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Prospect of Algal Biodiesel Production in Bangladesh: Overview from Developed Countries

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Abstract: *In recent decade's world's energy demands are fulfilled by coal, natural gas as well as petroleum though the price of oil is skyrocketing. Moreover, geopolitical tensions around the world may push it higher and demand also increasing as well. The world is faced two new problems severely like energy crisis and environmental degradation. If this continues, global recession is unavoidable and depletion of world reserve accelerates undoubtedly. To produce more fuels and energy more environmental hamper is done by the world that's why many investigations have been done to find out an environment friendly, economically competitive and technically feasible alternative source of energy. Very recently, Biodiesel is found to be more sustainable, non toxic and energy efficient technology which is biodegradable. Around 350 oil bearing crops rapeseed, soybean, jatropha, sunflower, linseed and coconut are the main sources of Biodiesel. But these edible material sources were proved to be unfeasible where demand is much higher than the production. But non-edible materials like algae is acceptable source of biodiesel not only in research but also many recently developed countries like China, Malaysia and India are accepted this technology in production and export. This paper provides an overview of algal biodiesel production at Bangladesh where fuel (oil, gas, coal) is too expensive day by day and to ensure a degradation free environment, alternative source of fuel (Biodiesel) is the time demanding decision for Bangladesh. Both mechanical and chemical methods of biodiesel production are analysed. In China, fundamental research on microalgae energy has a strong engineering and technological base. Several projects were taken from 2005 and algal biodiesel would be the giant source of energy within few years at China. National Biofuel policy of Malaysia increasing productivity and maximising returns in the sector of second generation biofuel technology like biodiesel from algae. In India, they started with jatropha based biodiesel and finally carried out extensive work to find out hydrocarbon at Indian water from hydrocarbon producing algae. For Bangladesh in fostering the development of biofuels industries, government have to play important role to adapt the technologies for their own condition, which raises issues of technology transfer. For both sustainable development and environmental protection, advanced technologies of biodiesel production is imperative for Bangladesh.*

Keywords: *Alternative source of energy, Biodiesel, Edible, Non-Edible, Algal Biodiesel*

I. Introduction

Fuels are such kind of materials that store potential energy in forms that can be practicably released and used as heat energy [1]. Huge sources of energy produced from fuels, to generate steam, electricity and power transportation systems. And although fuels have become synonymous with modern industrial society, their potential to solve some of the challenges of everyday existence has been understood throughout history [2]. The most common sources of fuels are oil, natural gas, coal and uranium. Together, oil, natural gas, coal and nuclear energy account for about 87 percent of the world's energy supply, a share that has changed little over recent decades [3]. But these are non-renewable energies & for solving the future energy crisis of the world it is high time to look for alternative sources. Some well-known alternative fuels include biodiesel, bio alcohol (methanol, ethanol, and butanol), chemically stored electricity (batteries and fuel cells), hydrogen, non-fossil methane, non-fossil natural gas, vegetable oil, and other biomass sources [4].

Biodiesel refers to a non-petroleum-based diesel fuel consisting of long-chain alkyl (methyl, ethyl or propyl) esters. Thus, the word "bio" refers to a biological source in contrast to the petroleum based- fuel. Biodiesel is made by chemically reacting lipids, typically vegetable oil or animal fat (tallow), and alcohol. It is a clean burning renewable fuel made through a chemical process which converts oils and fats of natural origin into fatty acid and methyl esters (FAME) [5]. Very recently, Biodiesel is found to be more sustainable, non toxic and energy efficient technology which is biodegradable. Biodiesel is a renewable, clean-burning diesel replacement that is reducing U.S. dependence on foreign petroleum, creating jobs and improving the environment. Around 350 oil bearing crops rapeseed, soybean, jatropha, sunflower, linseed and coconut are the

