Biodiesel from Microalgae as a solution of third world energy crisis

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Abstract: The world is heading towards the crisis of petro fuel. The excessive use of petrofuel is causing global warming. Now it is high time to search for alternative fuel source that will be environment friendly. The crisis for energy is more acute in Bangladesh, as there is no petrofuel source but only natural gas, the reserve has also dropped down to an alarming level. Again the global warming is threatening Bangladesh to be climate change victim. So there is no alternative for Bangladesh rather than renewable energy sources. Biofuel from microalgae can be a solution of this problem. Oil from the algae lipid can be turned into biodegradable and carbon neutral Biodiesel. Use of this diesel can reduce air pollution at remarkable level. This study focuses on algae cultivation in Bangladesh. A lab scale production of *Chlorella* and B*otroyococcus braunii* was executed in open pond and bioreactor system. Then diesel was produced by transesterification from collected algae oil. Later data was collected from this experiment. Cost analysis was prepared to get a clear concept of the actual scenario of algae fuel probability. This study indicates high potentiality of algae based fuel to be used in Bangladesh replacing diesel for energy production. It can be a model for any third world country to mitigate the energy crisis with a greener solution.

Keywords: *Transesterification, Biofuel, Microalgae ,Lipid*

1. Introduction

Our world is heading towards a severe dilemma of petrofuel usage for the next decades. The price of petrofuel is hiking up rapidly. On the other hand, the supply of fossil fuel will come to an end by 2050 considering a 5% flat increase in demand. Even though, if we can get, we cannot use those because excessive use of fossil fuel causes CO_2 increase in atmosphere and we are already facing tremendous effect of this, vicious change of climate. With the rapid growth of technology and civilization spreading over the world, from 1955 to 2005 the emission of CO_2 at atmosphere simply got twice from 3 billion tons of Carbon to 6 billion tons of Carbon, which certainly results in temperature increase, sea level hike, deviation of biodiversity and ecological imbalance. Most of the CO_2 emission is caused by USA, China and EU countries, but the high risked counties of the impact of this phenomenon are underdeveloped countries like Bangladesh, where Bangladesh causes less than 0.1 tons of Carbon emission/Person compared to almost 6 tons of Carbon emission/Person of USA. The production of natural gas is 100% domestic and the oil supply totally depends on import in Bangladesh. Major of 1961 MMCFD gas produced locally is consumed for power generation and rapidly growing industries. 96.7% of its 5271 MW power generation depends upon fossil fuels. The requirement of natural gas in Bangladesh is 1.5 times higher than the actual production.

Biodiesel can be a strong and ultimate solution to overcome this problem for Bangladesh. This carbon neutral fuel stops CO_2 increase rate in atmosphere and lowers pressure on fossil fuel. Microalgae are one of the sources of biodiesel that can be a major source of energy for future rather than Soya bean and Sugarcane. Microalgae are rich in lipid which can be used for producing Biodiesel.

The paper studies the probability of algae oil as an alternative of fossil fuel in Bangladesh. In particular, different species of algae were investigated for cultivation in different suitable process, diesel was produced from algae lipid by transesterification, their fuel and chemical properties were analyzed. Also we analyzed data for productivity, practicality and potentiality to gain a cost benefit analysis for the commercialization of algae oil production in Bangladesh perspective.

2. Methodology

2.1. Potentiality of microalgae biodiesel in Bangladesh

The amount of diesel run Power plant in Bangladesh is 4% of its Total 5271 MW generation. to replace this by biodiesel of different sources, the amount of land required is shown in Table-1. From the table we can see, microalgae give us highest amount of oil. If we go for harvesting other oilseeds like soyabean, mustard oil and others these will occupy almost 30% of our available land for harvesting. Suppose, to get biodiesel from mustard oil it will require 1.28 M Ha land which is 3.6 times of the available land for mustard oil seed being harvested at present. So, this type of biodiesel production will create an immense pressure on the land available for harvesting in Bangladesh to mitigate its food crop demand.

Table 1: Comparison of sources of Biodiesel in Bangladesh for diesel supply of 230 MW power generations:

Crop	Percentage of Oil %	Oil yield (L/Ha)	Land required (Million Hectare)	Land at present (Million Hectare)
Mustard Oil	39-44	91.5	1.28	0.35
Ground Nut	48-50	156.0	0.75	0.087
Sesame	42-44	55.2	2.13	0.076
Soyabean	19-20	52.0	2.26	0.530
Sunflower	42-44	91.0	1.25	0.042
Microalgae	70	136900	0.00086	-
Microalgae	50	58700	0.002	

Source: Bangladesh Oilseed Harvesting Instruction, DAE and FAO/UNDP Project

This scarcity can be mitigated dramatically if we think of microalgae. These can contain up to 70% of their weight as lipid oil and the oil yield per Hectare is extremely high compared to other oil sources. Oil content of microalgae varies according to the species but most of them contain enough lipid oil to produce biodiesel from it. From Table -2 we can get an idea of the lipid oil content of different microalgae. Again microalgae grow almost twice in amount in every 24 hour in Bangladesh climate. So, thinking microalgae as a source of alternative fuel for Bangladesh can mitigate its continuous fuel crisis.

