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PERFORMANCE OF MUSTARD AND NEEM OIL BLENDS WITH DIESEL FUEL IN C.I. ENGINE

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ABSTRACT

To study the feasibility of using two edible plant oils mustard (*Brassica nigra*, Family: Cruciferae) and neem (*Azadirachta indica*, Family: Meliaceae) as diesel substitute a comparative study on their combustion characteristics on a C.I. engine were made. Oils were esterified (butyl esters) before blending with pure diesel in the ratio of 10:90, 15:85, 20:80, and 25:75 by volume. Pure diesel was used as control. Studies have revealed that on blending vegetable oils with diesel a remarkable improvement in their physical and chemical properties was observed. Cetane number came to be very close to pure diesel. Engine (C.I.) was run at different loads (0, 4, 8, 12, 16, and 20 kg) at a constant speed (1500 rpm) separately on each blend and also on pure diesel. Results have indicated that engine run at 20% blend of oils showed a closer performance to pure diesel. However, mustard oil at 20% blend with diesel gave best performance as compared to neem oil blends in terms of low smoke intensity, emission of HC and NO_x. All the parameters tested viz., total fuel consumption, specific energy consumption; specific fuel consumption, brake thermal efficiency and cylindrical peak pressure were improved. These studies have revealed that both the oils at 20% blend with diesel can be used as a diesel substitute. Further, esterified mustard oil at 20% blend satisfies the important fuel properties as per ASTM specifications of biodiesel as it lead to an improvement in engine performance and emission characteristics without bringing any modifications in the engine.

Keywords: edible oils, mustard, neem, bio-diesel, transesterifications, combustion characteristics, engine performance.

1. INTRODUCTION

An enormous increase in the number of automobiles in recent years has resulted in greater demand for petroleum products. With crude oil reserves estimated to last only for a few decades, therefore, effort are on way to research now alternatives to diesel. Depletion of crude oil would cause a major impact on the transportation sector. Of the various alternate fuels under consideration, biodiesel, derived from esterified vegetable oils, appears to be the most promising alternative fuel to diesel due to the following reasons [1, 2].

- Biodiesel can be used in the existing engines without any modifications.
- Biodiesel obtained from vegetable sources does not contain any sulfur, aromatic hydrocarbons, metals or crude oil residues.
- Biodiesel is an oxygenated fuel; emissions of carbon monoxide and soot tend to reduce.
- Unlike fossil fuels, use of Biodiesel does not contribute to global warming as the CO2 so produced absorbed by the plants. Thus in nature CO2 is balanced.
- The Occupational Safety and Health Administration classify biodiesel as a non-flammable liquid.
- The use of biodiesel can extend the life span of diesel engines because it is more lubricating than petroleum diesel fuel.
- Biodiesel is mostly obtained from renewable vegetable oils/animal fats and hence it may improve the fuel or energy security and thus leading to economy independence.

A lot of research work has already been carried out to use vegetable oil both in its pure form and also in modified form. Studies have shown that the usage of vegetable oils in pure form is possible but not preferable [3]. The high viscosity of vegetable oils and their low volatility affects the atomization and spray pattern of fuel, leading to incomplete combustion and severe carbon deposits, injector choking and piston ring sticking. The methods used to reduce the viscosity are pyrolysis, blending with diesel, transesterification, and emulsification.

Among these, the transesterification is the most commonly used commercial process to produce clean and environmental friendly fuel [4]. Methyl/ethyl/butyl esters of sunflower oil [5, 6], rice bran oil [7], palm oil [8], mahua oil [9], jatropha oil [10], karanja oil [11], soybean oil [12], rapeseed oil [13] and rubber seed oil [14, 15] have been successfully tested on C.I. engines and their performance has been studied. Vegetable oils that can be blended with existing petroleum-based fuel have a distinct advantage because they can be used when ever available and the vehicle can also be fueled with conventional fuels when the alternative fuels are not available [16]. Biodiesel is environment friendly alternative diesel fuel consisting of alkyl monoesters of fatty acids from vegetable oils and animal fats. One drawback however, of biodiesel is that there is an inverse relationship between biodiesel's oxidative stability and its cold flow properties [17], which leads to reduction in the performance of engine.

