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# Microalgae as a Renewable Energy Source for Biofuel Production

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**The world is in front of deteriorating liquid fuel reserves at a time when energy demand is exploding. The requirement of energy is growing constantly due to the upturn in population mass and industrial development. Currently, the persistent use of petroleum-based fuels is considered as unsustainable because of the running down supplies and the involvement of these fuels in the addition of carbon dioxide in the atmosphere leading to intensification of global warming. As supply diminishes and expenditures increases, countries will be compelled to employ substitute energy sources e.g. natural gas, coal, hydro electrical and nuclear. In order to accomplish a safe and sound energy source that does not cause ecological destruction, renewable energy sources must be discovered and favorable technologies needs to be established with the passage of time. Biofuel derived from microalgae has the capability for high volume and economical production. It can be carbon unbiased and manufactured intensively on non-agricultural land. The superiority of the fuel product is as good as to petroleum diesel that can be incorporated with negligible change into the current fuel set-up. The use of microalgae as a prospective feedstock source for biofuel production offers many global environmental and socio-economic advantages, namely faster growth rates, high biomass and lipid production. In the past decades, wide-scale screening of naturally occurring algal strains have been done all over the world. This paper analyses the existing position of various microalgae species for biofuel production as well as its comparison with other available feedstocks.**

**Key words:** Microalgae, renewable energy, biofuel production.

The world is currently depend on the elementary sources of energy e.g. petroleum, natural gas, coal, hydroelectrical and nuclear. The necessity of energy is growing constantly due to the upsurge in population and mechanization. The persistent use of petroleum-based fuels currently known as unsustainable because of the running down supplies and the involvement of these fuels to the buildup of carbon dioxide in the ecosystem leading to rise of global warming. It is expected that fossil fuel reserves will be depleted by the year 2100 at the current rate of global oil consumption[1]. Renewable and environmentally sustainable alternative sources of fuel are thus an immediate priority, not only to replace fossil fuels but also to overcome fuel demand and supply. In particular, fuel substitutes for the transportation sector are clearly required, as it is the sector with the highest oil demand[2].

A conceivable alternative renewable biomass source that is suggested for biofuel production is microalgae. During the last years, numerous studies have been conducted on biofuels for replacing fossil fuels and to decrease the greenhouse gas release[3-6]. Microalgae found to be the best source of renewable, biodegradable and environment friendly biodiesel that is proficient of meeting the worldwide mandate for transportation fuels[4,7]. The knowledge of using microalgae as a source of fuel is not new, but now a day it is focused intensively because of the growing price of petroleum and more considerably,

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the developing anxiety about global warming that is connected with burning fossil fuels[8]. Microalgae can deliver different kinds of renewable biofuels, including methane, biodiesel (methyl esters) and bio hydrogen[8-10].

Microalgae are among the few photosynthetic oleaginous organisms[11] i.e. they directly produce and accumulate storage lipid in quantities averaging 26-46% of dry weight and up to 85% of dry weight[12-13]. Thus, given their high-lipid producing capacity, coupled with their fast growth rates and relatively unfastidious nature, for the same quantity of biodiesel produced, microalgae would require only 23% of the land used for crops, as compared to 61% if palm plantations, one of the most productive oil producing crops, were to be used[14-15]. Isolation of microalgae strains bearing significant oil content will help in addressing these issues largely. Studying the phenotypic aspects of microalgae growing in diverse habitats have further advantages, as it do not compete for agricultural land or fresh water for its biomass production.

**Microalgae characteristics**

Microalgae are a diverse group of living organisms (>50,000 species), which are photosynthetic in nature. They can be existed as prokaryotic or eukaryotic microorganisms and found in different habitats throughout the world[16-18]. Microalgae appeared ~ 3 billion years ago in the oceans consuming the atmospheric $CO_2$ through photosynthesis while exchanging it with $O_2$ utilized by other living organisms in the earth planet[19]. Microalgae also played a significant role in food chain and used to be a food for many zooplankton, fishes as well as humans. They are present both in aquatic and terrestrial ecosystem demonstrating a huge diversity of species existing in different environmental conditions[20]. Figure 1 shows a schematic picture of the biodiesel production from algae, beginning with the photosynthesis (Carbon dioxide, nutrients and sunlight), then oil accumulation by algal cells, followed by oil conversion to biodiesel.

