GUJARAT TECHNOLOGICAL UNIVERSITY

Gujarat Technical University

LUKHDHIRJI ENGINEERING COLLEGE
MORBI

A Project Report
On

PRODUCTION OF BIOFUEL FROM ALGAE

B.E. Semester –VIII

(Chemical Engineering Department)

Submitted by

Sr.	**Name of student**	**Enrollment No.**
1.	Karan Gupta	130310105015
2.	Mehul Patel	130310105041
3.	Arjun Savania	130310105052
4.	Devarshi Tadvi	130310105057

Prof. A.D. Kalariya
(Faculty Guide)

Academic year
(2016-2017)

CERTIFICATE

CERTIFICATE

Date: _______

This is to certify that **Karan Gupta, Mehul Patel, Arjun Savania, Devarshi Tadvi** of B.E. Semester VIII (Chemical Engineering) has completed their work titled "PRODUCTION OF BIOFUEL FROM ALGAE" satisfactorily in partial fulfilment for requirement of course, Gujarat Technical University, Ahmedabad, in the academic year 2016-2017.

Prof. A.D. Kalariya
(Project Guide)

Prof. A.D. Kalariya
(Head of Department)

ACKNOWLEDGEMENT

As a part of our study for B.E. in Chemical engineering, final year at Lukhdhirji Engineering College, Morbi, we have undertaken a project on “Production of Bio-fuel from Algae”.

It gives me immense pleasure in submitting this project report at the end of 8^{th} semester. To show me deep sense of gratitude towards them, the word thanks is not satisfactorily, but I would like to thank them to express my gratitude in words.

I would like to present my heartiest thanks to the Prof. A.D. Kalariya, the Head of Department and the faculty guide in our project. I would also like to thank all other faculty members of Chemical department who have helped and guided us to give us broader understanding on the subject.

ABSTRACT

Now-a-days many researchers are performing various experiments on ways to substitute petrochemicals such as petrol and diesel. Till now, there is not even a single acceptable substitute for it. Researchers have come up with a partial substitute, i.e.: mixing alcohol (specifically ethanol) with petrochemicals up to a certain percentage. In this project, we aim to classify and find out a perfect, cheaper and easier way to produce ethanol from biodegradable wastes that is available plentiful in nature, like algae.

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CHAPTER-1: INTRODUCTION

1.1 Introduction: [1]

Biofuel is the name given to fuel for Diesel engines created by the chemical conversion of animal fats or vegetable oils. Pure vegetable oil works well as a fuel for Diesel engines itself, as Rudolf Diesel demonstrated in his engine at the 1900 world's fair with peanut oil as the fuel. The United State Fuelling stations make biodiesel readily available to consumers across Europe and increasingly in the USA and Canada. This is an indication that biodiesel can operates in compression ignition engines like petroleum diesel without requiring no essential engine modifications. Moreover it can maintain the payload capacity and range of conventional diesel unlike fossil diesel, pure biodiesel is bio-degradable, nontoxic and essentially free of sulphur and aromatics. This work involves the study of biofuel production from green micro algae.

In 1942 Harder and Von Witsch were the first to propose that microalgae be grown as a source of lipids for food or fuel. Following research began in the US, Germany, Japan, England, and France on culturing techniques and engineering systems for growing microalgae on larger scales, particularly species in the genus Chlorella. Meanwhile, H. G. Aach showed that Chlorella pyrenoidosa could be induced via nitrogen starvation to accumulate as much as 70% of its dry weight as lipids.

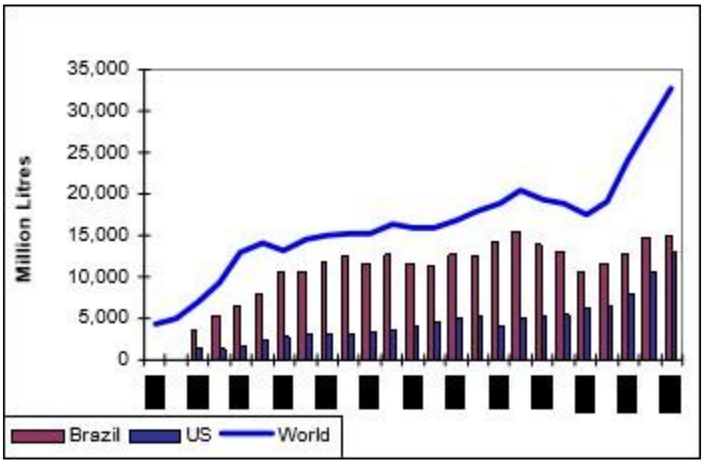

Fig. 1: Global biofuel production

Biofuel is by far the most widely used biofuel for transportation worldwide. Global production reached 33 million litres in 2013,

1.2 Aim of the Project:

To replace the conventional petrochemical fuels with biofuel as an alternate fuel.

1.3 Objective of the Project:

To make a cost effective fuel used in vehicles.
To make some type of fuel that cannot be extinguished.
To derive energy for a fuel from renewable resources whose frequency of availability is not fluctuating in nature due to natural or weather conditions.
To increase the efficiency of fuel used for automobile.
To reduce the carbon emission due to burning of fuel.
To reduce the presence of toxic substances in fuel and thereby causing a reduction a pollution level.

1.4 Brief literature review and Prior Art Search (PAS): [2]

Method for producing biodiesel:

Inventors: Christoph Benning, East Lansing, MI (US); J. Michael Younger, Holt, MI (US)

The present invention relates to the production of biodiesel. In particular, the present invention provides systems and methods for fermenting biomass materials with transgenic plant materials expressing the transcription factor. Accordingly, the present invention provides methods comprising first plant material from a plant comprising an exogenous lignocellulose plant material from a second plant. Contacting the first plant material with the lignocellulose plant material under conditions such that triacylglycerol's are produced by the first plant material. In some process, the first plant material is selected from the group consisting of canola, corn, soybean, and sunflower and safflower plant material. In further process, the first plant material is selected from the group consisting of seeds, leaves, germinated seeds, seedlings and combinations thereof. In some process, the lignocellulos plant material is selected from the group consisting of perennial grass, annual grass, perennial woody plants, and crop residue. Then lignocellulose plant material is treated to hydrolyse cellulose and hemi cellulose contained in the material. In some process, the lignocellulose material is treated by a method selected from the group consisting of chemical and enzymatic treatment. The WRI1 gene is at least 70% identical to SEQID NO: 1. The WRI1 gene is operably linked to a promoter selected from the group consisting of 35S CMV promoter, Universal Seed Promoter, 2S Seed Storage Protein Promoter, Crucifer in promoter, and vicilin promoter. The methods further comprise the step of extracting the triacylglycerol's from the first plant material. The methods further comprise the step of refining the triacylglycerol’s. In some method lignocellulose material is pre-treated prior to the chemical or enzymatic treatment.

