

# INVESTIGATE THE PERFORMANCE OF CI ENGINE USING DEE FUMIGATION TECHNIQUE WITH VEGETABLE OIL BLENDS

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**Abstract:** The proposed work is to study and compare the effect of DEE fumigation (i.e. the addition of DEE to the intake air manifold) and waste vegetable bio diesel fuel blends on the performance and emissions of a single cylinder diesel engine. An attempt is to determine the optimum percentage of DEE that gives lower emissions and better performance. This will be investigated by using a simple fumigation technique, the performance and emission characteristics of single cylinder di diesel is subjected to addition of diethyl ether by fumigation into the inlet manifold with waste vegetable bio diesel blended diesel as fuel. Use of methyl ester biodiesel in diesel engines leads to a marginally inferior performance and higher smoke emissions due to their high viscosity and carbon residue. The performance of methyl ester biodiesel can be improved by injecting a small quantity of diethyl ether (DEE) along with air. The main objective of this study is to improve the performance, emission and combustion characteristics of a direct injection diesel engine fuelled with methyl ester biodiesel through DEE injection at different flow rates. A single cylinder diesel engine with rated output of 5.2 kw at 1500 rpm will be converted to operate in the DEE injection mode. Dee is injected into the intake port during suction stroke, while methyl ester biodiesel is injected directly inside the cylinder at the end of compression stroke and all parameters are to be investigated.

**IndexTerms - DEE, HC, CO, NO<sub>x</sub>, BP, BSFC, WVOME**

## I INTRODUCTION

Transportation and agricultural sector is one of the major consumers of fossil fuels and biggest contributor to environmental pollution, which can be reduced by replacing mineral-based fuels by bio-origin renewable fuels. There are a variety of bio fuels potentially available, but the main bio fuels being considered globally are biodiesel and bio-ethanol. Bio-ethanol can be produced From a number of crops including sugarcane, corn (maze), wheat and sugar beet. The last two are currently the main sources of ethanol in Europe [4]. Biodiesel is the fuel that can be produced from straight vegetable oils, edible and non-edible, recycled waste vegetable oils, and animal fat [5–8]. Europe has committed to promotion of the use of biofuels or other renewable fuels as a substitute for gasoline or diesel in the transport sector [24]. It requires EU member states to set indicative targets for biofuel sales and the reference values are 2% biofuel penetration in gasoline and diesel by 2005, raising it to 5.75% by 2010. There are several factors that need to be taken care before recommending any alternative fuel to be used in existing technologies on a large scale. These factors are stated below

## II DIETHYL ETHER (DEE)

Diethyl ether (DEE) has attracted increasing attention world- wide owing to their excellent characteristics of reducing emissions DEE injection with vegetable oil can reduce the problem of high smoke emissions due to faster diffusion combustion with DEE. The cetane number of DEE is very high and highly volatile as compared to diesel and vegetable oil. It has a reasonable energy density and the oxygen content is 21% by weight. Hence, these oxygenates can help in complete combustion of vegetable oils. Flammability limits of oxygenates are broader than those of many fuels. The burning velocity of DEE is very high and hence it im- proves the flame speed of vegetable oils. The cetane number of DEE is higher compared to neat vegetable oils, and therefore a shorter ignition delay is expected with DEE injection compared to neat vegetable oil. There may be reduced combustion duration due to the lower auto ignition temperature of DEE. Due to the presence of oxygen, combustion produced emissions such as car- bon monoxide (CO), unburnt hydrocarbons (HC), smoke and particulates will be lower than that of neat vegetable oil operation.

**Table I Properties of different fuel and additive**

Property	Diesel	Diethyl ether (DEE)
Specific gravity	0.83	0.714
Viscosity (mm <sup>2</sup> /s))	2.52	0.23
Flash point ( °C )	65	?40
Calorific value (kJ/kg)	42,900	33,857
Iodine value	38.3	-
Acid value	0.062	-
Cetane number	47	>125

DEE is a liquid at ambient conditions, which makes it attractive for fuel handling and infrastructure requirements. Storage stability of DEE and blends of DEE are of concern because of a tendency to oxidize, forming peroxides in storage. Wndholz et al [2] suggested that antioxidant additives may be available to prevent storage oxidation. Concerns about detrimental impacts on air quality from DEE are related to its volatility and to its propensity toward peroxidation. Although peroxidation in the liquid phase follows a different mechanism than that which occurs in the atmosphere.

