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Research Article

METHYL ESTER (BIODIESEL) PRODUCTION FROM MICRO ALGAE AND LINSEED MIXING OIL: PERFORMANCE CHARACTERISTICS OF DIESEL ENGINE

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A B S T R A C T

Pollutant emissions from diesel engines have caused major impacts in disturbing the ecological system. To overcome these problems, focus is towards alternative sources. Biodiesel, derived from vegetable, non vegetables oils and algae is the future prospect. Higher viscosity is found as the major problem in use of non vegetable oil directly in engine that is removed by converting it into biodiesel by transesterification reaction. This paper discusses a detailed study on the production of Mixed Methyl Ester (MME) using a mixture consist of Schizochytrium micro algae oil and linseed oil in different volume percentage say 15:85ml through two-step trans-esterification process. An experimental test was performed to determine the efficiency and the contaminating characteristics of the diesel engine powered by blends ofMME (B10 & B20). A mixture of *Schizochytrium* microalgae oil and linseed oil ME (MME) is tested in a direct injection diesel engine with a single cylinder. Performance results revealed that most of the MME gave higher brake thermal efficiency and lower brake-specific fuel consumption. Emission results showed that in most cases, NOx is increased, HC and CO emissions are decreased. B_{10} blend of MME with diesel was found the best suitable blend for engine. Experimentally, it shows apart from its potential for implantation, that MME-powered compression ignition engine

INTRODUCTION

Biodiesel is a green fuel produced from renewable resources. It is a clean-burning alternative fuel, which has drawn the attention of energy researchers for the last two decades. The increase in demand for diesel fuel and limited petroleum resources has led to the development of biofuels as substitutes for petroleum based fuel in an effort to alleviate future energy and economic crises. Biodiesel is one of the potential alternatives to petroleum diesel, as its properties are very comparable to diesel. Biodiesel is technically defined as "the mono alkyl esters of long chain fatty acids derived from the renewable liquid feedstock such as vegetable oils and animal fats for use in compression ignition (CI) engines" [1]. Biodiesel is renewable, biodegradable, nontoxic, and essentially free of sulfur and aromatics compared with petroleum-based diesel. Biodiesel has carbon mitigation potential [2].

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Biodiesel provides support to local economies, provides rural employment, and improves the energy security of the nation [3]. The most commonly used oils for the production of biodiesel are linseed, soybean, palm, rapeseed, canola, and jatropha. The direct application of vegetable & non-vegetable oils as a fuel in compression ignition engines has been limited due to its highly viscous nature. The viscosity of these oils can be reduced by converting into alkyl esters using a transesterification reaction. The use of biodiesel has not expanded into developing countries due its higher price compared with conventional diesel. The higher cost of biodiesel is due to its production, which has been done primarily from expensive, high-quality virgin oil. Moreover, biodiesel is mainly derived from renewable feedstocks like edible, non-edible oils or animal fats [4]. The main advantages of us ing biodiesel are it's portability, being readily availabile, better combustion efficiency, lower sulphur content, higher cetane number, higher biodegradability, domestic origin, higher flash point and improved lubrication property [5,6]. Researchers have found that with use of biodiesel nitrogen oxides (NOX) emission increases whereas hydrocarbon (HC), carbon monoxide (CO), and particulate matter emissions (PM) decrease in comparison to diesel fuel [7,8].

Consistent scientific investigations are performed to produce biodiesel that is competitive in price with petroleum diesel by using mixed feedstocks.Growing bio-diesel could be a sustainable process, using the energy of the sun and waste carbondioxide to produce useful lipids that can be processed into bio-diesel fuel. This could be a useful natural solar panel transforming sunlight into the chemical energy of oil. Our reliance on fossil fuels has caused carbon dioxide enrichment of the atmosphere, and is the primary contributor to the generally-accepted phenomenon called global warming. Because using coal produces even greater CO_2 emissions than oil, the depletion of oil will be unlikely to improve this pattern of CO_2 enrichment. In order to realize a stable energy alternative that will meet world demand while mitigating climate change, it is necessary to develop renewable clean fuels [9]. In the conventional trans-esterification process, linseed oil, micro algae oil methanol and KOH in various concentrations were refluxed together in a 500 ml round bottom flask equipped with magnetic stirrer and water condenser. After the complete conversion of the oil, the reaction was stopped and the mixture was allowed to stand for phase separation: the ester mixture formed the upper layer and glycerine formed the lower layer. The residual catalyst and unreacted alcohol were distributed between the two phases. After phase separation, using a separating funnel, the ester mixture was dried over anhydrous sodium sulfate.