1.5 Plan of Work: [3]

1.5.1 Possible ways to produce bio-fuel:

Most of the world's ethanol is produced by fermentation of crops (93%) with synthetic ethanol (7%) being produced by direct hydration of ethane.

The fermentation of plant material (for example, barley and rice) is the route by which alcoholic drinks (e.g. beer, whiskey, gin and vodka) are produced. It is also how bioethanol for biofuels is produced. Of the uses of bioethanol, easily the most important is as a fuel for cars but an increasing one is in the manufacture of ethane. The main uses of ethanol produced from ethane are as the chemical intermediate for:

glycol ethers
ethanolamine’s/ethylamine’s
ethyl propionate

It is also used as a solvent in the manufacture of cosmetics, pharmaceuticals, detergents, inks and coatings.

Recently, bioethanol has become an important, used to make many polymers.

Table 1: Comparison of some sources of biodiesel

Crop	Oil yield (L/ha)	Land area needed (M ha)
Corn	172	1540
Soybean	446	594
Canola	1190	223
Jatropha	1892	140
Coconut	2689	99
Oil palm	5950	45
Microalgae[(a)]	136,900	2
Microalgae[(b)]	58,700	4.5

(a) 70% oil (by wt.) in biomass. (b) 30% oil (by wt.) in biomass.

Due to saponification reactions (i.e. soap formation), the oil and alcohol must be dry and the oil should have a minimum of free fatty acids. Biodiesel is recovered by repeated washing with water to remove glycerol and methanol.

1.5.2 Advantages of Algae over crop-based Biofuels:

Algae produces up to 300 times more oil per acre than conventional food crops, such as palms, grape seed, soybeans, or Jatropha.
Algae has a harvesting cycle of 1–10 days, it allows several harvests in a very short time-frame, a differing strategy to yearly crops. Algae can grow 20 to 30 times faster than food crops.
Algae can be grown on land that is not suitable for other established crops, for example arid land, land with excessively saline soil or drought-stricken land.

Table 2: Oil content of different types of microalgae:

Microalgae	Oil content (% dry wt.)
Botryococcus braunii	25–75
Chlorella sp.	28–32
Crypthecodinium cohnii	20
Cylindrotheca sp.	16–37
Dunaliella primolecta	23
Isochrysis sp.	25–33
Monallanthus salina	20
Nannochloris sp.	20–35
Nannochloropsis sp.	31–68
Neochloris oleoabundans	35–54
Nitzschia sp.	45–47
Phaeodactylum tricornutum	20–30
Schizochytrium sp.	50–77
Tetraselmis sueica	15–23

1.5.3 Factors for selection of suitable type of algae for maximum biofuel production:

1.) High oil content.
2.) Easier growth of algae.

Hence, as per the selection factors, we have selected Chlorella type of algae for our project because of its special features and higher side of oil content which will be eventually useful to produce more amount of bio-fuel. It is a freshwater algae which is easily available in freshwater resources like rivers. It is rich with phytonutrients, including amino acids, chlorophyll, beta-carotene, potassium, phosphorous, biotin, magnesium and the B-complex vitamins.

1.6 Materials/Tools required [4]:

1.6.1 Water:

Algae cultures are very dilute, typically containing 0.02-0.06% ds. Harvesting 1 kg of algal biomass requires separating 2,000-5,000 kg of water. The amount of water consumed during algae production process depends on the type of production system employed. For example, open ponds are subject to evaporation, and, therefore, require more water than closed systems.

The amount of water lost due to evaporation can be estimated by the class A pan evaporation rate which, in Gujarat, is about 165 cm/yr. At this rate, a 600 ha (1,500 acre) open pond algae farm would require 23 million L/day (6 million gallons/day) of make-up water. Conversely, rainfall into open ponds can be unpredictable and can cause culture instability resulting in lost productivity. Closed, or covered, systems can avoid such significant water fluxes by reducing environmental influences, but may be prohibitive in terms of costs and energy consumption. Therefore, finding a reliable supply of water remains a challenge for a potential alga production facility.

1.6.2 Nutrients:

The minimum nutritional requirements for algae can be estimated based on the approximate molecular formula for microalgae biomass, CO-0.48, H-1.83, N-0.11, and P-0.01. Similar to land based crops; main nutrients required by algae to grow and are N-P-K (Nitrogen, Phosphorus, and Potassium). These elements come in the form of typical fertilizers such as urea, phosphate, potash, that once solubilized in water, are easily accessed by algae; which contributes to their fast growth rates compared to land based crops. Fertilizer nutrients represent a major cost for alga production facilities, estimated to be 30% of operating costs. Therefore, in order to compete economically as a fuel an algal biodiesel production facility must be located near a consistent supply of nutrients.

Municipal wastewater facilities have been suggested as a source for nutrients such as P, K, and N. One study showed that over 80% of nitrogen and 89% of phosphorus was removed from municipal wastewater by algae in only 14 days. Most MW locations, however, typically don't produce power, and thus may not have the required CO2 or energy availability for a potential algal biofuel production facility.

1.6.3 CO_2:

The concentration of CO_2 in air is 0.04%, which is too low to support high growth rates of algae required for biodiesel production. For each ton of alga produced, 1.83 tons of CO_2 are sequestered. In order to produce volumes consistent with transportation fuels, a concentrated source is required that can provide hundreds of metric tons of CO_2/day. Therefore, algae production naturally gravitates toward energy producing facilities. Combustion flue gasses such as those from natural gas or coal fired boilers generally contain between 12-15% CO_2 by volume. Biomass fired boilers have been shown to produce lower concentrations of compounds toxic to algae such as SOx and NOx.

1.6.4 Land:

Further assessment of locations where algal biodiesel production may be viable limits this technology to climates with average annual temperatures greater than 15^{o}C due to the low productivity of algae in cold environments. Ample rainfall and minimal evaporation are also key climate factors for algal biodiesel production.

Currently, commercial alga production facilities do not produce fuels, and instead focus on high-value products like food supplements or nutraceuticals, where they can be economically competitive. The largest algae production facility in operation in the US is Earthrise Nutraceuticals (earthrise.com) with 108 acres of open ponds that can produce about 500 tons/yr. of dried Spirulina biomass for human consumption. Comparatively, a commercial scale biodiesel production plant defined as at least 3.785 million L/yr. or 1 million gallons/yr., would require a facility roughly 1,500 acres - 14 times larger.

Table 3: India's Capacity of Algae for Open pond

Continental shelf	372, 424 sq. km
EEZ	2,103,415 sq. km
Coastline	7500 km
Total seaweed flora	841 species
Total standing stock	600,000 tons fresh wt.

