Microalgae as Source of Renewable Source of Energy-The Process Review

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Abstract: ***The energy is wheel of all economic activities running in the world and main driver are fossil fuels. The fossil fuels are finite in nature; therefore, alternate source of energy is need of the day to replace the fossil fuels. Many sources of renewable energy are assessed and utilizing to drive the wheel of economic activities and third generation source of energy as microalgae has promising result and expectation. Microalgae are simple photo-autotrophs and ubiquitous. It can be utilized for production of biofuel such as biodiesel, hydrogen production. The biology and production of microalgae is the key of future expectation. Although the microalgae has many promising result but a long way has to go to get desirable products.***

Keywords: Microalgae, Biodiesel, renewable energy, Biofuel.

1. Introduction

"The nature has solution for our every problem, only the matter we have to find it out" nowadays the availability of oils is the major requirement of all the economy of the world and it is one of the criteria to be powerful country. According to an estimate proven oil reserve can only last for next 40 years. There may be more availability of oil reserve but still not infinite. Further, the distributions of oil distribution are also not equal and OPEC countries controls more than 60% of the world oil production. Therefore the availability of oils reserve is also influence economy and policy of the country. The sustainable availability of oil is major challenge of present scenario and it forces us to think from non-renewable source of our energy to renewable and sustainable availability of source of energy. The most promising alternate fuels include biomass as source of energy. Biomass can be converted into biodiesel, Bioethanol, Biobutanol, Ethanol etc. The main biodiesel producing countries are USA 38088 Thousand metric Tonnes (TMT), Brazil 21375 TMT, Indonesia 4849 TMT, Germany 3445 TMT, China 3099 TMT. Among biomass without compromising basic requirements the algae emerged as one of the most promising source of energy. Among algae, the microalgae have promising result. The photosynthetic activity (ability to convert solar energy in to carbohydrate with the aids of water and minerals) is the same as found in higher plants. The cellular structures are very simple in compared to higher plants but the efficiency is relatively higher than other plants. The algae are simple photoautotrophic organism and have capacity to grow in all habitats. Micro-algae are unicellular/filamentous/colonial microscopic forms with diverse forms. Microalgae are source of many bio-products including bio-fuel and have capacity to replace the fossil fuel. Microalgae have capacity to grow very fast and required very less area as compared to other plant. Therefore, if bio-fuel is only solution to replace the fossil fuel then microalgae is the answer. The question is that we have to make microalgae so efficient and powerful up to desired level (through genetic engineering); so that it can overcome the difficulty arises. Many pilot projects have been done for the same and many viable projects are running. The main problem of using algae up to industrial level is design of culture system, selection of suitable strain and unavailability of post harvest refineries. The microalgae also generate many bio-products that can be very useful for pharmaceutical and agriculture industries. The microalgae can be feed by waste product of various anthropogenic activities. Therefore, if we use microalgae as source of bio-fuel it can solve several simultaneously. The per unit area yield of oil from algae is estimated to be from between 5,000 to 20,000 gallons (18,927 to 75,708 liters) per acre, per year; this is 7 to 31 times greater than the next best crop, palm oil (635 gallons *or* 2,404 liters). The main advantages of deriving biodiesel from algae oil include: rapid growth rates, a high per-acre yield (7 to 31 times greater than the next best crop – palm oil), certain species of algae can be harvested daily, algae bio-fuel contains no sulphur, algae bio-fuel is non-toxic, algae bio-fuel is highly bio-degradable, and algae consume carbon dioxide as they grow, so they could be used to capture CO2 from power stations and other industrial plant that would otherwise go into the atmosphere.

