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# Biodiesel Production from Microalgae

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## ABSTRACT

Technology for creating also applying biodiesel has been recognized for more than 50 years. Microalgae are a various type of prokaryotic as well as eukaryotic photosynthetic microorganisms that grow rapidly due to their simple structure. Biodiesel is considered as a renewable fuel because it can be obtained from the transformation of vegetable oils, cooking greases or animal fats. Microalgae are sunlight-driven cell factories that convert carbon dioxide to potential biofuels, foods, nourish also high-value bioactives. In addition, these photosynthetic microorganisms are beneficial in bioremediation applications nitrogen fixing biofertilizers. This article focuses on microalgae as a potential source of biodiesel.

**Key words:** Biodiesel, Microalgae, Renewable Fuel

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## 1. INTRODUCTION

Biodiesel is a clean burning alternative fuel, created from domestically increased, renewable resources. Biodiesel comprises no petroleum products, but can be blended at any concentration with diesel from fossil sources to create a biodiesel blend (1). Biodiesel is an alternative energy source and a substitute for petroleum-based diesel fuel (2). Biodiesel creation from algae is a promising mechanism. Three classes of aquatic plants have been examined for energy production: macroalgae, emergents and microalgae (3). Table 1, Comparison of some sources of biodiesel (4).

**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** | 1,36,900 |
| **Microalgae** | 58,700 |

Microalgae have the potential to produce 5,000 – 15,000 gallons of biodiesel per acre per year (5). Microalgae have been investigated for the production of a number of different biofuels containing biodiesel, bio-oil, bio-syngas, and bio-hydrogen. The creation of these biofuels can be coupled with flue gas $CO_2$ mitigation, wastewater treatment, and the production of high-value chemicals (6). However, there are challenges. These include high yield of algae biomass with high lipid content and the effective technique to harvest the grown algae, extract the algal oil and Trans esterify the oil to biodiesel (7).

Algae have numerous advantages over terrestrial plants:

1. They use solar energy with efficiencies 10 times higher compared with terrestrial plants, fixing higher quantities of

$CO_2$.
2. They can grow in fresh, salty waters and even in wastewaters.
3. They can be used as metal absorbers (Cu, Cd) in wastewater treatments.
4. Algae harvesting can be acted following a few days once the culture has began, which does not happen with crops.
5. Flue gases from power plants can be directly used in algae culture, recovering carbon and nitrogen dioxides.
6. Algae production systems can be installed in surfaces next to industries and in non-cultivable surfaces, avoiding competition for the lands.
7. Several studies affirm that more quantities of oil can be obtained from microalgae compared from oilseeds (8).

Microalgae have much more oil than macroalgae also it is much faster and easier to grow and yields high measure of lipids. Oil contents of microalgae are commonly between 20-50% (dry weight) Table 2 (4, 9, 10). More than 50,000 microalgae species exist in the world, but only 30,000 species have been studied and analysed (11). This article focuses on microalgae as a potential source of biodiesel.

**Table 2. Lipid content of different microalgae**

| *Microalga* | *Oil content (% dry weight)* |
|---|---|
| *Botryococcusbraunii* | **25-80** |
| *Chlorella protothecoides* | **23-30** |
| *Chlorella vulgaris* | **14-40** |
| *Crypthecodiniumcohnii* | **20** |
| *Cylindrotheca sp.* | **16-37** |
| *Nitzschia sp.* | **45-47** |
| *Phaeodactylumtricornutum* | **20-30** |
| *Schizochytrium sp.* | **50-77** |
| *Spirulina maxima* | **4-9** |
| *Neochlorisoleoabundans* | **35-65** |
| *Dunaliellasalina* | **14-20** |

## 2. Algae culture systems

Algae are organisms that grow in aquatic environments and use light and carbon dioxide ($CO_2$) to create biomass. There are two classifications of algae: macroalgae and microalgae. Macroalgae are the large (measured in inches), multi-cellular algae frequent observed developing in ponds. These larger algae can grow in a difference of methods. The largest multi-cellular algae are called seaweed; an example is the giant kelp plant which can be more than100 feet long (12). The first mention of seaweed culture dates back to 1690, in Japan and China are still the main producers of cultured seaweed (13). Seaweeds are often used as food, both for people and livestock. For example, seaweed is often used in food preparation in Asia. Seaweed is rich in many vitamins, including A, B1, B2, B6, C, and niacin. Algae are also rich in iodine, potassium, iron, magnesium, and calcium (14). Microalgae, on the other hand, are tiny (calculated in micrometers), unicellular algae that usually raise in suspension within a body of water. Algal biomass includes three central factors: carbohydrates, proteins, and lipids/natural oils (12). For algae to grow, a few relatively simple conditions have to be met: light, carbon source, water, nutrients and a suitably controlled temperature (15). Algae are traditionally cultivated either in open ponds, known as high rate ponds (HRP), or in enclosed systems known as photobioreactors. Each system has its own advantages and disadvantages (16).