1.7 Current Processing Technologies and Limitations: [5]

There are many different process options available to carry out the six main steps in the algal biodiesel production process. Figure shows the technologies that were considered for algal biodiesel production in this study. Technologies were evaluated based on their dewatering performance, productivity (scalability), and energy intensity.

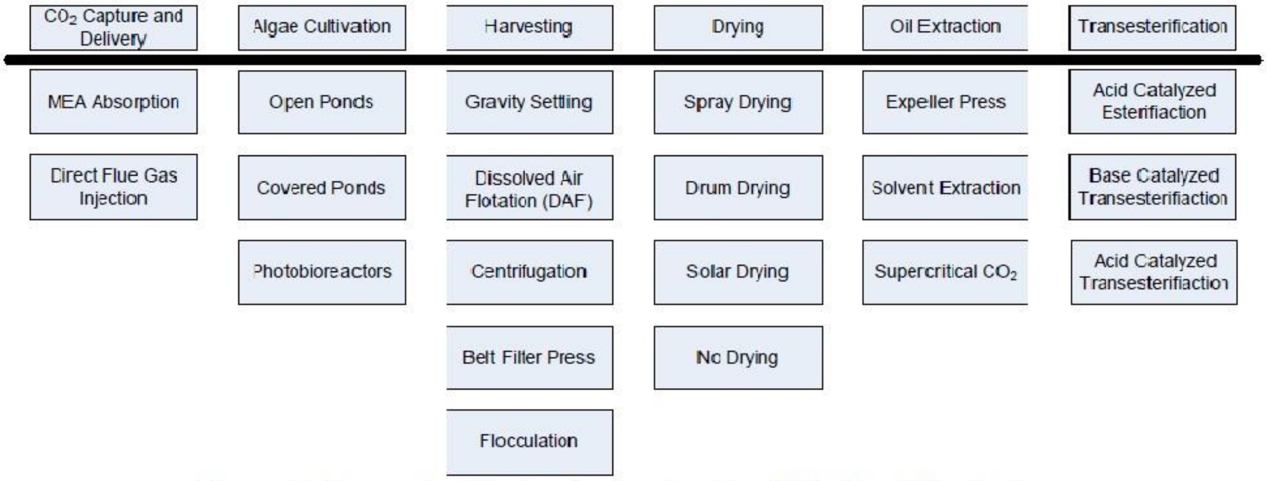

Figure 2. Processing Technologies for Algal Biodiesel Production.

The number of different options available for processing algae is vast and continues to grow almost daily. It follows that different processing scenarios will have different resource requirements. Many authors have published a wide range of estimates for the energy required and overall performance of numerous technologies. As is immediately apparent, drying consumes 2-3 times more energy than any other step. Depending on the technique used, drying alone can consume more energy than is contained in the algal oil. Estimates range from 45-90% of the energy required to produce algal oil is due to the drying requirement.

Estimates can vary by more than 100%, there is a general agreement that drying is a main bottleneck in the process, requiring many times the energy requirement of the other stages. The span between the studies is due to different assumptions used, and emphasizes the importance of geographical location (for access to resources), selection of the most efficient processing technologies depending on the available resources, particular species of algae being cultivated and desired end product.

CHAPTER 2: BUSINESS MODEL CANVAS

2.1 Key Partners:

2.1.1 Key Partners:

Businessmen
Government
Petroleum Companies like that Shell, IOCL, Reliance, and ESSAR

2.1.2 Key Suppliers:

Transportation agencies
Railways
Tankers

2.1.3 Key Resources acquired from partners:

Pure petrol
Pure diesel
Funding

2.1.4 Motivation for Partnerships:

Business in a very large scale

2.1.5 Key activities by partners:

Production for petroleum product and supplying it to petrol pump as well as to manufacture of biofuel
Investment

2.2 Key Activities:

Revenue streams- Recycling, Wastes, Government compensation, Tax benefits
Blending of biofuel with petroleum products
Distributed by tankers and by rail
Free customers service and assistance through helpline number
Production of ethanol by fermentation process
Maintaining appropriate, pressure and desire nutrients
Producing biofuel on a very large scale

2.3 Value Propositions:

Forming a management team for getting the job done
Advertisements
Newness
Performance
Lower cost
No engine modification
Free customer service
Automated services
Dedicated personal assistance
Lower exhaust emission
Sustainable fuel

2.4 Key Resources:

Proper and adequate amount of fermentation
Process like that extraction and distillation
Higher octane number and lower Cetane number for less exhaust emission
Complete blending with petrochemicals
Human resources: Management team, Supervisors, Labour

2.5 Cost Structure:

Value driven: Environment friendly
Fixed cost: Salaries, Rents, Utilities
Inherent important cost: Fixed capital for refineries and industries, establishing biofuel pump
Variable Cost: Petroleum prices
Expensive key resources: Manpower and skilled-labour, Pay role for administration
Expensive key activities: Collection of waste biodegradable raw materials from various places, cultivation of algae, Distillation process

2.6 Customer Relationships:

Type of relationship desired: Free customer services and assistance
Established relationship: Helpline number
Personal assistance: Cleaning of car glasses
Dedicated personal assistance: Free oil check
Automated services: Customers filling their tanks with biofuel only by scratching their credit card
Self-service: Pumping air in tyres

2.7 Channels:

Awareness through advertisements on T.V. and banners
Customers will purchase because of the benefits
Our value propositions will be delivered through petrol pumps
After sales support will be by customer helpline number and email id
Blending of petrol with biofuel is the most cost efficient

2.8 Revenue Streams:

Currently paying for the full price of petrol
Customers willing to pay for better fuel with lower cost
Currently paying by cash
Would prefer to pay by credit card
Real-time market price would be RS. 10 less as compared to that of petrol and diesel

2.9 Customer Segments:

Truck drivers
Taxi drivers
People owning car
People whose are using vehicles daily
Mass market: Automotive industry
Niche market: Petroleum industries
Segmented market: diesel and petrol markets
Diversified market: Diversification of petrol and diesel to biofuel

