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A STUDY ON THE DEVELOPMENT OF *Mesua ferrea* L. SEED OIL BASED MICROEMULSIFIED FUEL SYSTEM

Plaban Bora[1,*], Jutika Boro[1], Dhanapati Deka[1]

[1]*Biomass Conversion Laboratory,*
Department of Energy,
Tezpur University
Tezpur-784028, India

**E-mail: bncplaban@gmail.com*

ABSTRACT

To meet the raising energy demands vegetable oils were initially considered as transportation fuels owing to their performance which was similar to that of diesel fuel. Vegetable oil is a promising alternative because of its portability, ready availability, and renewability etc. However, long-term usage of vegetable oils in diesel engines causes engine durability problems due to its high viscosity. Out of the several methods for reduction of viscosity of vegetable oil, one of the major techniques is microemulsification. The technique of microemulsification has the advantages in terms of its simplicity, time saving, in-situ, energy conservative production technology over biodiesel and is therefore more economically viable. In this study a new microemulsified fuel system containing different volume percentages of vegetable oil extracted from *Mesua ferrea* L. seed, butan-2-ol and ethanol is tried to develop. Different parameters such as physical stability, density, dynamic and kinematic viscosity of the prepared system are investigated and compared with those of diesel and biodiesel. The experimental results of various fractions of the samples prepared show that the properties of the fuel systems meet the requirements for biodiesel or/and diesel fuel. Interestingly, the different characterization carried out for the samples prepared in this study show that the fuel properties of *Mesua ferrea* L. seed oil could be improved by microemulsification technique.

Keywords: *Mesua ferrea* L. seed oil, biodiesel, butan-2-ol, ethanol, microemulsion

1. INTRODUCTION

The depletion of petroleum energy resources as well as their inherent environmental concerns has raised interest in the development and use of non-petroleum-based renewable fuels. The use of alternative fuel in order to replace the fossil fuels has many advantages such as renewability, biodegradability and better quality exhaust gas emissions, which do not contribute to raise the level of carbon dioxide in the atmosphere [1,2]. To meet the raising energy demands vegetable oils were initially considered as transportation fuels owing to their performance which was similar to that of diesel fuel. Vegetable oil is a promising alternative because of its portability, ready availability, renewability, higher heat content, lower sulfur and aromatic content and biodegradability. [3, 4]

However, long-term usage of vegetable oils in diesel engines causes engine durability problems. The major problem with the vegetable oil to be used as engine fuel is due to its high viscosity; which in turn leads to problems in pumping, combustion and atomization in the injector systems of a diesel engine. [4]

Therefore, a reduction in viscosity is of prime importance to make vegetable oils a suitable alternative fuel for diesel engines. Four methods to reduce the high viscosity of vegetable oils to enable their use in common diesel engines without operational problems such as engine deposits have been investigated namely, blending with petrodiesel, increasing pyrolysis, transesterification to produce biodiesel and microemulsification [3-5].

Out of the four methods for reduction of viscosity of vegetable oil, one of the major techniques is microemulsification. Microemulsions are microheterogeneous, transparent, thermodynamically stable colloidal equilibrium dispersion of optically isotropic fluid microstructure spontaneously from two normally immiscible liquids. In this technique, the viscosity of vegetable oil is reduced through the formation of self organized system called fuel formulation or microemulsion. The microemulsions form spontaneously when suitable surfactants are used to sufficiently reduce the interfacial tension between the dispersed and continuous phases. [6-8]. The advantages of an emulsion fuel are reductions in the emissions of nitrogen oxides (NO_x) and particulate matters. This is attributed to improved combustion efficiency and reduction in exhaust gas temperatures, which are imp. factor in reducing pollutant emissions[3,9,10].

The present study aims to contribute to the development of a microemulsified fuel system and observing the physical stability and changes in density and viscosity of various fractions. The Microemulsified fuel system investigated in this study consist of *Mesua ferrea* L. seed oil, ethanol and butan-2-ol.