Oil rich microalgae have emerged as the most realistic feedstock for the large-scale production of bio-fuels as they do not require fresh water (Stephenson et al., 2011). The photosynthetic organisms are known to fix sun energy into biomass at efficiencies exceedingly higher than terrestrial plants on a land area basis (Klok et al., 2014). Many oleaginous micro-algal species accumulate very large amounts of lipids in the form of triacylglycerol (TAG), the convenient source of biofuel often exceeding 70% of dry cell weight in certain species (Scott et al., 2010). Apart from this, some microalgae produce valuable co-products such as pigments, antioxidants, edible proteins, long-chain polyunsaturated fatty acids, and specialized bio-pharmaceuticals, favoring biorefineries to help to offset the biofuel production cost (Klok et al., 2014; Jagadevan et al., 2018).

Some countries like India it becomes more profitable due to pressure of population on natural resources and unavailability of fossil fuels. The microalgae are also major source of available fossil fuel; therefore, history has its own answer. The technology, genetic engineering, great idea of culture design together with sustainable vision can make microalgae as viable source of future energy. Many research are going on to overcome the problem of using as viable source of energy but still waiting for major breakthrough knowledge.

2. Result and discussions

2.1 Biofuel

The Biofuel are categorized into I[st] generation, II[nd] generation and IIIrd generation. The I[st] Generation biofuel includes both gaseous and liquid which includes Biodiesel, Vegetable oil, Bio-ether and Bio-alcohols. The raw materials for I[st] generation biofuel are oil bearing seeds and edible crops rich in starch, carbohydrates, and lipid contents. The main crops utilized for biofuel productions are Sugarcane, rapeseed, palm, animal fat etc.

The II[nd] generation biofuel includes non-edible biomass and oil from Jatropha,Jojoba, Sea mango, Neem, rubber seed, Dry Wood, used oils of restaurants etc.

Many projects have been take place to explore the viability of I[st] and II[nd] Generation biofuel but they failed due to various issues like Food security, land availability, poor production, high production cost, burning issues etc.

III[rd] generation bio-fuels includes microalgae as future source of energy and various pilot project have been take place throughout the world to assess the viability of algal fuel as source of future energy. The microalgae emerged as suitable raw materials for production of bio-fuels due to various reason like low area requirement, per unit area high production, vast diversity, high quality fuels etc. Many projects have been taking placed in the world to assess the viability of algal fuels like US Government under "The aquatic species". The lipid contents of algae are converted into Biodiesel and Carbohydrates are converted into Bioethanol and biobutanol. Several multinational companies and government have invested in algal fuels and present value of algal fuel is420 Million US$ which will surely increases in near future. Several steps and technique are used for production of various products from biomass of algae as shown in figure below

