BIOFUEL FROM MICROALGAE: ALTERNATIVE, SUSTAINABLE AND RENEWABLE FUEL

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Abstract

The demand on fossil fuel is increasing due to the increases of population growth rates and higher fuel prices. Therefore, finding alternative clean and renewable source of energy is one of the most substantial needs nowadays Biodiesel is one of the potential renewable resources of energy which produces low emission gases, is sustainable, and can be produced using existing available technologies. The new resource of fuel has to be convincing, microalgae is one of the most promising sources of biodiesel and an economical substance due to its low coast and the availability. Microalgae has the highest of oil productivity and can produce many times more than crops The characteristics of microalgae's biodiesel are very similar to diesel's and it can be blended with diesel in any ratio. High oil prices, competing demands between foods and other biofuel sources and the world food crisis have ignited interest in farming algae for making biofuels. Using land that is not suitable for agriculture, using ocean and wastewater for producing and fast growth are algal fuels' attractive. About half weight of algae is oil that this lipid oil can be used to make biodiesel and this oil is capable of yielding 30 times more oil than the crops currently used in biofuel production.

Keywords: Renewable Energies, Microalgae, Biodiesel

1. Introduction

Algae are some of the fastest growing plants in the world. Oil is almost 50 percent of algae weight. The oil lipids can be used to make biodiesel fuel for all kinds of vehicles. Algae fuel also called algal fuel is member of the 3rd generation biofuels. Compared to other biofuels most of them made from crops, algae is growing much fastest and contains much more energy per unit of weight. Microalgae considers as a great alternative fuel due to several factors: It is renewable and environmentally friendly and it can contribute to reducing the CO_2 levels in the atmosphere because microalgae consumes CO_2 and converts it to oil [1]. Microalgae biodiesel characteristics are similar to those of biodiesel according to the ASTM standard, which means there is no need for major changes in diesel engines [2]. Microalgae biodiesel production per unit of area is many times higher than crops biodiesel. The productivity of diatom algae is about 46,000 kg of oil per hectare per year [3]. Some microalgae oil content about 80% of dry weight [4]. Depending on the species, microalgae can be cultivated under very different conditions. It can grow in fresh, waste or marine water, therefore it can be grown without affecting the fresh water supplies [5]. Microalgae can be produced in areas unsuitable for agricultural purposes to avoid affecting arable land [6]. Microalgae biofuel is non-toxic, contains no sulphur and is highly bio-degradable. After extracting oil the remaining material can be used as soil fertilizer or to produce ethanol [7]. The cost of microalgae biodiesel can be less than crops oil if produced on a large scale under suitable conditions and using appropriate technology [8]. The cost of biodiesel is usually over $US 0.5 per Litre, while common diesel $US 0.35 per Litre [9] and the cost of microalgae oil is around $US 0.487 per Litre [10]. Algae biofuel contains no sulfur, is non-toxic and highly biodegradable, algae have been of considerable interest in the biofuel production as they can accumulate very high levels of lipid that can be easily transesterified to biodiesel, Oil content in microalgae can exceed 80% by weight of dry biomass [11]. Biodiesel produced from microalgae is not resource limited and has the potential for yields 50-100 times greater than biodiesel from crops. This high production level can be achieved sustainability with high-energy return on investment and with little impact on food production and prices [12]. Feedstocks such as rapeseed, soybeans, palm oil and sunflower are considered to be first generation biodiesel feedstocks because they were the first crops to be used to produce biodiesel. To reduce the dependency on edible oil, alternative biofuel sources such as non-food feedstocks, have been developed to produce biodiesel. Crops such as jatropha, mahua, jojoba oil, tobacco seed, salmon oil, see mango, waste cooking oils and animal fats are also considered 2nd generation feedstocks. The cost of biodiesel production, inefficiency and un-sustainability of these 1st and 2nd generation biodiesel feedstocks caused scientists concentrate on 3rd generation biodiesel feedstocks which are derived from microalgae [13, 14]. In the recent years much thrust has been put on to examine the possibilities of using algae as a source of bio-oil and biogas for energy

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applications. The commercial viability of algae-based biofuels production shall eventually depend on economics of the technology. 1 kg of dry algae biomass utilizes about 1.83 kg of CO_2, thus the microalgae biomass production can help in bio-fixation of waste CO_2 with respect to air quality maintenance and improvement [15, 16]. It shall be mentioned that existing engines can use microalgae biofuel without modification and microalgae biofuel can be mixed with conventional petroleum at any ratio.

