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Combustion and emission analysis of CI engine fuelled with methyl esters of dates seed oil with various diesel blends

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Abstract
Fossil fuels are commonly used fuel for automobiles. The exhaust gas emission of fossil fuel causes a serious problem. This arises the need for alternative fuels. Biodiesel is a renewable fuel produced from plant and animal material by trancesterification process. Transesterification is base catalyzed reaction, they convert triglycerides into mono alkyl esters. The main problem of biodiesel is its high cost which could be reduced by use of less expensive feed stock. Dates seed oil is obtained from the extraction of dates seed. Dates seed oil is used for production of biodiesel. Since, the dates oil is extracted from the dates seed, which is a waste, the usage of dates seed for the production of dates seed biodiesel becomes very inexpensive and feasible. The calorific value of dates seed biodiesel is 38000 KJ/kg while the density is 879 kg/m^3, flash point is 122 °C, viscosity is 5.2 mm^2/s and cetane number is 42. A single cylinder, 4 stroke, water cooled diesel engine of Kirloskar Oil Engine TAF 1 is used for evaluating combustion and Emission characteristics of dates seed biodiesel blends and diesel. The cylinder pressure for all the dates seed biodiesel blends is lower than the diesel and the Emissions parameters HC, NOx, CO, Smoke are lower than the diesel where the exhaust temperature, CO2 are higher than diesel, it indicates the complete combustion of biodiesel blends.

Keywords: Dates seed oil, Bahri dates seed, Transesterfication, Methanol, Potassium Hydroxide

1. Introduction

Taking into consideration of the present scenario, with the increasing number of vehicles there is a demand for more fuel. This demand can deplete the non-renewable petroleum products over the years. So, there arises the need for alternative fuels. Alternative fuels from renewable source that are environmentally acceptable have been the focus of extensive research in view of increasing demand for energy and environmental awareness. Keeping in view the significance of non-conventional feed stock for biodiesel production, an attempt has been made to produce biodiesel from dates seed oil (Bahri type). Fahad al juhaimi, Kashif ghafoor, Megmet Musa Ozcan [3] studied the seven different varieties of dates seed and reported the existence of following fatty acids in the Bahri dates seed oil.

Table 1: Fatty acid composition in date seed oil.

Fatty acid	% of acid in oil
Caproic acid(C 6:0)	0.28
Caprylic acid(C 8:0)	0.34
Lauric acid(C 12:0)	19.21
Mystric acid(C 14:0)	12.22
Palmitic acid(C 6:0)	9.95
Palmitoleic acid(C 6:1)	0.056
Stearic acid (C 18:0)	2.61
Oleic acid (C 18:1)	45.41
Linoleic acid (C 18:2)	9.28
Linolenic acid (C 18:3)	0.19
Arachidic acid (C 20:0)	0.08
Gadoleic acid (C 20:1)	0.28
Behnic acid (C 22:0)	0.06

Abdul Afiq M.J, Abdul Rahman R, Che Man Y.B, Al-Kahtani H.A and Mansor T.S [1] suggested that the free fatty acid composition of dates seed oil is very low (0.53% - 1.05%). Previous studies showed that the oil with higher fatty acid content will result in more catalyst needed in order to balance the acidity of the oil. Therefore, this low free fatty acid content of dates seed oil highlights its usage as a biodiesel feed stock. From the above facts, the present work focuses on emission and combustion analysis of methyl esters of dates seed oil with various diesel blends.

1.1 Bahri dates seed oil extraction.

The Bahri type of Dates seeds were collected from Pazhani, Tamil Nadu, India and were dried under sunlight for two days. Currently there is no commercial production of dates seed oil available in market. So, the dried seeds are pulverised into small pellets for the purpose of using it in the Soxhlet as a raw material. The oil was extracted in the laboratory using Soxhlet extractor with hexane as a solvent for a period of 24 hrs in a ratio of 1:6 w/v at 60° [23]. Then the solvent is removed by heating the oil in the heater to a temperature of 80 °C. Now, the obtained raw oil is filtered for removal of impurities.

1.1.1 Trans esterification

The transesterification reaction is a reversible reaction that proceeds essentially by the mixing of reactants. The reaction is carried out by taking Dates seed oil in 500 ml flask with anhydrous methanol in the molar ratio of 1:4 using 2.5gms of Potassium hydroxide as catalyst and at a temperature of 60 °C for 90 minutes. After completion of reaction, the mixture is transferred to separating funnel for separation of glycerol and methyl ester for 24 hrs. Separation of both the phases and removal of excess solvent in each phase afforded biodiesel in good yield. As a part of purification process methyl ester was washed with distilled water to remove suspended catalyst and residual amount of glycerol. Further, traces of solid were removed by filtration to afford reasonably pure biodiesel required for most of the practical purpose.

