Fundamentals of Production of Algal Oil Biodiesel

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Abstract: The abundant usage of fossil fuels by industrialization is causing them to run out on a daily basis. Alternative energy sources had to be used in place of fossil fuels, as anticipated by energy specialists. Biofuel, which is derived from renewable biological sources, is one of the alternatives that are most likely to replace fossil fuels. Algal-derived biodiesel is one type of potential biofule. This review paper describes the process of turning algal biomass into biodiesel.

Keywords: Biodiesel, Algal, Production, transesterification, Alternate energy

INTRODUCTION

Global pollution is increasing as fossil fuels run out. Algal biofuels represent a highly promising alternative approach to energy generation. Biofuel is energy produced by biological processes or taken from the biomass of living things, including bacteria, plants, and microalgae [1].

According to current research, biofuels are essentially carbon neutral since the carbon released during burning comes from recently fixed atmospheric CO2 either directly or indirectly. Algal biomass has emerged as the third-generation feedstock of today. It has high levels of vitamins, lipids, amino acids, and polysaccharides. It is lignin-free and doesn't require any arable land. Furthermore, by fixing CO2, algae may develop quite quickly. Straw, wood material, wood waste, energy plants, sugarcane, manure, and several other agricultural coproducts or byproducts make up the majority of the feedstocks used to produce biofuel [2].

An alternative to petroleum fuel that is potentially renewable is biodiesel made from oil crops [3].Petroleum diesel fuel and biodiesel are perfectly miscible and are typically tested together. Fuel efficiency will increase when engines run on pure or mixed biodiesel. Depending on the kind of biomass utilized in the process, biodiesel may be classified into four generations. Microalgae had a number of advantages over crop-based biodiesel, including a higher growth rate, a higher lipid content, and a reduced land demand. Due to its quick growth rate, microalgae are now considered the perfect feedstock for third-generation biofuels. Aerating, salinity, temperature, pH, light, and nutrient amount and quality are some of the key factors in microalgae production that affect the growth behavior and photosynthetic activity of the algae [4].

Algae

Similar to other plants that can undergo photosynthesis to convert inorganic compounds into organic ones, algae are a varied group of aquatic organisms that have chlorophyll.Compared to most land-based plants, they have quicker cell development, a significantly better photosynthetic efficiency, and the ability to absorb nutrients and CO2 quickly. We used repeated dilution to accomplish monoculture for a particular algal culture. For cultivation, algae need a temperature range of 15-35 degrees Celsius.Algae are divided into two categories based on size: macroalgae (seaweed) and microalgae. They are crucial to the environment because they prevent the aquatic food chain that sustains all of the island's and ocean's fisheries [5].

Microalgae

Through the process of photosynthesis, microalgae are unicellular or multicellular photosynthetic microorganisms that can convert carbon dioxide, water, and light into biomass and oxygen [6]. The four primary classes of microalgae are golden algae, blue green algae, green algae, and green algae. Microalgae have a greater concentration of nitrogen, phosphorus, and potassium in addition to carbon, hydrogen, and oxygen in their chemical makeup.

Microalgae are also classified according to how much carbon they consume. The four main phases of microalgal development are the lysis, lag, exponential, and stationary phases. Microalgae are cultivated in extremely low nutrient environments, and their primary function is to absorb carbon dioxide, which contributes to the world cycle and fixes nitrogen, which is used as biofertilizer in Figure 1.