Similar to alcohol fuels, biodiesel has lower energy content and different physical properties than diesel fuels and this may require engine-setting adjustments to improve engine performance and emissions. These experiences have led to the use of modified vegetable oils as fuel. Among liquid bio-fuels,

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bio-diesel derived from vegetable oils is gaining acceptance in Europe and the United States [18].

Biodiesel has become more attractive recently because of its environmental benefits and the fact that it is made from renewable sources [19]. Breuer [20] studied the fuel properties on heat release through experiments conducted with rapeseed oil and its methyl ester. Vaughn *et al.*, [21] conducted experiment on the ignition delay of a number of Bio-Esters by droplet ignition delay experiments. Kinoshita *et al.*, [22] evaluated the combustion characteristics of biodiesels derived from coconut oil and palm oil, while Sinha *et al.*, [23] investigated the in cylinder pressure and heat release patterns of 20% rice bran oil methyl ester- diesel blend. Hamasaki *et al.*, [24] had analyzed the rate of heat release of waste vegetable oil methyl ester. Studies of Rao *et al.*, [25] on pongamia, jatropha and neem methyl esters as biodiesel on CI engine have revealed that their diesel blends showed reasonable efficiencies, lower smoke, CO and HC. Pongamia methyl ester showed better performance compared to jatropha and neem methyl esters.

Recently, Anbumani and Singh [26] investigated the use of esterified vegetable oils as biofuel for CI engine. Their studies have revealed that among the different vegetable oils used in their studies, esterified sunflower oil blend at 15% by volume with diesel fuel exhibited best combustion and performance in terms of total fuel consumption, specific fuel consumption, brake thermal efficiency and cylinder peak pressure etc.

In the present studies; combustion and performance characteristics of single cylinder diesel engine was evaluated using two vegetable oil blends (mustard oil and neem oil) with the aid of pressure-crank angle diagram obtained by employing piezo electric pressure transducer and TDC encoder. The performance parameters were compared with the engine run on pure diesel. The vegetable oils and diesel were blended in following four ratios were 10:90, 15:85, 20:80, and 25:75.

2. METHODOLOGY-TRANSESTERIFICATION OF VEGETABLE OILS

Two plant oils viz., mustard and neem oils were selected for the present studies. A total of four different blends (10%, 15%, 20%, and 25%) with diesel were made. Oils were esterified so as to obtain their butyl esters before blending. The main aim of transesterification was to lower the viscosity of vegetable oils so as to obtain very close to diesel fuel [27, 28]. Esterification also improved their physical properties as follows (Table-1):

$$
\begin{array}{lccccccc}
CH_2OOR & & & & & & & CH_2OH \\
| & & & & & & & | \\
CHOOR & + & 3CH_3OH & \rightarrow & 3CH_3OOCR & + & & CHOH \\
| & & & & & & & | \\
CH_2OOR & & & & & & & CH_2OH \\
\text{Triglyceride} & & \text{Butanol} & & \text{Butyl Esters} & & & \text{Glycerol}
\end{array}
$$

Table-1. Properties of vegetable oils as compared with diesel (ASTM D975).

Before blend			
Properties	**Diesel**	**Mustard**	**Neem**
Cetane number (CN)	45-55	37	31
Specific gravity	0.83	0.953	0.968
Viscosity (20°C) mm^2/sec	4.7	24.67	37.42
Calorific value (MJ/kg)	42	32.43	29.97
Carbon (%)	86	74.45	78.92
Hydrogen (%)	14	10.63	13.41
After blend (20% by volume with diesel)			
Cetane number (CN)	45-55	54	48
Specific gravity	0.83	0.914	0.934
Viscosity (20°C) mm^2/sec	4.7	5.65	6.3
Calorific value (MJ/kg)	42	34.562	31.142
Carbon (%)	86	76	83
Hydrogen (%)	14	11.3	15

3. EXPERIMENTAL PROCEDURE AND SETUP

The experiment was laid down as shown in Figure-1.

