PRODUCTION OF BIODIESEL FROM CHLORELLA PROTOTHECOIDES MICROALGAL OIL

Ph.D. THESIS

by

MUKESH KUMAR

ALTERNATE HYDRO ENERGY CENTRE
INDIAN INSTITUTE OF TECHNOLOGY ROORKEE
ROORKEE-247667 (INDIA)
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MUKESH KUMAR

ALTERNATE HYDRO ENERGY CENTRE
INDIAN INSTITUTE OF TECHNOLOGY ROORKEE
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ABSTRACT

Energy is the key determinant for the economic and sustainable growth worldwide. The energy demand is increasing rapidly with increase in population. The primary source of energy is fossil fuels, which are inadequate to meet the rising energy demand due to limited availability. In addition, these resources are also responsible for environmental degradation. Owing to the above problem, there is a need to search alternative renewable biofuels like biodiesel and bioethanol. The biodiesel is considered worldwide as a potential alternative to petroleum diesel which is used in large quantities for transport, agricultural, captive power generation etc.

Biodiesel, mono-alkyl esters of triglycerides i.e. edible, non-edible, microalgal oils or animal fats, offers the suitable substitute to petro-diesel and can be produced by transesterification reaction which aims to bring down the viscosity of parent oil in the range of diesel. The biodiesel from edible oil resources is impractical and infeasible, 80% of the edible oil is imported and indigenous production is highly inadequate to meet the fuel demand. Further, non-edible oil resources are considered as second generation potential feedstocks for biodiesel production all over the world e.g. Jatropha, Pongamia in India. Slow growth rates and lower oil productivities have led to non-availability of sufficient oil for biodiesel production. Next it, microalgae are identified as third generation oil feedstocks due to having advantages like need of less land area for cultivation, less time for maturity and higher oil productivities compared to I and II generation feedstocks. Though this resource is also not available in plenty. But new and high oil yield species, methods for cultivation and oil extraction are being developed by different investigator and is considered as main source of biodiesel in India as well as in other countries.

Literature review shows that not much work available on biodiesel production from microalgal oil and therefore, microalgal oil have been selected for the work. Based on Oxidation Stability Index (OSI) and Cold Flow Properties (CFP) computed using fatty acid composition from literature, classification of oils has been developed by us for the first time which will be helpful for manufacturer/industries to select best oils for biodiesel production. Using this classification we have selected *Chlorella protothecoides (C. protothecoides)* microalgal oil. The oil was purchased from M/s Soley Biotechnology Institute, Turkey.

We did not carry out the experimental transesterification of oil in the laboratory but based on the parameters like methanol to oil molar ratio, catalyst concentration, reaction time, reaction temperature, taken from literature, range of parameters were proposed and help of software tools like Response Surface Methodology (RSM) and Combined ANN-GA (Artificial Neural Network- Genetic Algorithm) has been taken to optimize and verify the parameters for biodiesel production. These optimum parameters can be recommended to manufacturer for commercial scale biodiesel production.

The kinetics study of transesterification is carried out under optimum conditions of reaction parameters as obtained above. The reaction was monitored with respect to methyl ester (ME). In the thesis, the biodiesel has been used in place of ME. The study found the transesterification reaction of first order and on the basis of activation energy and rate constant, it is found that the conversion process requires less energy for the complete process and take less time in conversion compared to Jatropha and waste cooking oil (WCO).

The fuel properties like oxidation stability, cold flow properties, thermal stability of *C. protothecoides* microalgal biodiesel (CPMB) were determined in the lab and compared with Indian Specification (IS-15607) and diesel. The results show that oxidation stability, thermal stability and cold flow properties of CPMB are compatible with Indian biodiesel standard, according to which it requires no improvement in OS and CFP but is slightly higher than diesel. This is followed by preparing different blends of biodiesel with diesel and fuel properties were determined. The results found B_{20} as the more suitable blend for engine application.

Thermal stability of *C. protothecoides* microalgal oil (CPMO), CPMB and its above blends is also studied under thermogravimetric analysis (TGA) techniques under different environment (air/nitrogen), different heating rates (5-20 ^{o}C/min) and different concentrations of antioxidant (0-500 ppm) to see the effect of temperature on fuel quality degradation of biodiesel and its blends. The results indicated that B_{20} has been found as the best blend in terms of thermal stability and CFP. The addition of Pyrogallol in blend is found to improve the thermal stability but without it, B_{20} is found thermally stable in working range of temperature. For further study, only B20 blend has been used.

An experimental engine test rig is operated using $CPMB_{100}$, B_{20} and diesel and data like Brake Thermal Efficiency (BTE), Brake Power (BP), Brake Specific Fuel Consumption (BSFC), Exhaust Gas Temperature (EGT), Cylinder Gas Pressure (CGP), Rate of Pressure Rise (ROPR), Heat Release Rate (HRR) and emission were collected at

different loads. The results of the study show that the engine performance and combustion evaluation of B_{20} blend found almost similar to diesel, however, NO_X emission was found higher than diesel.

NOx emission is undesirable to the environment as well as living species on the earth. Released NO_X reacts in the atmosphere to form ozone and is one of the major causes of photochemical smog. It is harmful to plants and trees and causes very heavy crop losses each year. The ternary blends of diesel-biodiesel-higher alcohols (1-butanol/2-propanol) were prepared to reduce NO_X emission from engine exhaust.

In view of the above work, it is concluded that $CPMB_{20}$ is found the most suitable blend for engine applications as it is found to have comparable OS, CFP, thermal stability and engine performance. For NO_X reduction, 1-butanol is found more effective than other higher alcohols.

The findings of the study can be recommends for implantations directly in the field, once the resource starts available in quantities sufficient for commercial production. Further, scope of the study includes the development pilot scale reactor and long term engine operation experience.

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