### III CONVENTIONAL DIESEL FUEL AND DIESEL ENGINES

Emissions from HCCI engines can be very low. HCCI engine also produces low levels of smoke and particulate emissions. This is attributed to the absence of diffusion-limited combustion and localized fuel-air regions, which discourages the formation of soot.

The two general types of diesel are the direct injection (DI) engine and the indirect injection (IDI) engine. In DI engines, the fuel is directly injected into a pre-chamber, which is connected with the cylinder through a narrow passage. Rapid air transfer from the main cylinder into the pre chamber promotes a very high degree of air motion in the pre chamber, which is particularly conducive to rapid fuel air mixing. Combustion beginning in the pre chamber produces high pressure and the fuels are subjected to high shear forces. The IDI engine is no longer used for heavy bus and truck engines due to somewhat lower efficiency and higher fuel consumption than the DI system is used because of its ability to cover the wider speed range may lead to a continued use of IDI engines in urban areas, where the demand for low emissions can be more important than somewhat higher fuel consumption combined with low annual mileage. The IDI engine is also less sensitive to fuel quality. Tests of biodiesel as a fuel have been performed on both DI and IDI engines.

### IV WASTE VEGETABLE OIL (WVO)

Waste cooking oil refers to the used vegetable oil obtained from cooking food. Repeated frying for preparation of food makes the edible vegetable oil no longer suitable for consumption due to high free fatty acid (FFA) content [10]. Waste oil has many disposal problems like water and soil pollution, human health concern and disturbance to the aquatic ecosystem [8,10], so rather than disposing it and harming the environment, it can be used as an effective and cost efficient feedstock for Biodiesel production as it is readily available [1,3, 5,8, 10, 13,14, 18,20]. Furthermore, Animal fats with high acid value and fat-containing floating sludge discharged in water systems are subject to environmental concern due to their high pollutant potential and it is a challenge for wastewater treatment plants to purify it. Therefore, conversion of low quality lipid-rich sources from slaughterhouses into commercial grade biodiesel is an opportune strategy for minimizing environmental damages while it can help meeting the energetic challenge [19]. WCO collected can also be used to prepare soaps and additive for lubricating oil [8]. Many researchers have successfully converted used vegetable oil into biodiesel [2]. Vegetable oil contains saturated hydrocarbons (triglycerides) which consist of glycerol and esters of fatty acids [8]. Used vegetable oil (UVO) is a by-product from hotels, fast food restaurants and shops selling fritter and by-product of an operating vegetable oil refinery [11]. For serving better quality food, they usually throw this waste cooking without any treatment [2,4]. In some places, UCO from restaurants were re-used by street sellers to fry their food, this waste oil is termed as second-used cooking oil can also be utilized by converting to biodiesel [3]. Distillate that is produced by deodorization of palm oil (DDPO) is also a promising and cost effective feedstock [23]. UCOs have different properties from those of refined and crude vegetable oils [3]. The chemical and physical properties of WCO are different from those of fresh oil since some changes due to chemical reactions - such as hydrolysis, oxidation, polymerization, and material transfer between food and vegetable oil occur during the frying process. The typical chemical and physical characteristics of WCO are shown in Table 1. The usual values for Properties like density, kinematic viscosity, saponification value, acid value and Iodine value are shown in the table [8].

### V TRANSESTERIFICATION OF NON-EDIBLE AND EDIBLE OIL

Transesterification is the general term used to describe the important class of organic reactions, where an ester is transformed into another ester through interchange of alkyl groups and is also called as alcoholysis. Transesterification is an equilibrium reaction and the transformation occurs by mixing the reactants. However, the presence of a catalyst accelerates considerably the adjustment of the equilibrium. The general equation for transesterification reaction is given below.



The basic constituent of vegetable oils is triglyceride. Vegetable oils comprise of 90-98 percent triglycerides and small amounts of mono-glyceride, diglyceride and free fatty acids. In the transesterification of vegetable oils, a triglyceride reacts with an alcohol in the presence of a strong acid or base, producing a mixture of fatty acid alkyl esters and glycerol. The overall process is a sequence of three consecutive and reversible reactions in which diglyceride and mono-glycerides are formed as intermediates. The stoichiometric reaction requires one mole of triglyceride and three moles of alcohol. However, an excess of alcohol is used to increase the yield of alkyl esters and to allow phase separation from the glycerol formed. Several aspects including the type of catalyst (base or acid), alcohol/vegetable oil molar ratio, temperature, purity of the reactants (mainly water content in alcohol) and free fatty acid content have influence on the course of transesterification. So in this work, the reactants of high purity have been used (methyl alcohol with 99.95% purity). In the base-catalyzed process, the transesterification of vegetable oils proceeds faster than the acid-catalyzed reaction. Also the alkaline catalysts are less corrosive than acidic compounds.