3.1 Technical specifications of the engine

Study was conducted on a 4-stroke, single cylinder, C.I. engine (Kirloskar Oil Engines Ltd., India). **Type:** single acting, totally enclosed, high speed, 4 stroke, vertical, bore and stroke-78x82mm, number of cylinders-1, capacity-425cc, maximum power-7.5 BHP, compression ratio-15.5:1, speed-1500 rpm, cooling system capacity-5 liters, crank case oil capacity-3 liters.

An eddy current dynamo meter was coupled to the engine to apply the load on the engine for loading the engine. The fuel flow rate was measured by timing the consumption for known quantity of fuel (10cc) from a burette.

The main purpose of smoke measurement was to quantify the black smoke emitting from the diesel engine. Visibility was the main criterion in evaluating the intensity of smoke. Bosch meter was used for measuring the diesel engine smoke. It consists of a sampling pump and evaluating unit. The sampling pump was used to draw nearly 300cc of exhaust gas by means of a spring operated pump and released by pneumatic operation of a diaphragm. The gas sample was also drawn through the filtering paper darkening it.

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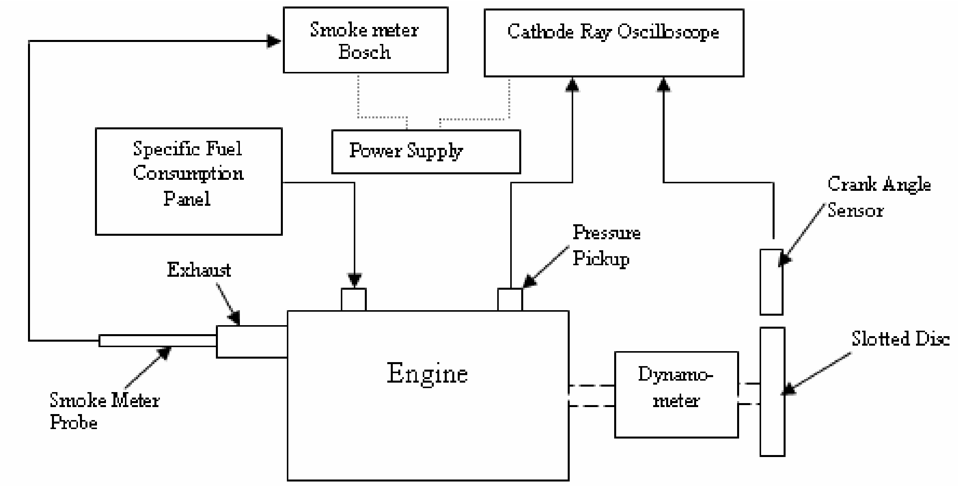

Figure-1. Experimental setup.

The spot made on the filter paper was evaluated by means of a precalibrated photocell reflectometer to give precise assessment of the intensity of the spot. The intensity of the spot was measured on a scale of 10 in arbitrary units, called Bosch smoke units for white to black.

The performance data were analyzed regarding smoke density, brake thermal efficiency, and specific fuel consumption of all fuels. Smoke meter was used to measure the smoke density of the exhaust. HORIBA-MEXA-324 FB was used for the measurement of CO and HC emissions.

Piezoelectric transducer was used to measure the pressure released in an engine cycle. Cathode ray oscilloscope (CRO) was used to obtain the graph. The potential difference between the outer and inner curved surfaces of the cylinder was a measure of the gas pressure.

3.2 Engine test procedure

This study was conducted to investigate the performance and emission characteristics of a stationary single cylinder diesel engine run on two different vegetable oils (mustard and neem) and their blends with diesel (10:90, 15:85, 20:80, and 25:75 by volume) and also on diesel fuel alone. The engine was coupled to an eddy current dynamo meter. Before initiating the studies, the engine was started and allowed to warm up for about 15 minutes. The engine was operated first on diesel fuel alone, followed by the two vegetable oils blends. In order to evaluate the performance of oil blends and pure diesel fuel, following parameters were recorded: (i) Cetane number (CN), (ii) Total fuel consumption (TFC), (iii) Specific energy consumption (SEC), (iv) Specific fuel consumption (SFC), (v) Brake thermal efficiency (BTE), and (vi) Cylindrical peak pressure (CPP), (vii) Smoke intensity.