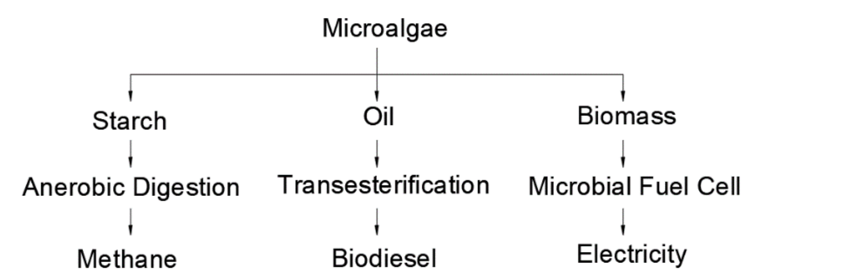

Figure 1. Use of the Microalgal Biomass

Utilizing Microalgae for Biofuels

The microalgal biomass may be used to produce biofuel as it contains macromolecules like proteins, carbs, and lipids. Microalgae's lipid content can be influenced by their species and growing circumstances. A high lipid content of 20% to 50% is typical for microalgae species including Chlorella, Dunaliella, Nannochloris, Scenedesmus, Nannochloropsis, and Tetraselmis [7].A number of procedures are involved in the manufacture of biofuels, including the selection, cultivation, separation, and drying of biomass, the destruction of cells to extract biomolecules, and, finally, the use of conversion processes for the creation of biofuels, as shown in Figure 2.

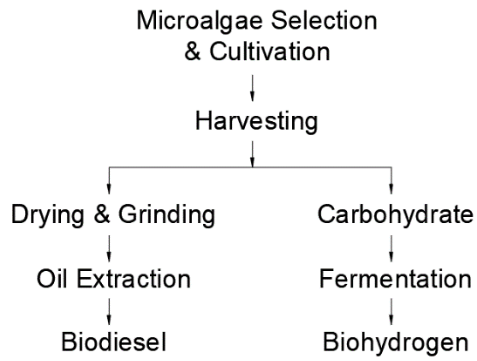

Figure 2. Overview of the use of microalgae in the synthesis of biofuels

Biodiesel Production

The mono-alkyl esters of long-chain fatty acids that make up biodiesel are mostly produced by the transesterification (also known as the ester-exchange reaction) process from triacylglycerols (TAGs). Oils and lipids produced from algal biomass are utilized in transesterification processes, where the alcohol to oil ratio is either 3:1 or 6:1 in the presence of chemical catalysts like acid and alkali or a biological catalyst like lipase [8, 9].

Glycerol is a by-product of the transesterification process, whereas methyl ester, or biodiesel, is the final result [10]. The alcohol/oil ratio, the kind of alcohol, the catalyst employed, the amount, reaction duration, temperature, and reagent purity are only a few of the variables that affect the transesterification process.

Steps in the manufacturing process of biodiesel;

- ***Raw Material Treatment -*** Prior to undergoing the transesterification process, certain feedstocks need to undergo pre-treatment. More than 4% free fatty acids in feedstocks, such as animal fats and recycled greases, necessitate pre-treatment by an acid esterification process. Feedstocks with fewer than 4% free fatty acids, such as vegetable oils and some food-grade animal fats, do not require pre-treatment [11]. This process turns the free fatty acids in the feedstock into biodiesel by reacting it with an alcohol such as methanol in the presence of a strong acid catalyst. The chemical process transforms the leftover triglycerides into biodiesel.
- ***Combining Alcohol with Catalyst -*** Prior to adding the oil, the catalyst and alcohol required to produce biodiesel must be combined. The alcohol also has to be water-free. The volume ratio

of alcohol to oil is 1:4, and titration is used to calculate the required quantity of catalyst while accounting for the oil's acidity [12].

- ***Transesterification -*** Alcohol and fat combine to generate esters and glycerol as a byproduct, a process known as transesterification (sometimes called alcoholysis). Typically, transesterification occurs at a temperature of between 50 and 60°C at atmospheric pressure [13]. Equation presents a typical transesterification process, where RCOOR' denotes an ester, R' OH an alcohol, R' OH glycerol, and RCOOR" an ester mixture.

  $$RCOOR' + R''OH \rightarrow R'OH + RCOOR''$$

- ***Separation of Glycerol and Biodiesel*** - Decantation is used to separate the reaction products; due to differing densities, the mixture of fatty acids methyl esters (FAME) and glycerin separates into two phases that may physically separate. Centrifugation may also be used in some circumstances to speed up the separation process.

