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# Algae is an Alternative Biofuel

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**Abstract :** Fossil fuel resources are depleting rapidly, most importantly the liquid fossil fuel will be exhausted by this century. In addition to that the fossil fuels are directly related to air pollution, land pollution and water degradation. In these critical circumstances, biofuel from renewable sources would be an alternative to reduce our dependency over fossil fuel and assist to maintain the global health, clean environment and economic sustainability. Production of biofuel from food stocks are generally consumed by humans or animals can be problematic and it could be the root cause of worldwide dissatisfaction. Production of biofuel from microalgae can be able to provide some distinctive advantages because of their rapid growth rate ability, greenhouse gas fixation and high lipid production ability. Here we have the review about the current and latest status of biofuel produced from algae which would be a renewable.

## 1. Introduction

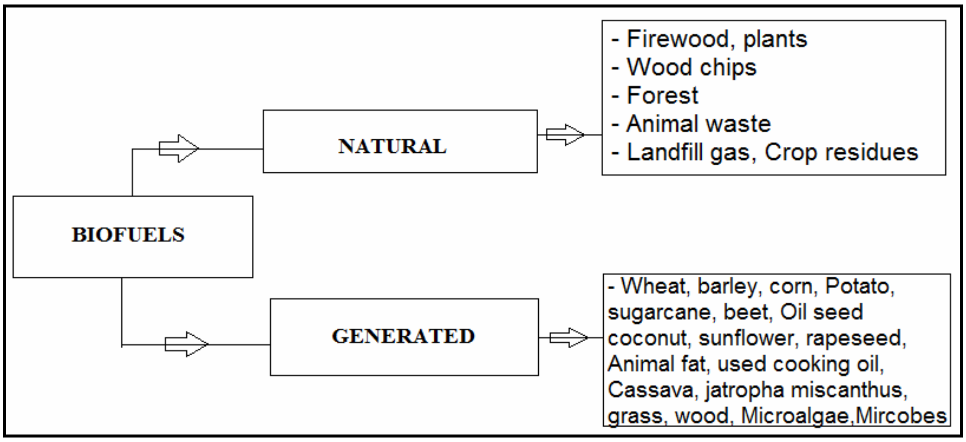


**Figure.1. Biofuel production sources of biomasses**[17]

The climate change in global, rising of crude oil price, rapid depletion of fossil fuel resources, and the need about energy security, land, soil and water degradation have forced governments, policymaking people, and researchers are in need to find an alternative energy sources including wind, solar, thermal and biofuels. The biofuel production from renewable sources will reduce fossil fuel dependency and helps to maintain the healthy environment and economic growth. The biofuel currently produced from human and animal food stock which is to be believed that it can cause the shortage of food and worldwide dissatisfaction specifically in the developing nations. To overcome this problem, microalgae can provide an alternative biofuel feedstock thanks to their rapid growth rate, greenhouse gas fixation ability (zero emission balance on net) and huge production capacity of lipids as microalgae do not going to compete with human and animal feed and it can also be grown on non-arable land and saline water. Biofuels generally known to solid, liquid or gaseous form of fuels derived from organic matter [13]. The classification of biofuels is shown in Figure. 1. These classifications are: Natural biofuels, and generated biofuels. Natural biofuels are generally derived from organic sources include agricultural waste, vegetables, animal waste. On the other hand, natural biofuels are fuel-woods used usually for burning, heat development, brick furnace and electric production. The generated biofuels are bioethanol and biodiesel produced by processing the biomass and which is used in transport sectors [13]. The generated biofuels are wheat, beet, oilseed, microalgae based on their different features such types of processing technology, feedstock and or their development levels[17].