The engine was tested under six different loads (0, 4, 8, 12, 16, and 20 kg) conditions at a constant speed of 1500 rpm, for each percentage of blending. Thereafter, time taken for 10cc of fuel consumption was noted for each load. The procedure was repeated for various blends used in studies.

4. RESULTS AND DISCUSSIONS

Studies have revealed that most of the properties of the esterified oils were almost similar to pure diesel fuel (Table-1).

4.1 Cetane number

CN of vegetable oils and their blends with diesel fuel was calculated and found almost equal in comparison with the diesel fuel (see Table-1). This validates the feasibility to run a diesel engine on esterified vegetable oils after blending with diesel fuel [8].

4.2 Total fuel consumption

Total fuel consumption at different BHP with all percentages of blending was found to be slightly decreased from 0.05 kg/hr to 0.0195 kg/hr.

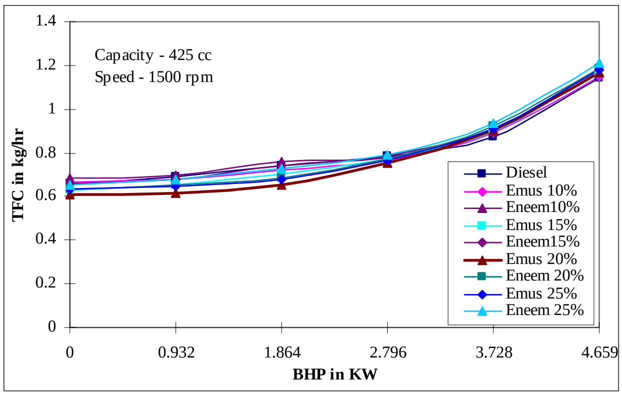

Figure-2. Variations in TFC with respect to BHP for four different blends of vegetable oils.

Improvement in TFC was perhaps due to better combustion of the fuel, because of an increase in calorific value of vegetable oils due to esterification, resulting in reducing the ignition delay (Figure-2).

4.3 Specific energy consumption

A decrease in SEC with increase in load was observed up to a load level of about 16 Kg, and thereafter, a slight increase was observed. The initial decrease in SEC may be attributed to the complete and high combustion of fuel. Once the load reached at full load level, the time taken for complete combustion of fuel was decreased, hence a slight increase in SEC was observed (Figure-3). Viscosity and specific gravity of the vegetable oils perhaps also played an important role in affecting the performance of engine at full load levels.

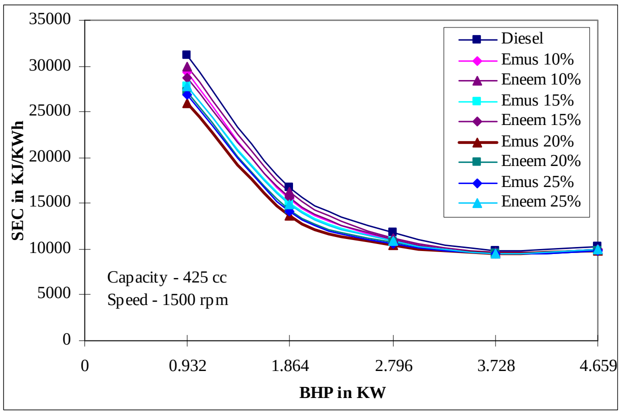

Figure-3. Variations in SEC with respect to BHP for four different blends of vegetable oils.

4.4 Specific fuel consumption

SFC at different loads with all percentage of blending was found slightly decreased from 0.135 kJ/kW-hr to 0.045 kJ/kW-hr. This improvement in SFC was perhaps due to better combustion of the fuel, which may be attributed to the presence of oxygen in the blend. Esterification also helps to lower the temperature reaction and better combustion. Since the cetane number of esterified mustard oil was high; hence SFC in its 20% blend was reduced from 0.123 to 0.021 Kg/KW-hr (Figure-4).

