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Green Fuel: The Next Generation Eco- Friendly Algal Bio- Fuel

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Abstract

The main objective of sustainable feedstock (algal biofuels) as fuels is due to the adverse environmental effects of fossil fuel, its combustion and their limited availability. Microalgal biomass containing high oil content is of great importance for the production of biodiesel. Another challenge in this field is Oil extraction which is easily addressed from the engineering techniques. There are three important steps for the extraction of oil from algae: first-oil press/expeller, second-hexane extraction, and third supercritical CO_2 fluid extraction. After extraction, due to chemical similarity of crude algae oil with crude fossil fuel oil, the engineering challenges associated with algae oil conversion to usable liquid fuels are also similar. From the micro-algae tested in present work, Neochloris Ole-abundans and Nannochloropsis species proved to be suitable as raw materials for bio fuels production, due to their high oil content (29.0 and 28.7%) respectively.

Keywords: Bio fuel; renewable sources; micro-algae; environmental friendly; economic sustainability.

Introduction

The importance of algal bio fuels as fuels attracts world over attention due to fulfil demand of ever increasing energy and replacement of fossil fuel as it has limited availability and adverse environmental effect. For the replacement of current rate of consumption of all transport fuels in the India would require 0.53 billion m^3 per year of bio fuels. Because current industrial sources of biodiesel will never be able to meet this demand; however, biodiesel production from microalgae may be able to fulfil this demand because it is capable of high oil yields in comparatively lesser land area and also consumption of microalgae for biodiesel will have limited impacts on other markets.

Algal bio fuels come under the carbon-neutral alternative fuels category. Algae are photosynthetic in nature which converts sunlight, water and CO_2 into various sugars and lipids Tri-Acyl-Glycols (TAG) and used as an eco-friendly, alternative, renewable and green fuel source for future in India.

A study made by the Energy Information Administration (EIA) projects a 50% increase in world energy consumption by 2030, arising political concerns. Another study done by the EIA projects the amount of energy consumed worldwide by fuel type. It is expected that world oil price will remain high and liquid fuels, are the slowest growing energy source. However, liquid consumption increases at the rate of 1.2% from 2005-2030 [2, 3].

Figure-1
World Marketed Energy Consumption, 1980-2030[1]

Material and Methods

Algal Biodiesel Opportunities in India: India is a rapidly expanding country w.r.t. population and economy. Like many developing and developed countries, economic growth in India also correlated with increased energy consumption. The consequence of this rapid economic growth there is continue increase in air, water, soil, radioactive, noise pollution, deforestation, water shortages and carbon emissions. Country's carbon emission is due to rapid industrialization, transportation sector growth and the wide-spread use of coal as a fuel. Due to which 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 we need for alternative sources of energy. Microalgae seem to be the promising renewable energy sources for India. India's tropical climate is very much suitable to grow various species of micro-algae, which serves as natural benefit also for the production of algal biodiesel. Because of large-scale biodiesel production and consumption we can lowers India's dependency on other countries. It also helps to improve air quality in metro cities like Delhi, Kolkata, Bangalore, Chennai, Mumbai etc. and reclaims unusable wastelands, Improve employments and increase the country's economy for its planned 8-10% annual GDP growth according to 11th five year plan of India [4-8].

Process Overview: Three major processes included in the production of algae biodiesel. i. Production of the algae biomass. ii. Algae oil is extracted from the algae biomass. iii. Algae oil is taken through a trans-esterification reaction to yield biodiesel.