Despite it having a potential to producing carbon neutral biofuels, the natural biofuels possess notable economic, environmental and political concerns. The most important issue associated with natural biofuels is that with the increase of production capacity, more cultivatable agricultural lands are needed for the production, feedstock resulting in reduction of lands of human or animal food generation area. The elevated pressure on arable land which have been currently used for food production leads to increased food shortages, especially in developing countries such as of Africa, Asia and South America over 799 million and above people have been suffering from hunger while the arable land is being decreasing. The extensive use of fertilizer, pesticides for cultivation and fresh water on limited farming lands may reduce not only food producing capacity of lands but also it will cause significant environmental issuses[11]. That's while, enthusiasms about natural biofuels have been reduced. Increasing use of natural biofuels will surely lead to increasing the price of food beyond the reach of the under privileged people. The political consequences are also about this could be difficult to contain. As natural biofuels are not viable and receive lukewarm acceptance, researchers focused on generated biofuels. The primary intention here is to produce biofuels using lignocelluloses of biomass, the woody part of plants which cannot compete with human food chain[17]. As shown in Figure.1, main sources for generated biofuels are agricultural by products, unused waste (e.g., trimmed out branch, leaves, straws, wood chips, etc.) forest harvesting residues, wood processed residues (e.g. saw dust) and non-edible components of corn, sugarcane, beet, etc. However, converting woody biomass into convertable sugars require sophisticated or more expensive technologies for pretreatment with special kind enzymes making generated biofuels economically may not be profitable for commercial production[17,21]. Hence, the focus of research is drawn to microalgae biofuels. It is currently considered to be a suitable alternative renewable energy resource for biofuel, overcoming the disadvantages of other biofuels[9,13]. The potential for biodiesel production from microalgae is 20 to 300 times more while compared to traditional crops on an area basis[17]. Furthermore while compared with conventional crop plants which are usually harvested once or twice a year, microalgae has a very short harvest cycle (2 to 10 days depending upon their process), continuous or multiple harvesting with significantly increased yields[17,11]. In Addition to that, the microalgae usually have high productivity than land based plants as some species could be ablilty to double its masses within a few hours and able to accumulate large amounts of triacylglycerides (TAGs). Most important, agricultural land with high quality is not required for producing microalgae biomass[18].

## 2. Biofuel Producing Potential of Microalgae

Micro-algae is single-cell microscopic organisms which is naturally found in fresh and marine water environment. They will be in position at the bottom of food chains. Microalgae is considered to be one of the most oldest living organisms in our earth planet. There are more than 300,000 species of micro algae present, diversity of it is much **greater** than plants[18]. These are thallophytes – plants without roots, stems, and leaves, they have chlorophyll, is their intial photosynthetic pigment, lack of sterile covering of cells found around the reproductive cells[21]. While the mechanism of photosynthesis in the microorganism is similar to that of the higher plants, microalgae are generally more effective and efficient converters of solar energy into their simple cellular structure, because the cells grow in aqueous suspension, they can more efficient access to water, Carbondioxide, and other nutrients[17,14]. Generally, microalgae are classified according to their colour. The current system of classifying microalgae based on a) pigment, b) chemical nature of product storage, and c) constituent of cell wall[17]. Some of the additional criteria are also taken into consideration including cytological and morphological characters of algae: occurrence of flagellate cells, structure of flagella, scheme and path of nuclear cell division, presence of an envelope of endoplasmic reticulum around the chloroplast, and possible connection between the endoplasmic reticulum and the nuclear membrane[3]. Some groups of microalgae are shown Table 1. The oil contents of various microalgae relative to their dry weight are shown in Table 2. It would be clear that various species of microalgae can have oil contents up to 80% of their dry weight. As mentioned earlier, some microalgae could double their biomass weight within 24 hours and the shortest doubling time around 3.5 hours during their growth is which makes microalgae an excellent renewable source for biofuel production[4]. The oil content, types of microalgae available at fresh water and marine water are shown separately in Tables 3 & 4.

**Table 1. Major microalgae groups based on their colours**

| | Colour | Group |
|---|---|---|
| 1 | Yellow-green algae | Xanthophyceae |
| 2 | Red algae | Rhodophyceae |
| 3 | Golden algae | Chrysophyceae |
| 4 | Green algae | Chlorophyceae |
| 5 | Brown algae | Phaeophyceae |
| 6 | Cyanobacteria | Cyanophyceae |

**Table 2. Oil contents of microalgae [2]**

| | Name of microalgae | (% dry wt) |
|---|---|---|
| 1 | Botryococcus braunii | 25- 75 |
| 2 | Crypthecodinium cohnii | 20 |
| 3 | Cylindrotheca sp. | 16-37 |
| 4 | Dunaliella primolecta | 23 |
| 5 | Monallanthus salina | 20 |
| 6 | Nannochloris sp. | 20-35 |
| 7 | Nannochloropsis sp. | 31-68 |
| 8 | Neochloris oleoabundans | 35-54 |
| 9 | Nitzschia sp. | 45-47 |
| 10 | Phaeodactylum tricornutum | 20 – 30 |
| 11 | Schizochytrium sp. | 50 – 77 |
| 12 | Chlorella sp. | 28-32 |
| 13 | Isochrysis sp. | 25-33 |
| 14 | Tetraselmis sueica | 15 – 23 |

