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Analysis for the Higher Production of Biodiesel from Scenedesmus dimorphus Algal Species

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Abstract

Algae are the fastest-growing plants in the world, this study demonstrates the production of algal biodiesel from *Scenedesmus dimorphus*, Biodiesel is an alternative fuel for conventional diesel that is made from natural plant oils, animal fats, and waste cooking oils. This paper discusses the economics of producing biodiesel fuel from algae grown in open ponds. Microalgae have been identified as a potential biodiesel feedstock due to their high lipid productivity and the process conditions are milder than those required for pyrolysis and prevent the formation of by-products. Algae are very important as a biomass source. Algae will someday be competitive as a source for biofuel. Algae can be grown almost anywhere, even on sewage or salt water, and does not require fertile land or food crops, and processing requires less energy than the algae provides. Algae can be a replacement for oil based fuels, one that is more effective and has no disadvantages. About 50% of their weight is oil. This lipid oil can be used to make biodiesel for cars, trucks, and airplanes. Microalgae have much faster growth-rates than terrestrial crops.

Keywords: Microalgae; Biofuels; Lipid; Biomass; Glycerol; Transesterification

Abbreviation: ASTM: American Society of Testing Materials; FAME: Fatty Acid Alkyl Ester; TAGs: Try Acyl Glycerol's; MFC: Microbial Fuel Cell; MAO: Microalgae Oil; TG: Triglycerides; PAHs: Polycyclic Aromatic Hydrocarbons

Introduction

The search for sustainable and renewable fuels is becoming increasingly important as a direct result of climate change and rising fossil-fuel prices. Current commercial production of biodiesel or Fatty Acid Methyl Ester (FAME) involves alkaline-catalyzed transesterification of triglycerides found in oleaginous food crops with methanol [1]. Biodiesel is produced from triglycerides derived mainly from vegetable oils or animal fats. Recently, new oil production methods have been investigated such as oil produced from algae and oleaginous yeasts indicating new sources of biodiesel which, contrary to energy crops, do not conflict with the cultivation of land for food, therefore they can offer alternatives to the food vs. fuels land use. Biodiesel has been thoroughly tested and can be used as an alternative fuel in both boilers and internal combustion engines either in a pure form or blended with petroleum-based diesel [2]. Petroleum-based fuels are recognized as unsustainable energy source due to their depleting supplies and contribution to global warming. Renewable biofuels are promising alternatives to petroleum-based fuels, among which biodiesel has attracted the most attention in recent years. Biodiesel is a diesel-equivalent fuel derived from biological feedstocks and is chemically referred to as a Fatty Acid Methyl Ester (FAME). Compared with traditional fuels, biodiesel is carbon neutral, contributes less emission of gaseous pollutants and hence is environmentally beneficial [3].

Competitive liquid biofuels from various biomass materials by chemically and biochemically have been found promising methods for near future. Liquid biofuels may offer a promising alternative to petroleum based transportation fuels. There are two global liquid transportation biofuels: bioethanol and biodiesel, respectively. Among emerging feedstocks, jatropha currently can be converted to biodiesel with commercial processes, while processes capable of converting algae, crop wastes, perennial grasses, wood and wood wastes are still at pre-commercial stages [4].

Cost and environmental impact of conversion process

For a sustainable future of the planet, we must look into renewable energy sources which implicitly include sustainable fuel sources. Based on the positive energy balance or life cycle analysis, biodiesel is shown to be sustainable. However, competition of feed source with food, and destruction of natural habitats resulting from energy crop plantation are some inevitable issues which require attention. Furthermore, various aspects in increasing the economic perspectives of the biodiesel are examined [5].

We highlight the important aspects of the biodiesel which will strengthen the prospect as the next generation green fuel. Four major areas are discussed:

(i) Cost and environmental impact of conversion processes

(ii) Efforts towards environmentally benign and cleaner emissions

(iii) Diversification of products derived from biodiesel glycerol

(iv) Policy and government incentives [6].

Flow digram of microalgal oil discription

High acidic value of Microalgae Oil (MAO) makes them an inconvenient raw material for the traditional biodiesel production. However, by means of a sequential acidic esterification/basic

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transesterification, coupled with a heat integration strategy, the opportunities of accepting microalgae oil as a biodiesel precursor will increase [7] (Figure 1).

Conventional production methods

The direct use of vegetable oils as biodiesel is possible only by blending them with conventional diesel fuel in a suitable ratio, but the direct usage of vegetable oils in diesel engines is not technically possible because of their: (i) high viscosity, (ii) low stability against oxidation (and the subsequent reactions of polymerization) and (iii) low volatility, which influences on the formation of a relatively high amount of ashes due to incomplete combustion [8].