**Comparison of microalgae with different oil crops**

Many researchers have identified, characterized and compared microalgae strains with other existing feedstocks for biodiesel production[4,6,13, 16-17, 21, 22-25] as shown in Table 1. Microalgae are capable to yield 15-300 times additional oil for biodiesel production than land dwelling crops per acre basis. Moreover, the crop plants reaped once or two times a year, whereas microalgae have short harvesting cycle (1-10 days subject to the process), permitting several or continuous harvests with considerably bigger yields. They are easy to cultivate on unconventional agricultural land, using water, which is inappropriate for human use and stress-free to acquire nutrients[6].

**First, second and third generation biofuels**

Biofuels obtained from organic matter in different forms i.e. in solid, liquid or gaseous. They are alienated into primary and secondary biofuels. Primary biofuels are usually derived from firewood, wood chips, pellets, animal waste, forest and crop residues, whereas secondary biofuels is divided into first, second and third generation principally based on diverse parameters including type of processing technology, feedstock and their level of development[26-27].

First generation biofuel based on food and oil crops, which embroils anxieties about alteration of crops from human feeding towards biofuels. As farming sector aspects, a worldwide task to nourish ~ 1 billion starved people and risks turning the rapidly expanding agriculture sector into an environmentally unsustainable practice for the world's grains and oils consumption can cause significant environmental problems[6].

Second generation biofuel based on lignocellulosic biomass e.g. straw, wood, and grass, which do not compete with our agriculture food. However, it also carries limitations like transforming the forested biomass into fermentable sugars is very expensive due to the pre-treatment process, which require special enzymes, Therefore it is, not economically feasible at commercial scale[28].

**Table 1.** Comparison of microalgae with different oil crops

| Crop | Oil yield (gallons/acre) |
|---|---|
| Corn | 18 |
| Soybeans | 48 |
| Canola | 127 |
| Jatropha | 287 |
| Oil Palm | 636 |
| Microalgae | 14641-16283 |

Source: [4]

Third generation biofuels based on microalgae, which is a conceivable alternative renewable biomass source that is being suggested for biofuel production[3-5, 17]. Though the mechanisms of photosynthesis in microalgae is analogous to that of higher plants, they are often more effective converters of solar energy to useful biochemical products like oil because of their modest cellular structure. Microalgae cells grow well in aqueous environment and can effectively

