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Potential of Nannochloropsis sp. Algae oil to be used as Engine Fuel: a Review

N. Vinothkumar[1], R. Arularasan[2] and S. V. Baranidharan[3]

[1] *Department of Mechanical engineering, E.S engineering College, Villupuram Tamilnadu, India*
[2] *Department of Mechanical Engineering, University College of engineering, Arni, Tamilnadu, India*
[3] *Dept of Mechanical Engineering, Sudharsana Polytechnic College, Kalipatti, Thiruchirapalli, India*

Abstract: The continuous increasing demand for energy and the depletion petroleum resources has led to the search for new alternative fuel which is renewable and sustainable. Biodiesel has gained much attention in recent years due to its eco-friendly, non-toxic, biodegradability and reduced or zero net carbon cycle compared to conventional diesel fuels. The quality and efficiency of Biodiesel fuel was found to be more when compared to petroleum diesel. In the current review, algal Nannocholoropsis sp. is being verified for potential for biofuel production. This species has been need to be analysed for its suitability of algal biofuel production because of its ease of growth and high oil content, mainly unsaturated fatty acids and a significant remarkable percentage of palmitic acid. It also contains enough unsaturated fatty acid linolenic acid and polyunsaturated acid for a quality biodiesel, the quality of Biodiesel depends on the type of feed oils.

Keywords: Algae Alageoil BioOil Biodiesel Fuel Nannochloropsis

1. Introduction

In recent years, global warming, world oil supply, energy demand have all played a part in the push for alternatives to petroleum-based fuels. The Intergovernmental Panel on Climate Change (IPCC) affirms that during the 20th century, the Earth's average temperature increased by 0.6°C and will continue to increase anywhere from 1.5°C to 4.5°C by the year 2100. This increase in global temperature is enough to cause flooding in coastal regions and make storms like Hurricane Katrina a more common occurrence (1). The need of our energy is increasing continuously, due to increase in industrialization as well as human population. The basic supply sources of energy are petroleum, natural gas, coal, hydro and nuclear. The major drawback of using petroleum fuel is atmospheric pollution and green house gas (GHG) emission. Petroleum diesel fuel combustion is a major source of greenhouse gases (GHG).

Apart from these, diesel combustion is also major source of other air contaminants including NOx, SOx, CO, particulate matter and volatile organic compounds which are adversely affecting environment and causing air pollution.(2) Although biofuels are still more expensive than fossil fuels, their production is increasing in countries all around the world which is encouraged by policy measures and bio fuels targets for transport, its global production is estimated to be over 35 billion litres. The main alternative to diesel fuel is biodiesel, representing 82% of total bio fuels production and is still growing in Europe, Brazil, and United States, based on political and economic objectives.(3)

2. Importance of Biodiesel

Fuel which is produced from biomass does not contribute to CO_2 atmospheric emissions. Biodiesel has lower amount of pollutants during and after combustion process. Engine lifetime can be improved due to the biodiesel viscosity which is twice higher than petroleum diesel. In the other hand high level of viscosity may have some difficulties with fuel pumping. Biodiesel is in liquid form with high combustion efficiency due to presence of oxygen. It has approximately 10–11% of oxygen. It also has lower content of sulphur and aromatic components compared to petrol diesel. Higher cetane number is an advantage of biodiesel, may have cetane number which is around 60–65 while petrol diesel has approximately 53. Reduction of carbon dioxide emissions by 78% can be obtained, as well as soot reduction.

Biodiesel is non-toxic and non-flammable type fuel. Reduction of particular matter can be achieved as well, biodiesel has great impact of unburned hydrocarbons reduction. During combustion of biodiesel, unburned hydrocarbons are reduced over 90%. High compression ratio in biodiesel engines is used which causes higher emissions of NOx. Early start of combustion occurs due to the high content of oxygen in biodiesel. It creates relatively higher NO_2 (approximately 14%). Small fraction of power loss is noticeable which is around 2% only. That power loss implements fuel consumption ratio, which may grow up to 10%. Biodiesel has excessive amount of carbon deposition which may occur gum formation (polymerization) (4)

3. Microalgae

Microalgae is the unicellular or simple multicellular structure microorganism that can grow rapidly in water and live in harsh conditions. Microalgae are sunlight-driven cell factories that can convert carbon dioxide to potential bio fuels, foods, feeds and high-value bio actives. In addition, these photosynthetic micro organisms are useful in bioremediation applications and as nitrogen fixing bio fertilizers. Microalgae can provide several different types of renewable bio fuels. These include methane Produced by anaerobic digestion of the algal biomass, biodiesel derived from microalgal oil and photobiologically produced bio-hydrogen. The idea of choosing microalgae as a potential source of fuel is not new to us, but it is now only being taken seriously because of the increasing price and pollution due to petroleum fuel and more significantly the emerging concern about global warming that is associated with burning fossil fuels.(5) Moreover, they do not require arable land or fresh water for cultivation, and can grow using CO_2 in flue gas, thereby reducing levels of this important greenhouse gas(6)

Microalgae are present in all existing earth ecosystems, not just aquatic but also terrestrial, representing a big variety of species living in a wide range of environmental conditions. It is estimated that more than 50,000 species exist, but only a limited number of around 30,000, have been studied and analyzed. During the past decades extensive collections of microalgae have been created by researchers in different countries. An example of freshwater microalgae collectin by University of Coimbra (Portugal) is to be considered as one of the world's largest, holding more than 4000 strains and 1000 species.