Therefore, the use of mixed oils for biodiesel production is a promising alternative to disposal, as it combines economic aspects with environmental preservation by preventing the contamination of water sources while producing a less polluting fuel. This paper presents a production of methyl ester (biodiesel) from a mixture of *Schizochytrium* microalgae oil and linseed oil ME (MME), performance and emission characteristics.

MATERIALS AND METHODS

Collection of Micro Algae

Microalgae was purchased from ETA, Kolathur, Chennai. The species of micro algae chosen was *Schizochytrium*sp.

Lipid Extraction

Soxhlet method is used to extract the lipid from micro algae. The organic solvents n-hexane was used. A mass of 20gm of dry microalgae was extracted with 150 mL of solvent. This type of extraction is based on the evaporation, condensation and percolation of the solvent through the microalgae during 4 hours [10] .After that, solvent was removed and lipids recovered by water bathing process. The total lipid content of *Schizochytrium* microalgae was obtained to be 0.1015 g/g biomass.

Mixing of Microalgae Oil (Schizochytrium) and linseed Oil

Microalgae (Schizochytrium) oil and linseed oil are mixed thoroughly in different volume percentage say 15:85 ml and checked the viscosity using redwood viscometer and density by density meter. The mixing ratio, the observed value of viscosity and density are shown in Table 1.

Table 1 Viscosity of Oil at Different Mixing Ratio

Mixing Ratios	Viscosity (at 50^0C)	Density (kg/m^3)
Microalgae oil	9.18mm^2/s	930
Linseed oil	7.77 mm^2/s	919
15ml microalgae oil +85ml linseed oil	9.05 mm^2/s	925

Pre-esterification Process

The blended oil has a high-free FFA and is pre-treated. With 20 percent v/v methanol and 0.5 percent v/v catalyst at 60^0C, the combined oil will be reacted in the pre-esteration process. The reactions were conducted in a round lower bottom flask with such a condenser and a magnetic stirrer of 500 ml. The tests took place at the reflux of methanol temperature. The round bottom flask was filled with algae oil, linseed oil, an acid catalyst and methanol and was heated for 1.5 hours at a constant agitation speed of 1,500 rpm. Pre-esterification was done to decrease the acidity of the algae oil from 29% to less than 1%. After the reaction was finished, the mixture was extracted to remove the catalyst and the excess methanol recuperated by washing. To reduce the water value of the oil, add sodium sulfate. The value of acid was calculated using the titration method.

Acidity (%) = $\frac{282*v*n}{1000*m}$ x100

Where

v- KOH solution volume (mL).

n- normality.

m- Weight of sample.

Trans-esterification Process

In trans-esterification process measured 0.5 gram of NaOH. Measured quickly since the catalyst absorbs water from the atmosphere rapidly and this water can interfere with the trans-esterification reaction. Then, mix the NaOH with 20 ml of methanol in a sturdy, heat proof glass bottle with a narrow neck to prevent splashing. Constantly mix or stir the solution to quickly dissipate the heat given off by the reaction. The mixing process takes about 15 minutes, pour 100ml of mixed oil in the container, and heat the container to about 50^oC. The trans-esterification reactions were carried out using a 500 ml round bottom flask equipped with a reflux condenser, and magnetic stirrer. The experiments were performed at methanol temperature reflux. The round bottom flask was filled with algae oil, linseed oil, NaOH and methanol and heated under constant agitation speed of 1500 rpm for 1.5 hours. Keep the temperature below 60^oC since methanol will boil at 65^oC and will be lost. Then allow the mixture to settle overnight. The system should be closed to the atmosphere to prevent loss of methanol during the reaction. The reaction will take about 12 hours to complete. Figure 1 shows the trans-esterification reaction.

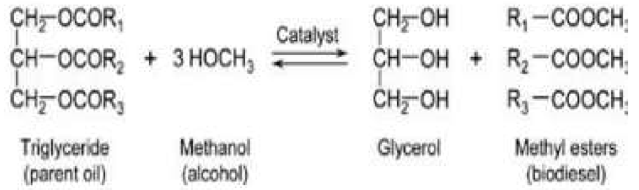

Figure 1 Trans-esterification Reaction [11]

Separation

As soon as the reaction is completed, pour the mixture from the round bottom flask into a separating funnel for settling and screw on the lid tightly. Allow the mixture to settle 12-24 hours. After settling, there will be two phases in the bottle with a clear interface. Dark colored glycerol byproduct will collect at the bottom, with crude methyl ester on top. The methyl ester varies in color depending on the oil used. Carefully remove the bottom layer. Be sure to not inadvertently mix up the glycerol layer with the methyl ester.