2. MATERIALS AND METHODS

Mesua ferrea L. seeds were donated by Forest Department of Govt. of Assam. Absolute ethyl alcohol and Butan-2-ol (Reagent Plus®, ≥99%) were procured from Changshu Yangquan Chemical (Chemical Reagent No.1) and Sigma-Aldrich respectively and used as received.

3. EXPERIMENTAL PROCEDURES

After removing the kernel, the seeds of *Mesua ferrea* L. were grinded into fine particles & 50gms of the grinded seed was taken into a thimble which was placed inside a soxhlet apparatus. The Soxhlet Extraction system corresponds to the AOAC official method 963.15, where petroleum ether (boiling range 40-60 °C) had been used as a solvent for the extraction of oil [11]. After extraction the solvent was collected, typically by means of a rotary evaporator at 40-50°C, while the oil extracted is left behind. The non-soluble portion of the extracted solid remains in the thimble and it was discarded.

The extracted vegetable oil from *Mesua ferrea* L. seed is filtered under vacuum separation several times in order to separate it from the solid contaminants and other impurities. It is then allowed to settle down under gravity to remove further impurities (if any) for 72 h followed by vacuum filtration once again. Different samples containing a mixture of oil is then mixed with varied ratios of butan-2-ol and ethanol in which butan-2-ol was employed as surfactant. The different samples prepared are stirred by using mechanical stirrer and are kept under room temperature for 30 consecutive days. Thereafter the characterizations of the final product are carried out. A simplified process flow diagram representing different steps of microemulsied fuel production from *Mesua ferrea* L. seed oil is given in Fig.1

3.1. Physical Stability of the microemulsified system

The physical stability of the microemulsion samples was conducted by storing samples in an environmentally controlled stability chamber at room temperature (30°C-35°C) for one month. The samples were visually inspected on hourly basis for their physical appearances, any sign of turbidity and phase separation. Temperature cycling was conducted over 30 days starting at 5°C for 24 h and then increasing to room temperature for 24 h. Microemulsion samples were centrifuged at 7000 rpm for 60 minutes using Eppendorf Centrifuge 5810R. Those samples which did not show any sign of phase separation even after 30 days are designated as 'stable' samples and those samples which did not form single phase microemulsion structures even after vigorous stirring are termed as 'unstable' samples. 'Stable' samples were taken for further characterizations [8].

3.2. Fuel characteristics analysis

Density and viscosities of microemulsion samples prepared were determined according to ASTM D1298 and falling-ball viscometer (Haake, Type C) respectively.

4. 4. RESULTS AND DISCUSSION

4.1. Feedstock analysis

Mesua ferrea L.(Nahar) is one of the attracting and promising oilseeds bearing indigenous medium sized to large evergreen timber plant species with short trunk that grows naturally in the northeastern parts of the Himalayan regions of India [12-14]. The oil seed contains 55-57 wt % non-edible, reddish-brown colored oil (the shelled kernel contains >75 wt % oil), which had been traditionally used as a fuel [12]. Nahar oil (mol wt 900) mainly contains mesuol ($C_{23}H_{22}O_5$) & mesuone ($C_{29}H_{42}O_4$). [14]. Earlier researches reported that *Mesua ferrea* seed oil contains 25.4-29.11 % of saturated fatty acids and 65.85- 68.31% of unsaturated fatty acids. [13]. Specifications of Diesel and Biodiesel Fuels along with some physicochemical properties of *Mesua ferrea* L. seed oil & it's Biodiesel (M-FAME) are presented in Table 1.

4.2. Microemulsion system analysis

4.2.1. Stability of the microemulsified system

The stability of the various fractions of *Mesua ferrea* L. seed oil, butan-2-ol, ethanol microemulsion system are presented in Table 2 and the following observations are made:

I. The stability is observed to increase with increasing butan-2-ol fraction and decreasing ethanol fraction for a constant volume percentage of *Mesua ferrea* L. seed oil. For example, It can be seen from the Table, $^{a}60/^{b}30/^{c}10$ sample is more stable than $^{a}60/^{b}20/^{c}20$ sample and $^{a}50/^{b}40/^{c}10$ sample is more stable than $^{a}50/^{b}30/^{c}20$, where (a) is *Mesua ferrea* L. seed oil, (b) is Butan-2-ol and (c) is ethanol.
II. Among the stable microemulsified samples, the samples with greater butan-2-ol /ethanol ratio have more stability than the samples with less butan-2-ol/ethanol ratio.