**Table 3. Oil contents of microalgae grown in fresh and marine water[4-6,7-9]**

| Water | Name of microalgae species | | (% Dry wt) |
|---|---|---|---|
| Fresh Water Algae | 1 | Botryococcus sp. | 25 – 75 |
| | 2 | Chaetoceros muelleri | 34 |
| | 3 | Chaetoceros calcitrans | 15 – 40 |
| | 4 | Chlorella emersonii | 25 – 63 |
| | 5 | Chlorella protothecoides | 15 -58 |
| | 6 | Chlorella sorokiniana | 19 – 22 |
| | 7 | Chlorella vulgaris | 5 – 58 |
| | 8 | Chlorella sp. | 10 – 48 |
| | 9 | Chlorella pyrenoidosa | 2 |
| | 10 | Chlorella sp. | 18 – 57 |
| | 11 | Chlorococcum sp. | 20 |
| | 12 | Ellipsoidion sp. | 28 |
| Marine Water Algae | 1 | Dunaliella salina | 6 – 25 |
| | 2 | Dunaliella primolecta | 23 |
| | 3 | Dunaliella tertiolecta | 18 -71 |
| | 4 | Dunaliella sp. | 18 – 67 |
| | 5 | Nannochloris sp. | 20-56 |

| | | | |
|---|---|---|---|
| | 6 | Nannochloropsis sp. | 12-53 |
| | 7 | Neochloris oleoabundans | 29-65 |
| | 8 | Pavlova salina | 31 |
| | 9 | Pavlova lutheri | 36 |
| | 10 | Phaeodactylum tricornutum | 18-57 |

## 3. Oil from Microalgae

The production of microalgae biomass for extraction of oil is generally more expensive and technologically challenging than growing crops. The growth of microalgae requires light, Carbondioxide, water and some inorganic salts. The temperature needs to be controlled strictly for better producivity. For every microalgae growth, the temperature will be remains within 20°C to 30°C. In order to reduce the cost, the biodiesel production rely on freely available sunlight, daily and seasonal variations in natural light levels [1,4,10]. In various ways the microalgae biomass can be converted into energy sources such as: a) biochemical conversion, b) chemical reaction, c) direct combustion, and d) thermochemical conversion. Figure. 2 illustrates a schematic of biodiesel and bioethanol production processes using microalgae feedstock [16].

## 4. Fuel from algae oil

As mentioned earlier, microalgae provide number of advantages over plants and seeds as they: i) synthesize and accumulate very large quantities of neutral lipids (20-50 % dry weight of biomass) and grow at high rates; ii) are ability of all year round production, therefore, oil yield per acre of microalgae cultures could greatly exceed yield of best oilseed crops; iii) require less water than terrestrial crops therefore reducing dependence on freshwater sources; iv) cultivation does not require pesticides application; v) uses $CO_2$ from flue gases emitted from fossil fuel-fired power plants and some other sources, thereby it can reduce emission of greenhouse gas (1 kg of dry algal biomass fix about 1.83 kg of $CO_2$), microalgae offer wastewater bioremediation by removing of $NH_4$, $NO_3$, $PO_4$ from wastewater sources (e.g. agricultural run-off, concentrated animal feed, industrial and municipal wastewaters). There is an ability to grow under harsher conditions and reduced needs for nutrients, microalgae can be grown in saline, brackish, coastal seawater and also on non-arable land, and need not to compete for resources with conventional agriculture. Depending on the microalgae some other compounds present in them may also be extracted, used in valuable applications in different industrial sectors, including a large range of fine chemicals bulk products, such as polyunsaturated fatty acids, natural dyes, polysaccharides, pigments, antioxidants, high-value bioactive compounds, and proteins [5,16,17,21,28].

