Conversion Techniques for Oilgae to Biodiesel for Automobile: Overview in Context to Indian Perception

Alpesh Mehta[1], Nirvesh Mehta[2]

[1]*Research Scholar, Faculty of Technology, RK University, Rajkot, Gujarat,*

[2]*Professor, Mechanical Engineering Department, LDRP, Gandhinagar.*

***Abstract*—The global economy thrives on energy. Affordable energy directly contributes to increase productivity, reducing poverty and improving betterment of life. Global population is increasing day by day, which, in a way is leading to the utilization of natural resources and fossil fuels. Fossil fuels cannot be replenished, once it gets depleted, it cannot be produced again and major cause of pollution. Declining fossil fuel production with a rising fuel demand provides the most compelling global reason for alternative fuels. So we have to think for production of such fuels which are not only potential alternatives for fossil fuels, but also are eco-friendly in nature and not get depleted.**

So one has to think about renewable energy sources - solar, tidal, wind, biomass, hydro etc.. Biodiesel derived from oil crops (biomass) is also a potential renewable alternative to petroleum. It is discussed about replacement of petroleum-derived transport fuel without adversely affecting the supply of food and other crop products, with keeping the environment clean. No serious research work has been carried out for conversion of oilgae to biodiesel in India. Present paper discusses various methods available for algae oil to biodiesel conversion. Out of them, fast pyrolysis is suitable method for production of biodiesel according to available technology in India.

***Keywords*— fossil fuel, pollution, biomass, algae oil, biodiesel.**

I. Introduction

Energy is essential for living and vital for development of all. Power consumption per capita represents the growth / development of the said nation and living standard of their citizens. Affordable energy directly contributes to increase productivity, reducing poverty and improving betterment of life. Declining fossil fuel production with a rising fuel demand provides the most compelling global reason for alternative fuels. So one has to think for production of such fuel which is not only potential alternatives for fossil fuels, but also eco-friendly in nature.

India meets nearly 33% of its total energy requirements through imports [1]. The continued use of fossil fuels is not sustainable, as they are finite resources, limited in amount, non-renewable in nature, and their combustion would lead to increased energy-related emissions of greenhouse gases (GHG).

Biodiesel derived from oil crops is also a potential renewable alternative to petroleum. However due to the various issues (one of them is debate between food v/s fuel), biodiesel from oil crops and animal fats is not a good choice. Moreover it can satisfy only a very small fraction of the existing demand for fuel.

Biodiesel derived from green algae is the most promising renewable biofuel in biomass with the potential to completely displace petroleum-derived fuel without adversely affecting the supply of food and other crop products, with keeping the environment pollution free. Algae biodiesel is the THIRD GENERATION biofuel. An algae grow naturally in entire world. Under optimal conditions, it can be grown in massive, almost limitless in amounts, and mature within one day. Its daily production, distribution and consumption of biodiesel in an automobile is possible.

II. Mapping Pathways for Algae to Biodiesel Production

Algae-to-biofuel production is divided into four stages, a) algae cultivation, b) biomass harvesting, c) algal oil extraction, and d) oil and residue conversion. Refer fig. 2[6].

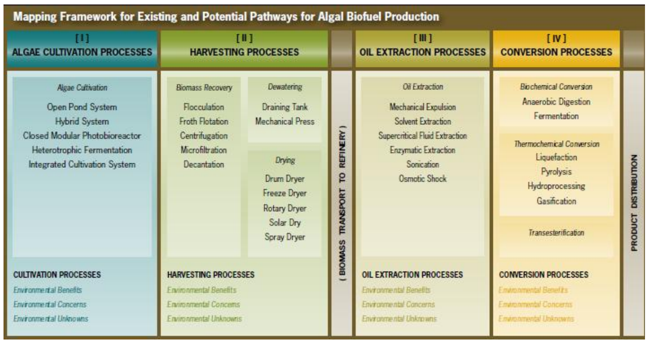

Fig. 2: Mapping Framework for Existing and Potential Pathways for Algal Biofuel Production [6]

A. *Algae Cultivation Processes*

The purpose of algae cultivation is to grow raw algal biomass for the downstream production of fuel, based on the oil and residual components found in the biomass. In order to flourish, algae need water, carbon dioxide, and essential nutrients (sulphur, potassium, metal etc) which are collectively referred to as the culture medium; algae cultivation facilities need land or other area to occupy; and, in most cases, algae need light to drive photosynthesis [8]. The various algae cultivation method includes open pond system, closed photobioreactors (PBR), hybrid system, heterotrophic fermentation, integrated cultivation system.