**Table 2**. Comparison of lipid content and biomass productivity potential in reported microalgae species.

| Microalgae Species | Lipid Content (% dry wt. biomass) | Lipid Productivity dry wt. (g $l^{-1}$ $day^{-1}$) | References |
|---|---|---|---|
| *Amphora sp*. (Persian gulf) | 24 | 0.16 | [42] |
| *Ankistrodesmus sp*. | 24.0-31.0 | 0.09 | [20] |
| *Botryococcus braunii* | 25.0-75.0 | 0.18 | [42-43] |
| *Chlorella emersonii* | 25.0-63.0 | 0.29 | [42] |
| *Chlorella salina* | 25.0-63.0 | 0.17 | [42] |
| *Chlorella sorokiniana* | 19.0-22.0 | 0.27 | [44] |
| *Chlorella vulgaris* | 5.0-58.0 | 0.46 | [42] |
| *Chlorella vulgaris* | 5.0-58.0 | 0.015 | [45] |
| *Chlorella pyrenoidosa* | 5.0-58.0 | 0.25 | [46] |
| *Chlorella protothecoides* | 14.6-57.8 | 2-7.70 | [20] |
| *Chlorella pyrenedoisa* | 2.0 | 2.90-3.64 | [20] |
| *Chlorella pyrenoidosa* | 2.0 | 0.05 | [47] |
| *Chlorococcum sp*. | 19.3 | 0.28 | [23] |
| *Crypthecodinium cohnii* | 20.0-51.1 | 10 | [20] |
| *Dunaliella sp*. (Persian gulf) | 16.7-71.0 | 0.12 | [42] |
| *Dunaliella salina* (shariati) | 23-25 | 0.05 | [42] |
| *Dunaliella salina* (UTEX) | 23-25 | 0.15 | [42] |
| *Dunaliella primolecta* | 23.1 | 0.09 | [42] |
| *Haematococcus pluvialis* | 25.0 | 0.06 | [20] |
| *Isochrysis sphacrica* | 7.1-33.0 | 0.017 | [45] |
| *Lyngbya kuetzingii* | | 0.016 | [45] |
| *M. pussilum* YSW08 | 24 | 0.11 | [48] |
| *Monodus subterraneus* | 16.0 | 0.19 | [20] |
| *M. afer* PKUAC | | 9 0.09 | [49] |
| *Pavlova salina* | 30 | 0.16 | [20, 4] |
| *Pavlova lutheri* | 35.5 | 0.003-1.9 | [20] |
| *Pavlova salina* | 30 | 0.16 | [20] |
| *Phaeodactylum tricornutum* | 18.0-57.0 | 0.14 | [20] |
| *P. tricornutum* | 18.0-57.0 | 0.017 | [45] |
| *Porphyridium cruentum* | 9.0-18.8/60.7 | 0.36-1.50 | [20] |
| *Scenedesmus sp*. | 13.3-31.8 | 0.10 | [42] |
| *Scenedesmus sp*. | 19.6-21.1 | 0.06 | [50] |
| *Scenedesmus obliquus* | 11.0-55.0 | 0.004-0.74 | [20] |
| *Scenedesmus obliquus* | 11.0-55.0 | 0.014 | [45] |
| *S. abundans* PKUAC 12 | 11.0-55.0 | 0.11 | [49] |
| *S. obliquus* YSR01 | 11.0-55.0 | 0.08 | [48] |
| *S. obliquus* YSR04 | 11.0-55.0 | 0.094 | [48] |
| *S. obliquus* YSR05 | 11.0-55.0 | 0.083 | [48] |
| *S. obliquus* YSW06 | 11.0-55.0 | 0.086 | [48] |
| *Skeletonema sp*. | 13-51 | 0.09 | [20] |
| *Thalassiosira pseudonana* | 20.6 | 0.08 | [20] |
| *Tetraselmis suecica* | 8.5-23.0 | 0.12-0.32 | [20] |

use water, CO2 and other nutrients. In addition, numerous algal strains have been shown in the laboratory to be capable of producing Ã50-80% of biomass as lipids and oil levels 20-50% [29]. For these reasons, microalgae are accomplished of generating a higher level of oil/unit area, compared to many oilseed crops, such as soybean, coconut and palm.

Microalgae generate numerous kinds of renewable biofuels as shown in Figure 2, which contain biogas formed by anaerobic digestion of the algal biomass[10]; biodiesel resulting from microalgae oil[8, 21, 30-33]; and photo biological production of hydrogen[9, 34-37].

**Biodiesel production from microalgae**

Currently researchers have focused on renewable biodiesel production from microalgal biomass, which is easy to incorporate into the available transport infrastructure to overcome the increasing demand for transport fuel as well as it will not compete with the existed terrestrial crops[38, 64]. The lipid content and biomass productivity potential in various reported microalgae species shown in Table 2.

Various research groups are interested in the microalgae species, which are fast growing and are able to accumulate abundant quantity of lipids under specific conditions i.e. *Botryococcus braunii*, *Dunaliella salina,* and various *Chlorella* species[39]. However, several microalgae strains have indeed a high lipid profile, which can be increased further by improving the growth defining factors i.e. control nutrient level (nitrogen and phosphorus), light intensity, temperature, salinity, CO2 absorption and collecting process. Oil level in microalgae can surpass 80% by weight of dry biomass[10, 28-29] subject to various species of microalgae and different types of lipids, hydrocarbons and other composite oils can be produced[33, 40-41].