Sources of biodiesel

There are more than 350 oil-bearing crops identified, among which only soybean, palm, sunflower, safflower, cottonseed, rape seed and peanut oils are considered as potential alternative fuels for diesel engines. Worldwide consumption of soybean oil is the highest in 2003 (27. 9 million metric tons). The world vegetable and marine oil consumption between 1998 and 2003. Vegetable oil is one of the renewable fuels. Vegetable oils have become more attractive recently because of their environmental benefits and the fact that these are made from renewable resources. Vegetable oils are a renewable and potentially inexhaustible source of energy with energy content close to diesel fuel. On the other hand, extensive use of vegetable oils may cause other significant problems such as starvation in developing countries. The vegetable oil fuels were not acceptable because they were more expensive than petroleum fuels [9].

Advantages of biodiesel as diesel fuel

The advantages of biodiesel as diesel fuel are liquid nature portability, ready availability, renewability, higher combustion efficiency, lower sulfur and aromatic content higher cetane number and higher biodegradability. Main advantages of biodiesel given in the literature include domestic origin, reducing the dependency on imported petroleum, biodegradability, high flash point and inherent lubricity in the neat form [10].

Availability and renewability of biodiesel

Biodiesel is the only alternative fuel so that low concentration biodiesel–diesel blends run on conventional unmodified engines. It can be stored anywhere where petroleum diesel fuel is stored. Biodiesel can be made from domestically produced, renewable oilseed crops such as soybean, rapeseed and sunflower. The risks of handling, transporting and storing biodiesel are much lower than those ones, associated with petrodiesel. Biodiesel is safe tohandle and transport because it is as biodegradable as sugar and has a high flash point compared to petroleum diesel fuel. Biodiesel can be used alone or mixed in any ratio with petroleum diesel fuel. The most common blend is a mix of 20% biodiesel with 80% petroleum diesel, or B20 under recent scientific investigations, however, in Europe the current regulation foresees a maximum 5.75% biodiesel [11].

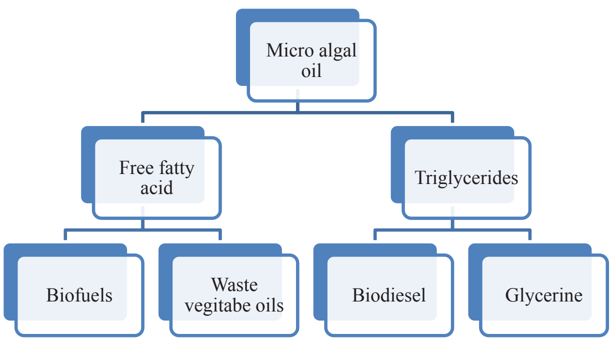

Figure 1: Overview of biodiesel production.

Lower emissions by using biodiesel

Combustion of biodiesel alone provides over a 90% reduction in total unburned Hydro Carbons (HC), and a 75–90% reduction in Polycyclic Aromatic Hydrocarbons (PAH s). Biodiesel further provides significant reductions in particulates and carbon monoxide than petroleum diesel fuel. Biodiesel provides a slight increase or decrease in nitrogen oxides depending on engine family and testing procedures. Many studies on the performances and emissions of CIEs, fuelled with pure biodiesel and blends with diesel oil, have been performed and are reported in the literature [12].

Disadvantages of biodiesel as diesel fuel

Major disadvantages of biodiesel are higher viscosity, lower energy content, higher cloud point and pour point, higher nitrogen oxides emissions, lower engine speed and power, injector coking, engine compatibility, high price and higher engine wear. The fuel American Society of Testing Materials (ASTM) standards of biodiesel and petroleum diesel fuels. Important operating disadvantages of biodiesel in comparison with petro diesel are cold start problems, the lower energy content, higher copper strip corrosion and fuel pumping difficulty from higher viscosity. This increases fuel consumption when biodiesel is used in comparison with application of pure petro diesel, in proportion to the share of the biodiesel content. Taking into account the higher production value of biodiesel as compared to the petrodiesel, this increase in fuel consumption raises in addition to the overall cost of application of biodiesel as an alternative to petro diesel [13].

Biodiesel economy

Economic advantages of biodiesel can be listed as follows: it reduces green house gas emissions, it helps to reduce a country's reliance on crude oil imports and supports agriculture by providing a new labor and market opportunities for domestic crops, it enhances the lubricating property and it is widely accepted by vehicle manufacturers. The major economic factor to consider for input costs of biodiesel production is the feedstock, which is about 80% of the total operating cost. Other important costs are labor, methanol and catalyst, which must be added to the feedstock. In some countries, filling stations sell bio diesel more cheaply than conventional diesel [14].

Algal strain and culture conditions

H. pluvialis samples were collected from rainwater in Bahía Blanca Buenos Aires Province, Argentina. Uni-algal cultures were obtained by means of serial dilutions. Biflagellate cells were cultured in Bold's Basal Medium, containing 3.4 mM of sodium nitrate. The cells were kept at 24oC with continuous bubbling of air (500–700 cm^3/min) containing 0.30 cm^3/min of CO_2. A12/12h light/dark photo-period and cool-white fluorescent lamps, which provide 90 µmol photons $m^{-2}s^{-1}$, were used. The pH was adjusted to 7.0 with NaOH before autoclaving. An inoculum of 45 x 10^3 biflagellate cells/ml was resuspended for a two-week period in one liter of: (i) full medium, under the same conditions as those indicated above. (ii) full medium, under 300 µ mol photons $m^{-2}s^{-1}$ of continuous light and without aeration (A-stress condition) and (iii) nitrogen-free medium, under 300 µ mol photons $m^{-2}s^{-1}$ of continuous light and without aeration (B-stress condition). In both stress conditions the samples were manually agitated twice daily and the first cysts appeared after four days of culture stress. Three replicates of the cultures were done [15].