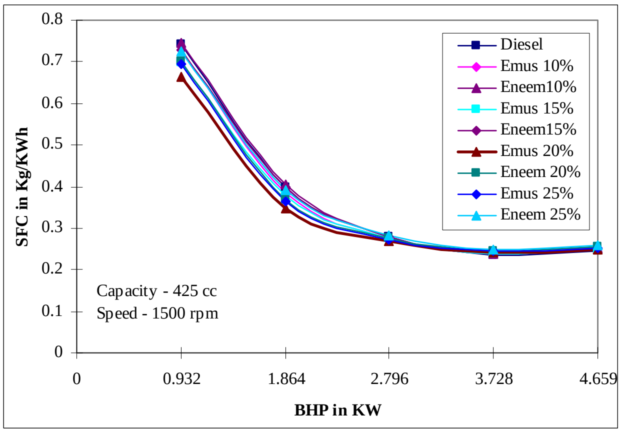

Figure-4. Variations in SFC with respect to BHP for four different blends of vegetable oils.

4.5 Brake thermal efficiency

An increase in BTE with increase in load was observed up to a load level of about 16 Kg and thereafter a decrease was observed. The initial increase in BTE may be attributed to the complete and high combustion of fuel, but once the load reached at full load level; the time taken for complete combustion of fuel was decreased, hence a slight drop in BTE was observed. Oxygen present in the blends perhaps also helped in complete combustion of fuel at no load and also at partial load conditions. At full load conditions the change of state from molecule oxygen to atomic oxygen perhaps has lead to a decrease in BTE. Similar finding were also reported by Bagby *et al.*, [30] while working on seed oils for diesel fuel. Specific gravity of the vegetable oils perhaps also played an important role in affecting the performance of engine at full load levels (Figure-5).

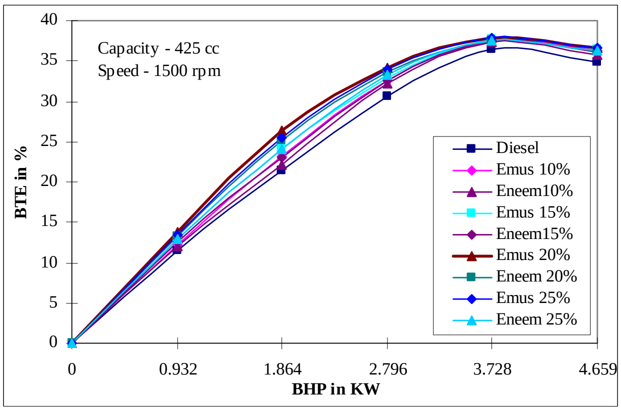

Figure-5. Variations in BTE with respect to BHP for four different blends of vegetable oils.

4.6 Cylindrical peak pressure

CPP was found to have increased at all load levels from 2 to 8 bars with blended fuel as compared to diesel. Increase in the pressure may be attributed to improved combustion of the fuel due to the presence of oxygen in the esterified vegetable oils. The presence of oxygen in the fuel particle perhaps has also enhanced the low temperature reaction to proceed in the proper direction. A maximum increase of pressure from 2 to 6 bars was observed at full load level when mustard oil at 20% blend was used (Figure-6(a), (b), and (c)).

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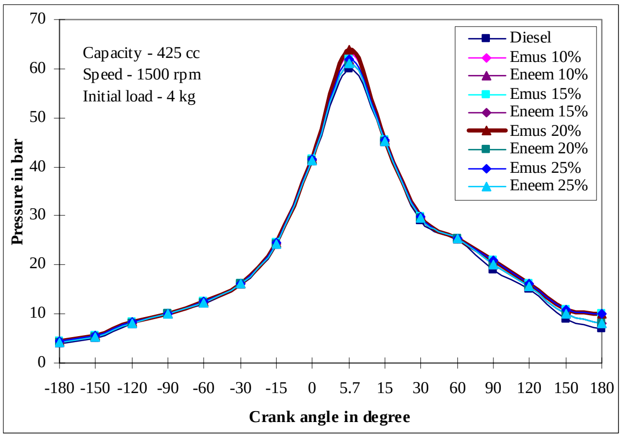

Figure-6(a). Variations in CPP at initial load with respect to crank angle for four different blends of the vegetable oils.