main sources of Biodiesel. But these sources are failed to meet up the high demand of fuels. In these vice-versa circumstances microalgae can be a feasible solution. Microalgae are microscopic algae, typically found in freshwater and marine systems. They are unicellular species which exist individually, or in chains or groups [6]. Microalgae are usually microscopic, prokaryotic or eukaryotic, and uni- or pluri-cellular organisms. Microalgae are sunlight-driven cell factories that convert carbon dioxide to potential biofuels, foods, feeds and high-value bio-actives [7, 8]. In addition, these photosynthetic microorganisms are useful in bioremediation applications [9] and as nitrogen fixing bio-fertilizers [10]. Microalgae can provide several different types of renewable biofuels. These include methane produced by anaerobic digestion of the algal biomass [11]; biodiesel derived from microalgal oil [12, 13] and photo-biologically produced bio-hydrogen [14, 15]. The idea of using microalgae as a source of fuel is not new [16] 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 [17]. There are numerous ways to remove the lipids, or oils, from the walls of algae cells. But surprisingly none of them are particularly earth-shaking methods. The experiments themselves consisted of two types, wet extract processes that focus on disrupting the algae cells in solution, and dewatering methods which remove the algae from aqueous water solution and then mechanically or chemically disrupt the cells [18].

Based on intensive literature review, this paper analyzes the necessity of biodiesel production for ensuring a safe environment as well as sound economy for Bangladesh. The prospect of biodiesel production in this country analysed very deeply and among many other sources, this paper represents the overview of biodiesel production from micro algae. Some developed country like China, Malaysia and India started their biodiesel production already though their productions were based on Guang Pi, Palm oil, and Jatropha respectively. But after long research each of those country take initiative to produce biodiesel from micro algae also which is more feasible than any other, which is also analysed in this paper. Further study is needed to specify the exact species of algae as different micro algae contains different amount of oil and having varied availability as well.

II. Algal Biodiesel And Its Extraction Process

On the basis of sources, biodiesel divided into four categories. They are edible sources, non edible sources, animal sources and algae/fungi sources. But analyzing the oil yield (L/Acre) between microalgae and some other sources of biodiesel it is clear that microalgae has highest oil yield (19000-57000 L/Acre) where corn has the lowest yield (68.13 L/Acre) and other famous sources like sunflower, jatropha and palm oil has 386.07 L/Acre, 788.33 L/Acre and 2403.47 L/Acre oil yield respectively [19]. More than 350 times less area is needed for microalgae comparing with corn, where 31 times and 10 times less land is requires with comparing jatropha and palm oil respectively [19]. Moreover, algae are eco-friendly sources of biodiesel because it reduces the amount of carbon dioxide at environment. More carbon dioxide is necessary when algae are growing and they have the highest consumption rate comparing with other plants. The algae growing facilities could be situated around power plants and the carbon dioxide that is being produced routed directly to the algae so that it can grow and produce oxygen. A coal power-plant flue gas, which contains about 10 to 30 times as much carbon dioxide as normal air, can be cleaned by this method [20].

Oil extraction from algae means to remove the oils or lipids from walls of algae cells. Basically there are two processes named, wet extract processes that focuses on disrupting the algae cells in solution, and dewatering methods which remove the algae from aqueous water solution and then mechanically or chemically disrupt the cells.

2.1 Wet extraction process

- Freezing: The expansion of the water inside the cell as well as the water around the cell will cause the cell walls to rupture from the inside out or be disrupted by the compressive forces. The samples are investigated for three freeze cycles and algae cells began to cluster together [21].
- Homogenization: To obtain a uniform media, in a mixture the particle size should be reduced. This reducing process is termed as homogenization. Through small valves by expelling mixture at high pressure this process is conveyed and two different tissue grinders of different homogenizing capabilities were tested to test the viability. Homogenizers having nano-tolerance are a potentially viable source of extracting oil on a lab scale but they are extremely difficult to reproduce on an industrial scale [21, 22].
- Sonification: To induce cavitation bubbles adjacent to the algae cell wall, ultrasonic waves can be used. These ultrasonic waves can be generated by using ultrasonic reactor. Cell wall will collapse when cavitation bubbles creating a pressure as well as shock and finally contained oil is released [22].