*2.1 Open Raceways*

Open ponds are the oldest and simplest systems for mass cultivation of microalgae. In this system, the shallow pond is commonly with about 1 foot deep; algae are cultured dependent circumstances same to the natural environment. The pond is commonly created in a “raceway” or “track” configuration, in which a paddlewheel provides circulation and mixing of the algal cells and nutrients (Figure. 1). They can be found as large open ponds, circulating ponds with a rotating arm and raceway ponds (2, 16).

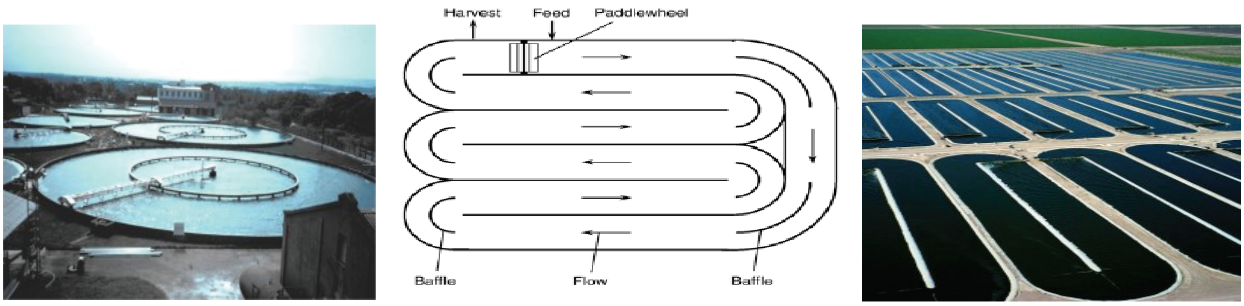


Figure 1. Open raceway ponds

This culture system has its intrinsic disadvantages. Since these are open air systems, they often experience a lot of water loss due to evaporation. Open ponds do not allow microalgae to apply carbon dioxide as efficiently, and biomass creation is restricted. Biomass productivity is also restricted by contamination with unwanted algal species as well as organisms that nourish on algae. In addition, optimal culture conditions are difficult to maintain in open ponds and recovering the biomass from such a dilute cell yield is expensive (5, 17).

*2.2. Photobioreactors (PBR)*

Bioreactor which is used for cultivating algae and purpose to fix $CO_2$ producing biomass is called an algae bioreactor or an algae photobioreactor. The main advantage of the PBR is that they can produce a large amount of biomass (17). The biomass productivity of photobioreactors can be 13 times more than that of a traditional raceway pond on average. Harvest of biomass from photobioreactors is less costly than that from a raceway pond, since the categorical algal biomass is about 30 times as focused as the biomass determined in raceways (5). There are many different shapes of bioreactors, but they usually fall into two broad categories: 1. Use of natural light and 2. Use of artificial illumination (18). Photobioreactors are often tubular to allow for a greater amount of light penetration. The tubes, whether helical or straight, allow for the greatest surface area to volume ratio and let the algae grow as they circulate throughout the design. (Figure. 2) (19).


Figure 2. Enclosed photobioreactor

Photobioreactors also have some disadvantages. Variations in light and temperature, common in all photoautotrophic systems, can cause suboptimal growth of the microalgae. The scale-up is very adverse in these systems, and warrants a high charge to do so. The beginning capital cost singles is very high, due to their complexity, also contrasts in design as well as combination. This cost can be justified when producing a high value product such as a pharmaceutical, but a low value commodity, such as fuel, cannot recover the initial cost of construction in any reasonable time (19, 20).

*2.3. Heterotrophic culture systems*

Some species of microalgae can also be grown heterotrophically. In this case, the alga gets its carbon from an organic carbon source in the medium, rather than through carbon dioxide, and does not undergo photosynthesis, so it doesn't require a light source. Heterotrophic algae normally produce high categories of lipids and less protein than photosynthetic algae. Heterotrophic culture is best applied in monocultures of a single alga species, and needs extensive sterilization of media and equipment. Heterotrophic production of lipids by microalgae is dependent on many factors, such as culture age, media nutrients, and environmental factors such as temperature, pH, and salinity (21, 22).

*2.4. Algae Turf Scrubbers (ATS)*

Attached culture systems such as Algae Turf Scrubber (ATS) systems are a different method of algal growth. They rely on keeping the algae in place and bringing the nutrients to it, rather than suspending the microalgae in a culture media (Figure. 3). There are a number of benefits to this method, such as the ability to harvest the algae on its substrate, rather than filtering it out of media. ATS systems were originally designed around the concept of surge flow in coral reef communities; water, washed over the algae at short time courses, alternating with full exposure to sunlight, could dominate any light inhibition problems are carry the maximum load of nutrients and gases to the algae. While ATS systems have only been used to cultivate macroalgae, they have proven to be productive and efficient. ATS systems are often employed to treat river water Turf scrubbers are easy to scale up, and have been scaled up to very large systems. Turf scrubbers have also been tested to treat manure effluent (23, 24).

