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ALGAL BIOFUELS: A SUSTAINABLE WAY FOR FUTURE ENERGY NEEDS

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ABSTRACT
Increasing global energy demand at a rate faster than the population growth has led the researchers to look for alternative fuel. The current fossil fuel reserves are not sufficient to meet the increasing demand and very soon be depleted irreversibly. Pollution, global warming, and turbulent oil prices have led the quest for renewable and carbon neutral energy sources. Algal bio-fuels represent a potential source of renewable energy. Algae, as the third generation feedstock, are suitable for biodiesel and bioethanol production owing to its' rich energy (lipid and carbohydrate) content, high growth rate, excellent biomass yield, inexpensive culture approaches, the notable capacity of CO_2 fixation and O_2 addition to the environment. Lately, there is an increasing research interest for the advancement of biofuel technologies. With their huge potential, algae are expected to surpass the first and second generation feedstocks hence can thus be used for increased biofuel production. This paper aims to analyze the integration approaches for sustainable micro algal biofuel production to meet the future energy needs of the society.

KEYWORDS: *Biofuels; Biomass; Microalgae; Renewable energy; Algal cultivation; Biofuel conversion; Bioenergy; Biodiesel; Sustainable energy.*

1. INTRODUCTION
The global economy literally runs on energy. An economic growth combined with a rising population has led to a steady increase in the global energy demands. Over last two centuries, the primary source of global energy demand has been fossil fuels - coal, petroleum, and natural gas. If the governments around the world stick to current policies vis-a-vis continued industrial growth the demand for fossil fuels is anticipated to grow 40% from 2010 to 2040.[1] Sun, wind and biomass are the major renewable energy resources. Biomass, derived from a biological precursor, has been used to produce biofuels and bio products over the last few decades.[2]

Progressively biofuels (solid, liquid, gases) are seen as potential alternative for eco-sustainable energy. Bioenergy, being a secondary renewable energy source can play a major role in conversion of solar energy into chemical energy through photosynthesis and thus maintains the flow of energy in the ecosystem. Due to environmental degradation, global warming and climate change, the promotion of biomass based renewable energy would act as a catalyst for future socially-responsible research and subsequent commercial promotions.

Traditional biomass based energy applications in most developing countries like India has been practiced since a long time. Biofuels generated from locally available renewable material would have a significant impact on carbon footprint, sustainability and thus help in creating import-neutral energy dependence. Thus, the development and deployment of biomass based energy generation need co-ordinated efforts from all the stakeholders like the policy makers, industry and particularly scientific community for targeted research, commercial production and adoption.

2. Types of biofuels
Depending on the type of biomass, there are first to fourth biofuel generations. Biofuels include biodiesel, bioethanol, biomethanol, biohydrogen, and bioethers (biodimethylether, biomethyltetrabutylether(bio-MTBE)) and bioethyltetrabutylether (bio-ETBE).[3] Biofuels are usually classified as follows:

2.1 First-generation Biofuels
First-generation biofuels include ethanol and biodiesel and are directly related to a biomass that is more than often edible. First biofuel generation (agrofuels) used specific cultivated plants including sugarbeet, sugarcane, maize, palm, soybean, and sweet sorghum as feedstocks for production. Agrofuel is produced through yeast fermentation of plant or starch to give bio-ethanol and the extracted plant oils to produce biodiesel.[4] These

processes greatly negatively impact both the food and water sectors.

2.2 Second-generation Biofuels

Second-generation biofuels are defined as fuels produced from a wide array of different feedstock's, from non-food plants like Jatropha, grass, switchgrass, silver grass and non-edible parts of current crops. Biomass used for production of second-generation biofuels is usually separated in three main categories: homogeneous, such as white wood chips; quasi homogeneous, such as agricultural and forest residues; and non-homogeneous, including low value feedstock as municipal solid wastes.[5]

2.3 Third-generation Biofuels

The most accepted definition for third-generation biofuels is fuels that would be produced from algal biomass, which has a very distinctive growth yield as compared to classical lignocellulosic biomass.[6] Production of biofuels from algae usually relies on the lipid content of the microorganisms. Usually, species such as Chlorella are targeted because of their high lipid content and their high productivity.[7] Advantage of using algal biomass reduces water and land utilization and negative impacts of pesticides hence giving an edge to algal biofuel.

