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INTEGRATED RESEARCH ADVANCES

Integrated Science

Experimental investigation on the performance and emission characteristics of compression ignition engine fuelled with various blends of water melon biodiesel

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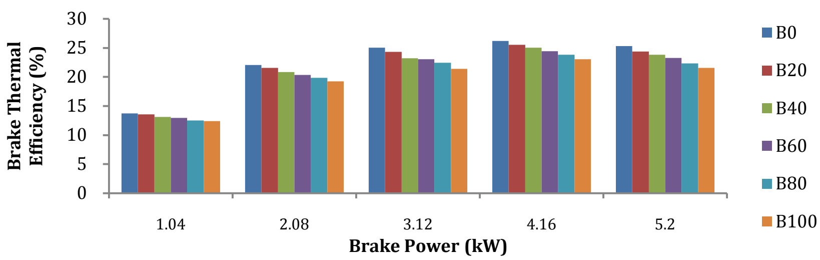
ABSTRACT



In the present study, an experimental work had been carried out to analyze the performance and emission characteristics of compression ignition engine fuelled with various blends of Water melon biodiesel. The engine tests are conducted on kirloskar, 5.2 kW, 4-stroke, single cylinder, 1500 rpm, water cooled, direct injection diesel engine with eddy current dynamometer with injection timing 23° bTDC and injection pressure 210 bar were maintained constant throughout the experiment. Different blends of biodiesel such as B0, B20, B40, B60, B80 and B100 are prepared to analyze the performance and emission characteristics. From the test results, it could be observed that among different blends B20 blend showed very close performance with the neat diesel.

Keywords: Biodiesel, Blends, Emission, Engine, Transesterification.

INTRODUCTION

Biodiesel derived from vegetable oils and animal fats is a promising substitute fuel for diesel since it is renewable and environment friendly. Investigations carried out with different kinds of edible and non-edible vegetable oils in their pure and modified forms confirmed their ability to replace diesel either fully or partially. Even though the investigated edible oils have the potential to replace the diesel fuel in different forms, it is tactically important for the countries to diversify the feedstock for biodiesel production. Utilization of edible oils as a feedstock for biodiesel production will increase its price and may affect the economy of the country. It was also suggested that the exploitation of new biomass resources and research in the production of biofuels from non-food biomass resources are the key areas for developing bioenergy for the future. Hence investigations were focused on non-edible vegetable oils as an alternative energy source for diesel. However, it has to be noted that the availability of non-edible vegetable oils studiedis very much limited. Utilizing a potential non-edible vegetable oil will be a more favorable solution for the present situation[1]. S. Saravanan et al.[1] reported that the crude rice bran oil methyl ester (CRBME) is an indigenous fuel and blending it with diesel for use in CI engines will reduce our dependence on oil import. G. Kasiraman et al.[2] found that the brake thermal efficiency of camphor oil (CMPRO) 30 blend is 29.1% at peak load compared to diesel brake thermal efficiency of 30.14% whereas it is 23.1% for neat cashew nut shell oil (CSNO). At peak load the NO emissions of CMPRO 30 blend, diesel fuel and neat CSNO are 1040 ppm, 1068 ppm and 983 ppm, respectively. The smoke emissions are higher for neat CSNO with a value of 4.22 BSU. For CMPRO 30 blend it is 3.91 BSU whereas it is 3.64 BSU for diesel. The peak pressure, maximum