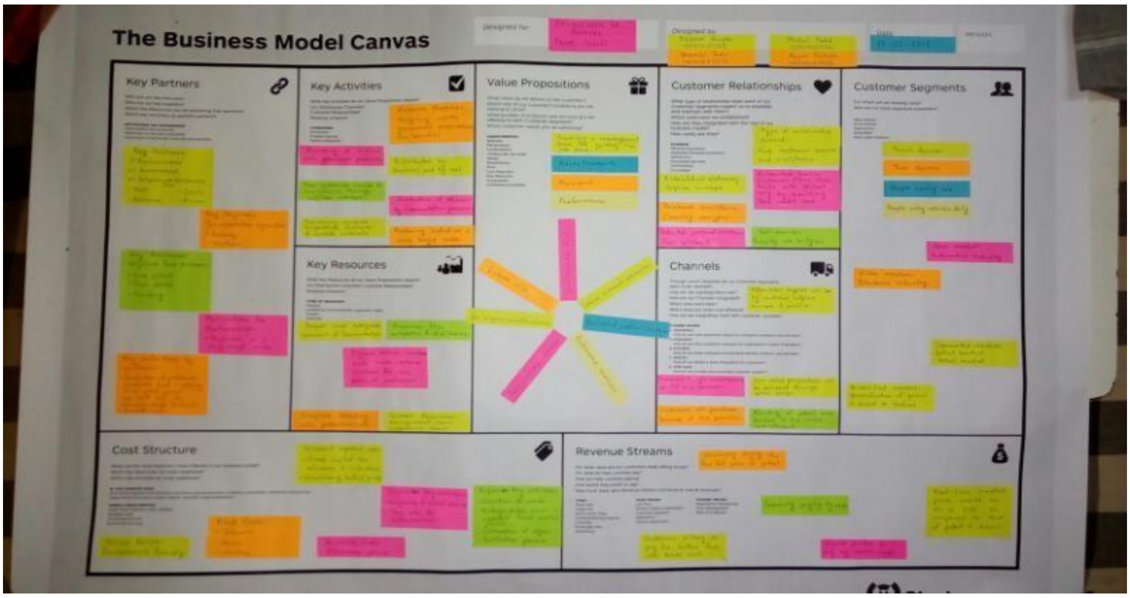

Fig. 3: Business Model Canvas

CHAPTER-3: IMPLEMENTATION

3.1 TYPES OF PROCESS:

3.1.1 Solvent extraction method [6]

The solvent extraction method recovers almost all the oil and leaves behind only 0.5% to 0.7% residual oil in the raw material. The solvent extraction method can be applied to any low oil content materials. It can also be used for pre-pressed oil cakes obtained from high oil content materials. Because of the high percentage of recovered oil, solvent extraction has become most popular method of extraction of oils and fats. The materials use are green algae, it was obtained from the open pond system and hexane.

Experimental setup:

The algae were obtained from the open pond system. It was dried by exposure to atmosphere. After drying, the algae were powdered. A 50 g sample of the dried algae was placed in the thimble of the Soxhlet apparatus. The thimble is made from thick filter paper, which is loaded in the main chamber of Soxhlet extractor. The Soxhlet extractor is placed onto a flask containing extraction solvent. The Soxhlet is than equipped with a condenser. The solvent is heated to reflux. The solvent hexane forms vapours, which travels up a distillation arm, and floods into the chamber housing the thimble of solid. The condenser ensures that any solvent vapour that cools drips down into the chamber housing the solid material. The chamber containing the solid material slowly fills with warm solvent. Some of the desired compound will then dissolve in the warm hexane. When the Soxhlet chamber is almost full, the chamber is automatically emptied by the siphon side arm, with hexane running back to the distillation flask. This cycle was repeated for varying time. During each cycle, a portion of the oil is dissolved in hexane. After many such cycles, desired oil was concentrated in the distillation flask. After extraction hexane was removed, yielding the extracted compound. The insoluble portion of the algae remains in the thimble. The same process was repeated but this time the open pond algae were 75% moist instead of complete dry. The same process was repeated but this time, the open pond algae were 50% moist instead of complete dry.

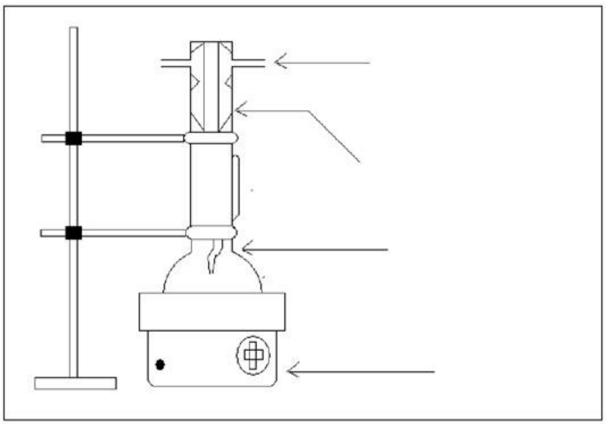

Fig. 4: Extraction of oil from algae by solvent extraction method (Soxhlet apparatus)

3.1.2 Oil expeller method [7]

The method is completely different than solvent extraction method. This is a mechanical method and made use of expeller to press the algae. Similar methods are screw expeller method, mechanical pressing method (by piston) and osmotic shock method. In the osmotic shock method the osmotic pressure is suddenly reduced. The raw materials are squeezed under high pressure in a single step. Expeller presses can recover 75% of the oil from algae. The alga was obtained from the open pond system. It was dried by exposure to atmosphere. In an expeller press, as the raw material is pressed, friction causes it to heat up; in some cases, the temperatures may exceed 50^0C.

The expeller is a screw type machine that presses oil seeds through a caged barrel like cavity. Algae entered the expeller press on one side of the press and products exit was on other side of the press. The machine used friction and continuous pressure from the screw drive to compress the filamentous algae. The algae were green in long strands like fibre. Initially, the algae did not move easily into the screw. Its surface had to be wetted with water for easy movement through the caged barrel. The oil seeps through small openings that do not allow the other components to seep through. Afterwards, the pressed algae almost form cake, was removed from the machine. Pressures involved in expeller pressing create heat in the range of 70-100^oC. Expeller processing cannot remove the last trace of oil from algae. A significant amount of oil was left in the cake formed. The cake formed was in large quantity. It was not subjected to solvent extraction, since the quantity of solvent required would have been much greater.

3.1.3 ASTM distillation [8]

This method is completely different from above method. This is a unit operation method which involves the simple distillation of the sample obtained from fermentation. In this test 100 ml of sample is distillate in a standard flask at a uniform rate of 5cc per minute. The distillate is condensed in a brass tube condenser, surrounded by a water bath kept at 0^oc by ice water mixture.

First drop from the condenser was available in 5-10 minutes after the heating started, at which the recorded temperature is maintained as initial boiling point of the sample. The vapour temperature is recorded at each successive 10cc distillate collected in a measuring cylinder. The test continues in the same way till 95% of fraction is condensed. At this juncture, the heat intensity may be increased to obtain the maximum boiling point, also known as end point. Fluctuation in temperature is common when last two or three ccs of sample are distilled. When the bottom of the flask shows dryness, the temperature recorded corresponds to boiling point. The distillate collected shall not be less than 98% and the difference is accounted as loss. This method is followed for most of the product specifications.