1.2 Characterisation of Biodiesel

The yield of biodiesel was around 88% at a temperature of 60 °C with a catalyst concentration of 2.5 grams. The ester obtained from the Bahri dates seed oil was analysed for fuel properties and these properties are dependent on the structure and type of esters formed during the transesterification process. The physical properties of all the biodiesel samples were evaluated according to the ASTM standards. The viscosity of transesterified oil was measured by red wood viscometer, density by hydrometer, flash point by open cup method and the heating values of the neat diesel and biodiesel were measured in an "ARICO bomb calorimeter." The required Physical Properties of the base diesel and biodiesel were analysed and presented in the following table. It is clear that density, viscosity, flash point, Pour Point for biodiesel will be higher than that of diesel but the Calorific Value of the biodiesel is lower than the diesel due to presence of saturated and unsaturated component and oxygen component in it.

Table 2: Comparison of date seed biodiesel properties with diesel fuel.

Fuel properties	Diesel	Dates seed biodiesel	ASTM standards
Density(kg/m^3)	824	879	860-900
Kinematic viscosity at 40°c(cst)	2.30	5.2	1.9-6.0
Calorific value(MJ/kg)	44	38	Nil
Cetane number	46	42	47
Flash point(°c)	53	122	100-170
Cloud point(°c)	-8	10	-3-12
Fire point(°c)	56	130	Nil
Pour point(°c)	<-3	0	-15 -16

1.3 Experimental Setup

The engine used was a single cylinder constant speed four stroke single acting stationary diesel engine. The injector nozzle was located in the centre of the combustion chamber and had an opening pressure of 205 kg/cm2. Fig.1 shows a setup which consist of test engine coupled with SWINGFIELD Electrical Dynamometer, fuel consumption metering equipment, 5 gas analyzer (DI GAS 444 AVL) and AVL IDIMICRA 602-T10602A acquisition unit, AVL 365C Angle Encoder Indi Advancsd, AVL 415 smoke meter. The specification of a test engine is shown in table 1. The experiments were conducted at five load levels viz, no load, 25%, 50%, 75% of full load and full load. For each load condition the engine was run for at-least 5minutes after which date was collected.

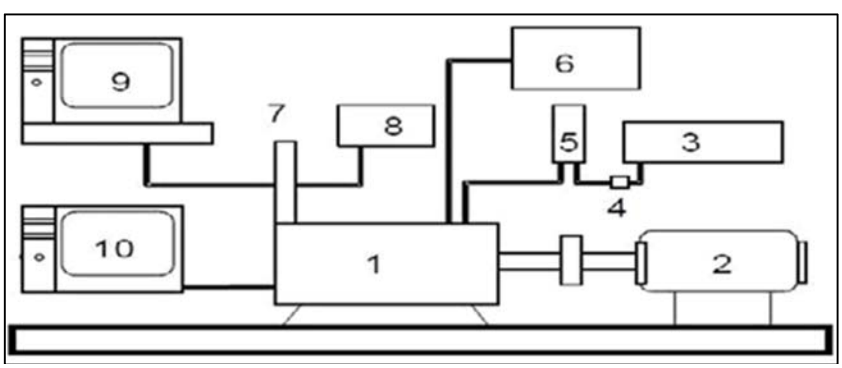

Fig. 1: Experimental setup.

1. Test engine, 2. Dynamometer, 3. Fuel tank, 4. Fuel filter, 5. Fuel burette, 6. Cooling tower, 7. Exhaust pipe, 8. Smoke meter, 9. Gas analyzer, 10. Data acquisition unit.

Table 3: Engine specification

Make	Kirloskar AV1
Type	4 stroke, single acting, CI engine
No. of Cylinders	1
Cubic Capacity (ltr)	0.553
Rated Speed (rpm)	1500
Bore (mm)	87.5
Stroke (mm)	110
Power rating (Hp)	5 (3.7kw)
Compression Ratio	17.5 : 1
Start of injection (^{0}BTDC)	23
Cooling	Water cooled
Type of fuel injection	Direct

2. Results and Discussions

Diesel engine performance, emission and combustion characteristics are analysed for all blends of DB2, DB5, DB10, DB15 and DB20 fuels and compared with diesel. All the performance and emission results are presented and discussed in this section.