Table 2: Oil contents of microalgae species:

Microalgae species	Oil content(% of Dry Mass)
Botroyococcus braunii	25-75
Chlorella sp.	28-32
Crypthecodinium cohnii	20
Cilindrotheca sp.	16-37

Source: (Chisti, 2007; Mathew, 2008)

Producing microalgae in an expensive method compared to general crop production. The basic requirements for microalgae production are light, CO_2, water and nutrients. Nutrients include Nitrogen (N), Phosphorus (P), Iron and Silicon. These growth nutrients are relatively less expensive. The Carbon that is contained in dry Biomass of algae (almost 50% of total weight) is collected from atmosphere by the following reaction:

$$6CO_2 + H_2O \longrightarrow C_6H_{12}O_6+6O_2+6H_20$$

Producing 1 Ton of algae biomass requires 1.83 ton of CO_2. It can be incorporated with the power plant flue gas. This will reduce air pollution and also will minimize the cost of the algae production. Thus the algae production is carbon neutral, can retain the amount of carbon from the atmosphere.

The water required for microalgae can be used from any source, even the wastewater from our industrial or domestic use. The waste water already contains N or P for algae. Thus this can minimize the production cost as well as mitigates the environment pollution.

Adequate light is another requirement for high rate of Microalgae production. Throughout the year, except some cloudy days in rainy season, sunlight is quite sufficient in Bangladesh for microalgae production.

Space is another requirement for algae production which is largely available in Bangladesh. At present there are 0.73 million Hectare of (Table-3) land those are not suitable for any crop production and instantly can be used for algae production. Also the saline lands can be used for algae production.

Table 3: Type of land in Bangladesh

Type of Land	Amount (Million Hectare)
Dry land	0.73
Ponds	0.31
Low marshy land	3.16
Coastal saline land	0.218

Source: 1. DAE and Agriculture Ministry, 2004 2.Fisheries Department, 2007

The only two practical methods that we have applied for microalgae production in lab is raceway pond and photo bioreactor. We have produced *Chlorella* and *Botroyococcus braunii* in natural environment of Bangladesh to expedite our experiment.

2.2. Raceway Pond

It is made of closed loop water channel. The material may be anything like concrete, plastic or compacted earth with a paddlewheel for proper mixing and circulation of water. During daylight, the culture must be fed in front of the paddlewheel. CO_2 generally collected from the environment, but for better production rate CO_2 can be circulated against the flow of water for the photo biosynthesis. Temperature control of the water totally depends on nature by evaporation. For better production temperature must be maintained from 20^o C to 30^o C.

Figure1: Raceway pond setup

Figure2: Raceway pond setup (Top view)

In our experiment we constructed a low cost raceway pond system. The base body was constructed with 3 inch radius PVC pipe, bends are PVC bends jointed to liner section of pipes together. We put a simple paddlewheel electrically operated for circulation of water. The total amount of water contained in the raceway is 1.5 ft^3. Nutrients are fed into the pond at regular interval manually.CO_2 is naturally taken from air. The setup was successful to produce algae at a satisfactory level.

2.3. Photobioreactor

Tubular photobioreactor consists of solar collectors, where algae collect energy from the Sun. (Figure 3)