3.2 RESULTS OF EXPERIMENTAL SETUP:

Algae Oil Separation by Distillation Method

We are using the ASTM distillation method because of the following reason:
1) Hexane Solvent can be harmful because of chemical reactions.
2) In oil expeller method the extract that we get is low.
3) ASTM distillation is quite cheaper than the other two methods.

The algae were taken from the open pond system. It was put for the fermentation process around 45-60 days. Initially in a vessel about 1 kg of algae was taken from the open pond for the fermentation process and about 2L to 2.5L of water was added to it. Now the mixture was kept for fermentation for about 45-60 days and the fermentation was carried out in absence of oxygen (anaerobically). After 45-60 days, a 250 ml of fermented sample was taken out from the vessel. It was then taken for the distillation operation. The distillation operation was carried out in ASTM distillation equipment.

Fig. 5: ASTM Distillation Apparatus.

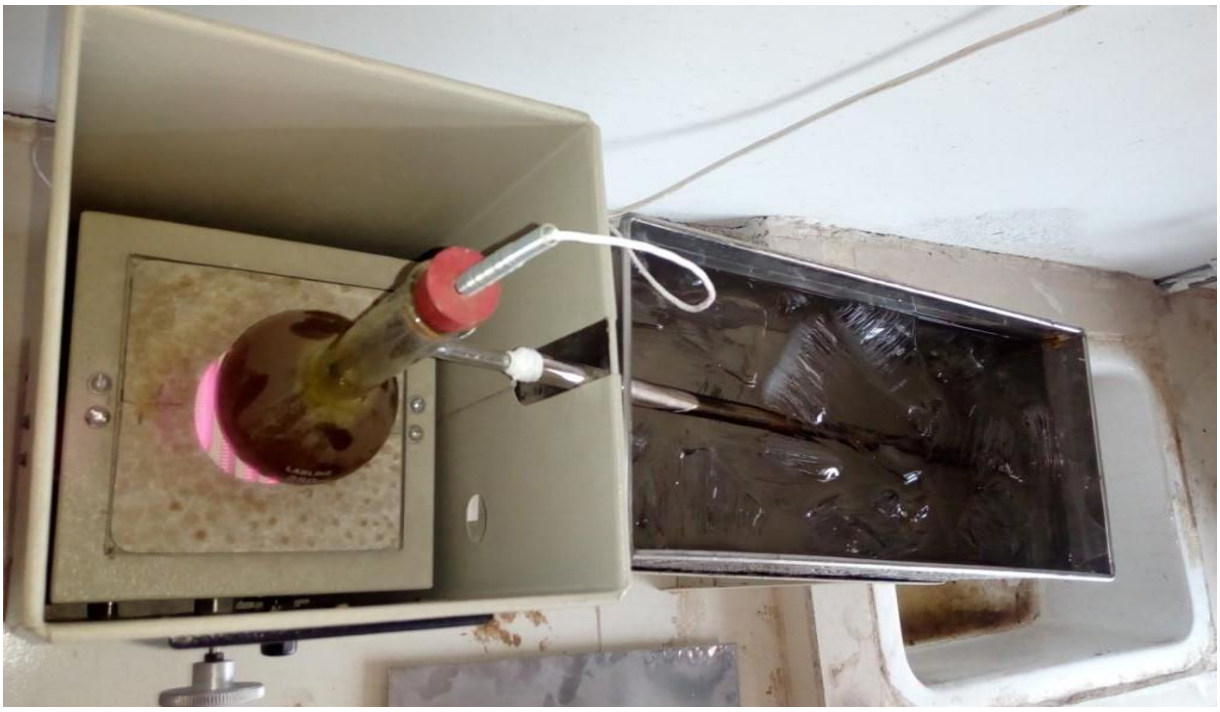

Fig. 6: Ice Tub of ASTM Distillation Apparatus.

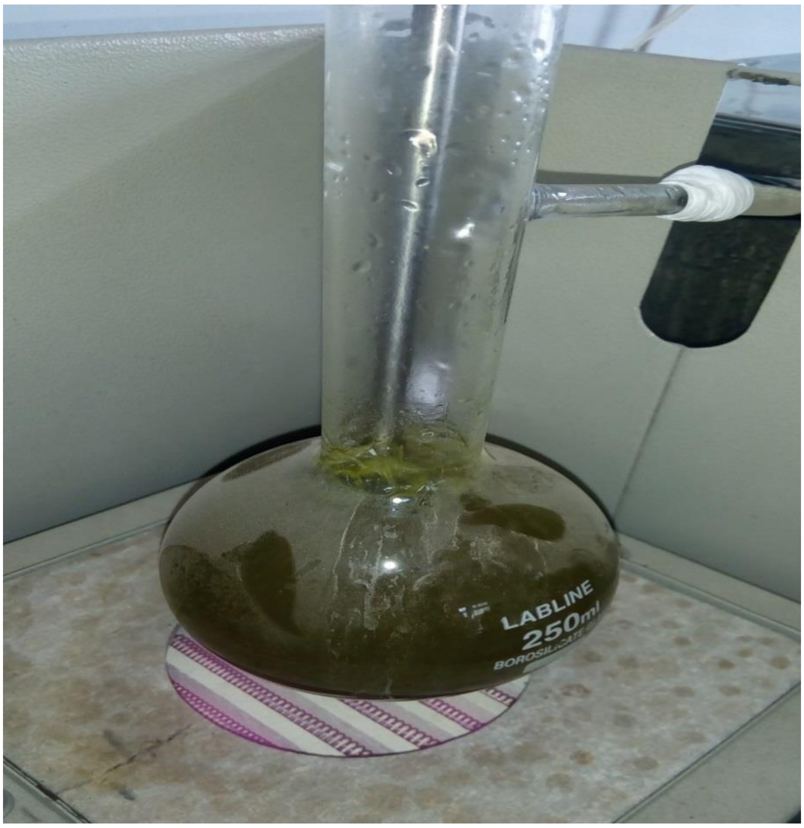

Fig. 7: 250 ml sample of algal oil.