**Microalgae culture systems**

After proper selection of microalgae strains for biofuel production, it is very important to utilize a wide variety of bioprocesses, which will make it feasible to grow at commercial scale. In order to develop microalgae products at industrial scale we require the application of bioreactor technology. Unfortunately very few microalgae species have been cultured to produce commercial scale products due to many parameters i.e. high

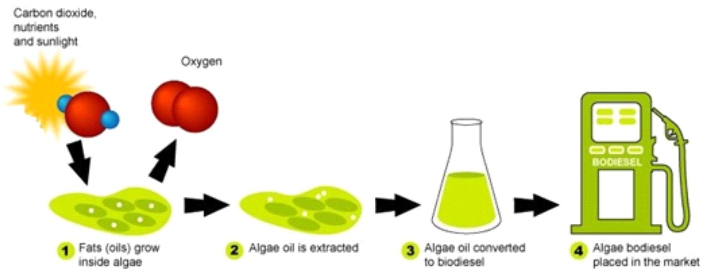


**Fig. 1.** Processing of algal biomass for commercial scale production of biodiesel[63]

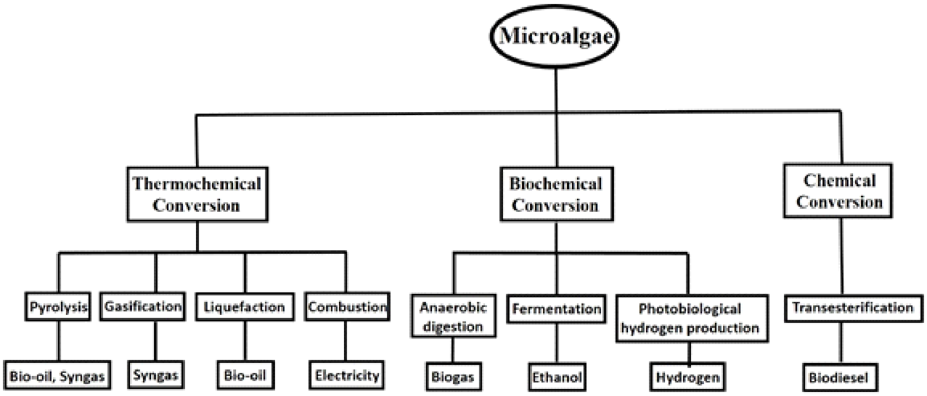


**Fig. 2.** Conversion process for biofuel production from microalgae biomass; adopted from[25]

biomass content; high lipid productivity; cost effective production (in terms of investment and maintenance costs); easy control of culture factors (temperature, pH, O2, turbulence); and consistency [51]. Many researchers have designed different types of photo bioreactor (PBR) for the large-scale growth of microalgae. Some have grown microalgae in open-air ponds while others have used PBR for aseptic culture. Since a couple of years, open-air systems used for the widespread growth of microalgae comprising of natural ponds, circular ponds, raceway ponds and inclined systems. The motives behind open-air systems are cost effectiveness, easier to build and operate for the commercial scale production of biofuel from microalgae. Moreover, water from the sewage water treatment plants can be channelized towards these open-air systems, which will make cheap bio renewable products[52-56].

**Genetically engineered microalgae for biofuel production**

Currently the researchers have focused on manipulating the genome of microalgae for the enhanced production of biofuel at commercial scale. Until date, 16 algal genomes are completely sequenced and the work is still in progress to sequence more genomes of commercially valuable strains. Different research groups have successfully manipulated the genomes of microalgae species, including *C. reinhardtii*, *Chlorella sp.*, *Haematococcus pluvialis*, *Dunaliella viridis*, *Dunaliella salina*, *N. oculata*, *Thalassiosira pseudonanna*, *Thalassiosira weissfloggi*, *Phaeodactylum triconuntumtricornuntum*, *Porphyridium sp.*, *Nannochloropsis sp.*, and *S. obliquus*[49, 57-60]. Moreover, the development of 'omics' fields including genomics, transcriptomics, proteomics, and metabolomics has produced a considerable amount of data concerning algal metabolism[61-62]. Due to the development of these potential molecular techniques, a large number of microalgae strains have been engineered which are able to grow quickly and tolerate the extreme environmental conditions. However, the mentioned disciplines of genetic engineering are in infancy and will grow up in the near future for the purpose of cost-effective renewable production of biofuel from microalgae.

## CONCLUSION

Microalgae has the potential to be an alternative source of biofuel production in the world due to its renewable, biodegradable and environment friendly nature. In order to develop microalgae-based biofuel production at industrial level, biotechnological approaches including "omics" will be effectively utilized in order to engineer potential microalgae strains. Moreover industrial improvements, including development in photobioreactor design, microalgal biomass harvesting, and processing are significant areas that may lead to enhanced and economical production of biofuel from microalgae.

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