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Microalgae:

potential source of third generation biofuel

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The energy requirement of global community is increasing day-by-day while traditional fuels are depleting with fast pace, so alternative sources for fuel production is a need of today. In recent past, microalgae have received a great attention as a novel source for the generation of biofuel. Microalgae are microscopic algae having immense role in production of various biofuels such as biodiesel, ethanol, biogas and biohydrogen. Cultivation of microalgae does not require arable land or fresh water – it can be carried out in shallow ponds on hardpan soils, using saline or brackish water, hence doesn't interfere in food grain production.

Key words: Biofuel, Microalgae

BIOFUELS are fuels produced directly or indirectly from organic biomass (including plant materials and animal waste). Biofuels may be derived from various agricultural crops (soybean, palm, canola, rapeseed etc.) and non-agricultural (*Jatropha*, *Pongamia*, fungi, algae etc.) crops. Now-a-days, biofuels derived from microalgae are getting importance because of its high productivity and environmental friendly aspect.

Microalgae are microscopic algae rich in chlorophyll that lack lignin or cellulose and contain proteins. Microalgae are mainly found in freshwater and marine systems. They are unicellular species which exist individually or in chains or groups. Microalgae are capable of performing photosynthesis; they produce approximately half of the atmospheric oxygen and use carbon dioxide to grow. Based on feedstock classification of biofuel, the sources for their production are illustrated in Fig. 1.

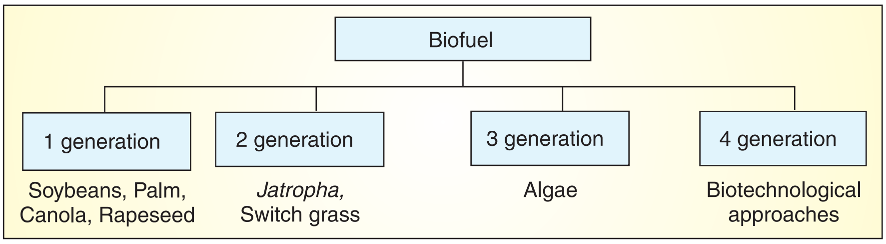

Fig. 1. Classification of Biofuels

MICROALGAE IN ARID AND SALINE ECOSYSTEM

Microalgae have several advantages over higher plants as source of third generation biofuels. Microalgae cultivation shows less dependence on seasonal variations than conventional agriculture, making cultivation in arid regions possible. The most important advantage of microalgae as source of biofuels is that they can be cultivated on land unsuitable for agriculture using saline or brackish waters. Microalgae can grow rapidly and have higher solar energy conversion efficiency than other terrestrial plants. Switch grass (2nd generation), the fastest-growing terrestrial crop, can convert only 0.5% of the solar energy to biomass energy on a yearly basis (less than 1 W/m^2). On the other hand, photosynthetic efficiency of microalgae could be in the range of 10 to 20% or even higher. Oil yield from microalgae is very high when compared with first and second generation crops (Table 1).

Table 1. Comparison of some sources of biodiesel

Crops	Biofuel category	Oil yield (l/ha)
Corn		172
Soybean		446
Canola	First generation biofuel	11,90
Oil palm		5950
Coconut		2,689
Jatropha	Second generation biofuel	1,892
Microalgae*	Third generation biofuel	58,700

Need for algal biofuel

The production of biofuels from agricultural crops such as soybean, palm, canola, and rapeseed (first generation biofuels) is causing a substantial rise of the world food prices. It also causes reduction of land area utilized for food production which ultimately causes food scarcity especially in developing countries like India. The increase of cereal prices could have an impact on the cost of first generation biodiesel production as the FAO Oils/Fats Price Index from 78 in 2000 A.D. to 278 in 2011 AODO, while use of microalgae for biofuel production would permit to reduce deforestation and preserving the forest heritage. Thus, the industrial production of microalgae could be considered as a sustainable solution to energetic, environmental and food problems.

Production systems of microalgae

There are mainly two methods for cultivation of microalgae for biofuel production:

Photobioreactors

Photobioreactors are different types of tanks or closed systems in which algae are cultivated. Algal cultures consist of a single or several specific strains optimized for producing the desired product. Water, necessary nutrients and CO_2 are provided in a controlled way, while oxygen has to be removed. Algae receive sunlight either directly through the transparent container walls or via light fibres or tubes that channel it from sunlight collectors.