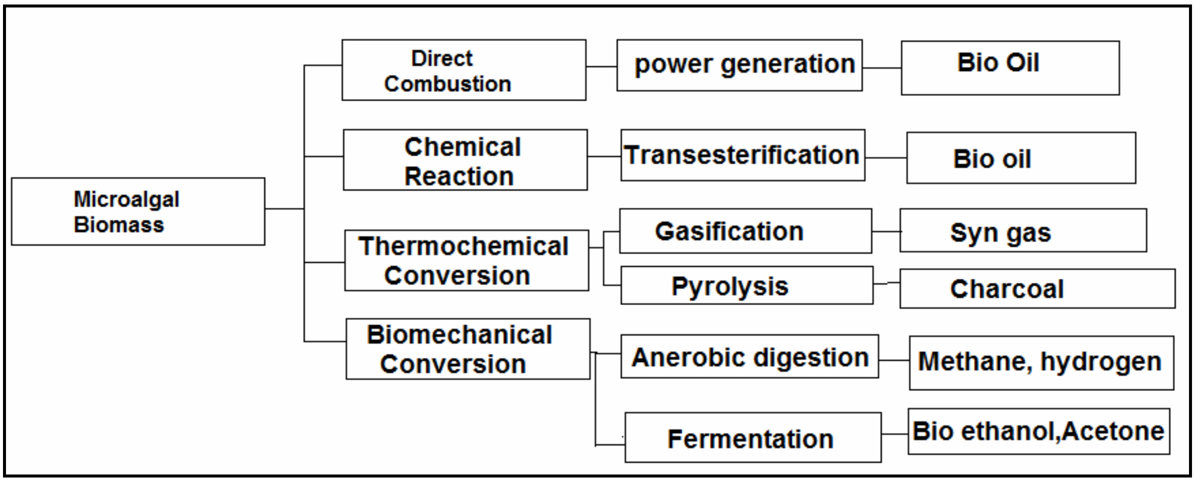


**Figure. 2. Biofuel production processes from microalgae biomass, adapted from [17,29]. There are different ways in which microalgae can be cultivated. However, two widely used cultivation systems are the open atmosphere system and photobioreactor system. The photo bioreactor system can be sub-classified as a) tabular photobioreactor, flat photobioreactor, and column photobioreactor. Each system has their own merits and disadvantages. More details about these cultivation systems can be found in [4,17,18].**

The production of biofuel is a little bit complex process. A layout of biofuel production processes from microalgae is shown in Figure 3. The process consists the stages of microalgae cultivation, harvesting, drying & cell disruption (cells separation from the growth medium), lipid extraction for biodiesel production through transesterification and starch hydrolysis, fermentation & distillation for bioethanol production. However, these processes are complex, technologically challenges and economically expensive. A significant challenge lies ahead for devising a viable biofuel production process [17,28-30].