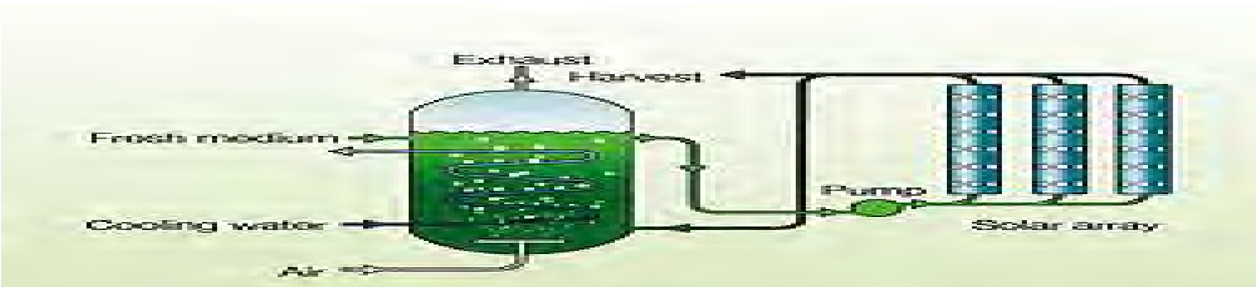

Figure 3: Conventinal PhotoBioreactor

This is generally made of plastic or glass. Tube diameter is limited to maintain proper penetration of sunlight. From the feeding vessel the flow progresses through a mechanical or diaphragm pump. Algae are collected from the vessel. The remaining algae pass through the closed loop. The solar collectors are oriented parallel to each other and flat above the ground to maximize the sunlight availability. The ground may be white painted or Alu foils may be used to maximize the sunlight capture. Biomass sedimentation can be prevented by using mechanical pump, airlift pump, diaphragm pump or peristaltic pump. To minimize higher concentration of O_2, at feeding vessel air is purged through the bottom. The cooling of the system can be maintained by heat exchanger at the feeding vessel.

Figure 4 and 5 shows the setup of low cost photobioreactor that we made at our Lab. Each of the three solar collectors is 9 inch long and diameter is 1.5 inch. Unit capacity is 0.0276ft^3 .Surface area is 0.88 ft^2 . The solar collectors are made of plastic tubes. The feeding vessel is 2 L HDP container. A small scale peristaltic pump is used for flow turbulence .There are three tubes fed into the feeding vessel, outlet and inlet from solar collectors and other for supplying air and CO_2 at the bottom of the vessel.

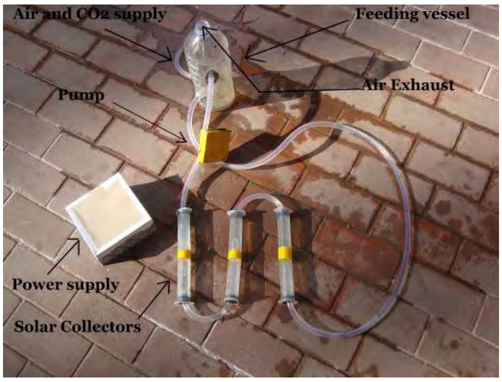

Figure 4: Details of PBR set up

Figure 5: Side view of PBR set up

2.4. Biodiesel Production

We collected set samples of Algae *(Chlorella 30 gm* and *Botroyococcus braunii 28 gm)* from and carried out the experiment at Chemistry Lab, Islamic University Of technology (IUT), Dhaka. Algae were ground by hand motor and pestle. The oil was extracted from the dry mass by drying the algae for 30 Minutes in 80^{o}C. Ether solution and Hexane was mixed to algae and the mixture was kept 24 hours for settling. Then by filtration the biomass was collected and oil was evaporated. A mixture of NaOH (0.25 gm) and 25 ml methanol was poured into a conical flask with the algae oil. The process than converts the algae oil into Biodiesel is called transesterification. It requires 3 mol of alcohol for each mole of triglyceride to produce 1 mol of glycerol and 3 mol of methyl esters. The conical flask is shaken for 4 hours at electric shakers.

$$\begin{array}{lcl} CH_2\text{-}OCOCR_1 & & CH_2\text{-}OH \quad\quad R_1\text{-}COOCH_3 \\ | & & | \\ CH\text{-}OCOCR_2 \quad + 3CH_3OH & \rightleftharpoons & CH\text{-}OH \quad\quad + \quad R_2\text{-}COOCH_3 \\ | & & | \\ CH_2\text{-}OCOCR_3 & & CH_2\text{-}OH \quad\quad R_3\text{-}COOCH_3 \end{array}$$

Triglyceride Methanol Glycerol Methyl Ester (Biodiesel)

After this reaction the solution was given time in idle for 20 Hours to settle the sediment layer to pour out the biodiesel. Then it is washed by 5% Water and dried under fan for 18 hours.

3. Results ad Discussions

3.1. Comparison between Raceway pond and Photobioreactor system lab experiment

Considering the productivity both by volume and area our experimental algae production from the PBR and raceway pond shows that (table 4), raceway pond system's productivity is lower than the PBR productivity by 11 times. But CO_2 consumption for both systems is almost same. It is possible to obtain more oil/ Hectare from PBR system rather than raceway pond. As the biomass concentration is higher in PBR (21.97 times), so we can extract more biomass in the same time from PBR and less from Raceway pond.