Table 4: Observation data

Observation	Reading
Initial weight of dry algae	1 kg
Water added	1 L
Sample taken	250 ml
Weight of product	25-30 ml

3.3 REPORTS OF TESTING AND VERIFICATION:

Testing and verification done by: CENTER OF EXCELLENCE IN DRUG DISCOVERY, SAURASHTRA UNIVERSITY, RAJKOT

3.3.1 Details of Analysis method:

Instrument: Perkin Elmer Clarus 500 (GC-FID)

Turbomatrix 40 (HSGC)

Column: ZB-5 30m*0.25mm*0.25um

Oven Program

Initial Temp: 40°C Hold 3.00 min

Ramp: 20 °C /min to 120°C holds for 5.00 min

Total run time: 12 min

Split ratio: 20:1
Detector: 160°C

Injector temperature: 150°C
Carrier Gas: N_2

Head Space condition

Oven: 80°C Needle:
85°C Transfer Line:
90°C Thermostat:
30 min

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Sample Number	:	002	Study	:	L.E.College
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Instrument Serial #	:	None	A/D mV Range	:	1000
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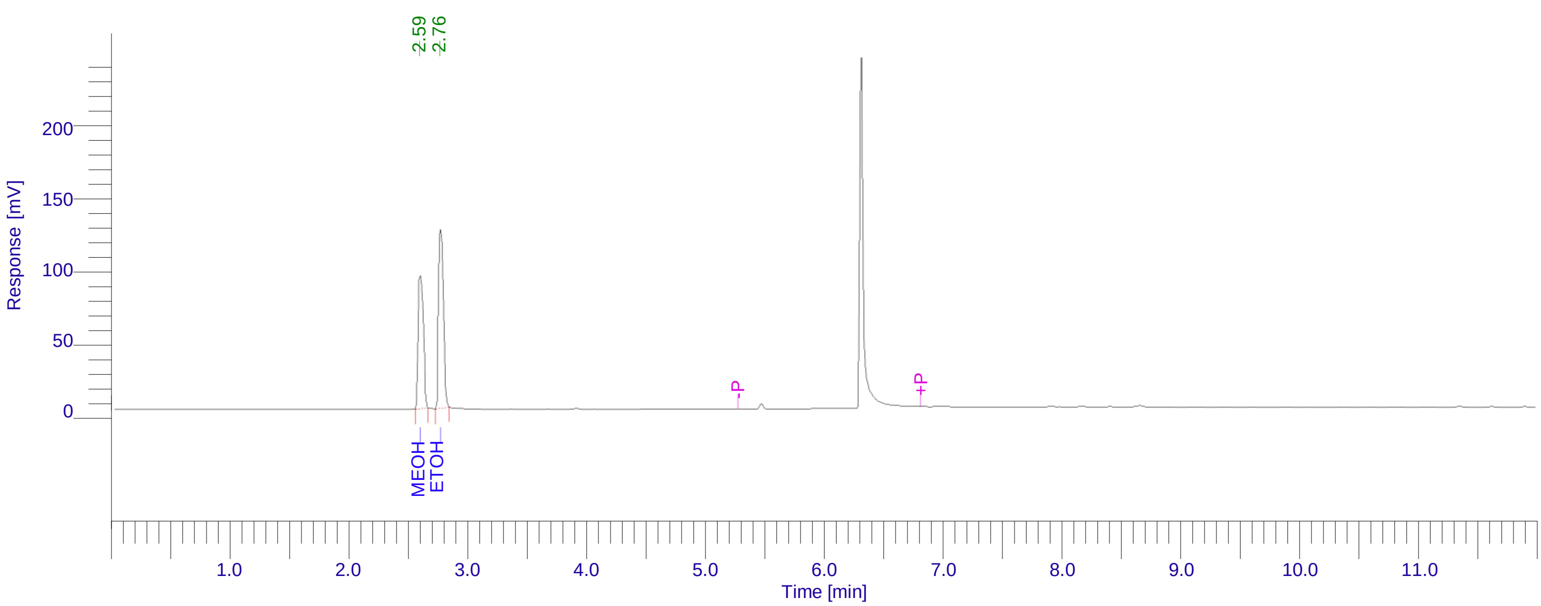

COE

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2	EtOH	2.765	370487.99	370487.99	127077.07	1.07	57.02
			649747.14	649747.14	222335.53		100.00

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AutoSampler	:	BUILT-IN	Rack/Vial	:	0/0
Instrument Name	:	clarus 500	Channel	:	A
Instrument Serial #	:	None	A/D mV Range	:	1000
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Sampling Rate	:	1.5625 pts/s			
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Sample Amount	:	1.0000	Dilution Factor	:	1.00
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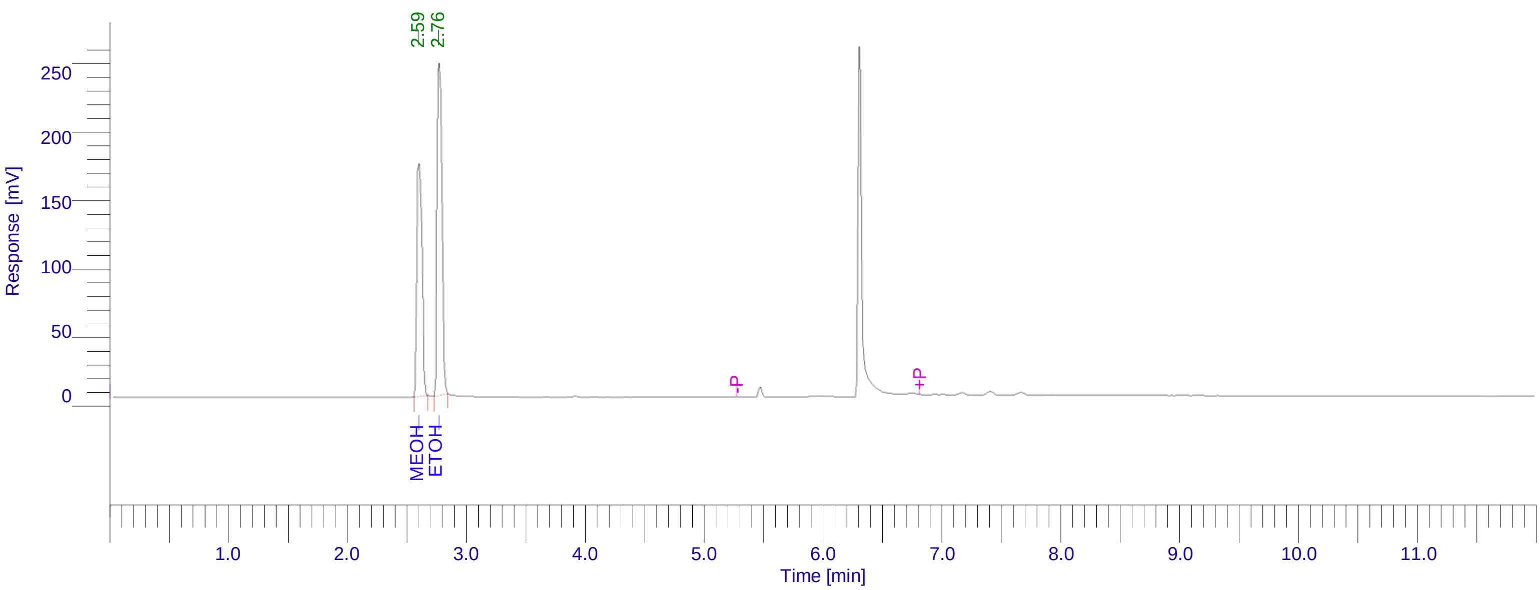

