass and the return on investment.[2]

LIPID- AN IMPORTANT COMPONENT FOR THE PRODUCTION OF BIODIESEL

The production of biodiesel involves an important role of lipid extraction from algae. A lot of research is being carried out for developing microalgal biodiesel technology by performing bioprospecting of high-lipid-containing strains as well as by inducing higher lipid production by various physiological and genetic strain improvement methods. Therefore, lipid extraction is an extremely important process for the production of microalgal biodiesel. There are also other methods such as algal biorefinery for the production of multiple algal products and thermochemical technology for the production of biocrude. As fuels are a commodity product, extraction of lipids from algae is technically and economically viable even in integrated concepts. When produced in huge quantities, extraction of lipid for biodiesel production from strains containing even around 10% lipid content will be feasible[9]. Sun drying, low pressure, shelf drying, spray drying, drum drying, fluidized bed drying, folch method, bligh and dyer method, ultrasonic-assisted extraction, bead beating, expeller press, freeze drying and RefractanceWindowTM technology drying and freeze dried cells are preferable for biodiesel production.[10, 11, 9]

The biomass residues that remain after extraction of the oil could be used as high protein animal feed, to produce biomass by anaerobic digestion, protein feed for livestock.[12]

CONVERSION OF MICROALGAL OIL TO BIODIESEL

Pyrolysis (cracking), microemulsion, thermal liquification and transesterification are the possible methods to minimize problems associated with feedstock use. The first two methods are costly and yield low quality biodiesel, whereas the latter, transesterification, is the most common method to transform oil into biodiesel.[13, 14, 15, 16, 1]

TRANSESTERIFICATION

Transesterification is a chemical process of transforming large and branched TG into smaller and straight chain molecules, which is similar in size to the molecules of the species present in diesel fuel[16]. This involves the reaction between TG and an alcyl acceptor (Carboxylic acids, alcohols, or another ester).

Transesterification stepwise reaction:

1. Conversion of triglycerides to diglycerides:
TG(Triglycerides) + Alcohol → Diglycerides + Fatty acid ester
2. Conversion of diglycerides to monoglycerides:
Diglycerides + Alcohol → Monoglycerides + Fatty acid ester
3. Conversion of monoglycerides to glycerin:
Monoglycerides + Alcohol → Glycerol + Fatty acid ester

Transesterification is reversible reaction of fat or oil (which is composed of triglyceride) with an alcohol to form fatty acid alkyl esters and glycerol.[12]

Lipases are found in all living organisms and are broadly classified as intracellular and extracellular microorganisms. Microbial lipases are mostly intracellular, produced by submerged fermentation or solid state fermentation. The important purification step for producing extracellular lipase is a complex process and it depends on the origin and structure of the lipase.[1]

ADVANTAGES

Microalgae are efficient in removing nitrogen, phosphorus and toxic metals from waste water and therefore, have potential to play an important remediation role, particularly, during the final (tertiary) treatment phase of waste water.[17]

The use of biodiesel will ultimately leads to reduction of harmful emission of carbon monoxide, hydrocarbons and particulate matter and to the elimination of SOx emission, which can also help in reducing the greenhouse effects and global warming.[18]

Depending on the microalgae species various high-value chemical compounds may be extracted such as pigments, antioxidants, β-carotenes, polysaccharides, triglycerides, fatty acids, vitamins, and biomass, which are largely used as bulk commodities in different industrial sectors (e.g. pharmaceuticals, cosmetics, nutraceuticals, functional foods, and biofuels).[19,20]

CONCLUSION

We all are victims of the problems created by the population overflow in the form of serious energy crisis. As our fossil fuel based energy resources are exhausting at a very faster rate which leads us to the chains of problems. Many countries have already taken steps to switch over to eco-friendly energy resource like biomass energy in order to provide us an environment with green energy. This paper has also focused on the various steps performed to isolate algal bio-fuel from biomass which has a most promising future. Innovative technology and genetic manipulation should be studied to increase the efficiency of bio-fuel to provide sustainable lifestyle worldwide.

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