- ***Purification -*** To meet set quality requirements for biodiesel, the mixture of fatty acids methyl esters (FAME) produced from the transesterification reaction needs to be filtered. FAME needs to be cleaned, neutralized, and dried as a result [14].

- ***Substrates for the Production of Biodiesel -*** Both large-scale production and cost-effectiveness must be met in the feedstock selection process for the manufacturing of biodiesel. Four categories apply to biodiesel substrates: The following vegetable oils are classified as non-edible: jatropha, mahua, linseed, cotton seed; (a) edible: soybean, palm oil, sunflower, rapeseed, and peanut; (d) Waste or recycled oil, such as cooking, frying, and pomace oil; (c) animal fats, such as cattle tallow, swine lard, yellow grease, chicken fat, and byproducts from fish oil [15]. Each of these was considered a feedstock for biodiesel of the second generation. Because of their high rate of lipid accumulation and most productive photosynthetic efficiency with net negative energy, microalgae are thought to be the most promising feedstock for third-generation biofuel (Table 1). greenhouse gas emissions [16].

Table 1. Biodiesel Feedstocks

Feedstock/Source	Oil Content (%)	Fatty Acids
Microalgae	30-70	---
Linseed	40-45	Linoleic, Oleic
Mahua	35-40	Palmitic, Oleic
Jatropha	50-60	Linoleic, Palmitic, Oleic
Cotton Seed	15-20	Palmitic, Linoleic, Oleic
Rapeseed	40-45	Oleic, Linoleic
Canola	40-45	Oleic, Linoleic
Sunflower	25-30	Linoleic, Oleic, Palmitic

Castor	40-50	Linoleic, Ricinoleic
Palm Oil	40-45	Oleic, Palmitic, Linoleic
Peanut	45-50	Palmitic, Oleic
Chicken Fat	30-35	Palmitic, Linoleic, Oleic
Mutton Tallow	40-60	Palmitic, Stearic, Oleic, Linoleic
Pork Lard	35-40	Palmitic, Stearic, Myristic

- ***Procedures for Biodiesel Production -***
  - ***Straight use and blending -*** In direct usage, 100% biofuel is used instead of diesel and gasoline (B100), and common variations such as B5, B10, B95, etc. are blended in. The engine does not need to be modified in order to utilize vegetable oil as diesel fuel. Vegetable oil, which makes about 80% of diesel fuel, has a number of benefits when used as diesel fuel, including its liquid form, portability, ease of supply, and high heat content. Vegetable oil's high viscosity, low volatility, and the reactivity of unsaturated hydrocarbon chains, which eventually cause issues are its main causes for worry when used as fuel [18].
  - ***Microemulsion -*** A micro-emulsion is a naturally occurring colloidal equilibrium dispersion of optically isotropic fluid microstructures, typically ranging in size from 1 to 50 nm. It is created by combining two typically immiscible liquids with one or more ionic or non-ionic amphiphiles. The use of solvents like methanol and ethanol in micro-emulsions to reduce the high viscosity of vegetable oils has been researched [19].
  - ***Thermal cracking -*** The process of converting one chemical into another by heat and a catalyst is called thermal cracking, or pyrolysis. It is not a process for making biodiesel. But this process is starting to look like a viable option since it yields chemicals and fuel that is similar to diesel. The feedstocks utilized and the conditions under which they are performed have a considerable impact on the composition of the products generated during pyrolysis [20].There are several feedstocks that can be pyrolyzed, some of which have very little fat content. The resultant combination may yield various valuable compounds in addition to transportation fuel, often referred to as bio-oil [21]. The process is typically difficult to manage since it demands high temperatures, which come with significant energy expenditures. It is also highly reliant on the environment in which it is carried out.
  - ***Catalytic cracking -*** Another form of thermal cracking is catalytic cracking, which is

widely employed in the petrochemical sector to generate a sizeable amount of the fossil fuel utilized today. This methodology may also be applied to the generation of biodiesel from an extensive range of feedstocks.By using a catalyst, it is possible to use softer pressure and temperature settings while yet having better control over the end products that are produced [22]. Cracking techniques for the generation of biodiesel may be developed and implemented using various combinations of reactors and catalysts.