2.4 Fourth-generation Biofuels

Metabolic engineering of the micro algal genome resulted in to fourth generation biofuels, technique helped in maximizing the yield leading to cost effective fuel.[8] Genetically modified microalgae had increased biomass production, lipid content and carbon capture capacity, as evident in many recent studies.[8,9]

3. Microalgae: an edge over other biomass

- Microalgae, use a photosynthetic process similar to higher plants and can complete an entire growing cycle every few days. In fact, the biomass doubling time for microalgae during exponential growth can be as short as 3.5h.[10] Some microalgae grow heterotrophically on organic carbon source. However, heterotrophic production is not efficient as using photosynthetic microalgae[10], because the renewable organic carbon source required is ultimately produced by photosynthetic crop plants. Microalgae are veritable miniature biochemical factories, and appear more photosynthetically efficient than terrestrial plants and are efficient CO_2 fixers.[11] The ability of algae to fix CO_2 has been proposed as a method of removing CO_2 from flue gases from power plants, and thus can be used to reduce emission of GHG.
- Many algae are exceedingly rich in oil, which can be converted to biodiesel. The oil content of some microalgae exceeds 80% of dry weight of algae biomass.[10]
- The use of algae as energy crops has potential, due to their easy adaptability to growth conditions, the possibility of growing either in fresh- or marine waters and avoiding the use of land.
- Furthermore, two thirds of earth's surface is covered with water, thus algae would truly be renewable option of great potential for global energy needs.
- It has been reported that microalgae will have more/very high potential to produce more energy per hectare of land use compared to that of conventional crops.

4. Extraction of microalgae oil

Oil/lipid from microalgae can be extracted in different ways. The conventional process of extracting oil is a mechanical and chemical process. The mechanical method can be further classified into oil expeller; microwave assisted extraction and ultrasonic assisted extraction process. Similarly, chemical extraction method can be categorized into accelerated solvent extraction, supercritical fluid extraction, and Soxhlet extraction process.[12]

There are some challenges in extracting oil from microalgae:

- In wet biomass there are weak interaction of chemicals.
- Drying cost is high.
- There is Excessive consumption of chemicals.
- The reaction of chemicals with other products.
- Separation of lipids from the liquid medium is challenging.
- Extraction depends on physical properties of the cells.

5. Types of Algal Fuels

As the third generation feedstock, microalgae have a huge potential for biofuel production due to their quick growth, great biomass yield, and high lipid and carbohydrate contents. **Biodiesel, biogas, bioethanol, and biomethane** are among the valuable biofuels produced by algae. Algal carbohydrates are used for producing bioethanol, while algal oils are used for biodiesel production. The remaining biomass is used for methane or fuel oil production. After biofuel production, the residual biomass can be used to produce nutraceuticals, protein supplements, therapeutics, omega-3 fatty acids (eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA)), biocontrol agents, fertilizers, and animal feed.

Biodiesel is a biodegradable fuel that reduces sulfur and particulate matter emissions while having engine performance similar to petroleum.[13] Bioethanol is obtained from fermenting sugars by yeast. Biogas or biomethane is produced through the anaerobic digestion of organic matter. Biogas is chiefly made of methane (65–75%) and carbon dioxide(25–35%).[14] Microalgal hydrocarbons can be converted to kerosene, diesel, and gasoline. Bio-syngas is produced by the biomass gasification to give methane, hydrogen, carbon monoxide, water and ashes in the presence of air, oxygen, or water vapor,[15] In absence of oxygen, microalgae can directly produce hydrogen, as a promising source of clean energy that does not emit greenhouse gasses, from sunlight and water.[16]

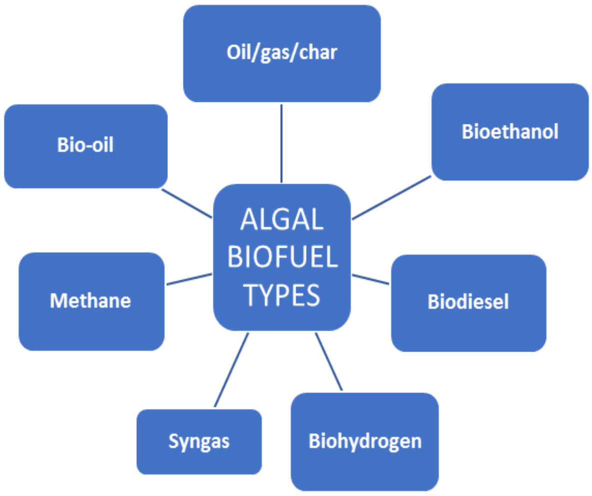

Fig I: Different types of Algal biofuels.