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rate of pressure rise, ignition delay, combustion duration and heat release rates of CMPRO 30 blend and diesel fuel are comparable. H. Sharon et al.[3] reported that B25 and B50 showed better performance. B75 showed huge reductions in emissions. Ignition delay was lower for biodiesel and their blends. B50 produced peak cylinder pressure. B. S. Chauhan et al.[4] found that the BTE was about 3-5% lower with Karanja biodiesel and its blends with respect to diesel. The peak cylinder pressure and heat release rate was lower for Karanja biodiesel. The oxides of nitrogen from Karanja biodiesel and its blends were higher than diesel fuel at all loads. While running the engine on biodiesel and its blends, emissions such as CO, smoke density and HC were reduced as compared to diesel. Gaurav Paul et al.[5] reported that the use of jatropha biodiesel in a conventional diesel engine decreases its torque and brake thermal efficiency, the decrease being more with increase in the biodiesel share in the blends. BSFC increases with the percentage of biodiesel in the blended fuels. Cylinder peak pressure increases and ignition delay period decreases with the increase in biodiesel share in the blended fuels. Use of jatropha biodiesel increases the NOx emission compared to pure diesel. An increase in the jatropha biodiesel share in the blends reduces the PM and smoke emissions. The addition of jatropha biodiesel into diesel engine causes higher amount of carbon dioxide at tailpipe. S. K. Nayak et al.[6] found that brake thermal efficiency increases with increase in additive percentage in Mahua biodiesel and it is lower in case of pure biodiesel. Brake specific fuel consumption is highest for pure biodiesel. Exhaust gas temperature is found highest for pure biodiesel. CO and HC emissions are highest for diesel and lowest for pure biodiesel. Smoke and NOx emissions are found highest for pure biodiesel. H. C. Ong et al.[7] found that CIB10 gave good improvement in the engine performance with higher BTE. There is an improvement in fuel economy with lower BSFC and EGT by using CIB10 compared to diesel fuel. CIB10 reduced the CO and smoke opacity compared to diesel fuel but NOx emission is slightly increased. Sanjid A. et al.[8] reported that MB10 and MB20 can be used in diesel engines without modifications. K. Vijayaraj et al.[9] found that, optimized blend is B25 with respect to performance, emission and combustion characteristics for all loads compared with diesel. B. M. Shrigiri et al.[10] reported that the brake thermal efficiency values of CSOME and NKOME in LHR engine are lower than that of diesel fuel in normal engine by 6.88% and 6.48%. At rated load, the brake specific fuel consumption values of CSOME and NKOME in LHR engine are higher compared to that of fuel in conventional engine by 28.57% and 10.71%. K. Bhaskar et al.[11] found that the brake thermal efficiency of FOME and its blends are found to be lower at all brake power outputs compared to diesel fuel. As the percentage of FOME in the blend increases there is corresponding decrease in brake thermal efficiency. At all brake power outputs, ignition delays are lower and the peak pressures are higher for FOME and its blends compared to diesel.[12,13,14] CO, HC and soot emissions for FOME and its blends are found to be lower at all brake power outputs compared to diesel. NOx emissions are higher for FOME and its blends. D.N. Basavarajappa et al.[18] reported that for biodiesel fuelled engine with CRDI system the BTE showed varying trend with its increased value observed up to -10° BTDC and beyond which it reduced. HC emissions reduced with retarded injection timing while CO and smoke emissions increased drastically up to -10° BTDC and decreased beyond the said injection timing. NOx emissions increased with advanced injection timings. N.R. Banapurmath et al.[19] found that the brake thermal efficiency with HOME, SOME and JOME is 29.51%, 30.4% and 29%, respectively, at 80% load and 31.25% with diesel. The HC and CO emissions with SOME, HOME and JOME are found to be slightly more than the diesel operation. All the esters result in slightly higher smoke emissions than diesel. All the esters show increased ignition delay and combustion duration as compared to neat diesel. Ranganatha Swamy L. et al.[21] reported that use of 5 hole injector with optimized injection timing of 23° bTDC, combustion chamber shape (SDCC), optimized injector orifice size resulted in overall improvement in the brake thermal efficiency and reduced emissions compared to engine operation under manufacturer specified conditions.

