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Biofuel Generation by Macro and Micro Algae as a Renewable Energy Source: A Systematic Review

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ABSTRACT

Recently, the fossil fuel consumption is increasing owed to industrial revolution which leads to serious human health and environmental problems. For sustainable energy generation and survival of human life and earth planet biofuel is an alternative source of energy. Non-renewable energy causes environmental effects which results in environmental degradation, to overcome these problems biofuel is the best environmental friendly option. Biofuel can be generated from different types of biomass, among these algae have potential to produce considerable amount of biofuel. But it is very difficult task to produce algal biofuel from specific type of algae. The present review compares and discusses the different types of feedstock, methods of oil production and improvement of method for biodiesel production and their utilization. This review mainly focuses on the cultivation and methodology for biofuel generation and recovery from algae for sustainable development.

Key words : *Micro algae, Macro algae, Biofuel, Renewable energy, Sustainable development*

Introduction

In India, the consumption of petroleum products is approximately 120 MT/Y. Microalgae can replace this large volume of natural oil than other feedstock (Bajhaiya *et al.*, 2013). During combustion of petroleum fuel harmful and hazardous compounds are released into atmosphere (Voloshin *et al.*, 2016). Biodiesel is substitutable in diesel engines due to it is similar characteristics to petro-diesel (Janda *et al.*, 2012). Biofuel is produced from biomass that has high sugar content or oil content in the form of liquid or gas.

Microalgae are ideal and environment friendly renewable resource of energy because of their high growth rate (Masjuki *et al.*, 2013). Algae have the capacity to produce more fuel than oil producing seeds (Potters *et al.*, 2010). The biofuels are produced from the residual parts of crops (biomass), industrial waste and algae (Janda *et al.*, 2012).

History of biofuel

In the beginning of 1700s different types of vegetable oil and fuel derived from animal fats were used for lighting the lamps. In the 1800s; whale oil was used till kerosene was developed in 1846. By the late 1830s, instead of whale oil ethanol was used mixing with turpentine. From 1900 to 1905 before World War I ethanol production was increased from 2.7 to 8.3 million gallons (Singh *et al.*, 2017). Before world war Germany was the country who created first largest biofuel industry for rural development

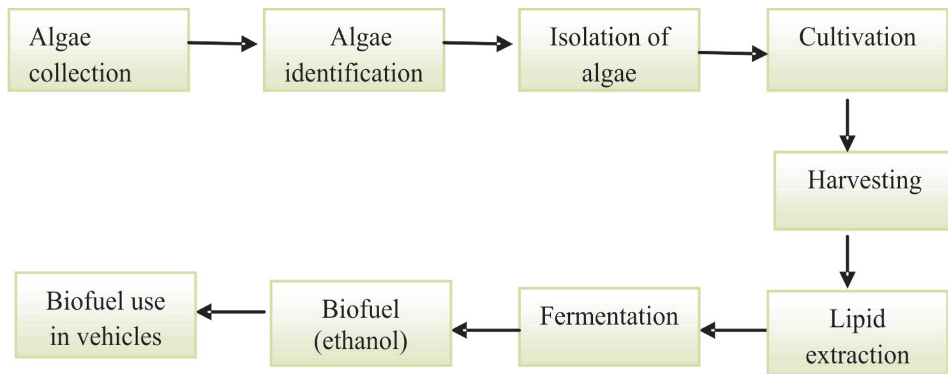

Fig. 1. Graphical Abstract of biofuel production from algae biomass

(Singh *et al.,* 2017).

Status of algal biofuel

In the present status of algal biofuel is the annual turnover of the micro algal biomass in present market is nearly US $1.25 billion (Patel *et al.,* 2012). In Brazil, raw material used for ethanol production have low price and for production high technology are adapted which reduces the cost of ethanol production (Araújo *et al*., 2017). India's new biofuel policy wants to achieve blending of conventional diesel with biodiesel and gasoline with ethanol by 2030 (Janda *et al.,* 2012). In 2007-08 ethanol share was highest among all types of biodiesel where production of biofuel was 62.2 billion tons. In the world Brazil and the USA produces nearly 87% of ethanol of its total biofuel production (Basavaraj *et al*., 2012). India produces 3.50 billion litres of alcohol every year from about 320 distilleries (Shinoj *et al*., 2015). In 2007, Indonesian Ministry of Energy and Mineral resources was produced about 520,000 t of biodiesel (Rasool *et al*., 2016).

