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A REVIEW ON MICROALGAE AS A BIOFUEL FEEDSTOCK

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Abstract: Fossil fuels have been creating critical conditions that affect the society by causing various problems such as greenhouse gases emissions, by causing global climate change and release of various toxic gases into the atmosphere. As a result the public health is affected making it difficult for the living organisms to sustain on the earth, it is necessary to find out other possible solution. In this review we would like to focus on the algae which are rich in lipid biomass and can develop a sustainable energy source that serves as alternative to the usage of fossil fuels. In recent developments, microalgae have been cultivated for the production of biofuel. This approach is said be a solution which employees the environmental sustainable technology. The photosynthetic rate of carbon fixation in microalgae reduces the release of greenhouse gases. Microalgae are vast and they have the ability to feed on various waste water systems making them efficient for water purification and producing the bio fuels & various bio fertilizers by generating biomass. The Current review focuses on different methods of bio fuel production using micro algal biomass.

Index Terms - **Biofuel, microalgae, transesterification, Lipids, biomass**

I. INTRODUCTION

In the recent years, there is worldwide demand for fossil fuels due to enormous increase of vehicle population. The future generation will be facing critical problems like greenhouse gases, air pollution, and sudden climatic changes occur which makes difficult for living systems to sustain on the planet [1]. The use of fossil fuels for our daily activities has to be reduced to protect the mother earth for the future generations [2].The supply of crude oil decreased continuously this led researchers to find out the new renewable alternative fuels such as biofuels. Biofuel is a fuel that is produced from renewable biological resources.

There are wide variety of different biomass feedstocks has been identified for the production of biofuel such as corn, cotton, Karanja, Rapeseed, Neem, soyabean, sunflower, Jatropa and oil palm etc. However, natural biofuel resources such as oil crops are not sufficient to cover worldwide fuel demand. Hence there is a need to explore other alternative sources for biofuel production. Microalgae are an alternative source for biofuel production which comes under third generation biofuels. These third generation biofuels are more advantageous since they do not require any farmland to grow, requires less water, higher photosynthetic efficiency, reduces carbon dioxide emissions, they have ability to take nutrients from waste ,it can be grown anywhere in presence of sunlight and contains higher lipid content [3-11].