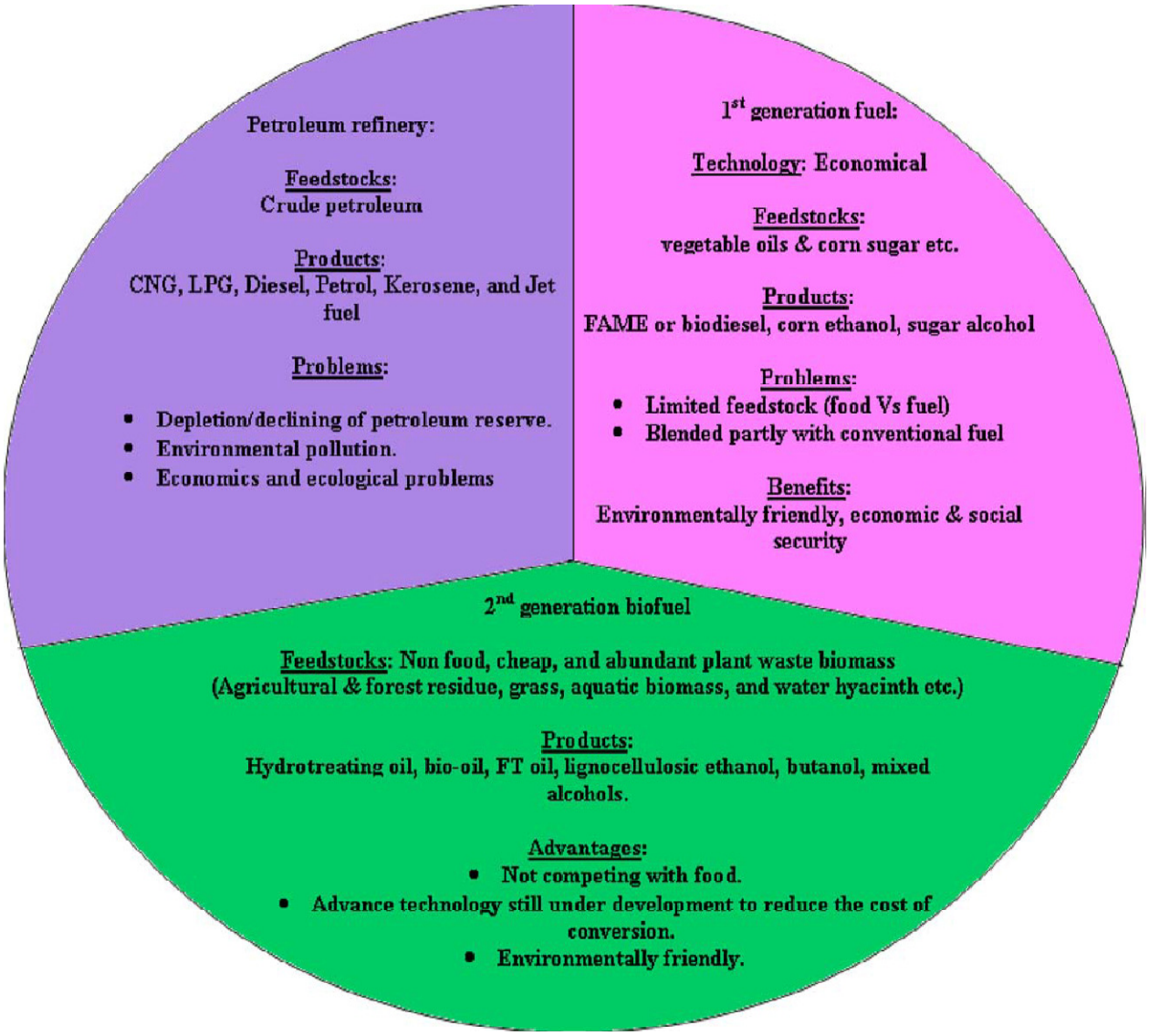

Figure-2
Comparison of First, Second Generation Bio fuel and Petroleum Fuel[9]