Raw material for biofuel / Production of biofuel from various plants

The National Mission on Biodiesel has studied that the seeds of Jatropha are the best for oil production (Masjuki *et al*., 2013). In India for ethanol production, sugarcane is the second-largest feedstock. In several countries, abundant amount of live feedstock are available which are used along with non-edible oil seeds to produce biodiesel (Romano *et al.,* 2011). The process of trans-esterification is used to produce biodiesel from oil seed crops (Janda *et al.,* 2012). In some regions of the world Sweet sorghum is an alternative feedstock for ethanol production due to fewer water requirements and higher FC levels than corn (Araújo *et al*., 2017).

In 2017 it was identified by The National Biodiesel Mission, among all non-edible oil seeds jatropha (*Jatropha curcas*) is the most suitable non-edible oilseed for biodiesel (Janda *et al.,* 2012). *Jatropha curcas* has rapid growth and high seed productivity. The members of the genus *Miscanthus* have the potential for bioenergy production (Rasool *et al.,* 2016). For the production of biodiesel, the species of *Stauntonia chinensis*, Alperujo, Milkweed *(Calotropis gigantea)*, Baobab *(Adansoniadigitata L.)*, *Syagrus romanzoffiana*, *Raphanus sativus (oilseed radish)* areused as a feedstock (Atabani *et al.,* 2014).

Algae as feedstock

In the production of bio-oil, macro algae are feasible biomass due to itsmaximum availability, high productive capacity, low investment, maintenance and harvesting (Hossein Rahbari *et al.,* 2019). Marine seaweeds are another raw material for biofuel due to high growth rates and can be withstand in extreme environmental condition (Meiron, 2019). In the algal biomass lipids constitute is approximately 30%, in genetically engineered microbes lipid content may be 80% (Patel *et al*., 2012). The main characteristic of algae is its oil content, the range of oil is from 50 to 70 % depends on type of algal species (Ramano *et al.,* 2011). *Nannochloropsis* sp. has high potential for biofuel production, because they are capable of producing 27% (dry weight) lipid content and can be grow fast which accumulate triacylglycerol's in large amount to produce biofuel (Prophy *et al.,* 2012). The oil produced from chlorella is in small amount as compare to other algal species (Janda., 2012). The species *Spirulina*, *Schizochytrium* and *Porphyridiumcruentum* carbohydrates, are utilized as the source of protein, lipid and carbohydrate (Rodionova *et al.,* 2017).

Algal Cultivation for Biofuel Production

During algal cultivation if the supply of nitrogen is limited then algae can accumulate maximum lipids which results in high calorific value biodiesel (Slade *et al.,* 2013). Silica, iron, and other trace elements, are important nutrients for algal growth (Achara *et al.,* 2012). The microalgae are mostly grown in the wastewater and playing a very important role in the phytoremediation and simultaneously producing viable biomass for various applications (Pacheco *et al*., 2015). The cultivation of algae in the sea water or brackish water can be used from aquifers, but the brackish water requires pre-treatment for removal of growth inhibiting component (Slade *et al*., 2013).

The micro algae require nitrogen and heavy metal for their growth, for these nutrients algae can be cultivated in waste water ponds (Porphy *et al*., 2012). For the growth of algae effluent water, industrial process water, or streams can be used as a source of nutrient (Achara *et al.,* 2012). For proper algal growth room temperatures and a neutral pH is necessary, where other microorganisms also grow at these conditions. The physical parameters along with macro and trace nutrient elements are the main chemical parameters required for the algal growth (Bodjui *et al.,* 2019). Very high CO_2 is required than the naturally available CO_2 concentration for maximize algal growth. The supply of high CO_2, fractions the flue gas is used (Bajhaiya *et al.,* 2013).