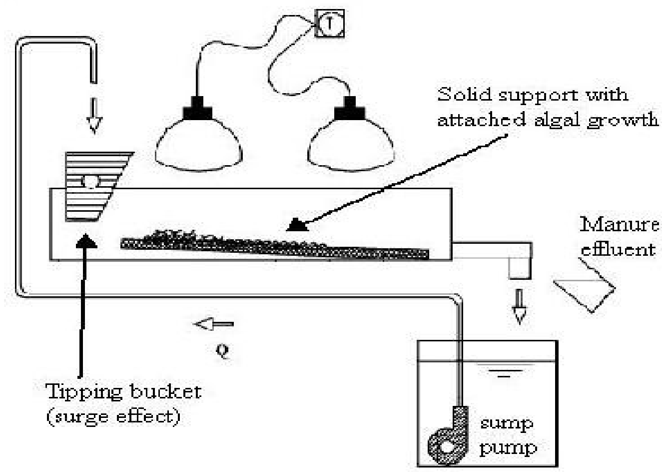


Figure 3. ATS system

## 3. Harvesting Techniques of Microalgal Biomass

Harvesting biomass represents one of the significant cost factors in the production of biomass. Efficient harvesting biomass from cultivation broth is essential for mass production of biodiesel from microalgae. The choice of harvesting methods is related on the characteristics of microalgae such as density, size, and price of the needed products. The major techniques presently applied to the harvesting of microalgae include centrifugation, flocculation, filtration, screening, gravity sedimentation, immobilization, flotation and electrophoresis (4).

## 4. Microalgae for Biodiesel Production

Biodiesel is a mixture of fatty acid alkyl esters obtained by transesterification (of vegetable oils or animal fats. These lipids feedstocks are included by 90–98% (weight) of triglycerides also small measures of mono as well as diglycerides, free fatty acids (1–5%), also residual measures of phospholipids, phosphatides, carotenes, tocopherols, sulphur compounds, and traces of water. Figure 4. (2, 25).

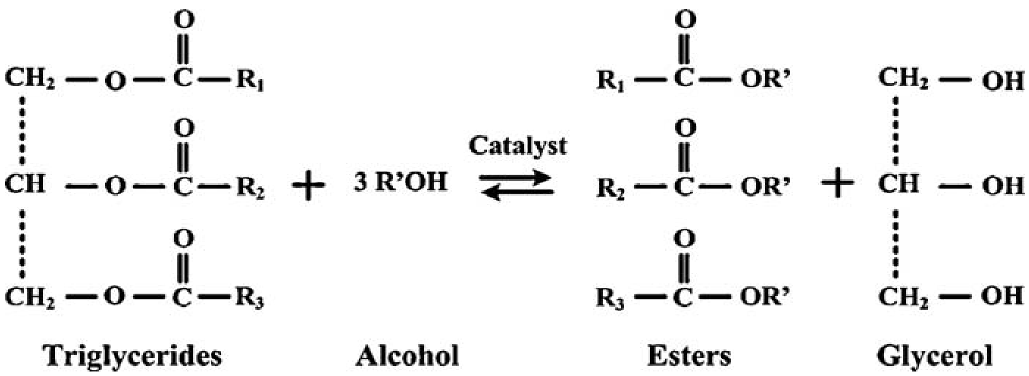


Figure 4. Transesterification reaction to produce biodiesel

Transesterification is a multiple step reaction, composing three reversible categories in series, where triglycerides are altered to diglycerides, following diglycerides are altered to monoglycerides, and monoglycerides are then converted to esters (biodiesel) and glycerol (by-product) (26, 27). Among the alcohols that can be used in the transesterification process such as methanol, ethanol, propanol, butanol and amyl alcohol. Methanol and ethanol are frequently used. Methanol is chosen for the commercial development due to its low price and its physical and chemical benefits (polar and shortest chain alcohol). Transesterification reaction can be catalysed both homogenous and heterogenous catalysts (28).

## 5. Other applications and products from microalgae

*5.1. Environmental applications*

- Flue gas $CO_2$ emissions as microalgae nutrient
- Wastewater nitrogen and phosphorous as

microalgae nutrients

*5.2. Microalgae fine chemicals and bioactive compounds*

- Microalgae applications in human health
- Microalgae for aquaculture and animal feed (2).

## 6. CONCLUSION

Algal biofuel is an ideal biofuel candidate which eventually could replace petroleum-based fuel due to several advantages, such as high oil content, high production, less land, etc. Currently, algal-biofuel production is still too expensive to be commercialized. Due to the static cost related with oil extraction and biodiesel processing and the variability of algal-biomass creation, forthcoming cost-saving activities for algal-oil creation should focus on the production method of the oilrich algae itself. This needs to be approached through enhancing algal biology (in terms of biomass yield and oil content) and Technological developments or culture-system engineering. Technological developments, including advances in photobioreactor design, microalgal biomass harvesting, drying, and other downstream processing technologies are critical extents that may direct to improved cost-effectiveness and hence, effective commercial implementation of the biofuel from microalgae aim.

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## AUTHORS CONTRIBUTION

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The authors declared no potential conflicts of interests with respect to the authorship and/or publication of this article.

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