- ***Transesterification -*** Oils and lipids produced from algal biomass are utilized in transesterification processes, where the alcohol to oil ratio is either 3:1 or 6:1 when chemical catalysts like acid and alkali or biological catalysts like lipase are present [8,9]. Methyl ester, or biodiesel, is the final product of the transesterification procedure, with glycerol resulting as a by-product [23]. Numerous factors affect the transesterification process, such as the alcohol to oil ratio, the kind of alcohol, the catalyst utilized, and the amount, reaction time, temperature, and reagent purity shown in Figure 3.

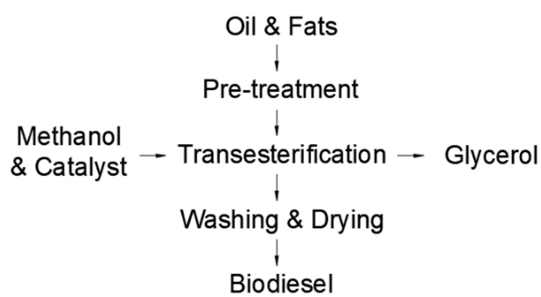

Figure 3. Transesterification Process

- ***Production Status of Biodiesel -*** There are greater options to raise cell density, algal biomass productivity, and cellular lipid content when microalgae grow heterotrophically, which is light-independent and utilizes organic substrates as carbon sources [24].The supply and concentration of nitrogen in the medium have an impact on the growth and chemical makeup of microalgae. In microalgal metabolism, physicochemical parameters including temperature, pH, and light intensity are crucial [25]. Numerous techniques for producing algal biofuels from wastewater were investigated, including raising algae in open ponds and bioreactors, as well as various technology for converting biomass and nutrient sources. The generation of microalgal biofuel from wastewater was shown to be superior to that of biofuel derived from freshwater. However, the nutritional profile, downstream processing, and availability of acceptable effluent further limited the process's efficacy and made large-scale deployment of these procedures impossible [26]. Biodiesel has the potential to be an alternative fuel since it is renewable and greener. It is a liquid fuel made of long chain fatty acid mono alkyl ester. It is made from many kinds of renewable lipids, including animal fats, waste vegetable oil (WVOs), virgin vegetable oil, and nonedible vegetable oil [27].

India's energy needs, along with those of the rest of the world, appear to be best met by biodiesel and other renewable energy sources [28]. One technically and financially viable solution to the various issues is biodiesel. Although edible oil is the primary source of biodiesel, it is thought that using a lot of edible oil in this process might cause a food scarcity in the majority of developing nations. Thus, the effect of biofuel on the price of agricultural commodities and the food fuel controversy have received particular attention. Vegetable oil usage in restaurants and as a fuel for automobiles has drawn a lot of interest.

The physical-chemical qualities of biodiesel have been shown to vary depending on the feedstock, and this has a significant impact on the engine's potential performance as well as the emission level's dynamic features. With a clear increase in fuel consumption and NOx emission, the use of biodiesel results in a decrease in harmful pollutants such as carbon monoxide, unburned hydrocarbons, and some particulate matter [29].

CONCLUSION

Microalgae have the ability to absorb CO2 that is directly released by fossil sources. It is well recognized that microalgal biofuels are a viable replacement for fossil fuels that may one day be able to supply the world's energy needs. It is necessary to look at and analyze a number of variables, including cost effectiveness, process efficiency, and biodiesel conversion technology. The technique will become more practical and cost-effective due to the synergistic approach to biofuel production.

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