When water, nutrients, and CO_2 are sufficient, microalgae production can take place, without land resource restriction (Moodya *et al.,* 2014). If nutrients, water and CO_2 can be obtained in lower cost the fuel producing cost can be reduced up to 50% (Slade *et al*., 2013). In different types of photo bioreactors the contamination of fungi and non-native algal or bacterial strains are frequently occurring (Patel *et al.,* 2012). The production of algal biofuel investment is mainly required for the growth, harvesting, dehydration and extraction of oils (Bodjui *et al.,* 2019). The mixotrophic growth process are significant to improve biomass productivity (highest cell density and growth rate), and reduces the costs of production by using glycerol and/or glucose as a carbon source (Pacheco *et al.,* 2015). During the algae cultivation certain bacteria play an important role in the growth of microalgae by providing required supplements. These bacteria help in degradation of nutrients such as nitrate or ammonia, which are taken by microalgae for their growth (Khan *et al.,* 2018).

Harvesting of Micro and Micro Algae

To accumulate maximum lipid and carbohydrate content in algae under nutrient deplete conditions, the growth period of algae should be 6 to 9 days. After the maturity of the algae, harvesting methods includes micro screens, centrifugation, flocculation, and froth flotation (Knoshaug *et al.,* 2018). Different physical techniques are used to harvest algal biofilm (Monford Paul *et al*., 2014). Traditionally chemical methods are used for harvestings of microalgae for oil production, but these processes are not cost effective, in 100% biomass after harvesting the oil part is only around 30% and the remaining 70% is wasted (Alama *et al*., 2012). For drying algal sludge, heat, agitation and water evaporation are necessary. For drying algae, the dryers or superheated steam are used (Patel *et al.,* 2012). Different types of advanced techniques are used to dry the algal biomass (Qi Ji *et al.,* 2016)

Biodiesel Methodology

Sugar is present in cellulosic materials, which are broken down by enzymatic action and these sugar are then converted into ethanol by fermentation (Potters *et al.,* 2010). Biodiesel is produced from raw materials by different methods such as thermochemical and biochemical methods (Araújo *et al.,* 2017). The conversion of organic biomass into biofuels or bioenergy is converted through thermochemical (combustion, gasification, pyrolysis), mechanical (chopping, palletization, and briquetting), and biochemical (fermentation and anaerobic digestion) conversion processes (Palamanit *et al.,* 2019). In fermentation of ethanol, a solid liquid separation method is used for the separation of molasses and solid material, but during this process some amount of sugar is exhausted.

The important worldwide used methods for biofuel generation are as under:

Fermentation

The conversion of different types of sugars, cellulose, or starch biomass into ethanol is called fermentation. For fermentation process, the biomass which contains sufficient amount of sugar must be dried, crushed and then water is added along with yeast