2.1 Combustion Characteristics

In a diesel engine the cylinder pressure depends on the fuel burning rate during the premixed burning phase this premixed combustion phase is controlled by ignition delay period, spray envelope of the fuel injected. Generally the fuel with lower viscosity and higher volatility gives higher cylinder pressure because of higher atomization rate and improved air- fuel mixing formation. The following graph shows the cylinder pressure with crank angle at 0%, 25%, 50%, 75% and 100% load. It is seen that cylinder pressure for dates seed biodiesel is lower than diesel because of lower ignition delay, higher viscosity and lower volatility, so the combustion starts earlier in biodiesel blends and it's further away from the TDC in expansion stroke. But in diesel, due to long ignition, low viscosity and higher volatility the cylinder pressure is higher [24]. Due to existence of higher oxygen content the cylinder pressure during the late phase of combustion is lower than diesel. It's due to complete combustion of biodiesel blends in the main phase of combustion phase where in diesel, combustion occurs in late combustion phase also due to its higher ignition delay. It can be seen that at 75% load the DB 15 blend gives higher cylinder pressure than diesel because at such load the DB 15 blend is supplied at improved air- fuel mixture.

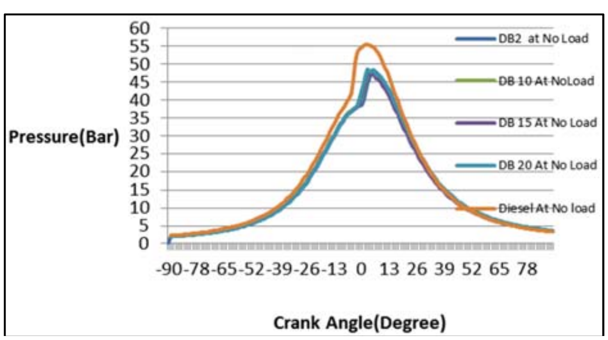

Fig 2: Variation of pressure with crank angle at no load condition.

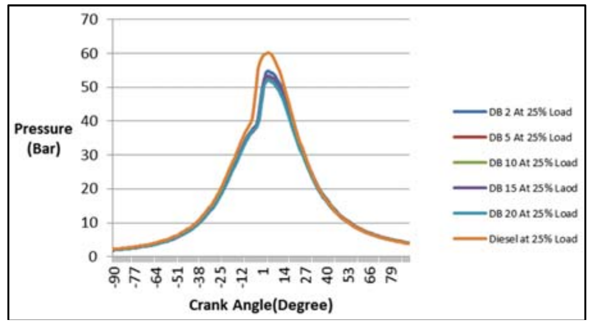

Fig 3: Variation of pressure with crank angle at 25% of load.

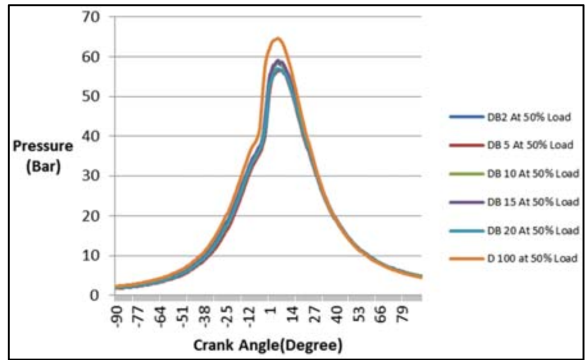

Fig 4: Variation of pressure with crank angle at 50% of load.

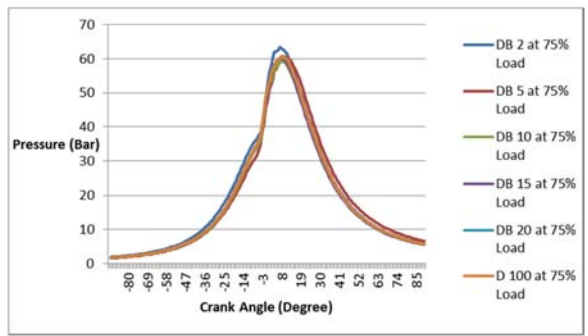

Fig 5: Variation of pressure with crank angle at 75% of load.