2. Growing, harvesting algae and extracting algal oil

The first step in growing microalgae is to select the most suitable species. The availability of the strain, the growing method and the reason for growing are the main factors in selecting the species. Different species of microalgae has been indicated in Fig. 1. The Chlorella species has a great potential to be a resource for biodiesel because of its fast growth and easy cultivation, however its lipid content is relatively low (14 to 30%) (Illman et al., 2000).

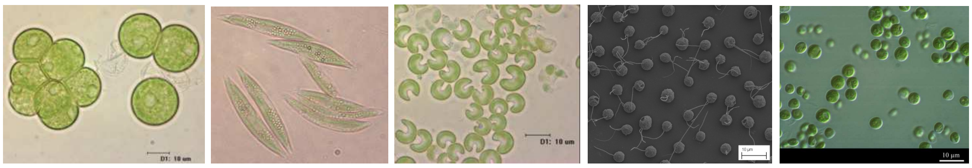
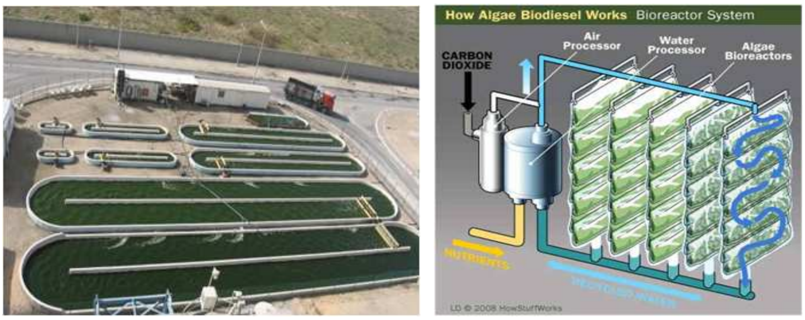


Figure 1. Process of converting microalgae to biodiesel

Microalgae can be produced in open pond systems and closed system photo bioreactors (Fig. 2).



(a) (b)

Figure 2. (a) open pond systems and (b) closed system photo bioreactors

Growing microalgae requires light, water, nutrients, CO2. Microalgae can be grown in many different ways in large-scale or small-scale photobioreactors (Fig. 3). Although an enormous number of photobioreactor designs have been proposed, only a few of them can be adopted for mass production of algae due to technical and commercial factors..

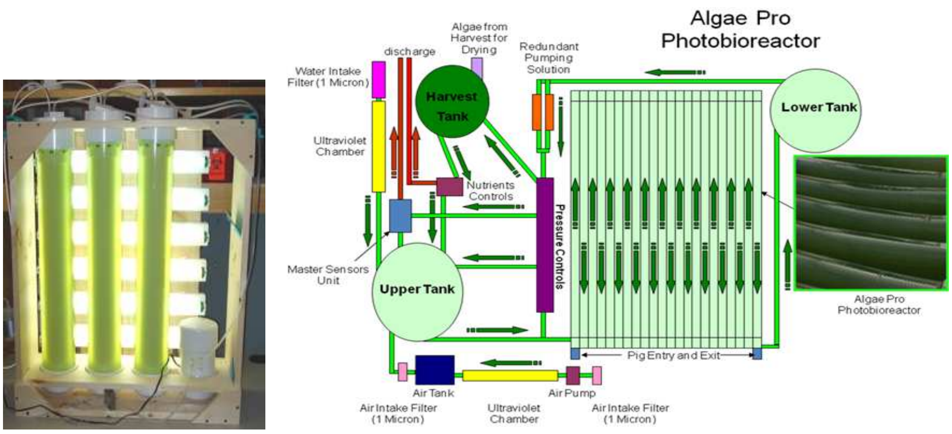


Figure 3. Algae Photo bioreactor (PBR) [www.biocentricenergy.com]

Different systems have been investigated in Fig. 4.