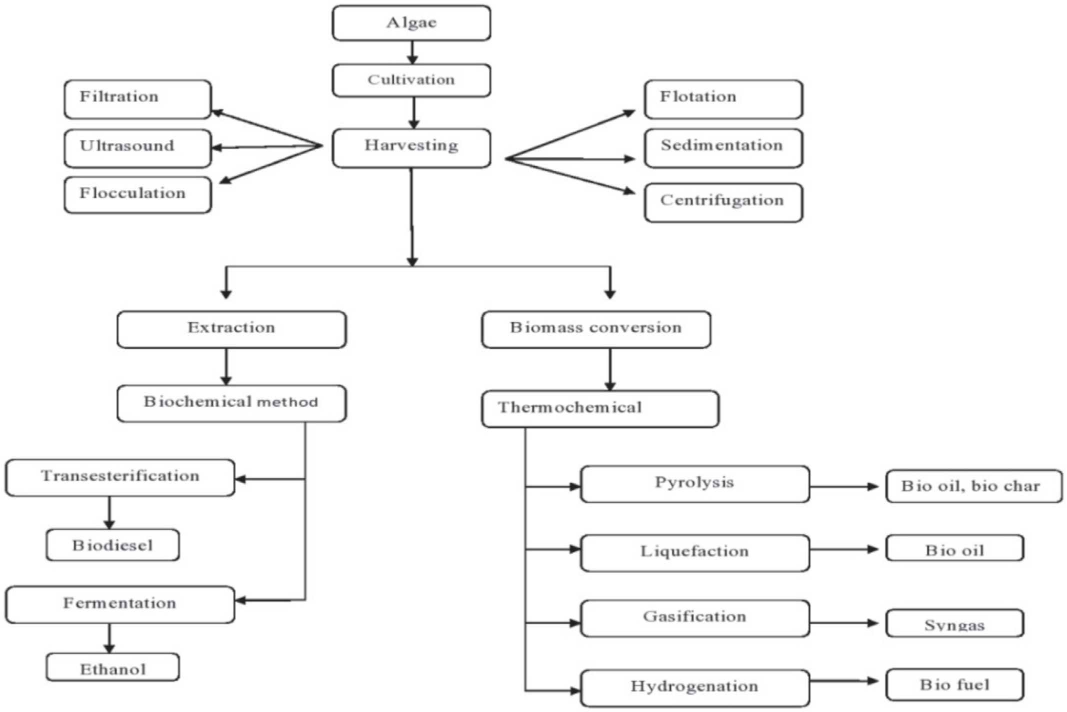

Fig. 2. Representation of Algal Biofuel Generation Processes

into bioreactor for ethanol production (Qi Ji *et al.*, 2016). For the fermentation process, the required optimum temperature is 25 or 35 °C for 24 hours' incubation period under anaerobic conditions (Cioroiutîrpan *et al.*, 2019).

Yeast strains are very important industrial biocatalyst microorganisms for fuel production (Yang *et al.*, 2016). Macro algae (seaweeds) and microalgae are used in lactic acid fermentation; the some species of *Lactobacillus* are used for inducing algal fermentation, with *Lactobacillus plantarum*, *Lactobacillus brevis*, and *Lactobacillus casei* showing a superior ability to dominate in seaweed fermentation cultures (Uchida *et al.*, 2013).

Pyrolysis

The technology in which biomass is converted into fuel through combustion of biomass is called pyrolysis (Msangi *et al.*, 2007). Char is formed during process by breaking alkyl-aryl ether bond and repolymerization of volatiles. Fast pyrolysis is best method to yields of aqueous products, by maintaining higher heating rates and lower residence times of volatiles (Vargas *et al.*, 2015). During pyrolysis bio-oil and flue gases are produced along with Biochar as a byproduct. After completion of pyrolysis, the stability of bio-oils is important due to its degradation rate and sometimes may react with other chemicals (Verma *et al.*, 2012).

Transesterification

Transesterification is the process in which triglycerides present in vegetable oils are converted to fatty acid methyl / ethyl esters to form liquid biofuel (Masjuki *et al.*, 2013). *Chlorella* and *Nannochloropsis* microalgae provided triacylglycerol's for biofuel generation through Transesterification (Janda *et al.*, 2012). In biodiesel production, the process of transesterification is mostly used but due to the high costs of heating methods that are employed for the manufacturing biodiesel results in high production costs (Rasool *et al.*, 2016).

Liquefaction

Liquefaction is the process where biofuel is produced directly from wet microalgae, which provide hydrogen for hydrogenolysis (Monford Paul *et al.*, 2014). The direct liquefaction of biomass involves hydrolysis fermentation and thermodynamic liquefaction for oil generation (Zhang *et al.*, 2019).

Conclusion

According to Bibia *et al.* (2017), algae have minimum susceptibility to contamination, high lipid content; and withstand to temperature and salinity fluctuation, which results in sustainable use of different algae for production of biofuel.

The energy requirement for pyrolysis of algal biomass is depends upon algal lipid concentration (Porphy *et al*., 2012). According to Msangi (2007), the ethanol have high octane rate which increases the combustion efficiency of biofuel. We can use biofuel directly or blending with gasoline (Patel *et al*., 2012). Due to lower pressure bio butanol can be translates into evaporative emissions and lower volatility (Araújo *et al*., 2017). The micro algal biodiesel has less kinematic viscosity of as compared to other type of biodiesel (Kumar *et al*., 2013). Many advanced technologies are available for converting waste into biofuels and other higher-value bio-chemicals, but are at an initial stage and need to be improved on a commercial scale (Aradhey *et al*., 2019).

In the future due to over demand of aquatic feedstock and production of biofuel there are chances of water pollution (Janda *et al*., 2012). Due to corrosive characteristic of Bioethanol, engine may face many technical problems (Alama *et al.*, 2012). For generation of engine biofuel algae are not mostly used as a raw material, instead of that in many cosmetic and pharmaceutical industries algae are used as a raw material (Voloshin *et al.*, 2016). Algal biofilms are used in many commercial industries such as pharmaceutical, chemical and bio plastic industries for production of many valuable products.

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