2.2 Dry extraction process

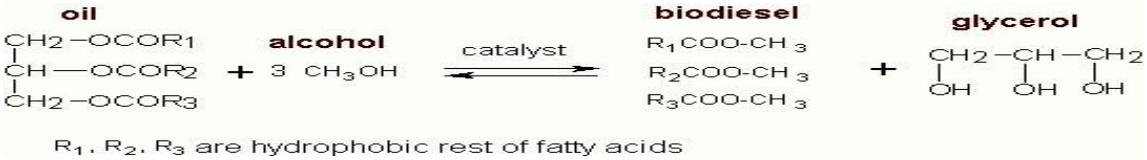
- Expeller Method or Mechanical Disruption: Pressing and Bead Milling which is commonly known as mechanical disruption. By this system micro-algal biomass like seeds or nuts are subjecting to high pressure or

pressing and it results the breaking of cell walls and finally it release the oil [21]. Bead milling is generally used in conjunction with solvents to recover oil, and is most effective and economical when cell concentrations are significant and when extracted products are easily separated after disruption [22]. Combination of mechanical pressing and chemical solvents in extracting oil is used by many commercial manufacturers of vegetable oil [23].

- Hexane Extraction: Inside the single cell of algae oil is trapped by the plasma membrane (cell wall). But degeneration of plasma membrane occurs when the algae cell becomes dry and it reduces the ability to retain oil. If hexane (an organic solvent) is mixed with those dried sample, the hexane penetrated through the cell wall and oil within the cell is dissolved. Then the hexane is removed from the algae sample and oil dissolving with hexane also transported outside of the cell. By distillation, hexane and oil are separated [21]. This system is more effective when it is used along with 'expeller method'. After oil has been extracted by expeller method the remaining pulp can be extracted by hexane extraction method and more than 95% oil of algae cells can be extracted by the combination of expeller and hexane extraction method [23].

III. Synthesis Of Biodiesel

The method which is used for converting the oil extracted from algae cells to biodiesel is termed as Trans-esterification also called alcoholysis. It converts the oil into biodiesel in presence of a catalyst. Degummed oil free of all forms of impurities is reacted with a reasonable alcohol (ethanol, methanol, butanol etc.)[24]. The reaction can be represented as:



Parameters named Temperature, Reaction time and Ratio of oil to alcohol have effects on the trans-esterification reaction [25]. Entropy change will tend to zero as both reactants and products of the reaction are liquid [26]. From thermodynamic parameters the feasibility of reaction can be fixed.

IV. Scenario Of Biodiesel Production In Developed Countries

There is growing interest in biofuels in many developed countries as a means of "modernizing" biomass use and providing greater access to clean liquid fuels while helping to address energy costs, energy security and global warming concerns associated with petroleum fuels. This paper overviews the condition of biodiesel production from algae in China, Malaysia and India for analysing the prospect of biodiesel in a developing county, Bangladesh.

4.1 Condition of China

- Since 2005, China started its algae based energy production. Intensive research works on many algae based oil extraction projects were conducted by their universities as well as research institute.
- Among them 'Ocean University of China' and 'Tsinghua University' works on microalgal oil production, 'Dalian Institute of Chemical Physics' works with microalgal hydrogen production [27].
- 'The 'Qingdao Institute for Bioenergy' developed a 'Bioenergy Infrastructure' with 200 researchers and they carried intensive research on microalgal biodiesel [28].
- ENN Group Corporation Ltd.' developed a technology which fix carbon dioxide and produce biofuel through photo-bioreactor systems [27] and a binding MOU was signed between the famous multinational Australian company 'Algae Tec Ltd.' and Chinese company 'Shandong Kerui Group Holding Ltd.' for constructing a 250 module algae biofuels facility in China [29].
- In 2008, marine microalgae bioenergy projects have been established in Shenzhen, Guangdong where diatoms are cultivated and harvested for biodiesel production [27].
- By 2020, to ensure 15% of total transportation fuels from biofuels China have started lot of alternative fuels campaign [30].

4.2 Condition of Malaysia

- In 2005, the National Biofuel Policy was adopted by the Malaysian Palm Oil Board to reduce dependency on fossil fuels, to exploit local technology for biofuel production, to mobilize local resources for biofuels and to mitigate climate change by reducing greenhouse gas emissions [31].
- In Pahang state of Malaysia, the world's largest microalgae farm is taking shape [32]. Malaysian Algae Valley will step up output in three phases and costing is approximately 383 million USD.

ꕤ Hundreds of open-air freshwater ponds will be constructed covering an area of about 1,400 hectares, with the rest of the land used for infrastructure, including a research and education center. When completed, the farm could produce about 500,000 tons of dry biomass a year, with an oil yield of about 30 percent, equivalent to 150,000 tons of biofuel per year [32].