B. *Harvesting Process*

Once an algal culture reaches maturity, the biomass is harvested from the culture medium and dried in preparation for conversion. At this stage, algal biomass from the preceding cultivation system typically carries high water content and, in most cases, is not suited for conversion to biofuel products until it has undergone some degree of dewatering and drying. There are three systemic components of the harvesting process: biomass recovery, dewatering, and drying. The most commonly implemented techniques are flocculation, froth flotation, micro filtration, centrifugation, and decantation [6].

C. Oil Extraction Processes

The actual oil content (20–80%), measured in gallons/acre/year, will depend on many parameters. Oil extraction from algal biomass yields algal oil (triglycerides or TAG lipids) and residue (carbohydrates, proteins, nutrients, ash). The percent yield of total available oil from the biomass will depend on the efficiency of the extraction method used [6].

D. Oil and Residue Conversion to Biofuels

Once the biomass is separated into raw algal oil and residue, the energy content of the two components can be thermally or biologically transformed to liquid or gaseous fuels or solid coproducts. Conversion processes are of varying efficiency— depending on reaction temperature, pressure, heating rate, and catalyst type, as well as algal species and quality of biomass—theoretically converting algal biomass (or components of biomass) into several possible biofuels and coproducts[6].Conversion pathways include transesterification, fermentation, anaerobic digestion, gasification, pyrolysis, liquefaction, and hydroprocessing. These pathways are discussed below according to whether the technology is biochemical or thermochemical [6].

III. CONVERSION PROCESSES

Conversion technology options include chemical, biochemical, and thermochemical processes, or a combination of these approaches.

A. Biochemical Conversion

Biochemical conversion is also known as biochemical fermentation. Fermentation is the more common biochemical approach to algal biomass conversion. Biochemical conversion breaks down sugars in the residue using enzymatic or chemical processes such as fermentation or anaerobic digestion. Primary fuel products of biochemical conversion include methanol, ethanol, butanol, and hydrogen. It is possible either by Anaerobic Digestion or by Fermentation[12].

According to Nafisa M. Aminu, Nafi'u Tijjani and Y.Y. Aladire[12], biochemical conversion technologies involve three basic steps: 1) converting biomass to sugar fermentation feedstock; 2) fermenting the feedstock using biocatalysts (microorganisms including yeast and bacteria); and 3) processing the fermentation product to yield fuels, chemicals, heat, or electricity. Fermentation (biochemical decomposition in the absence of air, essentially converting sugar to carbon dioxide and alcohol) is the more common biochemical approach to algal biomass conversion. Biochemical conversion breaks down sugars in the residue using enzymatic or chemical processes such as fermentation or anaerobic digestion. Primary fuel products of biochemical conversion include methanol, ethanol, butanol, and hydrogen. No heat inputs and elimination of several process steps (e.g., oil extraction) and their associated costs in the overall fuel production process are advantages and required sugars could prove environmentally burdensome at commercial scale in above method[12].

B. Transesterification

The chemical transesterification reaction is employed to convert triacylglycerols extracted from algae to FAMEs (fatty acid methyl esters). Transesterification is the reaction between an ester (TAG) and an alcohol (methanol) to form a different ester (methyl esters) and alcohol (glycerol) in the presence of a catalyst, usually sodium ethanolate for algae oil production, the equation of the reaction is presented in fig. 2[12].

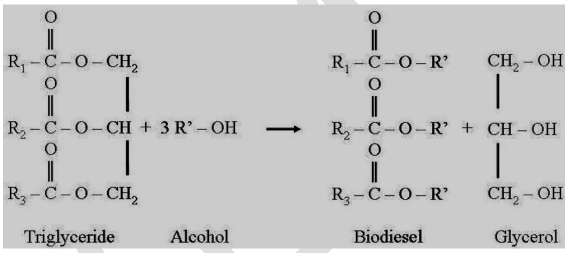

Fig. 2: Transesterification Reaction[12]

Transesterification can be performed via catalytic (ethanol and sodium ethanolate) or non-catalytic reaction systems using different heating systems that are required to initiate the reaction. During conversion, glycerol is periodically or continuously removed from the reaction solution in order to drive the equilibrium reaction toward completion [6].