4.2.2. Density

The density of the oil extracted from *Mesua ferrea* L. seed is measured as 890 Kg/m³ at a temperature of 20 °C. The density at 20°C measured for the microemulsified samples are presented in Table 2 and meet the requirement for diesel and biodiesel fuel and it is in agreement with the earlier studies [16, 17].

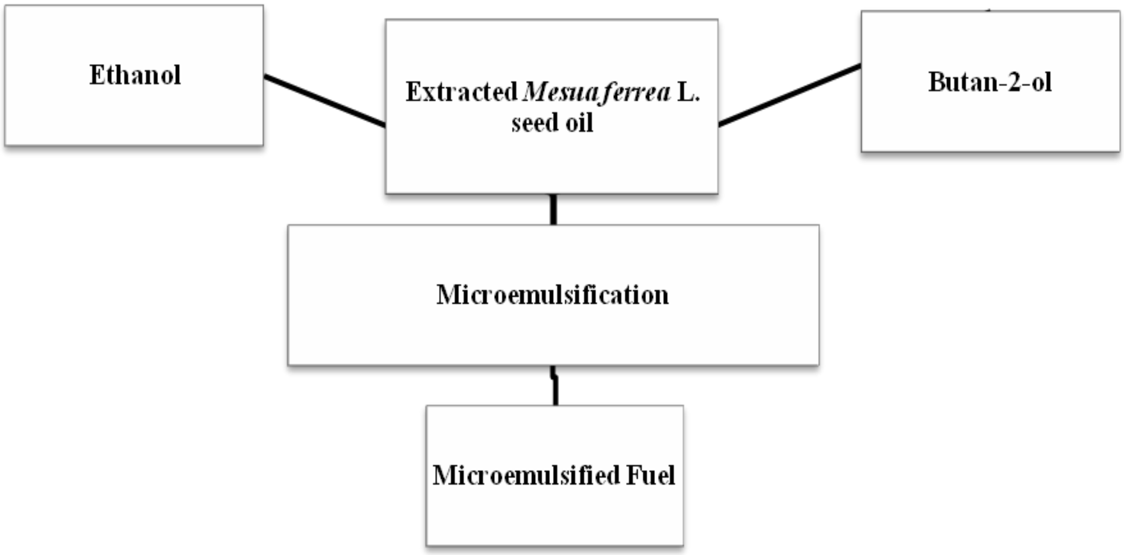

Fig.1. Process flow diagram representing different steps of microemulsied fuel production from *Mesua ferrea* L. seed oil

Table 1. Specifications of Diesel and Biodiesel Fuels [15] along with some physicochemical properties of *Mesua ferrea* L. seed oil & it's Biodiesel (M-FAME) [13, 14]

Fuel property	**Diesel**	**Biodiesel**	***Mesua ferrea* L. seed oil**	***M-FAME***
Fuel standard	**ASTM D 975**	**ASTM D 6751**		
Kinematic viscosity cSt @ 40 °C	1.3–4.1	4.0–6.0	20.589	5.83
Specific gravity	0.85@ 15.5 °C	0.88 @ 15.5 °C	0.9287-0.952 @ 31 °C	0.897 @ 31 °C
Density, @ 15 °C	848 Kg/m^3	860 Kg/m^3	Not reported	Not reported

Table 2. Physical Stability, density and viscosity of the microemulsified systems of *Mesua ferrea* L. seed oil