Crude Methyl ester Washing and Filtering

The crude biodiesel still contains contaminants such as soaps, excess methanol, residual catalyst, and glycerol. It can be purified by washing with warm water to remove residual catalyst or soaps. The methyl ester was washed by 5% water until it was become clean. The washing procedure is effective because the residues are more readily dissolved in water. The ester mixture was dried over anhydrous sodium sulfate. In filtration process, it is filtered with the use of a filter paper.

Elemental analysis

The CHNOS analyzer find utility in determining the percentages of Carbon, Hydrogen, Nitrogen, Sulphur and Oxygen of organic compounds (figure), based on the principle of "Dumas method" which involves the complete and instantaneous oxidation of the sample by "flash combustion". The combustion products are separated by a chromatographic column and detected by the Thermal Conductivity Detector (TCD), which gives an output signal proportional to the concentration of the individual components of the mixture.

Physico chemicalproperties of MME

Biodiesel are characterized by their carbon chain, kinematic viscosity, specific gravity, calorific value, density, cetane number, iodine value, cloud and pour point, flash point etc. These parameters are all specified through the biodiesel standard, ASTM D6751.

Emission Characteristics

In a diesel engine smoke, oxides of nitrogen, carbon monoxide and unburned hydrocarbon emissions are considered as main pollutants. In this investigation, these emissions are measured and analyzed.

Performance characteristics

Important engine performance parameter, such as brake thermal efficiency for MME in IC diesel engine are calculated, analyzed and compared with diesel in normal engine..

RESULTS AND DISCUSSION

Elemental analysis

The methyl ester consists of three basic elements namely:1-Carbon.2- Hydrogen.3- Significant amount of Oxygen. The increase of O_2 in methyl ester is related to the reduction of C and H causes the lower calorific value of biodiesel that produced, as compared to that of diesel. A mixture consist of Schizochytrium micro algae oil and linseed oil methyl ester (MME) contains 70% carbon and 11.43% hydrogen and 9.46% oxygen. All the elements reached ASTM standards which is suitable for environment (Table 2). Table 3 shows that the properties of MME and conventional diesel. The study shows that the properties of the MME are very close to the conventional diesel.

Table 2 Elemental composition and C/H ratio Comparison of MME with ASTM biodiesel standards

Element (wt%)	Petro Diesel	(Algae and linseed) MME	ASTM
Carbon(C)	86.25	70.96	77
Hydrogen(H)	12.5	11.43	12
Nitrogen(N)	0	1.31	----
Sulphur(S)	0.25	0.15	0.05
Oxygen(O)	1	9.46	11
C/H Ratio	6.9	6.20	----

Table 3 Properties of MME and Conventional Diesel

Parameter	MME (15 ml +85 ml) (Microalgae oil + Linseed oil)	Diesel
Density (kg/m^3)	850	859
Viscosity (mm^2/s) at 50^{0}C	2.6	4.2
Acid value mg/KOH gm	0.33	-
Flash point (K)	399	341
Fire point (K)	403	351
pH	7	7

Performance Characteristics of Diesel Engine

Time taken for fuel consumption

The time taken for the 10 CC consumption of fuel for different loads from no load (zero) to 10 kg is observed from the diesel engine check with various blends (B10, B20) A mixture consisting of *Schizochytrium* microalgae oil and linseed oil ME (MME) Comparison contrasted to that with standard diesel fuel (Table 4). The table showed that fuel consumption Time values for B10 were very similar to diesel values. B10 is therefore taken into account for further experiments.

Table 4 Time taken for fuel consumption (sec)

Load(kg)	Diesel	B10	B20
0	87	86.54	85.26
2	71	69.63	65.45
4	58.36	55.32	54.66
6	50.18	49.66	48.32
8	43.4	41.84	40.56
10	38.53	36.38	35.11

Brake Thermal Efficiency for Diesel

Tables 5 and Figure 2 show a disparity difference in the brake thermal efficiency with MME (B10) and diesel power in a single cylinder, a 4-speed diesel engine. The lower thermal efficiency of MME than diesel fuel can be attributed to problems with fuel flow because of higher viscosity and density. Furthermore, decreased combustion efficiency due to reduced fuel vaporisation and atomisation could also reduce MME thermal brake efficiency. Results show that the thermal brake output of MME in the standard motor is close to that of diesel [93].