Open pond systems

Open pond systems are shallow ponds in which algae are cultivated. Nutrients can be provided through runoff water from nearby land areas or by channelling the water from sewage/water treatment plants and saline water. The water is typically kept in motion by paddle wheels or rotating structures. Algal cultures can be defined (one or more selected strains) or are made up of an undefined mixture of strains.

Algae have great potential in production of various biofuels such as Biodiesel, Bioethanol, Biogas and Biohydrogen from microalgae.

Algae biodiesel is algal-derived biofuel with future commercial feasibility. Many species of algae produce large amounts of lipids as storage products; it may vary from 50 to 60% of their dry weight. Upon transesterification, these lipids are chemically similar to other oilseed

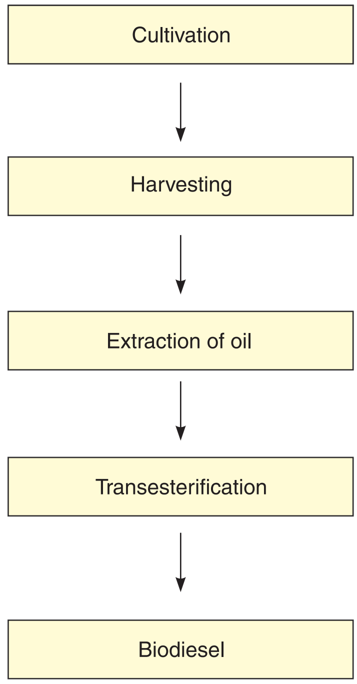

Fig. 2. Steps of biodiesel production


Fig. 3. Growth of algae in BBM


Fig. 4. Centrifugal algal inoculums

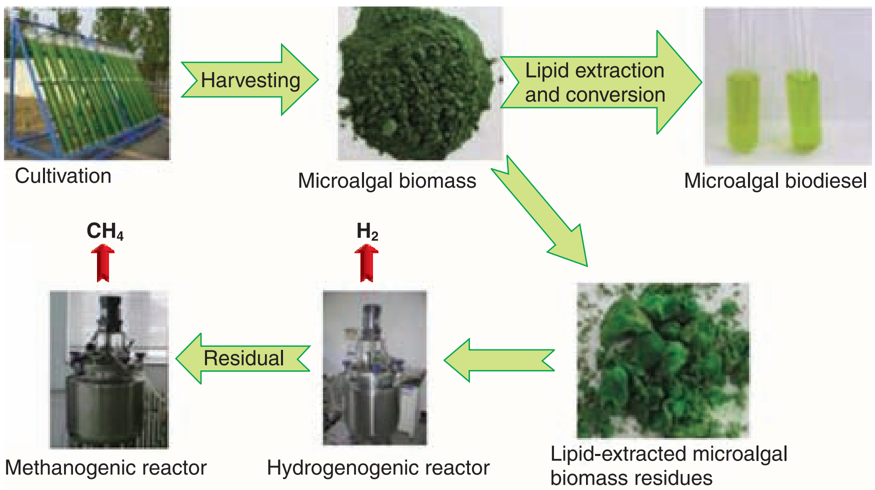

Fig. 5. Hydrogen and methane production from lipid-extracted microalgal biomass

crop derived lipids making algae a very productive potential source of biodiesel. The systematic diagram of biodiesel production is shown in Fig. 2; Algae were grown in BBM (Bold's Basal Medium) culture media as shown in Fig. 3; Algae culture were centrifuged to get concentrated biomass as shown in Fig. 4. After harvesting of dry algal biomass, lipid was extracted and converted in to biodiesel and subsequently in methane (CH_4) and hydrogen (H) are shown in Fig. 5.

Lipid content from microalgae

Microalgae have a high lipid content of 30% to 60% of the dry biomass. These lipids can be converted into biodiesel through transesterification. Algae lipids are esters of glycerol i.e. polyunsaturated fatty acids (PUFAs). Lipids content of microalgae is shown in Table 2.

