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Current status of Research on algal bio-fuels in India

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Abstract

India is the sixth largest and one of the fastest growing energy consumers in the world due to raising population and consumption power of India. Vehicular pollution contributes to about 70% to the total air pollution and is estimated to have increased 8 times in the last 2 decades. Due to limited crude oil reserves, India meets about 72% of its crude oil and petroleum products requirements through imports, which are expected to expand further in coming years. Bio-fuels promise to be an appropriate option to be fixed as a solution to these problems. Bio - fuels have been developing in stages and have come up a long way. Bio-fuels were produced initially using waste oil as raw material and then as the demand rose up various generations of technologies using different raw materials mushroomed up as options for bio -fuels production. Various companies and research setups for algal fuels are coming up and are backed by big investors in India.

Introduction

Algae have recently received a lot of attention as a new biomass source for the production of renewable energy. Some of the main characteristics which set algae apart from other biomass sources are that algae (can) have a high biomass yield per unit of light and area, can have a high oil or starch content, do not require agricultural land, fresh water is not essential and nutrients can be supplied by wastewater and CO_2 by combustion gas. The first distinction that needs to be made is between macro algae (or seaweed) versus microalgae. Microalgae can provide several different types of renewable bio-fuels. These include methane produced by anaerobic digestion of the algal biomass [Spolaore *et al.*, 2006] biodiesel derived from micro algal oil [Thomas, 2006; Roessler *et al.*,1994; Banerjee *et al.*, 2002] and photobiologically produced bio-hydrogen[Gavrilescu and Chisti, 2005; Fedorov *et al.*, 2005]. The idea of using microalgae as a source of fuel is not new [Kapdan and Kargi, 2006, Chisti, 1980-1981] but it is now being taken seriously because of the escalating price of petroleum and, more significantly, the emerging concern about global warming that is associated with burning fossil fuels [Sawayama *et al.*, 1995]. Bio-ethanol is currently being produced by fermentation of sugars found in plants such as sugarcane and corn. Many social concerns have barred the adoption of their future use, so other feedstock is being considered as substitutes. Algae are one of that feedstock.

However, algae do not produce as much starch as corn, and do not have firm agricultural practices. However, there is reason to believe that algae will play a role in the future bio-ethanol market. In order to lower the cost of producing this fuel, other products from algae will have to be processed and sold. Bio-ethanol is one of those products. Using everything that algae have to offer is the best route towards more favorable economic models for these low- value high-volume products

Indian contribution towards algal bio- fuels research - Macro algae:

Extensive work has been done by Indian scientists on utilization of seaweeds for food and pharmaceutical applications. In India, seaweeds collected from natural vegetation are used for the production of phycocolloids such as agar and alginates. CSMCRI has long been working on the cultivation of various seaweeds and recently forayed into value addition for seaweed products. Seaweeds like *Gracilaria*, *Gelidium*, *Kappaphycus* etc are being cultivated in large scale. Rengasamy, CAS in Botany, University of Madras, has also successfully demonstrated outdoor cultivation of two species of *Sargassum* for the first time (Rengasamy, 2008). But very few investigators have concentrated on bio- fuels from seaweeds. CSMCRI, Bhavanagar for the first time in India has been able to produce ethanol using a seaweed polysaccharide. Rengasamy and his team have successfully developed a technology to produce biogas from seaweeds (Rengasamy, 2009). More work has to be done before these can be commercialized.

Micro algae: *Freshwateralgae*

Ravishankar and his team from Plant Cell Biotechnology Department, Central FoodTechnological Research Institute, Mysore have done extensive work on isolation and characterization of hydrocarbon producing micro alga Botryococcus braunii from Indian waters.(Dayananda et al. 2005, 2006 and 2007; Dayananda *et al.,* 2005; Tripathi *et al.,* 2001). Recently, Rengasamy and his team from University of Madras have successfully cultivated Botryococcus braunii in open raceway pond without any contamination (Rengasamy, 2007, 2008 and 2009).Simrat Kaur *et al.,* (2009) from Bio- energy Division, Defense Research Laboratory, Tezpur, India and Department of Biotechnology, Gauhati University, India have done preliminary work on Algal diversity as a renewable feedstock for biodiesel. Thajuddin (2009) from Bharathidasan University, Tiruchirappalli,Tamilnadu has started working on algal biodiesel production from micro algae.