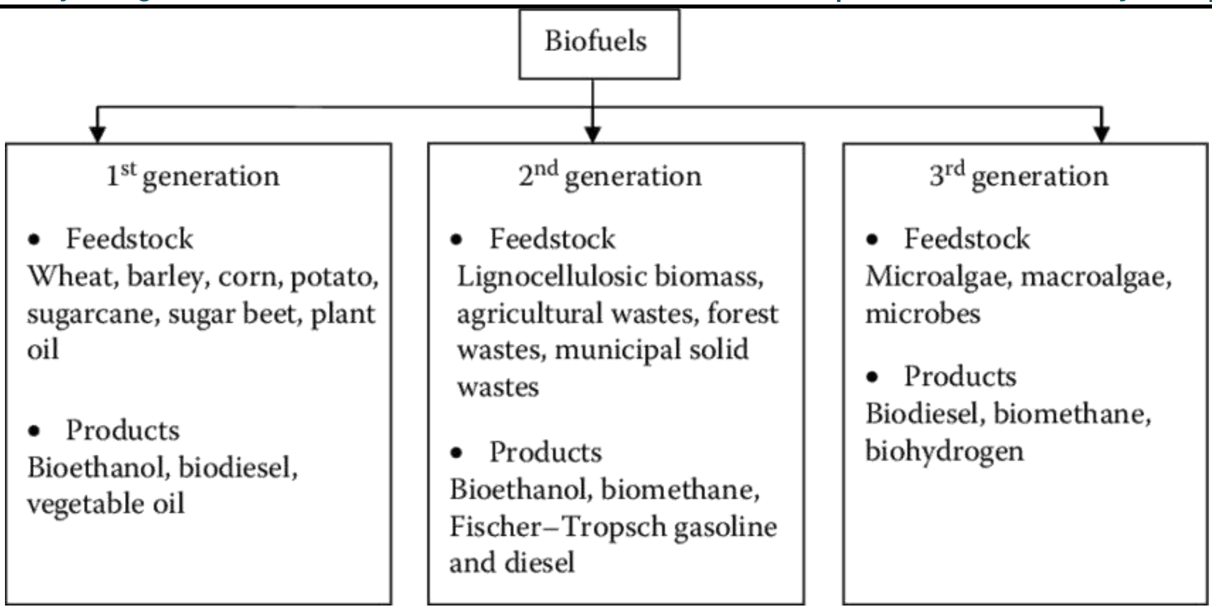


Fig 1: The three generations of biofuel

Microalgae are photosynthetic organisms that are present in aquatic environment. They use sunlight, water and carbon dioxide and convert into energy compounds such as starch and fatty acids. It is best source for oil extraction and may be it is utilized to synthesize a variety of diverse biofuels such as biomethane, biodiesel and biohydrogen. Growing Algae also used in removal of pathogens, nutrients and other contaminants. It produces higher rate of biomass production under favourable conditions comparing to land crops [12]. It can grow in waste water and even in brackish water [13-15]. Biofuels obtained from microalgae are employed to reduce GHGs and carbon fixation [16]. During photosynthesis, the algal cells store nonpolar lipids like triacylglycerol [17-19]. The triacylglycerol (TAG) converts into fatty acid methyl esters in a transesterification process. These fatty acid methyl esters are a form of biodiesel. The triacylglycerols are composed of three long chain fatty acids and cannot be used as fuel due to its higher viscosity. Hence, it should convert into esters to reduce its viscosity by transesterification process.

Transesterification process is a chemical reaction in which it converts the triacylglycerols into fatty acid methyl esters and glycerine [20-22]. The fatty acid methyl esters are known as biodiesel and glycerine is a by-product. The biodiesel which is produced contains low viscosity and can be used as fossil fuels. The physical characteristics of biodiesel produced are very similar to those of fossil fuel. The by-product glycerine is purified and used in food and cosmetic industries.

Microalgae are the promising feedstock for production of lipids. In order to produce biofuel, lipids contained in microalgae should be extracted. Lipids stored in the components of plasma membrane of the microalgae. For extracting lipid, we need to disrupt the cell wall of microalgae. Lipid extraction from microalgae is the process characterized by high energy consumption. Usually, Solvent extraction method is widely used for extraction of lipids. For small scale, Soxhlet extraction and butt extraction are used. For larger scale purpose, Merz extractor, belt system extractor, rotacell extractor and Crown extractor are used.

II. CLASSIFICATION OF MICROALGAE

Microalgae classified based on the characteristics such as cell wall, life cycle, storage products, cell wall components and habitat as given in table 1. Chlorophyta are green algae, due to the presence of chlorophyll (a&b) pigments. Rhodophyta are red algae due to presence of phycocyanin. Chrysophyta are golden algae due to presence of yellow pigments such as β-carotene, lutein. Phaeophyta are brown algae due to the presence of fucoxanthin.

Table 1: Classification of microalgae

S. No	Name of the Microalgae	Storage products	Cell wall components	Habitat
1.	Chlorophyta (green algae)	Sugar, starch	Proteins or cellulose	Fresh water,
2.	Rhodophyta (red algae)	Glycogen	Agar or some with calcium carbonate	Salt water
3.	Chrysophyta (golden algae, diatoms)	Chrysolaminarin	Cellulose, silica	Fresh water
4.	Phaeophyta (brown algae)	Laminarin, oil	Cellulose, alginic acid	Brackish water