6. Conversion Techniques

According to species type, cultivation system and processing of biomass different products can be obtained from algae. Energy products from algae include biodiesel, biokerosene (jet fuel), gasoline, ethanol, methanol, hydrogen and syngas.[17] Algae can be processed in different ways to obtain a large number of end-use energy products. Algal biomass can be processed through different conversion processes as given below:

6.1 Thermo chemical Conversion

Thermo chemical conversion involves the thermal breakdown of biomass then organic chemical reformation into biofuels through pyrolysis, gasification, combustion or hydro thermal liquefaction this biomass converts into biofuel.[2]

6.2 Biochemical Pathways

The biochemical pathway of conversion hydrolysis of cell walls by bacteria into fermentable sugars takes place.[2]

6.3 Transesterification

In this conversion process triglycerides react with an alcohol (commonly methanol or ethanol) in the presence of an acidic or a basic catalyst and give biodiesel and glycerol as end product.[18]

6.4 Photosynthetic Microbial Fuel Cell

In recent years, microbial fuel cells (MFCs) were developed a result of the imminent energy crisis. MFC activity depends on photosynthetic oxygen generated at cathode to cause increment in the electron transfer from the anode. The synergy between bacterial fermentation at the anode and theoxygenic photosynthesis of microalgae at the cathode supports decent power output. During the day, the algal photosynthetic activity also results in elevating dissolved oxygen (DO) concentration.DO contributes to enhancing the reduction reaction rates at the cathode, which in turn improvesbio-electrogenic activity. During night-time, the small DO levels lead to a drop in power output.[19]

Table 1: Common microalgae used for & biofuel production.

Microalgae name	Fuel Type	Description in brief
Chlamydomonas reinhardtii	Bioethanol	Genetically modified by sex-cross, contains high amount of carbohydrate, lipid and protein in cell wall
Chlorella sp	Biodiesel	Unicellular green microalgae, source availability of tropical water with enough solar light
Spirulina platensis	Bio-oil	Spiral-shaped multi-cellular microalgae (with no true nucleus), fresh water habitant, contains lipopolysaccharides and peptidoglycan (carbohydrate components) in cell wall as well as cyanophycean and starch are the main carbohydrate storage products.
Chlorella vulgaris	Bio-oil	Spherical shaped, single cellular (with nucleus) microalgae, grows in both fresh and marine water with adequate sunlight, contains cellulose and hemicelluloses (carbohydrate components) in cell wall and starch is the main carbohydrate storage product.
Phaeodactylum tricornutum	Bio-oil	Salt water diatoms
Nannochloropsis sp.	Biodiesel	Grown in both saline and fresh water, genetically modified and paralleled recombinant microalgae type
Symbiodinium sp.	Methane	Source availability in sea water, advanced eukaryotic, dinoflagellates Phytoplanktons Either prokaryotic or eukaryotic Usually autotrophic, source availability at saline and tropical water sources such as lakes, ponds with sufficient solar energy.

CONCLUSION

Sustainable growth can only be achieved when we have access to economical and clean fuel.

In the current scenario, production of biofuels for commercial use is not just in very nascent state and for cost effective production methods scientific community do need encouragement and handholding from policy makers. Governments and industry need to upscale the plans to meet the targets set by the International Energy Agency (IEA). From 2020 to 2030 global biofuel output has to increase by 10% each year to reach IEA's goal. Only 3% growth annually is expected in the next 5 years. In this paper, we summarised different generations of biofuels, advantages of algal fuel, process of extractions of oil, different conversion techniques, types of common algae used for different type of biofuel production. The key challenges are the huge infrastructure, operation, and maintenance costs, selection of algal strains with high lipid content. Innovative and efficient techniques are necessary to make algal biofuel production preferable. Enhanced biofuel production will help in natural resources conservation and in turn preserving the environment.

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