WATER MELON (*CITRULLUS LANATUS*)

Watermelon (Citrullus Lanatus) is a vine-like flowering plant originally from southern Africa. It is a worldwide economically important member in family Cucurbitaceae. It has been cultivated for a long time in Africa, the Middle East and Egypt. The water melon fruit has a smooth thick rind (exocarp) and fleshy center (mesocarp and endocarp) including red pulp and watery juice. Watermelon fruit contains 60% flesh, of which 90% is a juice that contains 7 to 10% w/v sugars. Thus, over 50% of the watermelon fruit is readily fermentable liquid. Watermelon is rich in useful antioxidants (mainly lycopene) which have been used to inhibit the growth of cancer cells and to reduce the risk of heart attack. Also, watermelon is a rich source of L-citrulline which is a naturally occurring amino acid involved in the detoxification of catabolic ammonia and also serves as a precursor for L-arginine, the amino acid centrally involved in the production of the circulatory vasodilator, nitric oxide. In addition, watermelon is considered as a source of many vitamins as vitamin A, thiamine, riboflavin, niacin and vitamin C.[15,16] Watermelon (Citrullus Lanatus) is cultivated mainly for its juice, nectars and fruit while its seeds are regarded as waste. The seed that could have been used as human food to compensate for its high cost is regarded as waste.[17] It has been reported that watermelon seeds can be utilized successfully as a source of good quality edible oil and protein for human consumption. The seeds are utilized for human consumption in India, some African and Arabian countries. The seeds have been reported to be rich in protein and lipids.[20] Bitter melon (*Citrullus Colocynthis L.*) known as Egusi in Western Nigeria on the other hand is cultivated for its seeds and oil. Its fruit is not edible because of its bitter taste, but the seeds are employed both as condiment and thickener in Nigerian local soup. The seed is very rich in oil (53%) and protein (28%). The seed oil has been investigated for its potential as a raw material for biodiesel production.[22,23]

TRANSESTERIFICATION REACTION

It is most commonly used and important method to reduce the viscosity of vegetable oils. In this process triglyceride reacts with three molecules of alcohol in the presence of a catalyst producing a mixture of fatty acids, alkyl ester and glycerol. The process of removal of all the glycerol and the fatty acids from the vegetable oil in the presence of a catalyst is called esterification. The Figure 2 shows the transesterification process in which the upper layer forms the ester and lower layer forms the glycerol. The parameter such as temperature, molar ratio and catalyst concentration that affect the transesterification of Water melon oil were optimized initially. The transesterification set up houses 2 L Capacity, round bottom flask provided with three necks that was placed in a water container for heating the oil. A heater with a temperature regulator was placed in the round bottom flask. A high speed motor with a magnetic stirrer was used for vigorous mixing of the oil. In the transesterification process triglycerides of Water melonoil reacts with methyl alcohol in the presence of catalyst (NaOH) to produce a fatty acid ester and glycerol. In this process 1000 g Water melon oil, 230 g methanol and 8 g sodium hydroxide pellets were placed in the round bottom flask. The contents were heated to 70°C and stirred vigorously for one hour to promote ester formation. The mixture was next transferred to a separating funnel and allowed to settle under gravity overnight. The upper layer in the separating funnel consists of ester whist the lower layer is glycerol which was removed .The separated ester with 250 g hot water and allowed to settle under gravity for 24 hours. Water washing separates residual fatty acids and catalyst and these were removed using a separating funnel. Finally the moisture from the ester was removed by adding silica gel crystals. Various biodiesel-diesel blends (B20, B40, B60, B80 and B100) were prepared for the experimental work.[24,25]

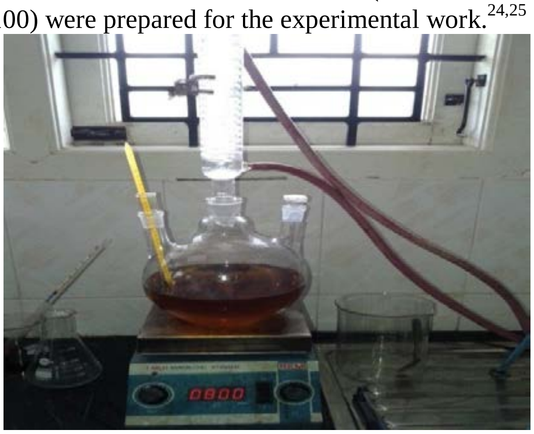

Figure 1. 3 mouth flask

Figure 2. Separating flask

Figure 3. Phase separation of hot water and biodiesel

PROPERTIES OF FUELS

Table 1. Properties of biodiesel blends compared with diesel

Properties	B0	B20	B40	B60	B80	B100
Density (kg/m^3)	827	836	844	853	861	872
Kinematic Viscosity at 40°C (cSt)	3.51	3.97	4.43	4.89	5.35	5.82
Flash point (°C)	52	75	98	122	149	168
Fire point (°C)	59	86	112	139	165	192
Calorific value (MJ/kg)	42.21	41.47	40.73	39.98	39.25	38.52