Table 4: Lab experiment result of algae production scaled up to 100000 kg production:

Parameters	Raceway Pond	Photobioreactor
Annual biomass production(kg)	100000	100000
Volumetric productivity($kgm^{-3}d^{-1}$)	0.103	1.1
Areal Productivity($kgm^{-2}d^{-1}$)	0.029	0.034
Biomass concentration(kgm^{-3} d^{-1})	0.137	3.01
Dilution Rate(per day)	0.22	0.275
Oil yield(L/H)	99400	136900
Annual CO_2 consumption(Kg)	183300	183300

3.2. Comparison of Oil extracted from Chlorella and Botroyococcus braunii

Table 5: Measurement of gross and dry weight, extracted oil and biomass of algae:

Specimens	Gross wt(g)	Dry Weight(g)	Oil(g)	Biomass(g)
Chlorella	30	9	1.86	4.05
		30%	6.2%	45%
Botroyococcus braunii	28	12.6	7.56	5.29
		45%	27%	41.9%

Source: Author's Lab Experiment

Percentage of dry weight algae is higher in *Botroyoccus braunii* than in *Chlorella* (Table -5). Oil extracted from *Botroyoccus braunii* also at higher percentage rate as we found in table 2. After extraction Biomass was found lower in *Botroyoccus braunii* than *Chlorella*

3.3. Properties of Microalgae Biodiesel over Diesel

Table 6:

Properties	[1]Microalgae Biodiesel	[2]Diesel
Density	0.864kg/L	0.838Kg/L
Viscosity	5 $x10^{-4}$ Pa s at $40^{o}C$	1.9 x 10^{-4} Pa s at $40^{o}C$
Flash Point	$75^{o}C$	75 ^{o} C
Heating value	0.35 MJ kg^{-1}	0.5 MJ kg^{-1}

Source: 1.Author's Lab experiment 2.PetroBangla Ltd

3.4. Cost Analysis of a project to run the 480 KW diesel generator of IUT (Islamic University of Technology, Dhaka) with biodiesel:

*Required diesel per hour at full load=120 L
*Total diesel required for 171 working days@ 6 hours time= 171 x 120 x 6=123120 L
*Total biodiesel B20 (20% Biodeisel-80 % Petrodiesel) = 24624 L=21275 Kg (table 6)
*Algae production required/day at 70 % oil Content=30390 Kg/year
*CO_2 produced by generator =278 Ton, CO_2 is fed into the algae production.
*CO_2 Consumed /year by the algae=30390 x 1.83 kg =55613.7 kg =55.6137 Ton
*Daily production required =83 Kg of Algae

*Required land=3000 Sqm at raceway pond system, productivity rate 0.103 kg/m^3/day and raceway depth 0.3 m.Total land with open spaces between the ponds=6000 Sqm.
*At a rate 560 Taka/Sqm (pipe, bends, cement, adhesive, paddlewheel, motor and other materials, labor and electricity) the total cost (fixed and variable) for 6000 Sqm stands =3360000 Taka=46666 USD. 1 Liter Oil price= (46666/24624) USD=1.88 USD

The cost for per Liter micro algae oil goes up to 136 taka or 1.88 USD at our project. The price is higher than diesel price (55 taka/L). The price can be reduced by attaining better efficiency and algae concentration in production. Also the pricing of microalgae oil can be bring in a relation with the crude oil price, so that it can be affordable to the limit of diesel price:
$C_{algae\ oil}=6.9 \times 10^{-3}\ C_{petroleum}$

4. Conclusion

As discussed here, we see that, microalgae oil is technically compatible like diesel. From Table -6 we find the properties are quite similar to diesel properties. So, similar engines or machines can be driven by microalgae oil instead of diesel .From Table-4, a comparative statement of both raceway pond and PBR is clear to us and surely this will encourage us for more diversified research on PBR in Bangladesh. From table-5, we understand which species of microalgae should be emphasized for biodiesel production at lower cost and higher efficiency. From earlier discussions it is clear that Bangladesh has a huge potentiality to produce microalgae as we still have available land and cheap labor for this. Both raceway pond and photobioreactor is possible in Bangladesh, but raceway pond can be introduced by mass level people in villages as the cost is lower and a huge supply of microalgae can be made available from this source and thus a revolution in energy sector can be ignited. Now we are working to find out the suitable, efficient and cost effective way for replacing the diesel that is being used in national energy production by scaling up the pilot work of microalgae oil use in IUT power generation. The most challenging part of this will be to reduce the price as lower as diesel or. Extensive researches need to be carried out for this work. Thinking of a better and greener Bangladesh, we must now rush towards this research more deeply and establish microalgae oil as a substitute of conventional diesel. This research can be implemented for third world countries to produce large scale microalgae oil and lessen the load from petrofuel.

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