Coproduct glycerol can be used /cycled as feedstock in heterotrophic fermentation processes. Increased waste management and alkali-catalysed transesterification reaction leads to soap formation in the biodiesel. The presence of methanol, the co-solvent that keeps glycerol and soap suspended in the oil, is known to cause engine failure. Hence certification is required to wash the biofuel[12].

C. Pyrolysis

Pyrolysis is the chemical decomposition of a condensed substance by heating in absence of oxygen. Pyrolysis, also known as thermal cracking, is a thermochemical pre-treatment process of induced decomposition conducted in the relative absence of oxygen. This process is applied at temperatures above 430°C (800°F); the typical range is between 500–600°C, at 0.1–0.5 MPa of pressure. Bio-oil is easily stored and transported and can be used directly as a fuel in boilers or gas turbines, or it can be used as a feedstock to produce chemicals or transportation fuels. The pyrolysis process is usually used for biochar production because the technique is relatively simple and inexpensive and allows considerable flexibility in both the type and quality of the biomass feedstock. Fast pyrolysis varies extensively from 18–80 percent efficiency. Carbon monoxide, charcoal, phenol-formaldehyde resins, and wastewater are common by-products of pyrolysis[14]. Relatively low energy inputs, accommodates biomass with high moisture content, negating the need for energy-intensive drying processes are major advantages of above method but product bio-oil must be upgraded before being introduced as a transportation fuel, yields contaminated water as a by-products, Energy needed to cool off-gases are limitations of above method[14].

D. Thermo-chemical Hydro-processing

Hydroprocessing uses a combination of heat and pressure in the presence of catalysts to upgrade a crude, intermediary feedstock to a market-ready fuel product. Both algal oil and bio-oil can be accommodated by hydroprocessing, which upgrades the oil feedstock to a high-quality, market-ready hydrocarbon biofuel such as green or renewable diesel, jet fuel, gasoline, or other light fuel [6]. By-product hydrogen can be continuously recycled through the process in the purification and hydro-cracking processes, quality market-ready fuels is available because of above method. But impurities (nitrogen, sulphur, oxygen, carbon) must be extracted (the more impurities, the more water and energy required for processing) and large quanties of water and energy requires to implement the purification and hydro-cracking processes [6].

IV. Conclusion

Lots of technical, environmental aspects must be considered while selecting most suitable oil conversion method in India. The environmental impacts include conversion method implemented, moisture content permitted in Indian algae, energy inputs and outputs, types and quantities of catalyst(s) available and used, as well as expected nonfuel coproducts and by-products ,their use / applications and their toxicity or reusability. Such variability in potential impacts exhibits the need for greater analyses of entire production pathways to determine the true energy balance and environmental costs and overall prospects for sustainability.

Acknowledgment

I acknowledge administrative help received from Prof P D Solanki, Professor & I/c Principal, Government Engineering College, Godhra for the co-operation and encouragement of my colleagues in the College. I am profoundly indebted to Dr. Sadanand Nam Joshi who took keen interest in the project right from the inspiration. I am also extremely thankful to Prof. H.R.Thakkar, ex-Professor in Mechanical Engineering Department, BVM Engineering College, Vallabh Vidyanagar for extending their kind assistance and providing invaluable information as & when required.

References

[1] A report on Energy Statistics 2013 by Central Statistics Office, National Statistical Organization, Ministry of Statistics and Programme, Implementation, Government of India,2013.

[2] Dr. Swarup Renu, a presentation on Biofuels - The Indian Scenario at TERI, New Delhi, India, 7th December, 2010.

[3] Chanakya H.N., Mahapatra et al., Sustainability of Large-Scale Algal Biofuel Production in India in Journal of the Indian Institute of Science-A Multidisciplinary Reviews Journal, ISSN: 0970-4140 , VOL 92:1, Jan.–Mar. 2012.

[4] Singh Jasvinder , Sai Gu , Commercialization Potential of Microalgae for Biofuels Production Renewable and Sustainable Energy Reviews ,Vol.14 2010 ,pp-2596–2610.

[5] Philip T. Pienkos, The Potential for Biofuels from Algae, A presentation at National Renewable Energy Laboratory National Bioenergy Center,USA, November 15, 2007.

[6] Catie Ryan, Cultivating Clean Energy: The Promise of Algae Biofuels, Report to Natural Resources Defense Council. USA, October 2009.