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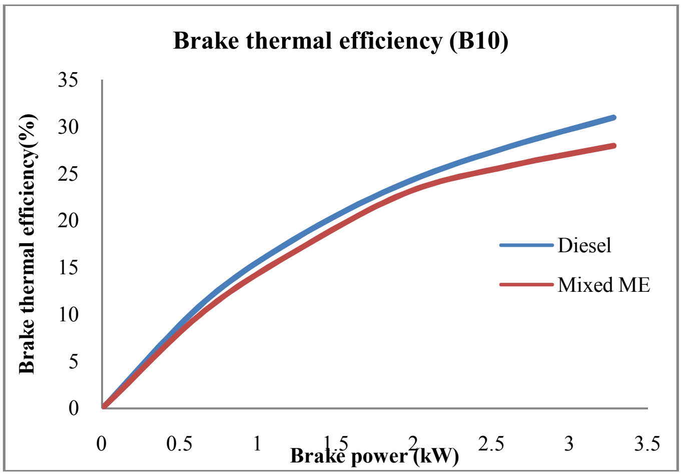

Figure 2 Brake thermal efficiency of MME (B10)

(BTE) brake thermal efficiency is the release of energy by combustion in brake power proportion [1]. For a diesel-powered engine, the Brake Thermal Efficiency at 2 kg is 11.42 percent, and the maximum efficiency at 10 kg (Table 5) is 30.99 percent.

Table 5 Brake Thermal Efficiency of Diesel

Load Kg	Brake power (kW)	Q(m^3/sec)	Mass of fuel Consumption (Kg/sec)	Heat Input (kW)	Brake Thermal Efficiency
0	0	1.15E-07	0.00010287	4.68	0
2	0.66	1.41E-07	0.00012606	5.74	11.42
4	1.31	1.71E-07	0.00015336	6.98	18.78
6	1.97	1.99E-07	0.00017836	8.12	24.22
8	2.62	2.30E-07	0.00020622	9.39	27.93
10	3.28	2.60E-07	0.00023229	10.57	30.99

Table 6 Brake Thermal Efficiency of B10

Load Kg	Brake power (kW)	Q (m^3/sec)	Mass of fuel Consumption (Kg/sec)	Heat Input (kW)	Brake Thermal Efficiency
0	0	1.16E-07	0.00010342	4.75	0
2	0.66	1.44E-07	0.00012854	5.91	11.10
4	1.31	1.81E-07	0.00016179	7.43	17.63
6	1.97	2.01E-07	0.00018023	8.28	23.74
8	2.62	2.39E-07	0.00021391	9.83	26.67
10	3.28	2.75E-07	0.00024601	11.31	28.99

A mixture 's brake thermal efficiency variations consist of MME fuel mixtures BTE of B10 was found to be less than diesel fuel and the average BTE fuel is 30.99%, and the maximum B10 fuel is 28.99% (Table.6).

Emission Characteristics

The emission characteristics were NOx, CO and HC. A mixture consisting of *Schizochytrium* microalgae oil and linseed oil, methyl ester (MME), CO and HC emissions, has been observed to be reduced. In comparison, emissions of NOx were higher than those of petrol.

Oxides of Nitrogen (NO_X)

A mixture of NOx variation consists of Schizochytrium microalgae oil and linseed oil methyl ester (MME) with increased engine load due to higher burning temperatures. In Figure 3, emissions of NOx were reduced for diesel fuel over a full load range compared to the MME (No full load).

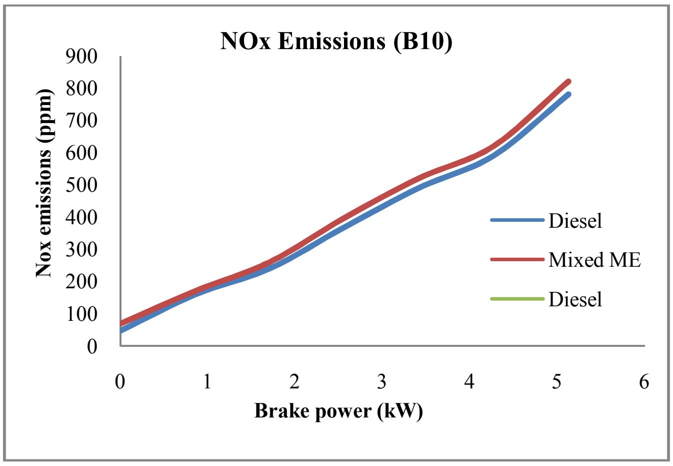

Figure 3 Variation of NOx Emissions with brake power

Carbon monoxide (CO)