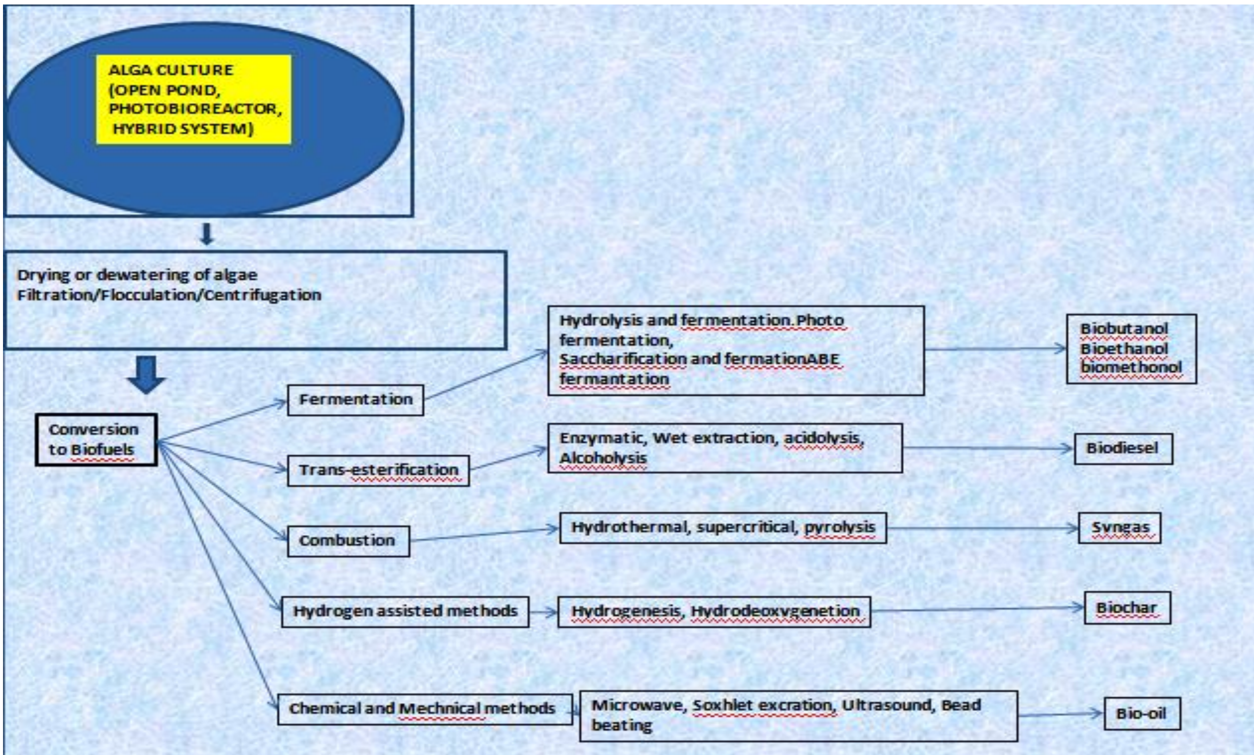

Fig- Techniques and steps involved in Bio-fuel production using Microalgae

2.2 Algal Bio-fuel process

2.2.1 Algae strain isolation, screening and selection

The ultimate vision of algae isolation and screening efforts are to identify and maintain promising specimen for cultivation and strain development to provide metabolic versality possible.

2.2.2 Isolation from natural habitat

Algae can be isolated from a variety of natural habitats from fresh water to brakish water, marine and hyper saline environment and soil. (Round, 1984)

2.2.3 Isolation technique

The isolation of new strain from natural habitats tradition enrichment method was used (Anderson and Kawachi 2005). This is sometimes takes more time to isolate some algal strain.

2.2.4 Screening criteria and method

A good screen would cover three major area growth physiology, metabolic production and strain robustness. The growth physiology includes maximum cell growth, max cell density, tolerance to environmental factors such as temperature, PH, light, oxygen level, Co_2 etc and nutrient requirement. Likewise metabolic production includes determination of cellular composition of protein, lipid and carbohydrate and also measured metabolites related to bio-fuel production. The specific method is requiring for specific bio-fuel required. The robustness of given algal strain includes culture consistency, resilience, community stability and susceptibility to predator present in environment. The main lacuna of algal strain is that the isolated strains generally not perform similarly in outdoor mass culture (Sheehan et al 1998). Therefore, a large number of culture conditions are to be tested.

3. Biology and Cultivation of Algae

Most of algae are capable of converting co_2 and light energy with input of inorganic nutrient into carbohydrate and lipid. Under starvation condition (low N_2, light) some algae tend to accumulates lipids such as triacylgycerol (TAG) up to 30 percentage of their dry weight as their carbon source. (Hu et al. 2008). Lipids and carbohydrate, hydrogen, alcohol are all potent bio-fuel precursors.

3.1 Light utilization efficiency

The efficiency to utilize light is one crucial point to determine the production of algae. Chisti (2007) theoretical estimated biomass production of algae ranges of 100-200 g/m^2/day but this value is not achieved yet now due to some factors. Therefore, the efficiency of photosynthesis should be enhanced by molecular tools (Zue et al 2007 & 2008). Several review are available to the biology of photosynthesis in algae (Nelson et al 1991, Eberhardd et al 2008, Nelson and Yocum 2006, Krage and Weise 1991, Chisti2007, Long et al 1994, Foyer et al 1994, Niyogi 1999, Polle et al 2002). The reducing of size of the chlorophyll antenna can increase the efficiency of light utilization.