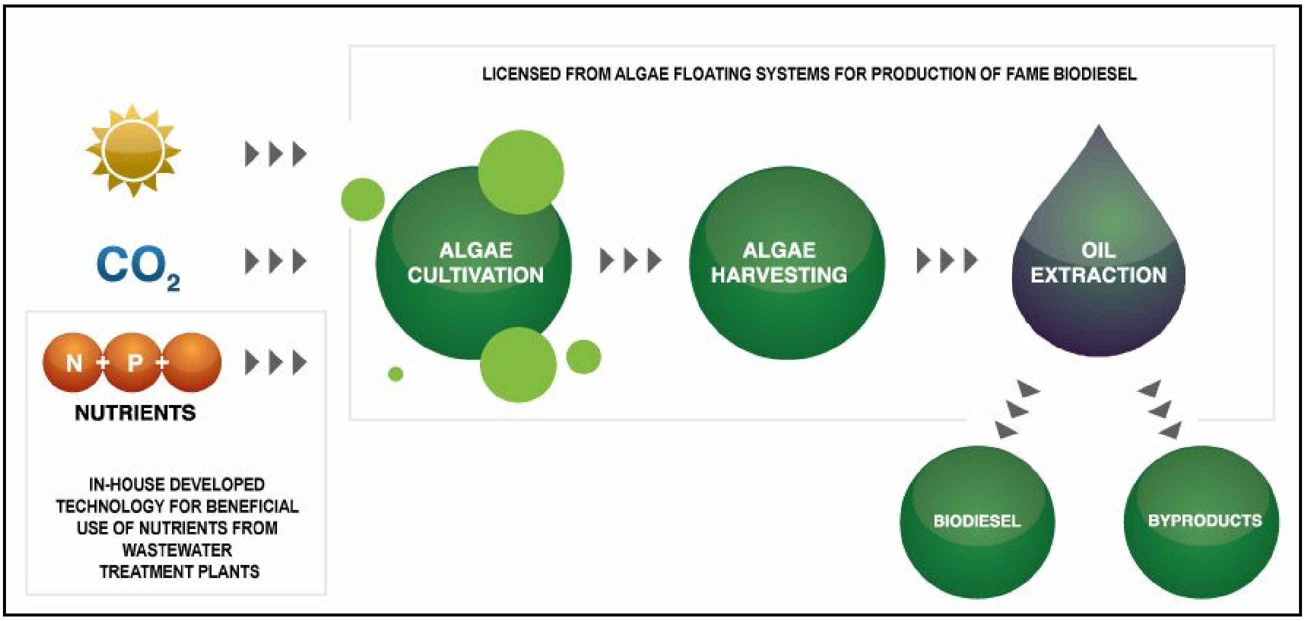


**Figure.3. Biodiesel and Bioethanol production processes from microalgae, adapted from [17]**

## 5. Conclusion

Many countries in world including the European Union (EU) have adopted policies on the percentage of renewable energy use for transport, industrial and other relevant sectors. In December 2008, the EU signed on to a directive which says 10% of member to come from renewable sources such as biofuels, hydrogen and green el policy towards mitigation of climate change and global warming. The EU directive also ensure that biofuels offer at least 35% carbon emission savings while compared to fossil fuels and this thing should rise to 50% in 2017 and debate among governments, policymakers, scientists and environmentalists about the commercially produced biofuels are derived from sources that compete with or belong to feedstock for human and animal consumption. In terms of greenhouse gas emission, the biofuels produced from microalgae is generally carbon neutral. The carbon dioxide emitted from burning biofuel is assumed to be neutral as the carbon was taken out of the atmosphere while the algae biomass grew.

Therefore, biofuels from microalgae will not add new carbon to the atmosphere. Biofuels can be a alternative to fossil fuels on short and medium term usage. In Addition, advanced biofuels made from residues or waste are also have the potential to reduce $CO_2$ emissions with 90% compared to fossil fuel.

While many years of research and development are still ahead, if successful, algae-based fuels can help meet the world's elevating energy requirement for transportation use while reducing greenhouse gas emissions. However, a number of challenges remain unsolved before algae to be used for mainstream commercial applications as the uncertainty of cost constitutes the biggest obstacle. There is no doubt about that research work on microalgae is still in primary stages. Currently, it is not clear that what kind or family of algae would be most appropriate in order to produce commercially viable for biofuels. Researchers are currently working on appropriate commercial cultivation process of algae biomass. At this point in time, there is no answer to an question if it is better to grow algae in photobioreactor system or open atmosphere air system. The algae are micro sized organisms of a size ten times smaller than human hair, it is a greatest challenge to harvest them from growing area. At present, the microalgal harvesting are based on either centrifugation, which push all the microalgae together, but this process associated with high cost [1,9]. Biodiesel production from algae biomass cannot be commercially suitable unless by-products are optimally utilised. As mentioned earlier, the lipid or the oil part is around 35% of the total algae biomass and the remaining 65% is currently wasted which can be used as nutrient, pharmaceuticals, cattle feed and bio-based products. The need of lipid as well as all by-products will allow the full potential of microalgae towards sustainable environment health and economy growth. At current, 75 -90% of the energy put into harvesting microalgae for fuel usually gets used into extracting the oil, they produce under current factory designs. It is obvious that new technologies are required to reduce high energy waste [13,23-27].

Microalgae which have intense potentials for biofuels production. However, these potentials largely depend upon utilisation of technology, input feedstock (CO2, wastewater, saltwater, natural light), barrenland and also in marine environment. on energy content base, available technology, land, it is hard to overemphasize that biofuels are short-term, but it will definitely not a long-term and large scale solution to energy needs and environmental challenges. Microalgae can be act as temporary resources of energy need, and with the appropriate growth protocols they may address some of the concerns raised by the use of first and second generation biofuels.

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