The CO Emission due to the fuel 's incorrect combustion and depend mainly on engine temperature and the (A / F) air-fuel ratio [12]. Figure 4 displays the difference in carbon monoxide (CO) of a mix of microalgae Schizochytrium oil and linseed oil ME (MME) and standard diesel. The CO emissions of MME are decreased with diesel fuel since biodiesel is an oxidised fuel, including oxygen that contributes to the complete combustion. And CO emissions have collapsed [13].

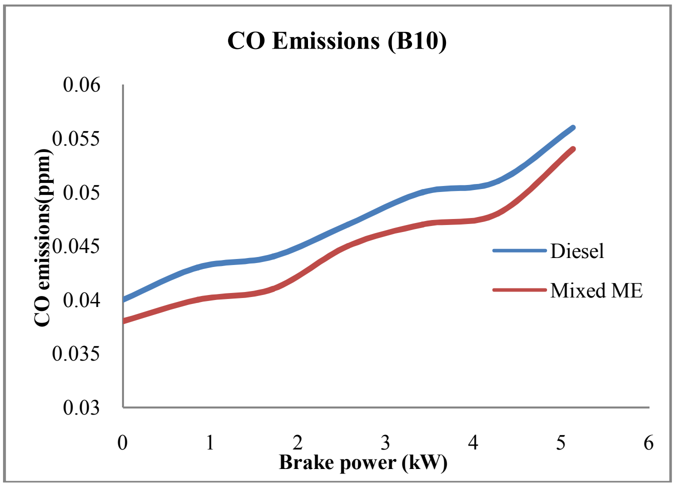

Figure 4 Variation of CO Emissions with brake power

Hydrocarbon (HC)

For a slight decrease in HC emission, a combination of Schizochytrium microalgae oil and linseed oil ME (MME) is used. It was because of higher oxygen fuel than diesel oil. As shown in Figure 5, MME levels of hydrocarbon are Less than diesel fuel. The HC emissions are reduced at partial load, but they tend to increase for both fuels at higher loads. That is because there is no fuel at a greater equivalence ratio regardless of engine operations. And a strong oxygen level leads to low HC [14].

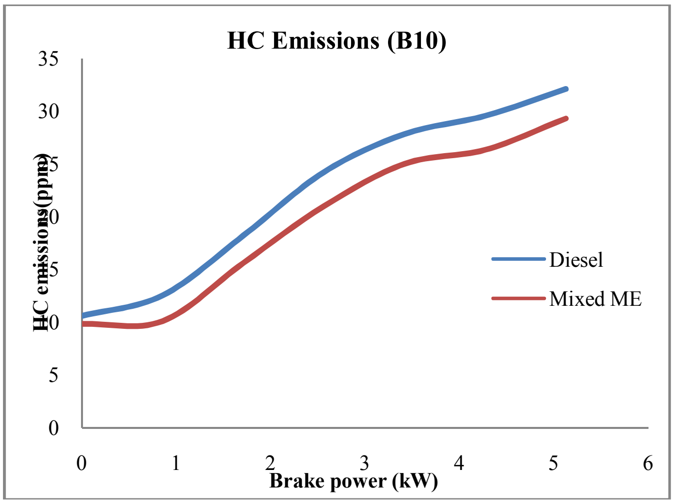

Figure 5 Variation of HC Emissions with brake power

CONCLUSION

The research work shows that various feedstocks like edible oils, non-edible oils and algae are available for production of biodiesel. The main problem with direct usage of vegetable oil in engine is the higher oil viscosity which can be removed by preheating or converting it into biodiesel. Fuel properties of biodiesel are comparable to those of petroleum diesel. Analysisof performance parameters like BSFC, BTE shows that as the blend ratio increases, the performance reduces. Emission characteristics show that commendable reduction in HC and CO emissions increases in NOx emissions. B_{10} blend of MME with diesel was found the best suitable blend for engine. Experimentally, it shows apart from its potential for implantation, that MME-powered compression ignition engine can make a significant contribution to twin problems of diesel oil shortages and pollution.

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