EXPERIMENTAL SETUP

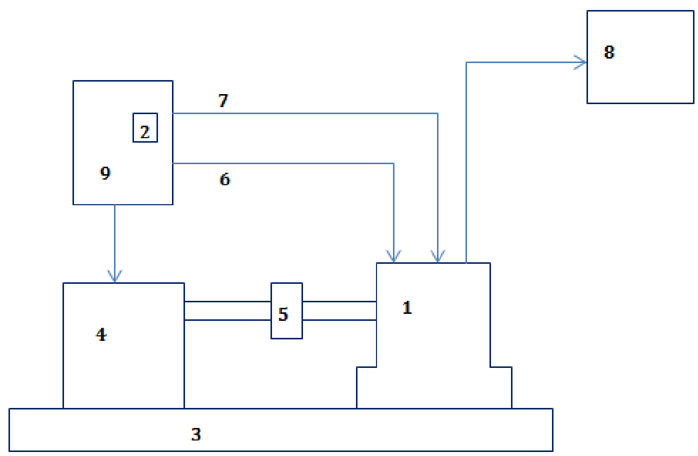

Figure 4. Experimental setup

1. Diesel engine
2. Burette for fuel measurement
3. Base
4. Dynamometer
5. Coupling
6. Air supply line
7. Fuel supply line
8. Exhaust gas analyzer
9. Control panel

A single cylinder, direct injection, four-stroke, water-cooled, Compression Ignition (CI) engine is used in the experimental study. The technical specification of the engine is given in Table2. The fuel flow rate was measured by noting down the time taken for the consumption of a known quantity of fuel (10cc) from a burette. The viscosity of raw as well as esterified oil was measured by red wood Viscometer, density by hydrometer, calorific value by bomb calorimeter, flash and fire point by open cup method. AVL-444 DI Gas analyzer was used to record the exhaust tail pipe emissions such as HC, CO, and NOx. Initially, before starting experimental tests, the engine was made to run under ideal condition as warm up phase and then the tests were conducted. The engine was started and allowed to warm-up for about 10 minutes. The engine was tested under five discrete part load conditions i.e. 20%, 40%, 60%, 80% and 100%.[26]

Table 2. Engine specifications

Engine Parameter	Specifications
Engine Type	Kirloskar
No. of Strokes	4
No. of Cylinders	1
Type of Cooling	Water Cooling
Type of Injection	Direct Injection
Bore	87.5 mm
Stroke	110 mm
Compression Ratio	17.5:1
Rated Power	5.2 kW
Rated Speed	1500 rpm
Injection Pressure	210 bar
Injection Timing	23° bTDC

Results and Discussion

Performance Characteristics

Brake Thermal Efficiency (BTE)

The variation of Brake Thermal Efficiency with Brake Power for different blends of biodiesel as shown in Figure 5. For all the fuels tested the Brake Thermal Efficiency increases with increase in load. This is due to, reduction in heat loss and increase in power with increase in load. The Brake Thermal Efficiency of biodiesel blends was found to be lower compared to diesel at all power output.[27,28] This is due to, the lower calorific value, higher viscosity, higher density which leads to poor atomization of biodiesel than diesel which results into increase of Brake Thermal Efficiency for diesel than biodiesel blends. At 80% load condition all tested fuels give higher Brake Thermal Efficiency than at 100% load condition.[29] This is due to the fact that, the power produced from the engine is less than the amount of fuel consumed to develop that power at 100% load condition so that Brake Thermal Efficiency decreases at 100% load condition as compared to 80% load condition.[30]

Total Fuel Consumption (TFC)

The variation of Total Fuel Consumption with Brake Power for different blends of biodiesel as shown in Figure 6. As the load increases Total Fuel Consumption increases for all fuels tested. Total Fuel Consumption for diesel is less as compared to biodiesel blends. This is due to higher viscosity, higher density which leads to higher fuel consumption of biodiesel than diesel.