Table 2. Lipid content in microalgae

Microalgae spp.	Lipid content (% dry biomass)
Chlorella sp.	28 to 32
Crypthecodinium cohnii	20
Cylindrotheca sp.	16 to 37
Dunaliella primolecta	23
Isochrysis sp.	25 to 33
Nannochloris sp.	25 to 35
Nannochloropsis sp.	31 to 68
Nitzschia sp.	45 to 47
Schizochytrium sp.	50 to 77

Biogas form microalgae

Microalgae also have an important role in production of biogas through anaerobic fermentaion. The efficiency of biogas production is species-dependent based on relative efficiency of cell degradation and on the presence or absence of molecules that may inhibit methanogenic arcaea. The production of biogas from algae may also play an important role in bioremediation as harmful algal blooms in lakes, ponds, or oceans can result in the production of toxic secondary metabolites that can have drastic effects on these ecosystems, and removing these algae for biogas production can reduce these impacts.

Currently, the production of biogas from algae is still limited due to the need to heat the digesters and the requirement for more land area and infrastructure to produce the same amount of energy as can be obtained for algae biodiesel. Some important feedstock for biogas production are given below:

Biogas producing strains are : *Laminaria* sp.: *Gracilaria* sp.: *L. sargassum; Macrocystis* sp.and *Ulva* sp.

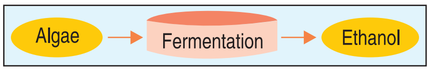

Fig. 6. Ethanol production from algae biomass

Ethanol

One of the most successful microorganisms for bioethanol production is *Saccharomyces cerevisiae* Wild-type strain has high bioethanol productivity and very tolerant to high ethanol concentrations and inhibitory compounds, it is unable to ferment pentoses (hemicelluloses). Generalized pathway for production of ethanol from algal biomass is shown in Fig. 6 and important strains for ethanol production are shown in Table 3.

Table 3. Ethanol producing strain

Feedstock	Ethanol Yield (g ethanol/g substrate)
Chlorococcum humicola	0.52
Chlorococcum infusionum	0.26
Chlamydomonas reinhardtii	0.24

Hydrogen

In the recent past, most algae research were focused on liquid fuels such as biodiesel and bioethanol; however, algae are also a potential source of commercial biohydrogen. Recent research has shown that the red algae *Gelidium amansii* and the brown algae *Laminaria japonica* are both potential biomass sources for biohydrogen production and anaerobic fermentation, but in the case of *G. amansii*, an inhibitory by-product of acid hydrolysis (5-hydroxymethylfurfural) decreases the hydrogen production rate by 50% due to non-competitive inhibition.

SUMMARY

Algae is highly productive third generation biofuel, contains high amount of lipids compared to oil yielding crop plants. Algae biomass has a vast potential in production of several biofuels as Biodiesel, Biogas, Bioethanol, Biohydrogen apart from that algal fuel has several social and environment benefits compared to conventional fuels. But biodiesel from microalgae still has not yet become economical, hence require a future research on economical industrial scale production of algal biofuels with lower cost.

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Attracting and Retaining Youth in Agriculture (ARYA)

Realizing the importance of rural youth in agricultural development especially from the point of view of food security of the country, ICAR has initiated a program on “Attracting and Retaining Youth in Agriculture.

The objectives of ARYA project are:

(i) To attract and empower the youth in rural areas to take various agriculture, allied and service sector enterprises for sustainable income and gainful employment in selected district;

(ii) To enable the farm youth to establish net work groups to take up resource and capital intensive activities like processing, value addition and marketing; and

(iii) To demonstrate functional linkage with different institutions and stakeholders for convergence of opportunities available under various schemes/program for sustainable of youth.

ARYA project will be implemented in 25 states through KVKs, one district, 200-300 rural youth will be identified for their skill development in entrepreneurial activities and establishment of related micro-enterprise units in the area of Apiary, Mushroom, Seed processing, Soil testing, Poultry, Dairy, Goatry, Carp-hatchery, Vermi-compost etc. KVKs will involve the Agricultural Universities and ICAR Institutes as technology partners. At KVKs also one or two enterprise units will be established so that they serve as entrepreneurial training units for farmers. The purpose is to establish economic models for youth in the villages so that youths get attracted in agriculture and overall rural situation is improved.

The trained youth groups will function as role model for other youths and will demonstrate the potentiality of the agri-based enterprises which will help in improving their confidence levels and encourage them to pursue farming as profession, generate additional employment opportunities to absorb under employed and unemployed rural in secondary agriculture and service related activities in rural areas.