COE

Peak #	Component Name	Time [min]	Area [uV*sec]	Area [uV*sec]	Height [uV]	Rel. RT	Area [%]
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2	EtOH	2.764	732920.36	732920.36	251941.95	1.07	58.47
			1253593.41	1253593.41	430191.97		100.00

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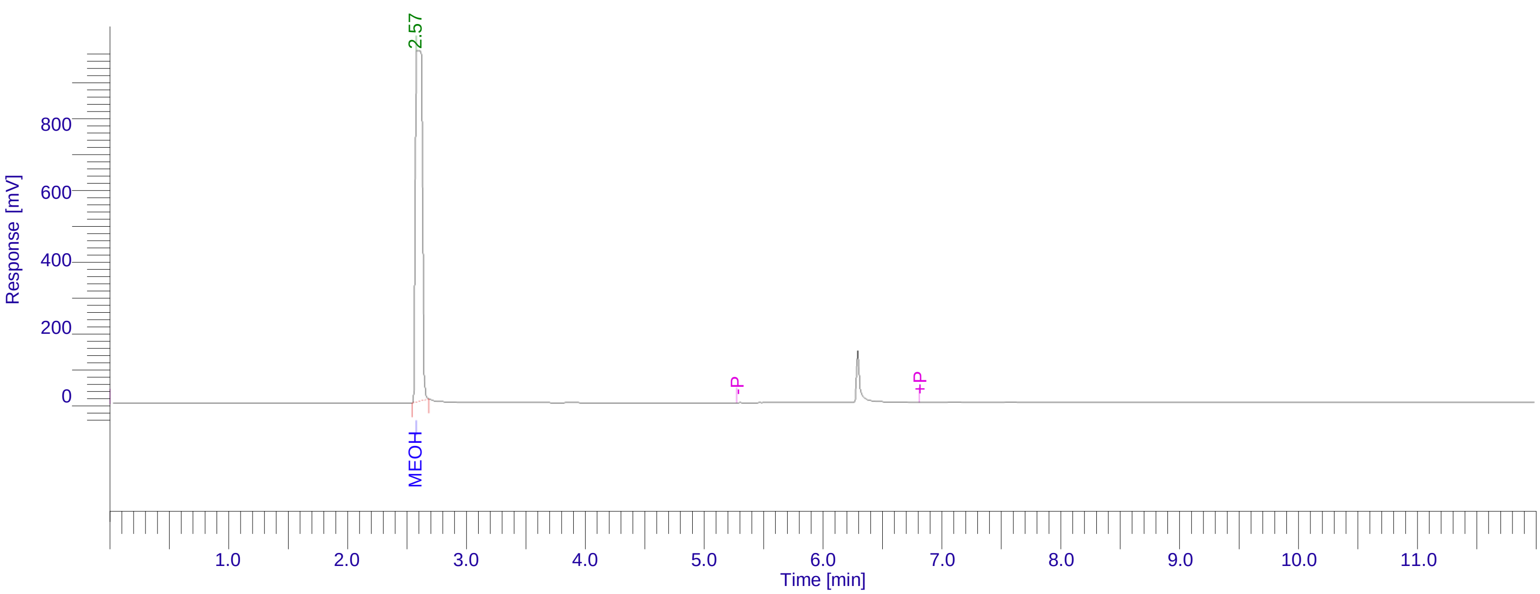
Operator	: Manager		Sample Name	: Sample 1ml
Sample Number	: 005		Study	: L.E.College
AutoSampler	: BUILT-IN		Rack/Vial	: 0/0
Instrument Name	: clarus 500		Channel	: A
Instrument Serial #	: None		A/D mV Range	: 1000
Delay Time	: 0.00 min		End Time	: 12.00 min
Sampling Rate	: 1.5625 pts/s			
Sample Volume	: 1.000000 ul		Area Reject	: 0.000000
Sample Amount	: 1.0000		Dilution Factor	: 1.00
Data Acquisition Time	: 4/19/2017 3:34:01 PM		Cycle	: 1

Raw Data File : D:\HSGC\data\Year 2017\April\18\Sample 1ml_005_005.raw
Inst Method : d:\hsgc\method\l.e.college_hsgc_180417_11.48 from D:\HSGC\data\Year 2017\April\18\Sample 1ml_005_005.raw
Proc Method : d:\hsgc\method\sam_syn_070716.mth from
Calib Method : d:\hsgc\method\sam_syn_070716.mth from
Report Format File: d:\hsgc\report\coe1.rpt
Sequence File : D:\HSGC\sequence\L.E.College_HSGC_180417.seq



COE

Peak #	Component Name	Time [min]	Area [uV*sec]	Area [uV*sec]	Height [uV]	Rel. RT	Area [%]
1	MeOH	2.571	3884266.61	3884266.61	986091.96	1.00	100.00
			3884266.61	3884266.61	986091.96		100.00

Warning -- Signal level out-of-range in peak

3.3.2 Preparation of standards:

1) MeOH + EtOH 1000 ppm (5+5)µL in 5ml Water + DMF (50:50)
2) MeOH + EtOH 2000 ppm (10+10) µL in 5ml Water + DMF (50:50)
3) Sample 1ml 1 ml in 5ml Water + DMF (50:50)

NO.	SAMPLE	VOLUME (ml)	MASS (gm)	DILUTION (Ml)	AREA
1	MeOH 1000 ppm	0.005	0.003957	5	279259.2
2	EtOH 1000 ppm	0.005	0.003945	5	370488
3	MeOH 2000 ppm	0.01	0.007913	5	520673.1
4	EtOH 2000 ppm	0.01	0.00789	5	732920.4
5	Sample 1ml	1	0.95	5	3884267
6	ETHANOL CONCENTRATION IN SAMPLE (PPM) in 0.95 gm	57.92808671	62.1386	90.0333454	

3.3.3 Result of analysis:

Sr.No.	Analyze	Concentration (%)
1	SAMPLE 1ML	90.0333454 Ethanol
2	SAMPLE 1ML	Methanol is absent in sample

CHAPTER-4: SUMMARY OF THE RESULTS

4.1 Cost Estimation for Production of Ethanol:

The primary influences on the cost of manufacture of biofuel are as follows:

- Capital and operating costs of the plant, including the processing plant, services, catalyst, feedstock and product storage, and buildings.
- Feedstock used in the process: tallow, vegetable or waste oil, and alcohol, most typically methanol.
- The glycerol by-product, which provides a secondary revenue stream to the biofuel produced or acts as an offset against the unit cost of biodiesel production.
- The yields and quality of the biodiesel and glycerol produced from the tallow/oil and methanol inputs.