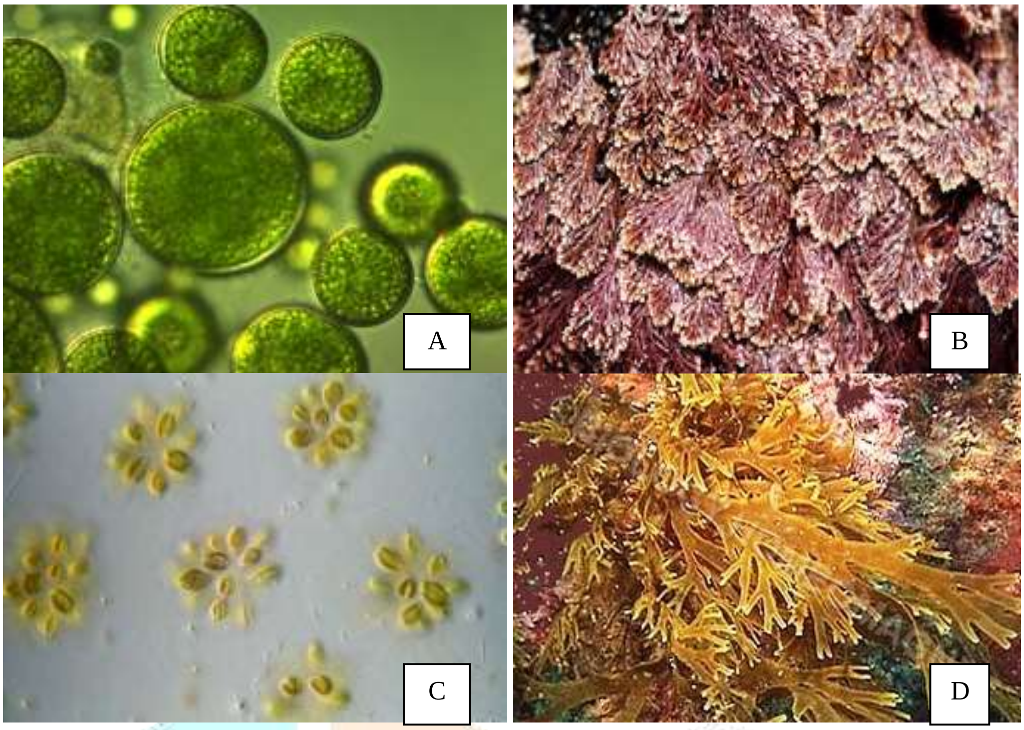


Fig 2: (A) Green algae (B) Red algae (C) Golden algae (D) Brown algae

III. METHODOLOGY:

3.1 Microalgae cultivation

Microalgae have the ability to accumulate bioproducts within their cells coupled with their photosynthetic efficiency make them suitable as industrial raw material. It doesn't require fertile land, fresh water, herbicides and pesticides for cultivation and thus it won't compete for resources. Furthermore, microalgae cultivation can also performed by using wastewater which helps in bioremediation of wastewater [23]. It also helps to reduce carbon dioxide through photosynthesis which contributes for tackling global warming and greenhouse effect [24]. Certain microalgal species such as Chlorella emersonii, Chlorella HA-1, and Chlorella ZY-1 used to capture carbon dioxide from the power station [25-27]. Various equipment and technologies have been improved to increase the microalgae production. The culturing system for microalgae cultivation should possess certain features such as (1) light source, (2) proper operation procedure, (3) low contamination, (4) high land efficiency (5) lower production cost. Microalgae culturing systems are classified into two groups. They are namely open pond and photobioreactor.

(a) Open pond

Open pond cultivation is one of the oldest and simplest ways to cultivate microalgae in larger scale. Due to its cheaper construction and maintenance, it is widely used in the industries. The other uses of open pond system are relatively cheaper, lower operation cost, less energy requirement for mixing and easy to scale up [28]. However, these systems face some issues such as risk of contamination from various animals and other microalgae (Chisti, 2007; Dragone etal., 2010); which causes the products to be harmful, rainwater runoff which affect the growth conditions like pH and salinity(Narala etal., 2016) and higher water turbidity might affect the microalgae productivity. Circular ponds and raceway ponds are types of Open pond system.

Circular ponds are the artificial pond employed for cultivation of microalgae in large scale. It is in circular shaped culture tank which consists a rotating agitator in it. It has depth of 40-80 cm and width of 45m .The rotating agitator employed for proper mixing and prevents biomass sedimentation. However, this system is restricted due its size since bigger pond may cause increased water resistance and stress on mechanical parts of agitator.