Acceptability of microalgal biodiesel

Microalgal biodiesel will need to comply with existing standards in the United States the relevant standard is the American Society of Testing Materials (ASTM) Biodiesel Standard D 6751. In European Union, separate standards exist for biodiesel intended for vehicle use and for use as heating oil. Microalgal oils differ from most vegetable oils in being quite rich in polyunsaturated fatty acids with four or more double bonds. For example, eicosapentaenoic acid and docosahexaenoic acid occur commonly in algal oils. Fatty acids and Fatty Acid Methyl Esters (FAME) with 4 and more double bonds are susceptible to oxidation during storage and this reduces their acceptability for use in biodiesel. Some vegetable oils also face this problem. For example, vegetable oils such as high oleic canola oil contain large quantities of linoleic acid and linolenic acid . Although the sefatty acids have much higher oxidative stability compared with DHA and EPA, the European Standard E N 14214 limits linolenic acid methyl ester content in biodiesel for vehicle use to 12% [16].

Improving economics of microalgal biodiesel

Cost of producing microalgal biodiesel can be reduced substantially by using a biorefinery based production strategy, improving capabilities of microalgae through genetic engineering and advances in engineering of photobioreactors. Like a petroleum refinery, a biorefinery uses every component of the biomass raw material to produce use-able products. Because all components of the biomass are used, the overall cost of producing any given product is lowered. Integrated biorefineries are already being operated in Canada, the United States, and Germany for producing biofuels and other products from crops such as corn and soybean. This approach can be used to reduce the cost of making microalgal biodiesel. In addition to oils, microalgal biomass contains significant quantities of proteins, carbohydrates and other nutrients. Therefore, the residual biomass from biodiesel production processes can be used potentially as animal feed. Some of the residual biomass may be used to produce methane by anaerobic digestion, for generating the electrical power necessary for running the microalgal biomass production facility. Excess power could be sold to defray the cost of producing biodiesel [17].

Enhancing algal biology

Genetic and metabolic engineering are likely to have the greatest impact on improving the economics of production of micro algal diesel. Genetic modification of microalgae has received little attention. Molecular level engineering can be used to potentially.

1. Increase photosynthetic efficiency to enable increased biomass yield on light.
2. Enhance biomass growth rate.
3. Increase oil content in biomass.
4. Improve temperature tolerance to reduce the expense of cooling.
5. Eliminate the light saturation phenomenon so that growth continues to increase in response to Increasing light level.
6. Reduce photo inhibition that actually reduces growth rate at midday light intensities that occur in temperature and tropical zones and
7. Reduce susceptibility to photo oxidation that damages cell [18].

Biorefinery based production strategy

Like a petroleum refinery, a biorefinery uses every component of the biomass raw material to produce use-able products. Because all components of the biomass are used, the overall cost of producing any given product is lowered. Integrated biorefineries are already being operated in Canada, the United States, and Germany for producing biofuels and other products from crops such as corn and soybean. This approach can be used to reduce the cost of making microalgal biodiesel. In addition to oils, microalgal biomass contains significant quantities of proteins, carbohydrates and other nutrients. Therefore, the residual biomass from biodiesel production processes can be used potentially as animal feed. Some of the residual biomass may be used to produce methane by anaerobic digestion, for generating the electrical power necessary for running the micro algal biomass production facility. Excess power could be sold to defray the cost of producing biodiesel. Although the use of microalgal biomass directly to produce methane by anaerobic digestion is technically feasible, it cannot compete with them any other low-cost organic substrates that are available for an aerobic digestion. Nevertheless, algal biomass residue remaining after the extract ion of oil can be used potentially to make methane. A micro algal biorefiner and simultaneously produce biodiesel, animal feed, biogas and electrical power. Extraction of other high value products may be feasible, depending on the specific microalgae used [19].

Conclusion

As demonstrated here, microalgal biodiesel is technically feasible. It is the only renewable biodiesel that can potentially completely displace liquid fuels derived from petroleum. Economics of producing micro algal biodiesel need to improve substantially to make it competitive with petro-diesel, but the level of improvement necessary appears to be attainable. Producing low-cost micro algal biodiesel requires primarily improvements to algal biology through genetic and metabolic engineering. Use of the biorefinery concept and advances in photobioreactor engineering will further lower the cost of production. In view of their much greater productivity than raceways, tubular photobioreactors are likely to be used in producing much of the micro algal biomass required for making biodiesel. Photobioreactors provide a controlled environment that can be tailored to the specific demands of highly productive microalgae to attain a consistently good annual yield of oil.

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