This collection attests to the large variety of different microalgae available to be selected for use in a broad diversity of applications, such as pharmaceutical purposes, food crops and as energy source. A bit all over the world, other algae collections attest for the interest that algae have risen, for many different production purposes. For example, the collection of the Goettingen University, Germany (SAG), that started in the early 1920s and has about 2213 strains and 1273 species. About 77% of all the strains in the SAG collection are green algae and about 8% cyanobacteria (61 genera and 230 strains). Some of them are freshwater red algae and others from saline environments. The University of Texas Algal Culture Collection is another very well known collection of algae cultures. It includes 2300 different strains of freshwater algae, including many marine macrophytic green and red algae species.((10) They have much higher growth rates and productivity when compared to conventional forestry, agricultural crops, and other aquatic plants, requiring much less land area than other biodiesel feedstock of agricultural origin, up to 132 times less when compared to soybean crops, for a maximum of 30% (w/w) of oil content in algal biomass. Therefore, there is no competition to arable soil with other food crops, in particular for human consumption, which is greatly reduced. Microalgae can be served as raw material for several different types of renewable fuel production such as biodiesel, biomethane, bio-hydrogen, and others. ((10) For the comparison of oil produced by various bio products are given below

Table 1
Comparison of some sources of biodiesel

Crop	Oil yield(L/ha)
Corn	172
Soybean	446
Canola	1190
Jatropha	1892
Coconut	2689
Oil palm	5950
Microalgae	136,900

(5)

Table 2
Comparison of various microalgae and its lipid content

Microalga Oil content (% dry wt)	Percentage of Lipid content
Chlorella sp.	28–32
Cylindrotheca sp.	16–37
Isochrysis sp.	25–33
Nannochloris sp.	20–35
Neochloris oleoabundans	35–54
Phaeodactylum tricornutum	20–30
Tetraselmis sueica	15–23
Botryococcus braunii	25–75
Crypthecodinium cohnii	20
Dunaliella primolecta	23
Nannochloropsis sp.	31–68
Monallanthus salina	20
Schizochytrium sp.	50–77
Nitzschia sp.	45–47

(5)

4. Algal oil

Most researches are focussing on microalgae to produce biodiesel, microalgae which are micro organism in size 4-500 μm-diameter and also which has high-photosynthetic potency. The biodiesel produced from vegetable oils are performing poor in a low-temperature atmosphere. The polyunsaturated of microalgae oils has lower freezing point than the monosaturated of other vegetable oils. High level of polyunsaturated algae biodiesel is most suitable for cold weather condition. The productions of biodiesel from microalgal oils can be carried out using transesterification process in liquid phase and base-catalyst, such as KOH, NaOH and combination of both types of base. (7)

5. Nannochloropsis sp.

Recent studies have reported that marine species *Nannochloropsis* sp. are a potential microalgae for biofuel production owing to the fact that they are capable of producing lipid content as high as 27% (dry weight) and high biomass productivity. This type of algae tends to accumulate larger proportion of triacylglycerols. Moreover, the commercial cultivation of these species is well understood. The lipid productivity of *Nannochloropsis* sp. is 82mg/L day with a biomass growth rate of 0.27g/L/day. *Nannochloropsis* sp. is capable of producing high concentration of important antioxidants such as zeaxanthin and canthaxanthin, which are high-value nutraceutical products. (8)

Microalgal oil had met the characteristics of biodiesel raw material, which has low free fatty acid content (less than 2%). That the free fatty acid content in raw material of biodiesel must not exceed than 2%. Other fatty acids in microalgal oil were also analyzed using gas chromatography. It was measured that the algal oil contains 77,16% of fatty acids (7).

6. Bio oil

Biomass is considered as clean energy because it contains negligible amounts of nitrogen, sulphur and ash compared to conventional fossil fuels, which results in lower emissions of SOx, NOx, and soot than do conventional fossil fuels. Pyrolysis is a rapid decomposition of organic materials in the absence of oxygen which results in the production of liquid, gaseous and charcoal products. It is a promising thermal approach that can be used to convert biomass into energy in the forms of liquid bio-oil, solid bio-char, and syn-gas composed of H_2, CO, CO_2 and lower molecular weight hydrocarbon gases.

Several of various advantages of pyrolysis over other methods of energy conversion are these are drastic reduction of solid residue volume, carbonaceous matrices containing heavy metals are relatively resistant to natural lixiviation, high energy value oil and gas products that can be potential fuels, and lower temperature of the process in comparison to incineration, thus limiting gas pollutants due to absence of air lowering dioxins.

For pyrolysis of biomass, the whole process generally proceeds through a series of complex reaction pathway or divides into four ranges: where < 220 °C is for moisture evolution; 220 °C to 315 °C for predominantly hemicellulose decomposition; 315 °C to 400 °C for cellulose decomposition; > 400 °C for lignin decomposition. In order to obtain maximum liquid product, high heating rates and short reaction time is needed. Fast pyrolysis could be achieved through rapid heating rates at short residence times, temperatures of 400 °C to 650 ^{o}C. The produced liquid is a homogeneous hydrophilic (oleophobic) mixture of polar organics and water from both the pyrolysis reaction and the original water in the feedstock (9)

7. Conclusion

The role of Nannochloropsis as a potential microalgal cell factory for lipid production has received ever-increasing attention in recent years. The integrated production of biofuels and the high-value product EPA, coupled with the environmentally beneficial applications like flue gas and wastewater treatment represents a promising direction toward cost-effective production process of Nannochloropsis, which requires better collaboration between biotechnologist and engineers. Research and development work should be given priority to the better understanding of molecular mechanism for lipid metabolism and the development of a more stable and robust genetic tool kit for Nannochloropsis to enable this micro-organism to be a true cell factory for the production of lipids.

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