One of the major factors how carbon is partitioned into lipid or/and/or carbohydrate could be very useful in strain development and designing cultivation strategies. Many algae has reserve food is starch; therefore, method to convert starch into lipid should be studied in details.

3.2 The lipid synthesis and regulation

Some microalgae naturally or under stress condition accumulates significant amount of neutral storage lipids such as Triglycerides (TAG) which main precursor of bio-fuel precursors. The TAG is formed by incorporation of the fatty acid into glycerol backbone via three sequential Acyl transform (from Acyl co A) into the ER. The understanding of lipid regulation and identify the key pathways, enzymes and gene should be studied in detail to maximize the production of lipid.

3.3 Stress physiology vs. lipid

Some algae accumulates lipid as their carbohydrate source under stress condition (Hu et al 2008). Therefore, understanding exact relationship between oxidative stress, cell division and storage lipid should be more clarified by further study.

3.4 Algae culture system

The diversity among algal groups is very vast ranging from macro-algae to microalgae group. Therefore, each group required specific system of algal culture according their nature and requirement. However following system are used for culture of algae.

a) Land based open culture system
b) Offshore cultivation systems
c) Photobioreactors
d) Heterotrophic cultivation
e) Specific methods for cultivation of macro-algae

Each of above system has its own advantage and disadvantage. Before cultivation of algae we must take consideration very carefully of these factors.

3.5 Lipids and Biodiesel

Lipids are one of the main components of microalgae; depending on the species and growth conditions 20-60 percent of the total cell dry matter (iffels, 2006), as membrane components, storage products, metabolites and storage of energy. In order to efficiently produce biodiesel from algae, strain have to be selected with high growth rate and oil content. From all energy carriers produced from the algae, biodiesel has received the most attention and is the only initiatives which is on the border of pilot-scale and full-scale deployment. Microalgae reported to produce 15-300 times more oil than tradition oil producing crops on area basis.

Table 1: Comparison of crop dependent biodiesel production efficiencies from plant oil
TAG: Triacylglycerols

Plant Source	Biodiesel L /ha/yr	Area required to produce global oil demand (hectare×10^6)	Area required as percentage global land mass	Area as percent global arable land
Cotton	325	15002	100.7	756.9
Soybean	446	10932	73.4	551.6
Mustard Seed	572	8524	57.2	430.1
Sunflower	952	5121	34.4	258.4
Rapeseed/Canola	1190	4097	27.5	206.7
Jatropha	1892	2577	17.3	130
Oil Palm	5950	819	5.5	41.3
Microalgae (10 g m^{-2}/day at 30% TAG	12000	406	2.7	20.5
Microalgae (50 g m^{-2}/day at 50% TAG	98500	49	0.3	2.5

3.6 Algae strain selection

Algae strain selection is the crucial point for better production of the bio-fuel. Algae have various group but for bio-fuel production five groups considered more important these are Diatoms, green algae, golden brown algae, Prysmeniophytes and Eustigmatophytes. BGA also may be valuable source. Each group of above has its own strain selection methods.

3.7 Algae bio-fuel conversion

Potential viable fuels that can be produced from algae are range from gaseous components like hydrogen and methane, to alcohol and conventional lipid hydrocarbon, to pyrolysis oils and coke. Attractive targets for this effort, however, are the lipid transportation fuels of gasoline, diesel and jet fuel. When a fuel meets all customer requirements, it is referred as “fit for purpose”. Therefore, a successful fuel conversion strategies will address the full range of desired fit for purpose property e.g. distillation, ignition characteristics, energy density. A large number of potential pathways exist for the conversion from algal biomass to fuel. These pathways can be classified into the following three general categories

a) Those that focused on the direct algal production of recoverable fuel molecules (e.g. ethanol, hydrogen, methane and alkenes) from algae without the need of extraction.
b) Those that process whole algal biomass to yield fuel molecules and
c) Those that process algal extract (e.g. lipid, carbohydrates) to yield fuel molecules.
d) The technologies are primarily based on similar methods developed for the conversion of terrestrial plant based oils and products into bio-fuel.