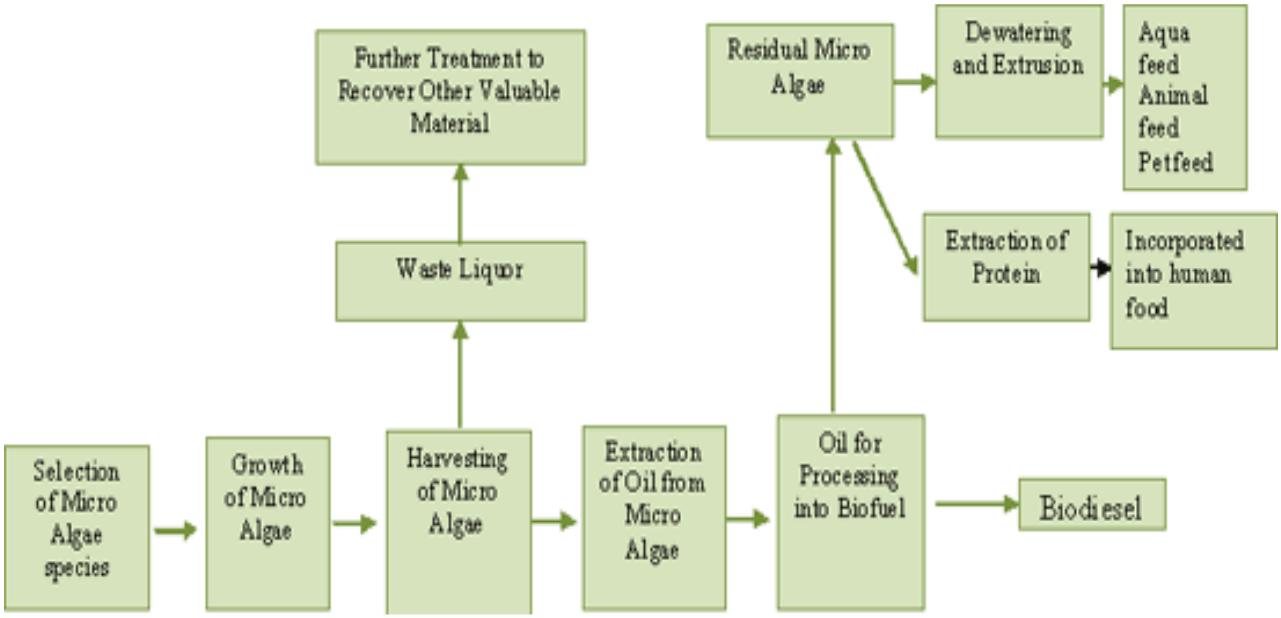

Figure-3
A Detailed Process of Biodiesel from Algae[9]

Table-1
Comparison of Biodiesel from Micro Algal Oil and Diesel Fuel

Properties	Biodiesel from Microalgal oil	Diesel fuel
Density Kg/L	0.864	0.838
Viscosity Pa s	5.2 x 10^{-4} (40 ^{0}C)	1.9 -4.1 x 10^{-4} (40 ^{0}C)
Flash point ^{0}C	65-115	75
Solidifying point ^{0}C	-12	-50-10
Cold filter plugging point ^{0}C	-11	-3.0 (-6.7 max)
Acid value mg KOH/g	.0374	0.5 max
Heating value MJ/Kg	41	40-45
HC ratio	1.18	1.18

Experimentation: Three types of samples (Chlorella, Nannochloropsis, Neochloris ole-abundans A, B, C respectively) were taken from different areas. The samples were kept for 8-10 hours for 5 days to induce photo chemical reaction in presence of sunlight.

Step-1 Sample Filtrations: These samples are filtered by using whatmann filter paper (42).The filtrate is than collected in 3 different tubes. The following water quality tests have done with all samples separately.

pH test: At room temperature (35^{0}C): The test is carried out by standard procedure. It has been noted that pH is shifted towards alkaline nature.

Table-2
pH Value of Different Species

Sample	Volume (1 ml sample + 9 ml distilled water)	pH value
A	10	8.05
B	10	8.13
C	10	8.04

Alkalinity test: The test is carried out by standard procedure(R): The alkalinity was found be 300-600 which is higher than the permissible level.

Table-3
Alkalinity of Different Species

sample	Volume (1 ml sample + 4 ml distilled water)	X (ml)	Alkalinity (ppm)
A	5	2.5	500
B	5	1.5	300
C	5	3.2	640

Hardness test: The test is carried out by standard procedure(R): It has been noted that hardness is found between 3200-3500 which is much higher than the permissible level.

Table-4
Hardness of Different Species

Sample	Volume (1 ml sample + 4 ml distilled water)	X (ml)	Hardness (ppm)
A	5	17	3400
B	5	16	3200
C	5	17.5	3500

Step-2 Extraction with n-hexane: After filtration process, we obtained 2 types of sample solid and liquid from sample A, B and C. Each sample has taken into 2 different tubes one in solid form and another in liquid phase. n-Hexane 7-8 ml approx mixes into these tubes with 3 ml liquid sample and NH_3 and H_2SO_4 2-3 ml approx. sample kept in tubes for chemical reaction at room temperature for a day.

From above procedure it has been observed that liquid sample A and C has oil formation potential, sample B remains unchanged.