Raceway pond is frequently used pond system for cultivation of microalgae. It consists of series of closed loop system and paddle wheel which enables recirculation of algae biomass. Due to its energy efficiency, it is named as most effective open pond cultivation system.

(b) Photobioreactor

Photobioreactor (PBR) is a closed bioreactor system used to culture microalgae. It doesn't allow exchange of material between culture and environment. It is used to overcome the problems faced by open pond system. PBR are more compact than open pond system, provides more land usage, and provides highly controlled growth conditions for cultivation. The highly controlled growth conditions promote higher biomass production. Nonetheless, they are more expensive in terms of operational costs and capital due to higher energy consumption and limited sunlight penetration [29]. They are other two types of PBRs widely used are tubular PBRs and flat PBRs.

Tubular PBRs are comprised of array of straight transparent tubes made up of either plastic or glass. It is arranged in parallel to maximise the capture of sunlight [30-31].It consists of mechanical pump to circulate the microalgal culture. The major disadvantage of using tubular PBR is low mass transfer due to differences in concentration of substrates and products along in the bioreactor design.

Flat PBRs are rectangular shaped chamber made up of transparent material with a depth of 1-5cms. The culture is mixed by recirculating airlift system inside the reactor. This design supports higher surface area for illumination, thus achieving higher photosynthetic efficiency. Due to the aeration design in this bioreactor, causes stress damage to microalgae.

IV. HARVESTING OF MICROALGAE

After microalgae cultivation, the biomass undergoes harvesting process to separate biomass from bioreactor effluent. Harvesting of microalgae makes up 15-30% to the total cost of biomass production (Li etal. 2008). Majorly used harvesting methods are filtration, centrifugation, flocculation Gravity sedimentation, Ultrasonication and floatation [32-33]. Under few circumstances, combinations of two or more harvesting techniques are used to maximize harvesting efficiency. Selection of particular harvesting methods depends on the microalgae characteristics such as size, desired products and the cell density.

Table 2: Harvesting techniques of microalgae

Technique	Advantages	Disadvantages
Flotation	-Able to process large volumes of biomass as air bubbles adhere tomicroalgae, making them buoyant	-Contamination with flocculation agent
Filtration	-Effective recovery for small sized microalgae	-High cost, algal species specific and clogging/fouling of filters
Centrifugation	-Rapid and efficient with 95% removal efficiency	High energy and maintenance cost
Gravity sedimentation	Low cost and energy efficient as microalgae biomass are left to settle naturally	Takes long time to settle and ineffective for small sized microalgae
Ultrasonication	-Can operate continuously	-Safety problem, disrupted cells unsuitable for further processing
Flocculation	-Cost effective	-Biomass unsuitable for further use (e.g., animal feed or anaerobic digestion); chemical flocculant contamination

V. LIPID EXTRACTION

After harvesting, the algal biomass must be processed because it has ability to spoil within few hours during a hot climate. Hence, drying of algal biomass is to be done which helps to increases the shelf life of the product. Freeze drying is commonly used for drying of biomass as it removes moisture content. For biofuel production, lipid content from microalgal biomass is to be extracted. For this, Solvent extraction method is widely used to extract lipids from the algal biomass. The principle behind this method is chemical bonding attraction by the solvents. Several organic solvents have been selectively used to extract lipid from microalgae. Commonly used organic solvents for lipid extraction are chloroform, methanol, petroleum ether, and hexane [34-35]. Generally, chloroform and methanol in the ratio 2:1 is used for extraction of lipids to the final volume twenty times the algal cell. The advantage of using organic solvents is it has less reactivity with lipids. It is used to wet biomass directly, but it is very slow and needs other toxic solvents.

Ultrasonication technique is used to disrupt thick cell wall of algae and increases the yield. The extracted lipid yield was increased from 4.6 % (in Soxhlet extractor) to 25.7% due to the effect of Ultrasonication techniques enhances mass transfer and internalize the solvents into the cells.

Supercritical extraction is a promising green technology that has a potential to replace the solvent extraction method. The extraction ability of supercritical fluid is a function of its density and also can be adjusted by altering the pressure and temperature. The physical properties of this fluid are intermediary between a gas and a liquid. This intermediary property allows penetration of fluid through cell which leads to high lipid yield within shorter period of time [36-38].