4.3 Condition of India

India is the world's fifth largest primary energy consumer and fourth largest petroleum consumer after United States, China and Japan. With an outlook for moderate to strong economic growth and a rising population, growing infrastructural and socio-economic development will stimulate an increase in energy consumption across all major sectors of the Indian economy.

- India's biofuel policy was prepared to (I) Strengthen India's energy security by encouraging use of renewable energy resources to supplement transport fuels. (II) Meet the energy needs of India's vast rural population, stimulating rural development and creating employment opportunities. (III) Derive biofuel from inedible feedstock grown on degraded soils or wastelands unsuited to food or feed production, thus avoiding a possible conflict of fuel- versus food security. (IV) Biofuel technologies and projects would be allowed 100-percent foreign equity through an automatic approval route to attract foreign direct investment (FDI), provided the biofuel is for domestic use only, and not for export [33].
- A National Algae Biofuel Network has been launched by the Centre in 2008-09 with the participation of 12 national laboratories/institutions/universities to work on algae biofuel focusing on the aspects like: (i) collection and characterization of algal strains from different ecological niches and deposition of the same in 3 repositories. (ii) Development of different production systems; improved algal strains for more oil/ lipid content and lastly. (iii) Design development and fabrication of low cost and pilot scale bio-reactors for cultivation of algae for biofuels and technology [34].
- This may call for an investment of around Rs 3,000 crores over a period of 5 years and around 500 dedicated scientists and engineers at different levels to achieve the objectives within the targeted period [34].
- B100 biodiesel was successfully developed by scientists in a salt farm in Bhavnagar. It was developed under an ambitious project 'New Millennium India Technology Leadership Initiative' (NMITLI) to bring out a viable and scalable process of biofuel from microalgae, initiated in April 2010 by the Council of Scientific and Industrial Research (CSIR) and the ministry of earth sciences (MoES) [35].
- World Health Energy Holdings has signed a letter of intent with Prime, an Indian industrial and transport company, to build a biodiesel production facility on a budget of $100 million. The proposed areas for the development are in Tamil Nadu and Karnataka, India and once built the facility will use 'algae enhancement technology', to grow algae for the production of biofuel [36].
- Various universities and research institutes like University of Madras, Centre for Advanced Studies in Botany undertaking research on algae fuel.
- Rengasamy and his team from University of Madras have successfully cultivated Botryococcus braunii in open raceway pond without any contamination. Major focus of this research group is on marine algae for biofuels, CO_2 cycling, production of value added products from algae [23].
- Ravishankar and his team from Plant Cell Biotechnology Department are carrying out extensive work on isolation and characterization of hydrocarbon producing micro alga Botryococcus braunii from Indian waters [23].

V. Present And Future Condition Of Biofuel In Bangladesh

The high cost of petroleum products, low coverage of the electricity grid, gasification and increasing scarcity of traditional fuel woods due to deforestation, created an energy deficit situation in rural Bangladesh. Environmental experts predicted massive deforestation if crisis is not being met from alternative source. Gas and electricity coverage cannot expand appreciably as both are in crisis now and need injection of huge capital [37]. A recent survey reveals that power outages result in a loss of industrial output worth US$1 billion a year which reduces the GDP growth by about half percentage point in Bangladesh. Renewable and environmentally friendly energy sources have therefore become crucial for defining economic and social sustainability of the country. Renewable energy sources including biomass, hydropower, solar, wind and tidal energy need to be built up and exploited [38].But biodiesel and bioethanol are still in their infancy in Bangladesh, although their future is promising. Algae are considered to belong to the third generation of biofuel feedstock in Bangladesh [38].

Accurate data is unavailable about oil-bearing plant families and their production and utilization in Bangladesh. Of course of those exploitation of which does not usually confront food security. Jatropha, Mahua and Pongamia plant are main candidates for biodiesel production in Bangladesh. During 2009, working in a project in Plant Biotechnology Division, Bangladesh Atomic Energy Commission, Jatropha and cassava were planted for a future biodiesel project. But there was no progress of this project due to lack of proper policy and

sufficient fund. In Bangladesh Khwaja Agri-Horticultural Research Centre (KAHRC) is the first organization to produce bio-diesel from Jatropha seeds at the Bangladesh Ansar and VDP Academy, Gazipur. Bangladesh environmental condition is favorable for Jatropha plantation as it can grow in dry subtropical region to tropical rain forest. Other energy crops and cellulosic crops may also be used for biodiesel production [38].