Brake Specific Fuel Consumption (BSFC)

The variation of Brake Specific Fuel Consumption with Brake Power for different blends of biodiesel as shown in Figure 7. As the load increases Brake Specific Fuel Consumption decreases. It is observed that Brake Specific Fuel Consumption for biodiesel blends is higher when compared with diesel. For effective burning of the fuel the calorific value of the fuel should be higher so that the evaporation of the fuel is also high. The calorific values of blends of biodiesel are lower when compared with diesel; hence the fuel evaporation is slower. Slower evaporation rates leads to higher brake specific fuel consumption.

Emission characteristics

Hydrocarbon (HC) emissions

The variation of Hydrocarbon emissions with Brake Power for different blends of biodiesel as shown in Figure 8. The neat diesel exhibit lower amount of Hydrocarbon emissions as compared to biodiesel blends. This is mainly due to, higher viscosity of biodiesel blends which leads to poor mixing of fuel and air results into incomplete combustion.

Carbon Monoxide (CO) emissions

The variation of Carbon Monoxide emissions with Brake Power for different blends of biodiesel as shown in Figure 9. The neat diesel exhibit lower amount of Carbon Monoxide emissions as compared to biodiesel blends. This is mainly due to, higher viscosity of biodiesel blends which leads to poor mixing of fuel and air results into incomplete combustion.

Nitrogen Oxide (NOx) emissions

The variation of Nitrogen Oxide emissions with Brake Power for different blends of biodiesel as shown in Figure 10. The neat diesel exhibit higher amount of Nitrogen Oxide emissions as compared to biodiesel blends. This is mainly due to, diesel having higher calorific value and lower viscosity than biodiesel blends. This results into better mixing of fuel and air which leads into complete combustion of fuel. The complete combustion of fuel results higher Peak Pressure Rise rate and higher Exhaust Gas Temperature which leads to higher value of Nitrogen Oxide emissions than biodiesel blends.