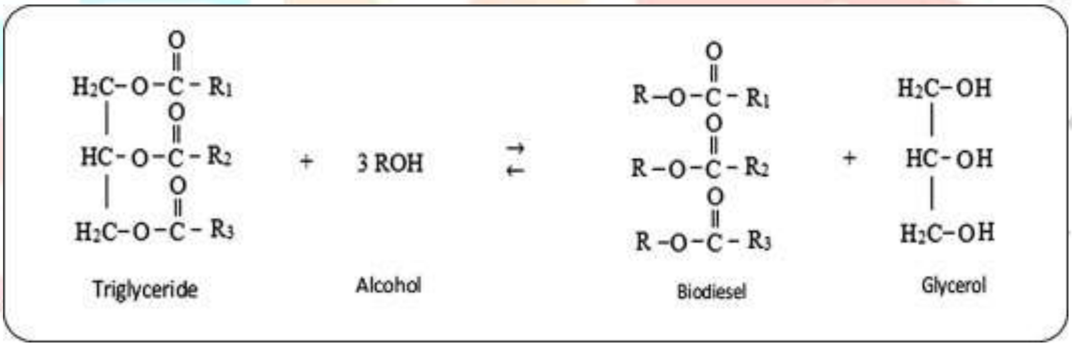
Supercritical CO2 extraction has been used for large scale for lipid [39]. It is harmless, rapid and produces solvent free lipids. Due to higher energy requirements limits the use of this technology. The results of supercritical carbon dioxide method were tabulated below.

Table 3: Supercritical carbon dioxide extraction of microalgal lipids and their results

Study	Microalgal species	Extraction pressure or *P* (bar)	Extraction temperature or *T* (°C)	Use of co-solvent	SC-CO_2 flow rate; extraction time	% of Lipid yield
Tang et al. (2011)	*Schizochytrium limacinum*	350	40	Ethanol (95%, v/v)	Not specified; 30 min	33.9
Mendes et al. (2006)	*Spirulina maxima*	100, 250, 350	50, 60	Ethanol; 10 mol % of CO_2	Not specified; Not specified	3.1
Santana et al. (2012)	*Botryococcus braunii*	200–250	50–80	None	Not specified Not specified	17.6
Cheung (1999)	*Hypnea charoides*	241, 310, 379	40, 50	None	1 l min^{-1}; 120	6.7
Cheng et al. (2011a, b)	*Pavlova* sp.	306	60	None	Not specified; 100	17.9
Andrich et al. (2006)	*Nannochloropsis* sp.	400, 550, 700	40, 55	None	0.17 kg min^{-1}; 360 min	25

VI. TRANSESTERIFICATION

Transesterification is a chemical reaction in which triacylglycerols are converted into fatty acids methyl esters in present of a catalyst. Triacylglycerols are energy storage and are more advantageous for biofuel production since they contain high fatty acids [40-41]. In transesterification process, triglycerides are converted into diglycerides, and then diglycerides are converted into monoglycerides. Finally, monoglycerides are converted to methyl esters (biofuel) and glycerol.
The below equation describes the transesterification reaction
R1, R2, R3 are the radicals which represent long-chain hydrocarbons (fatty acids)



Transesterification reaction is generally may either be conventional or in situ. Conventional transesterification demands drying and extraction of lipid is done before the actual process (Razzak etal. 2013). In case of in situ transesterification, it omits lipid extraction step. When compared to conventional process, in situ is simpler and cheaper process of algal biofuel.

VII. Conclusion

Microalgae are one of the mostly abundant sources for the production of biofuels. They are useful to mitigate the elevated carbon dioxide levels and wastewater treatment. The algal lipids extracted from microalgae are converted to biodiesel used as transportation fuel. The biofuel production yield will be higher, when the rate of biomass production is increased. Microalgae are one of the intellectual ways of handling the pollution in control. Hence, microalgae should be studied more effectively and its efficiency has to be improved.

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