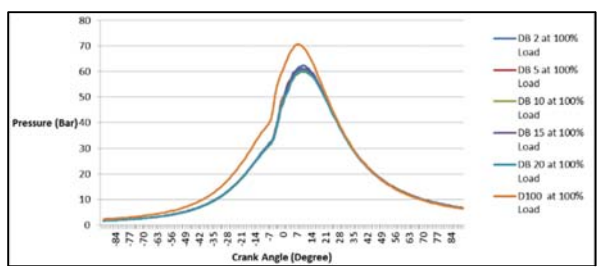

Fig 6: Variation of pressure with crank angle at full load condition.

2.2 Emission Analysis

2.2.1 Exhaust Temperature

The combustion temperature is an indicator of amount of heat energy released during combustion process. The graph below compares the exhaust temperature of various dates seed biodiesel blends and diesel. It was observed that the exhaust temperature increases gradually with the increasing the load, it is due to better utilization of oxygen present in the biodiesel blends and higher viscosity of biodiesel blends promotes the combustion process with peak temperature which leads to higher exhaust temperature [22]. The gradual increase of exhaust temperature on increasing the load indicates that there is higher amount of heat to be reclaimed when running on biodiesel [21].

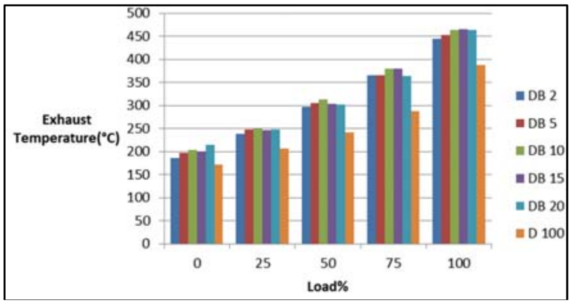

Fig 7: Exhaust gas temperature vs load.

2.2.2 Carbon monoxide Emission

Carbon monoxide (CO) emission occurs due to the incomplete combustion of fuel. The following graph shows the comparison of CO emission of various biodiesel blends and the base diesel. For each fuel, there is a decrease of CO emission on increasing the engine load. This is due to generation of higher combustion temperature at higher load contributes to the general decreasing trend. It is seen that on increasing the biodiesel ratio, the CO emission level get decreases because of higher oxygen content in the fuel mixture enhances complete combustion in the cylinder along with reduced CO emission [30].

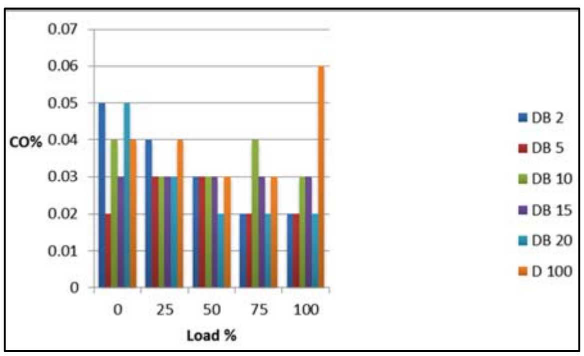

Fig 8: Carbon monoxide vs load.

2.2.3 Hydro carbon Emission

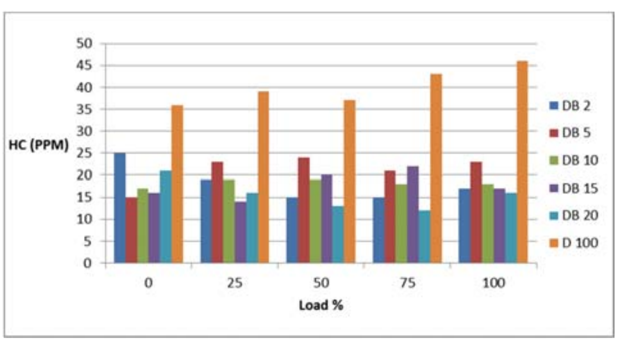

Fig 9: Hydro carbon emission vs load.

The following graph shows the comparison of HC emission of diesel with various biodiesel blends. It was observed that the level of HC emission will be lower than conventional diesel at all loads. The reason is due to higher temperature of combustion gases prevent the deposition of fuel particles over the cervices, piston rings and the other areas responsible for HC emission and by the presence of higher oxygen content in the biodiesel, the injected fuel undergoes complete combustion so ultimately the level of unburnt HC in the exhaust stream is lower than diesel [22, 23].

2.2.4 Carbon di oxide Emission.

The level of CO2 emission is the factor of completeness of combustion process. It was observed that the level of CO2 emission will be gradual increasing on increasing the load and it's higher than diesel at all loads, this is due to higher oxygen content and shorter ignition delay and complete combustion of fuel during the burning phase. At lower load the amount of oxygen availability for conversion of CO into CO2 is lower so the amount of CO emission is higher and CO 2 (29) emission is lower where in higher load the availability of oxygen for conversion of CO into CO2 is higher, so there will be higher CO2 emission and lower CO emission.