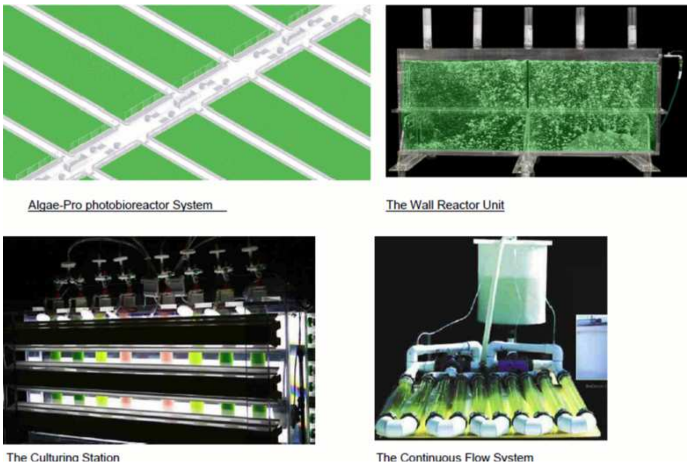


Figure 4. Different cultivation system for microalgae [www.biocentricenergy.com]

Harvesting microalgae was described as one of the major challenges aspects of producing algae due to the low cell diameters ranging from 2 to 20 μm . However, microscreen, centrifugation and flocculation are the most common harvesting methods currently used . Centrifugation is efficient and reliable, but expensive for producing microalgae as energy. The extraction of microalgae oil from the biomass can be in physical or chemical methods. Ultrasound can assist in oil extraction by using an ultrasonic reactor to crack the cells' membranes by the action of cavitation bubbles which break the cell wall. The lipid has also been extracted by Liu et al. (2008) using chloroform and methanol (2/1, v/v). Hossain et al. (2008) weighed the microalgae biomass after filtration to determine the biomass productivity, and then the oil was extracted by drying the algae at 80oC for 20 minutes. The dried algae were mixed with a mixture of 20 mL each of hexane and ether solution. After that the mixture was left to settle for one day, and then the mixture was filtered to separate the biomass. The oil was evaporated using a rotary evaporator to release the hexane and ether solution.

3. Converting algal oil to Biodiesel

The main components of typical algae are proteins, carbohydrates, lipids and other valuable components, e.g. pigment, anti-oxidants, fatty acids, vitamins etc. [1 , 9]. Fig. 5 shows a schematic of the production of biodiesel from microalgae. The first step is the selection of an appropriate species with the relevant properties for the specific culture conditions and products [1]. For algae cultivation, most companies pursuing algae as a source of biofuels are pumping nutrient-laden water through plastic tubes that are exposed to sunlight called as photobioreactors or PBR. In PBR system, algae are cultivated in suspension, but the system is closed and water is circulated by pumps. Artificial light and heat is used. In a closed system (not exposed to open air) there is not the problem of contamination by other organism blown by the air, the problem for a closed system is finding a cheap source of sterile CO_2. Another main cultivation system is open pond that refers to a simple open tank or natural ponds. Algae are grown in suspension with additional fertilizers. Gas exchange is via natural contact with the surrounding atmosphere and solar light. Microalgae can be harvested using microscreens, sedimentation, centrifugation, flocculation or membrane filtration.

The harvested biomass is then dried and oil is extracted. Various methods for extraction of lipids from microalgae have been reported in literature, methods are expeller/oil press, liquid-liquid extraction (solvent extraction), supercritical fluid extraction and ultrasound technique. The most popular extraction method is Soxhlet extraction using hexane as a solvent and an extraction time of 4h, oil will be separated from the solvent extract by distillation process, then oils are converted to biodiesel using transestrification method (Fig. 6) [8]. Biodiesel is typically produced through the reaction of algal oil with methanol in the presence of catalyst to yield glycerine and methyl esters, this process for making biodiesel is relatively simple and can be low extremely low-technology, the process is known as transestrification. Actually biolipid algal oil consists of hydrocarbon compound that are not suitable for diesel engines, so it can be modified for use in engine using transestrification. Biodiesel include no sulfur or particular matter that contributes to air pollution. Sulfur and PM have been responsible for black smoke and sour odor problems commonly attributed to dirty diesel fuel. Biodiesel has greater lubricity than petroleum diesel, in addition algal biodiesel is a carbon-natural fuel, which means it assimilates about as much CO_2 during algal growth as it release upon fuel combustion [10].