Algal biomass production integrated with Phycoremediation

Sivasubramanian and his team from Phycospectrum Environmental Research Centre (PERC), Chennai, have been involved in developing algae based technology to treat industrial effluents and wastewater. Algal technology for treating effluents has been implemented in a number of industries by PERC for the past 10 years. Algae based solution has been delivered to alginate industry, leather processing chemicals industry, detergent industry, electroplating industry, confectionery industry, textile dyeing industries, oil drilling effluent treatment plant, petrochemicals and copper smelting industry (Mohan *et al.,* 2009; Gurukasi Rajan *et al.,* 2009; Ranjithkumar *et al.,* 2009; Sivasubramanian et al., 2009; Hanumantha Rao *et al.,* 2009; Murugesan *et al.,* 2009; Bharanidharan *et al.,* 2009). The main advantage of phycoremediation is complete avoidance of chemicals normally employed by various industries to correct pH, remove colour and odour, remove sludge etc. The industries save lot of chemicals and huge amount of energy. Algal technology involves maintenance of the critical level of algal biomass for effective remediation of effluents.

World's First Phycoremediation plant to treat industrial effluent was commissioned in SNAP Natural and Alginate products at Ranipet, Tamilnadu based on the research support from PERC (Sivasubramanian *et al.,* 2009). This industry generates huge volume of highly acidic effluent with a high TDS. Algal technology is being effectively employed to correct pH and reduce sludge with lots of benefits to industry as well as to the environment. In the process this industry also generates huge amount of algal biomass which is being incorporated into a bio- fertilizer product. PERC is working on other possibilities of utilizing algal biomass including biogas, bio-ethanol and biodiesel. Studies conducted by PERC have shown that algae grown in the effluent is highly suitable for biodiesel application.

Other industrial effluents which PERC has found favourable for algal biomass production are textiledyeing industry effluent and effluents from confectionery industries. PERC has successfully grown *Chlorella* species in confectionery industry effluent to correct pH and remove sugars. Chlorella sp grown in confectionery effluent produces higher amount of lipids. One of the textile dyeing industries which employs algal technology to remove dyes and reduce BOD and COD, is harvesting algae, dry the slurry and the dried algal cakes are being used in boilers along with firewood. The calorific value of algal cake has been analyzed by PERC and it was found to be superior. Sludge produced by various industries could be also used as nutrient source for growing certain types of micro algae. PERC has investigated the biochemistry of sludge grown algae and found highly suitable for biodiesel production. Algal biomass production integrated with remediation is the best option since it will not encroach upon agricultural land and water. Growing algae in waste water will make the whole process very cheaper and economically viable one. Senthil Chinnasamy *et al.,* (2009) from Laboratory of Soil Microbiology, Division of Soil Science and Microbiology, Central Rice Research Institute, Cuttack, Orissa has done investigations on biomass production potential of waste water alga Chlorella vulgaris.

Marine phytoplankton:

Many research laboratories in India are also involved in developing biodiesel technology based on marine phytoplankton species including diatoms. Rengasamy and his team (2009) from University of Madras are in the process of isolation and characterization of suitable marine phytoplankton for biodiesel production. Ramachandra *et al.,* (2009) have done studies on bio-fuels production from species of diatoms. PERC has been working on cultivation of selected diatoms species in seawater and extraction of oil. Work on standardization of nutrient supplement, harvesting and extraction is complete. Further work is on progress to optimize other parameters to enhance the production of oil by diatoms in pilot scale open race way ponds. Oil percentage of 30 to 40 % could be achieved.

Work to be done:

There is numerous challenges and problems to be addressed to take the technology to industry level implementation. Right from species characterization, isolation, cultivation, harvesting and processing there are still many issues which may be effectively addressed in another 10 years time before algal biofuel technology is commercialized.

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