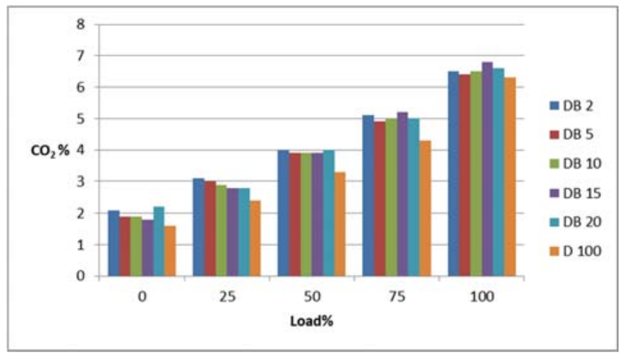

Fig 10: Carbon dioxide emission vs load.

2.2.5 NOX Emission

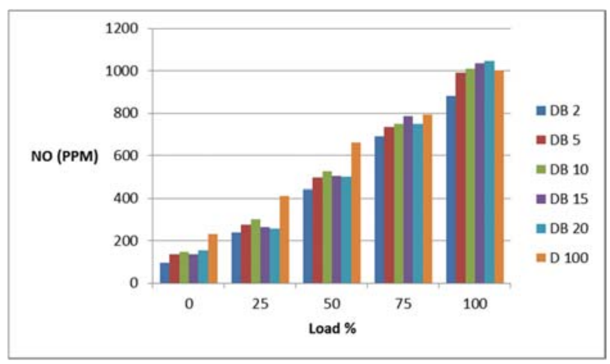

Fig 11: NOX emission vs load.

Due to existence of double bonded molecules, higher oxygen content and faster reaction rate can leads to produce higher NO emission, but in case of dates seed biodiesel by the existence of natural antioxidant can prevent the NO formation. The following graph shows the comparison of NO emission of diesel with various dates seed biodiesel blends at various load. It can be seen that at 0%, 25%, 50% and 75% load the level of NOx emission is lower than the diesel, but at full load condition the combustion pressure and temperature is higher which enhance the reaction rate of NOx formation, so the level of NOx formation is higher. DavidM. Fernandes [8] states that by blending artificial amines, the free radical responsible for causing NOx formation is prevented where in this case the natural antioxidant present in the dates seed oil will carry out such function. The results are in accordance with the researchers like Mohammed EL- Kasaby, Medhat A, Nemit-allah [9] and Mohamed. F. Al Dawody, S.K. Bhatti [12].

2.2.6. Smoke opacity

Smoke opacity means the degree to which the smoke reduces the passage of light. It means, more smoke in the exhaust will have high smoke opacity and vice versa. It can be seen that at higher load the density of smoke emission is higher than lower load because at higher load in order to achieve maximum power, maximum amount of fuel is injected into the cylinder. It result in the formation of rich mixture and poor fuel economy. This leads to formation of carbon spheres in rich zone when there is insufficient amount of oxygen for converting all carbon to CO2, so there will be higher emission at higher load and the reverse phenomena occurs at lower load [29].

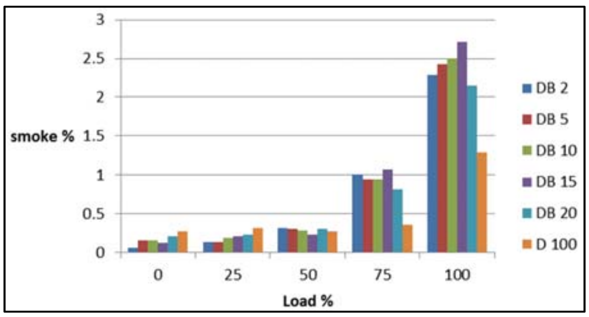

Fig 12: Smoke emission vs load.

3. Conclusion

Dates seed oil is a promising and relatively new feed stock for biodiesel production. Dates seed biodiesel showed promising fuel properties compared to other conventional biodiesels. Engine Combustion, Emission characteristics were also found promising. As a conclusion, DB 5, DB 10 and DB 15 can be used in diesel engines without modifications for the following reasons.

1. It produces lower NO emission.
2. It Produces less HC emission.
3. It undergoes complete combustion by emitting large amount of carbon dioxide and higher exhaust temperature than diesel.

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