Volume % of components in the microemulsified system			**Stability of the system**	**Density(Kg/m^3) at 20 $^{\circ}$C**	**Dynamic Viscosity(m.Pa.s or cP) at 20 $^{\circ}$C**	**Kinematic Viscosity(cSt) at 20 $^{\circ}$C**
***Mesua ferrea* L. seed oil (a)**	**Butan -2-ol (b)**	**Ethanol (c)**				
	30	30	Unstable			
40	40	20	Stable	860	4.48	5.20
	50	10	Stable	858	4.86	5.66
	20	30	Unstable			
50	30	20	10 hrs	799		
	40	10	Stable	828	7.40	8.93
	10	30	Unstable			
60	20	20	12 hrs	820		
	30	10	Stable	824	11.02	13.37

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4.2.3. Density

The density of the oil extracted from *Mesua ferrea* L. seed is measured as 890 Kg/m^3 at a temperature of 20 °C. The density at 20°C measured for the microemulsified samples are presented in Table 2 and meet the requirement for diesel and biodiesel fuel and it is in agreement with the earlier studies [16, 17]. Moreover the results obtained in our study are better than other researchers who have reported density of biodiesel from *Mesua ferrea* L. seed oil is 897 Kg/m^3 at 31ºC.[14]

4.2.4. Dynamic and Kinematic viscosity

The dynamic and kinematic viscosity of the oil extracted from *Mesua ferrea* L. seed oil is obtained as 69.06 cP and 77.35 cSt, at 20°C respectively. The viscosities of all the microemulsified samples are found to be reduced. From Table 2 the following observations can be made:

The viscosity of the sample ^{a}**60/**^{b}**30/**^{c}**10** is higher than the usual values for diesel and biodiesel fuel and cannot be used directly in diesel engine. But, dynamic and kinematic viscosity of other samples measured at 20°C satisfies ASTM D6751, EN 14214, IS 15607 standards for biodiesel, ASTM D 975 standard for diesel and IS 1460-1974 standards for High Speed Diesel (Table 2), which is in agreement with the studies carried out by different researchers [16-18]. Based on the results obtained, it is expected that the prepared hybrid fuel system might give comparable engine efficiency with respect to diesel / biodiesel fuel. Moreover the results obtained in our study are better than other researchers who have reported kinematic viscosity of biodiesel from *Mesua ferrea* L. seed oil is 5.83 cSt at 40ºC.[14]

5. CONCLUSION

The different characterization carried out for the samples prepared in this study shows that the fuel properties of *Mesua ferrea* L. seed oil could be improved by the microemulsification of *Mesua ferrea* L. seed oil, butan-2-ol, and ethanol. The attainment of such new systems shows the great versatility of the microemulsified renewable fuels and the influence of concentration of each of the components as well as the ratio of concentration of butan-2-ol/ethanol on the fuel properties. The engine efficiency is expected to be similar compared to diesel engine as the viscosity of the renewable source *Mesua ferrea* L. seed oil is reduced to close to that of biodiesel and diesel using the microemulsification technique. The *Mesua ferrea* L. seed oil, butan-2-ol and ethanol based hybrid fuel hold a very promising future for obtaining a complete bio based fuel containing 'bio-butanol' and 'bio-ethanol'.

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AUTHOR BIOGRAPHY

Plaban Bora: is a Research Scholar at Department of Energy, Tezpur University, Tezpur, India. He has completed his BE in Chemical Engineering from Assam Engineering College,Guwahati and M.Tech in Energy Technology from the Department of Energy,Tezpur University. His research interest includes biofuel production from various non-edible oil feedstock

Jutika Boro: is a Research Scholar at Department of Energy, Tezpur University, Tezpur, India. She has completed her M.Sc in Physics from Department of Physical Science, Tezpur University and M.Tech in Energy Technology from the Department of Energy,Tezpur University. Her research interest includes development of heterogeneous catalyst for biodiesel production from non-edible oil seeds.

Prof. Dhanapati Deka is a faculty of Department of Energy, Tezpur University, Tezpur, India. His research interst includes bioenergy, energy and environment etc. He has several publications in various national and international journals. He is a reviewer of two international journals of bioenergy research. He is the PI of an ongoing DST sponsored collaborative Indo-Finish Project and a UGC sponsored project.