At present there is actually no working projects running in Bangladesh for producing biofuels. But in future some initiatives should be taken care of. According to Energy-Bangla, Japanese industrial giant Honda Denki Co. Ltd has expressed its interest to invest up to US$1 billion in Bangladesh's green power, biofuels and sugar sectors [39]. Bangladesh is a developing nation with an ever-growing need for energy.

Presently, Bangladesh has an annual demand for fuel of around 37 lac tons, including 24 lac tons of diesel and imports the entire amount from Kuwait, Saudi Arabia, United Arab Emirates and India [37]. In search of bio fuel energy resources, Bangladesh have potential in alternative fuel energy resources from algae, as well although unlike Jatropha bio fuel, algae still needs more research. Bangladesh can set up small or medium size biodiesel industry vis-a-vis increasing demand for energy and sufferings due to shortage of crude oil as well as heavy dependence on imported oil for its economic and social development. It is believed that with the modification of relevant laws and regulations, and close co-operation among scientific researchers, institutes, and enterprises, advanced technologies would be put into large scale application in the near future. Advanced technologies are imperative for both sustainable development and environmental protection [38].

Some recommendations are made after analysing the all developed county's scenarios and taken steps regarding algal biodiesel. The recommendations for Bangladesh are:

- Bangladesh needs to develop a national algal research center.
- Bangladesh has to develop the molecular tools to make algae a biotechnological platform.
- Petroleum and Refining Industries should use algal farm to serve as GHGs mitigation option, since algae require huge amount of CO_2 to grow.
- It has to develop strains of algae for economic biofuel production.
- The whole water source of the country should be used to collect algae for producing biodiesel & it will be really a sustainable & cheaper way.
- All technical universities and research institutes should be active in researching of algal biodiesel.
- Bangladesh must try to learn lessons from developed world for bio fuel and specially bio diesel production. Bangladesh may try to acquire technology which may produce food, fuel and chemicals from biomass.
- We need fuel for economic growth but we need food for living. We cannot let our agricultural land get squeezed for growing crops for generating bio fuels. We must strike some balance.

VI. Conclusion

In industrial growth and in provision of required services energy is an essential factor that improves the quality of life of mankind. Energy derives from many sources but it is necessary to identify an environment friendly and feasible source. This paper identifies overview of production of biodiesel from micro algae which is termed as 'algal biodiesel', at some developed countries like China, Malaysia and India. As micro algal biodiesel is technically feasible, it is the only renewable biodiesel that can potentially completely displace liquid fuels derived from petroleum. To make it competitive with petrodiesel, economics of producing microalgal biodiesel need to improve substantially. Micro algal farming can mitigate CO_2 gas as well as it is potential in waste water treatment. Freshwater shortage can be mitigated by marine micro algal species utilization as they use sea water as a medium. Among all sources of biodiesel, algae are more feasible and eco friendly but still it is debatable issue for its high cost. But to minimise the cost of algal biodiesel production lot of research is ongoing throughout the world and Bangladesh can introduce it with successfully. Bio-refinery concept and photo-bioreactor engineering can lower the cost and tubular photo-bioreactors are likely to be used in producing much of the microalgal biomass required for making biodiesel. The global oil productivity is declining but demand for oil increasing enormously in all developing countries including Bangladesh also. The current strain on petroleum supply increases its price and at that case biofuels can emerge as a supplement in Bangladesh which can be readily introduced into the existing transportation infrastructure.

Bangladesh placed 1st in the vulnerability list of global climate change, that's why like all other developed countries Bangladesh also have to move towards environment friendly biodiesel for meeting the increasing demand of fuel. Biofuels can reduce the net life cycle of green house gas as compared with other petroleum alternatives. To keep active and increase the speed of production of industries and save the environment simultaneously, Bangladesh has to take rapid initiative for introducing those eco-friendly technologies in the sector of fuel production. Algal biodiesel can ensure a pollution free and safe environment as well as can meet the demand of fuel in the midst of present crisis of fuel. Some recommendations focusing on more intensive research and investigation regarding algal biodiesel are made based on other developed countries scenario. Through those recommendations 'algal biodiesel' can be an effective and efficient energy source for upcoming decade at Bangladesh.

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