For solid sample again filtrate the samples A, B and C after some time we observed that sample A and C shows some oil layer and bubbles into the sample. Sample B remains unchanged. So from above observation we can say that sample A and C has oil potential [10-20, 5-8].

Trans-esterification- When oil is extracted from algae, vegetable oil is the resulting product called green crude, which is quite similar to crude oil. This green crude cannot blend with crude petroleum due to the presence of large amount of oxygen. Algal biomass would be a poor blend stock because the oxygenated reagents could react with the unsaturated hydrocarbons present in it at high temperatures which are used in different techniques viz. crude distillation and causing polymerization or undesirable reactions. The two important techniques of converting lipids from the extracted algae to bio fuel are trans-esterification and catalytic conversion.

In trans-esterification process, methanol and ethanol is substituted for glycerol of the triacylglycerol from the algae extraction. Trans-esterification of algal oil is commonly done with ethanol where sodium ethanolate is used as catalyst. The triglycerides of the algal oil react with ethanol and produce an ester fuel with similar characteristics to diesel. Trans-esterification reactions reported yields of 95% - 98% by weight at 60^0C. Below this temperature the yield is drastically decreases, while above this temperatures yield becomes between 80% - 90%.

Results and Discussion

The species can further be utilized for extraction of bio-fuels as they exhibit potential of bio-fuel generation.

Calorific Value of Microalgae: The calorific value of algae has been found to be between 3.58 and 5.47 Kcal/g (paine and vadas 1969). Using these values it is possible to estimate the calorific value of algae for a range of algal oil contents as shown in table. For a 20% content in the algae calorific value would be 5.2 Kcal/g [(0.2 x 9.4) + (0.8 X 4.2)]. Using the estimated calorific value and law of conservation of energy it is possible to calculate the total amount of algal biomass (potential calorific value of biomass/calorific value of algae) displayed in table–

Algae oil content can be high over 70% with oil levels of 20% - 50% being reasonably common, but it is 10 - 30% when grown under nutrient replete conditions. The NREL study found that in certain species oil yields up to 60% and maximum productivity levels were lower oil contents[21-24].

Table-5
Calorific Value and Algal Oil Content Comparison of Microalgae

Algae oil Content	Calorific Value	Yield Algae	Yield Algal Oil	Yield Algal Oil
% oil	Kcal/g	Metric Tons/Hectare/Year	US Gallons/Acre/Year	Barrels/Acre/Year
10.00%	4.7	401	4667	111
20.00%	5.2	361	8408	200
30.00%	5.8	328	11474	273
40.00%	6.3	301	14032	334
50.00%	6.8	278	16198	386
60.00%	7.3	258	18057	430
70.00%	7.8	241	19669	468
80.00%	8.4	226	21081	502

SWOT Analysis: SWOT (Strengths, Weaknesses, Opportunities and Threats) analysis is developed for clearing all the possibilities and threats of this technology. SWOT analysis is a common tool used to plan and understand the 4 major categories involved in any project, business or technology.

SWOT analysis originated from a research conducted at Stanford Research Institute (1960-1970). SWOT is used as a part of strategic planning process. The main objective is the massification and use of algal bio fuels over the next 30 years[25].

Conclusion

Micro algal biodiesel is very feasible in nature and also economic than petro diesel. Their production, harvesting and extraction must be optimized. We can improve their algal biology nature through different techniques viz. genetic and metabolic engineering. In present work, Neochloris oleabundans and Nannochloropsis species Proved to be suitable as raw materials for bio fuels production because they posses high oil content (29.0 and 28.7%, respectively). These are fresh water and marine microalgae, respectively, which enhance the cultivation possibilities and do not compete with food crops. So, we can conclude that microalgae produce bio fuel because of the accumulate lipids in it and their very high photosynthetic yields; about 3-8% of solar energy can be converted to biomass whereas observed yields for terrestrials plants are 0.5%.

Future Scope: Algal biomass is an important sustainable feedstock for the production of biodiesel. Comparatively other oil producing crops it can produce up to 30 times more oil. Therefore algae can be widely used in future for bio fuel production. It can replace the use of fossil fuel and become an environment friendly and produce new energy sources in future so that alternative method of oil extraction can be used for oil production. The best method for oil extraction from biomass is Chemical Extraction with Soxhlet Extractor with the use of n-Hexane as a solvent.

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