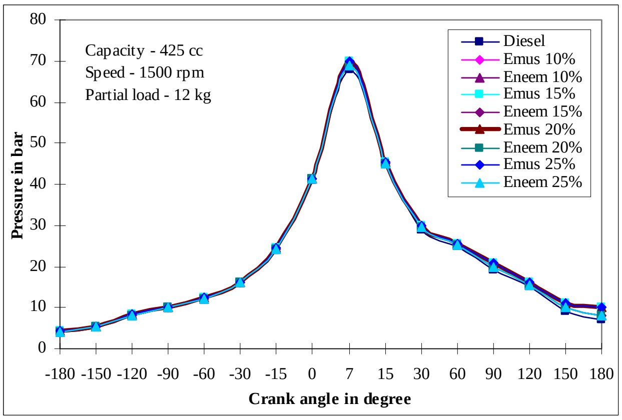

Figure-6(b). Variations in CPP at partial load with respect to crank angle for four different blends of the vegetable oils.

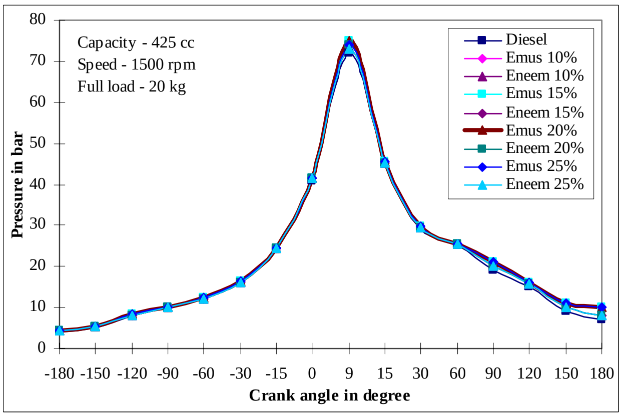

Figure-6(c). Variations in CPP at full load with respect to crank angle for four different blends of the vegetable oils.

4.7 Smoke intensity

Not much variations in smoke intensity was observed among the two oils and their blends, however, a marginal decrease in smoke intensity was observed in 20% blend, more so in case of mustard oil blend (Figure-7).

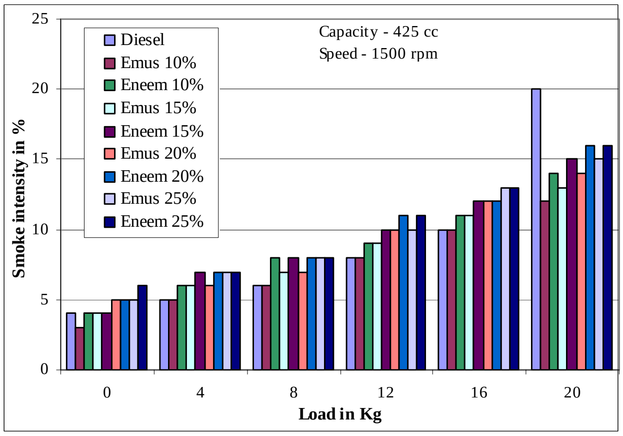

Figure-7. Variations in smoke intensity at four different blends of vegetable oils with respect to load.

5. CONCLUSIONS

Butyl ester of mustard oil at 20% blend with diesel gave best performance in terms of low smoke intensity, emission of HC and NO_x. Cetane number, total fuel consumption, specific energy consumption, specific fuel consumption, brake thermal efficiency, and cylindrical peak pressure were almost equal when engine was run on pure diesel.

- The transesterification process, used for making biodiesel, is simple and cost effective to solve viscosity problems encountered with vegetable oils.
- The cost of dual fuel can be considerably reduced than when pure diesel is used.
- Esterified mustard oil and esterified neem oil as a biodiesel satisfies the important fuel properties as per ASTM D975 [35].

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