[7] Mary Solecki, Anisa Dougherty, Bob Epstein, Advanced Biofuel Market Report 2012- Meeting U.S. Fuel Standards, USA, 2012.

[8] Ferrell John, Valerie Sarisky-Reed, National Algal Biofuels Technology Roadmap Workshop and Roadmap sponsored by the U.S. Department of Energy Office of Energy Efficiency and Renewable Energy Office of the Biomass Program Publication Date: May 2010.

[9] Sayadi M.H., Ghatnekar S.D., Kavian M.F., Article on Algae a promising alternative for biofuel, Proceedings of the International Academy of Ecology and Environmental Sciences, 2011, 1(2):pp-112-124.

[10] Kumar Mukesh, Sharma M.P., Dwivedi Gaurav, Algae Oil as Future Energy Source in Indian Perspective, International Journal of Renewable Energy, Vol.3, No.4, 2013, pp13-921.

[11] Angeles Cancela , Rocio Maceiras et al. Microwave-Assisted Transesterification of Macroalgae, Energies 2012, 5, 862-871; doi:10.3390/en5040862.

[12] Nafisa M. Aminu, Nafi'u Tijjani and Y.Y. Aladire, Overview of Biodiesel Production from Algae in Nigeria and Some Developing Countries, International Journal of Scientific & Engineering Research ,ISSN 2229-5518,Volume 4, Issue 1, January-2013 ,pp 1-9.

[13] Nailwal Shweta, Nailwal Tapan Kumar, Sharma Meenakshi, Physico-Chemical Characterization of Algal Oil of Kumaun Himalayan Origin for Potential Biofuel Application, Journal of Applied Phytotechnology in Environmental Sanitation, 2013,2 (4): 91-98.

[14] Kanyaporn Chaiwong , Tanongkiat Kiatsiriroat , et al., Biochar production from freshwater algae by slow pyrolysis, Maejo Int. J. Sci. Technol. , ISSN 1905-7873,2012, 6(02),2012 ,pp186-195.

[15] Qingyu Wu, Xiaoling Miao, A presentation on 'Biofuels production from Microalgae after heterotrophic growth ' from Department of Biological Sciences and Biotechnology, Tsinghua University, Beijing 100084, P.R. China.

[16] Bajhaiya A. K., Mandotra S.K, et al., Algal Biodiesel: the next generation biofuel for India, Asian J. Exp. Biol. Sci. Vol 1 (4) ,2010, 729-739.

[17] Rajvanshi Shalini i, Mahendra Pal, Microalgae: A Potential Source of Biodiesel, http://dx.doi.org/10.4236/jsbs.2012.23008, Journal of Sustainable Bioenergy Systems, 2012, 2, 49-59 .

[18] Xiaodan Wu, Rongsheng Ruan, et al., Current Status and Prospects of Biodiesel Production from Microalgae, Energies,2012, 2667-2682; doi:10.3390/en5082667.

[19] Leonard Wagner, Research report on Biodiesel from Algae oil to MORA ASSOCIATES, July 2007.

[20] Deep Satapathy, New Dimension to Algae Fuel: Far from Light and Closer to Human Needs, Open Access Scientific Reports, http://dx.doi.org/10.4172/scientificreports.671, Volume 2 , Issue 3 , 2013.

[21] Antonio Jose de Jesus de San , Juan Bosco Echevarria Parres, Process and Apparatus for Extracting Biodiesel from Algae, United states Patent Application Publication, US2011/0189741 A1, Aug 4, 2011.

[22] Daniel Chaumont, Biotechnology of algal biomass production: a review of systems for outdoor mass culture, Journal of Applied Phycology 5: 593-604, 1993.

[23] Al Darzins and Philip Pienkos , Algae as a Feedstock for Biofuels - An Assessment of the Current Status and Potential for Algal Biofuels Production, NREL, US, July, 2011.

[24] Benemann J., "Japanese NEDO RITE Project 1990-2000, Overview: Algae Oil to Biofuels, November 3, 2008, http://www.nrel.gov/biomass/pdfs/ benemann.pdf.

[25] Annam Renita, D. Joshua Amarnath, and S. Sivasubramanian, A Study on the Optimization of Algal Biodiesel Reaction Parameters Using Response Surface Methodology, International Journal of Chemical Engineering and Applications, Vol. 3, No. 5, October 2012,pp 311-314.