3.8 Direct production of Bio-fuel from algae and pyrolysis

The direct production of bio-fuel through heterotrophic fermentation and growth from algae biomass has certain advantage in term of process cost because it can eliminate several process steps (e.g. oil extraction) and their associated costs in the overall fuel production process. Heterotrophic growth also allows for maintaining highly controlled conditions, which first could be oriented towards biomass production and the oil production. Such a system can generate extremely high biomass and high percentage of that biomass as lipid (over 50%). The system is readily scaled up and there is an enormous potential to use various fixed carbon feedstocks, which would bring down the cost of the production. These approaches are quite different from the usual algal bio-fuel processes that use algae to produce biological oils which is subsequently extracted and used as a feedstock for lipid fuel production, typically biodiesel. There are several bio-fuels that can be produced directly from alga, including alcohols, alkenes and hydrogen.

The pyrolysis is direct thermal decomposition of biomass at high temperature (400^0C to 1000^0C) in the absence of catalyst and o_2 to produce bio-oil into solid (Char or coke), liquid(Bio-oil) or gaseous forms. The pyrolysis of Algal biomass from different sources have various oils contents e.g. 44% biofuel from waste water treatment (M. Adamczyk et al, 2017), 78% from flash pyrolysis (Y. Li, W. Zhou, 2012), 59% from open pond system (F. Li, S.C. Srivatsa, et al 2019). The bio-oil produced by pyrolysis has its positive (easy to store, transport, low production cost, required fuels can be processed easily) and negatives (low caloric value, highly viscid, harsh and lacks thermal stability, resemblance to the reactant oil as it has predominant oxygenated molecules) (D. Woolf et al 2017, I.Y. Mohammed et al 2020, S. Kumar, et al., 2020; X. Chen, 2019)

3.9 Hydrogen production and Microalgae

Hydrogen is emerged as main alternate renewable energy source and also considered future fuel. The present H2 production methods are energy consuming, high production costly and also not environmental friendly. The Bio-hydrogen is less costly and clean. Microalgae are also considered as best source of hydrogen production due following reason 1. Well known culture system open/photo bioreactors. 2. The biology of microalgae is simpler than other plants. 3. Genetic manipulation is simpler in compare to other plants. 4. The production per unit area is higher. The major problem of bio-hydrogen production is High production cost, technical difficulties in storage, transport, conversion. (Saifuddin and Priatharsini, 2016, M L Ghirardi, 2000, Dincer, 2012)

2. Resources
The availability of resources is main requirement before start algae as source of bio-fuel production. There are several factors which must be studied in detail (e.g. sunlight and temperature needs; preferred geographic region; seasonal consideration; water requirement, carbon source, availability of land etc.)

2. Other benefits of alga
Algae is simple autotrophic organisms that has many benefits for our requirement, most importantly are waste water treatments, food supplements, fodder, manure, proteins source, medicines, scientific experiment organisms, bio-fuel, industrial raw materials for various industries etc.

4. Conclusion

The exploration of non conventional source of energy is an important tool for growth of next generation. The first generation and second generation renewable source of energy are not viable due various reason of economic, social and area factors. The algal fuel as third generation fossil fuels has many promising aspects and has ability to replace the fossil fuel. The input of different aspect of algae culture will make it more suitable in coming years. The microalgae are simplest organisms which can be transformed into super fuel producing organism due to input of genetic engineering, technology and research. We hope that in near future the algal fuels will be more economic viable and also fulfill the need of energy of world. Although many project on algal fuel have been failed due heavy use of fertilizers and chemicals as well as high production cost but further research are needed to make algal fuel viable in every aspects.

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