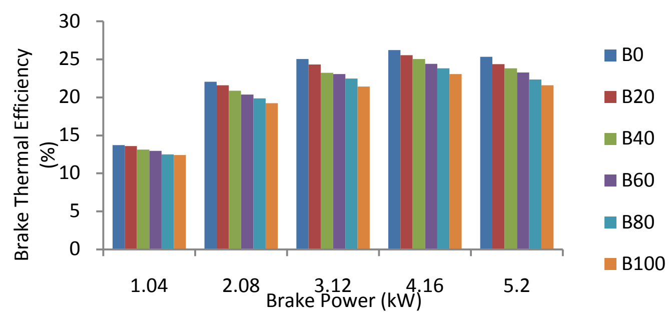

Figure 5. Variation of brake thermal efficiency with brake power

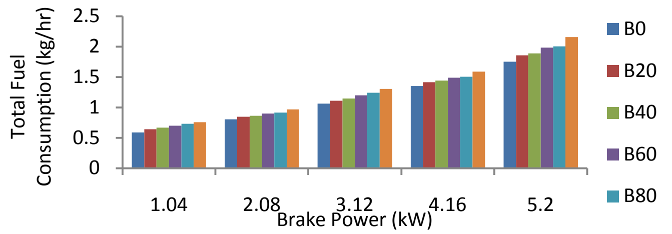

Figure 6. Variation of total fuel consumption with brake power

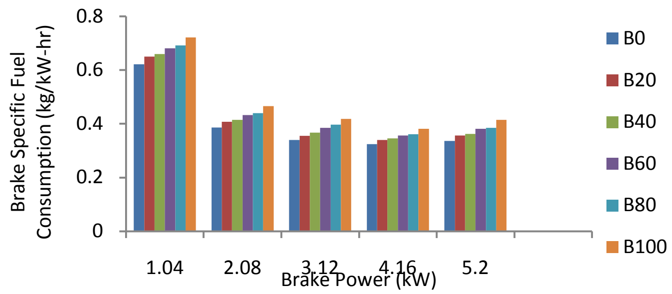

Figure 7. Variation of brake specific fuel consumption with brake power

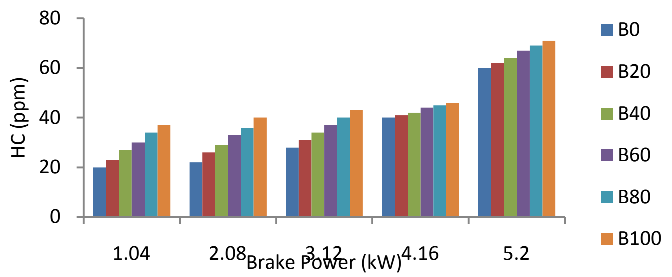

Figure 8. Variation of Hydrocarbon emissions with Brake Power

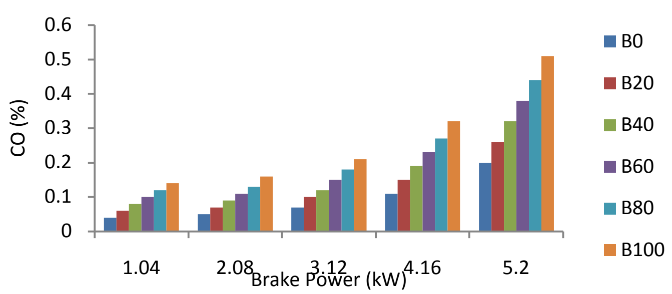

Figure 9. Variation of Carbon Monoxide emissions with Brake Power

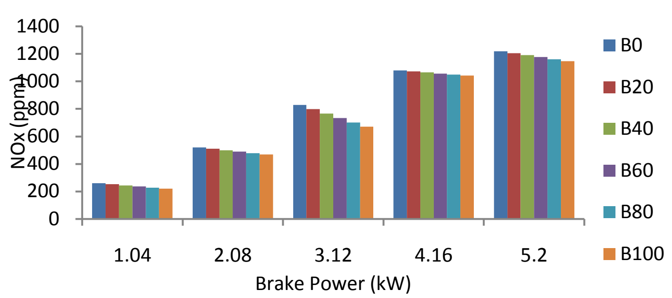

Figure 10. Variation of Nitrogen Oxide emissions with Brake Power

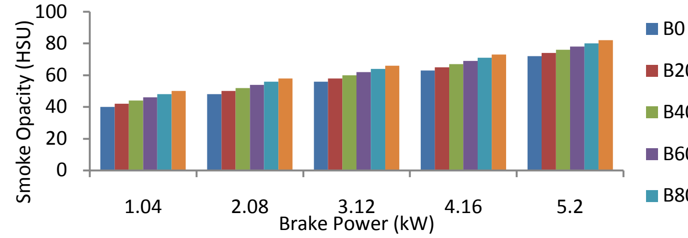

Figure 11. Variation of Smoke Opacity with Brake Power

Smoke Opacity

The variation of Smoke Opacity with Brake Power for different blends of biodiesel as shown in Figure 11. The neat diesel exhibit lower amount of Smoke Opacity as compared to biodiesel blends. This is due to, higher viscosity of biodiesel blends the atomization of fuel becomes poor and this leads to higher smoke emissions.

Conclusion

The Brake Thermal Efficiency of biodiesel blends was found to be lower compared to diesel at all power output. Total Fuel Consumption for diesel is less as compared to biodiesel blends. Brake Specific Fuel Consumption for blends of biodiesel blends is higher when compared with diesel. The neat diesel exhibit lower amount of Hydrocarbon emissions as compared to biodiesel blends. The neat diesel exhibit lower amount of Carbon Monoxide emissions as compared to biodiesel blends. The neat diesel exhibit higher amount of Nitrogen Oxide emissions as compared to biodiesel blends. The neat diesel exhibit lower amount of Smoke Opacity as compared to biodiesel blends. Among the biodiesel blends tested, B20 gave the best performance with reduced emissions. The BTE of the engine with the B20 blend at 80% power output which is closer to diesel operation. Hence B20 blend is recommended for existing diesel engine.

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