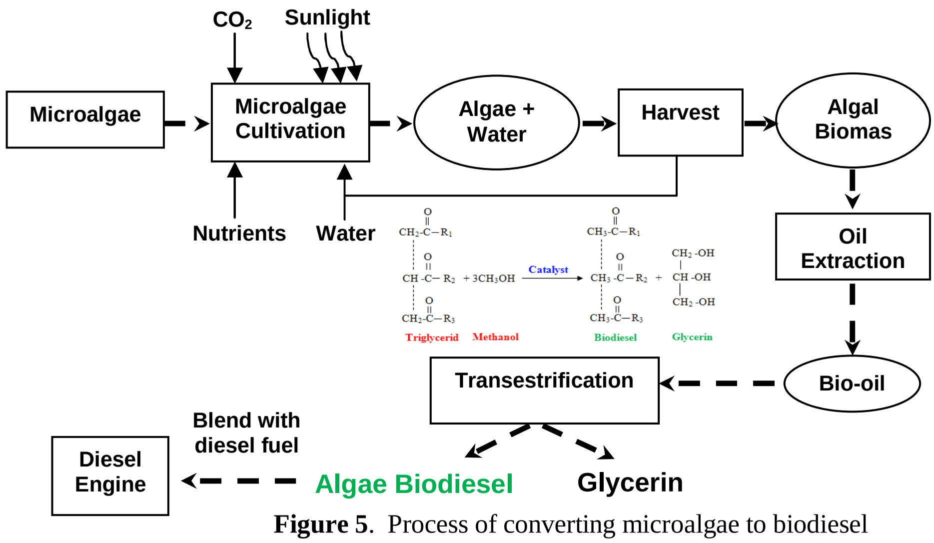


Figure 5. Process of converting microalgae to biodiesel

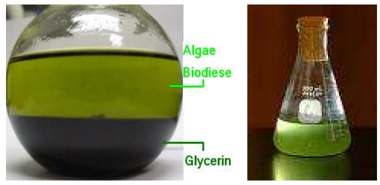


Figure 6. Microalgae biodiesel

Biodiesel can be used in diesel engines as 100% biodiesel or as a blend with diesel in different ratios. Many different vegetable oils such rapeseed, sunflower, palm and soybean have been tested by many researchers [4]. Biodiesel produced from microalgae has been found to have properties, such as density, viscosity, flash point. Most of these parameters comply with the limits established by the American Society for Testing and Materials (ASTM) for biodiesel quality [1]. Algal biodiesel has also been found to meet the International Biodiesel Standard for Vehicles (EN14214). A comparison of typical properties of fossil oil and bio-oil obtained from microalgae indicated that bio-oil from microalgae has a lower heating value, lower viscosity and higher density compared to fossil oil (Table 1).

Table 1. Comparison of typical properties of fossil oil and bio-oil from microalgae [1].

Properties	**unit**	**Standard**	**Fossil oil**
Density	Kg/l	ASTM D-6751	0.75-1
Viscosity	Pa s	ASTM D-445	2-1000
Heating value	MJ kg^{-1}	ASTM D-6751	42
Stability	-	ASTM D-6751	-

3. Conclusions

Algae have great potential as a sustainable source for production of biodiesel. Research for producing of biofuels from microalgae is in the beginning stages and there is a substantial need for more research to study other economic issue related to biofuels. Among the renewable sources, Iran has high biofuel energy potential. The Iranian government is considerable attention to the utilization of renewable energy, especially biofuels. Iran has enough land in order to algae cultivation that does not compete with food production. A salt lake (Lake Orumieh) in Iran's West Azarbaijan province, Maharlu salt lake in Iran's Fars province, Qom salt lake in Iran's Qom province have given rise to a new species of algae for biofuel. Algae are frequent in the shallow-marine lime stones in Zagros Mountains in north of Fars province. Greenish blooms of algae can be seen in the Persian Gulf and Caspian Sea, south and north of Iran respectively. Producing biodiesel from the microalgae can ideally replace 5% of total total diesel fuel consumption in the first step. By managing this biofuels, an AB5 (5% Algal Biodiesel and 95% diesel fuel) can be an optimum fuel for Compressed Ignition (CI) engine since there is no major engine modification required to use biodiesel.

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