Basis: We take 50 litre of algal oil in one batch of distillation. Like that, we are calculating for 12 batches in a day. Hence, all the calculations done here are based on daily basis.

Heat requirement, $q = m.C_p.dT / t$

where, C_p of ethanol = 2.46 kJ/kg.^oC
m of algal oil = 50 kg
dT from 25^oC (room temperature) to 65^oC = 40^oC
t, total time over which the heating process occurs (in seconds) = 3600 s

Thus,

$q = (50)\,(2.46)\,(40) / 3600$
$= 1.36$ kW

Amount of steam, $m_s = q / h_e$ [11]

where, m_s = mass of steam (kg/s)
q = calculated heat requirement
h_e = evaporation energy of steam (kJ/kg)

The evaporation energy at different steam pressures can be found in the steam table [12]. Hence, value of h_e at atmospheric pressure (101.33 kPa) = 2257 kJ/kg.

Thus,

$m_s = 1.36 / 2257$
$= 0.00060257$ kg/s
$= 2.17$ kg/h

To covert 1 L of water into 1 kg of steam at 1 atmospheric pressure, 2.26 MJ of energy is needed. Hence, 4.9 MJ of energy is needed to produce 2.17 kg of steam.

MJ/h	kW	
3.6	1	
4.9	(?)	= 1.361 kW of electricity is used per hour

Rate of torrent power for commercial usage for less than 5 kW (MJ/h) = Rs.70 / kW [10]
= Rs.95.27 / batch of 1 h

We intend to use 12 batches (each of 1 hour) in a day. Hence for a day, the cost of electricity required would be (Rs.95.27/batch X 12 batch) = Rs.1144

Suppose we keep 1 ton capacity of fermentation pond.

1) Transportation cost of 500 kg raw chlorella algae for 250 km = Rs.2250
2) Cost of nutrients and enzyme = Rs.1000
3) Cost of treated water (Rs.1/litre) = Rs.500 for 500 litre
4) Labour cost for 2 labours (Rs.300 per labour) = Rs.600/day
5) Cost of heat required for distillation (Rs.95.27/batch) = Rs.1144/day (for 12 batches)

Total costs for a month = Rs.5494

Each batch is of 50 L algal oil as feed. After distillation, we get 5 L of product containing 90% pure ethanol. Hence 4.5 L of ethanol is obtained from each batch of 50 kg feed.

In one day, we produce 54 L of ethanol from 12 batches.

Hence,
The production cost of ethanol = (total costs for a day) / (total liters of ethanol produced in a day)
= Rs.5494 / 54 liter
= Rs.101.70/liter

4.2 Algal Biofuel performance: [13]

The microalgae biodiesel have many advantages over the traditional diesel fuel, it can reduce net carbon dioxide emission by 78% on a life-cycle basis as compared to traditional diesel fuel. Biodiesel also contain little or no sulfur or aromatic compound; in conventional diesel, the sulfur lead to formation of sulfur oxide and sulfuric acid, while the aromatic compound also increase particulate emission and are considered carcinogens. In addition to reduce CO and particulate emission, the use of biodiesel confers additional advantages, including a higher flashpoint, faster biodegradation and greater lubricant. The higher flashpoint helps in safer handling and storage, whereas biodegradability of biodiesel is particularly advantageous in environmentally sensitive areas. The lubricant of biodiesel is also greater than conventional diesel fuel, and blending biodiesel with low sulfur fuel restores lubricant.

However, the biggest advantage of algal biodiesel is that, it's a sustainable source of liquid transportation fuel and derives energy from sun. The combustion of biodiesel in place of conventional diesel fuel can also reduce greenhouse gas emission up to 40%.

4.3 Algal Biofuel Opportunities in India: [14]

India is a rapidly expanding country in terms of both its population and its economy. According to CIA (Central intelligence agency) Fact book, India's current population is about 1,166,079,217 (Till July 2009). Economic growth in India, as in many developing and developed countries, is currently correlated with increased energy consumption. The environmental issues often discussed in public policy debates in India arise because of two factors, the sectors responsible for energy use and where economic development is happening.

As the consequence of India's rapid economic growth there is severe increase in air and water pollution, deforestation, water shortages, and carbon emissions. The country's carbon emission is also rising due to rapid industrialization, transportation sector growth, and the wide-spread use of coal as a fuel. Due to this large amount of urbanization and industrialization there is sudden rise in utilization of non-renewable energy sources, which can cause large amount scarcity of these fuels in future. So to prevent such conditions there is an urgent need for alternative sources of energy. According to current research, microalgae seem to be the promising renewable source of energy for India. The final factor making biodiesel production in India attractive is the potential to cultivate cheap feedstock. India's tropical climate is conducive to grow various species of micro-algae, which serves as natural benefit over other countries for the production of algal biodiesel. The micro-algae produce sufficient quantity of biodiesel to completely replace petroleum. While traditional high oil crops, such palm can produce 2000 to 2500 litre of biodiesel per acre, algae can yield 19,000-57,000 litre per acre. So the adoption of large-scale biodiesel production and consumption can potentially lower India's dependence on foreign countries for oil and helps improve air quality in major cities, reclaims unusable wastelands, employs unemployed Indians, and keeps the country's economy on track for its planned 8 to 10% annual GDP growth according to 11th five year plan of India.

4.4 Conclusion:

Today, demand for fossil fuels cannot be met with current reserves and increasing oil prices with economic and political crisis and effects of global warming are led countries to use renewable energy sources. Algae as third generation feedstock have a great potential because of their characteristics. Different valuable products can be obtained from algae such as biodiesel, bioethanol, biogas, pharmaceuticals and nutraceuticals. Nowadays algae are mostly utilized for biodiesel production due to their high lipid content. However algae have also high carbohydrate content that cannot be ignored. Thus they can be utilized for bioethanol production directly or with the remains which are obtained after oil extraction. In this study, potential of algae as a bioethanol feedstock, important steps of bioethanol production especially pre-treatment techniques have been mentioned. In production sections, pre-treatment techniques and fermentation processes are explained in details. Recently, bioethanol production from algae is very new technology and open to development. Innovative and efficient fermentation processes and pre-treatment techniques are needed to make ethanol production preferable. In conclusion, algae will with their huge potential will outclass the first and second generation feedstock’s and lots of improvements for usage of it will carried out in the future.

Hence, as mentioned above, we intended to produce ethanol by a cheaper and eco-friendly process. The commercial price of ethanol in India is Rs.49.5/litre, but as per the calculations shown above in point 4.1, we can produce it up to Rs.101.70/litre by fermentation of algae. We have taken batch process into consideration, due to which the price is high as compared to its market price. If it is to be produced in large quantities, its price can be greatly reduced.

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