The mechanism of the base-catalyzed transesterification reaction of vegetable oil is shown in the Figure 2.1. The first step (Eq. 1.) is the reaction of the base with the alcohol, producing an alkoxide and the protonated catalyst. The nucleophilic attack of the alkoxide at the carbonyl group of the triglyceride generates a tetrahedral intermediate, from which an alkyl ester and the diglyceride are formed. The latter deprotonates the catalyst, regenerates the active species, and enables it to react with a second molecule of the alcohol thus starting another catalytic cycle. Diglycerides and monoglycerides are converted by the same mechanism to a mixture of alkyl esters and glycerol.

Table II Specifications of test engine

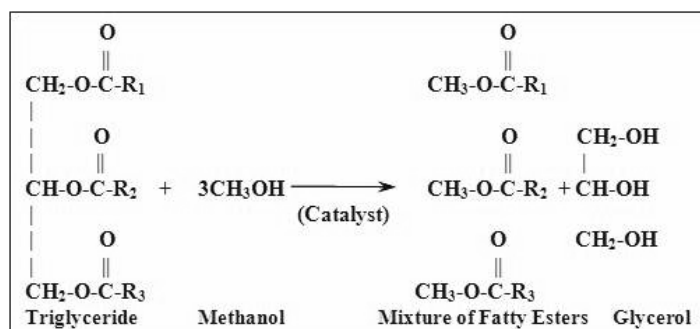
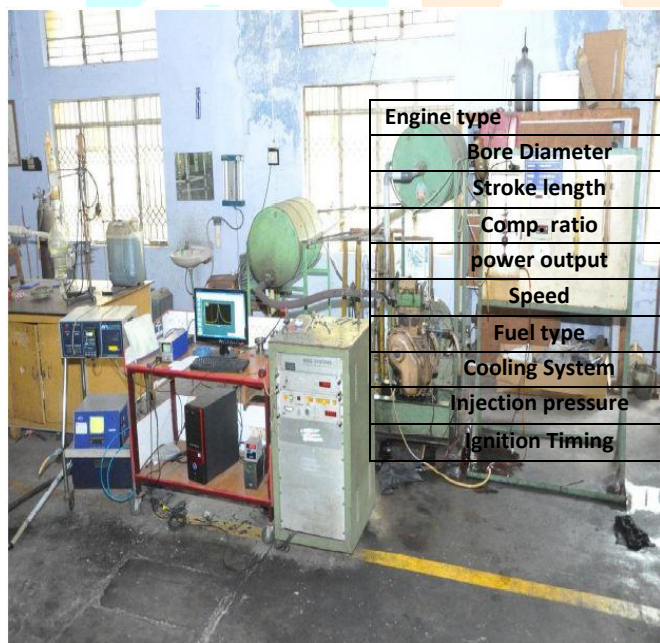


Figure 1 Mechanism of the base-Catalyzed Transesterification Process

Alkaline metal alkoxides (such as  $\text{CH}_3\text{ONa}$  for the methanolysis) are the most active catalysts since they give high yields in short reaction times even if they are applied at lower molar concentrations. However, they require the absence of water which makes them inappropriate for typical industrial process. Alkali metal hydroxides (KOH and NaOH) are cheaper than metal alkoxide, but less active. Nevertheless, they are good alternatives since they can give the same high conversions of vegetable oils just by increasing the catalyst concentration by 1 or 2 folds.

## VI EXPERIMENTAL SET-UP

The experiment is conducted on Kirlosker engine. Technical specifications of the kirlosker engine are tabulated in Tab. 2. The engine ran at constant speed at 1500 rpm for different load conditions. The eddy current dynamometer was used for applying loads to the engine.. The arrangement of experimental setup was placed in Fig. 1.2



Engine type	Singlecylinder,4stroke,DI
Bore Diameter	87.5 mm
Stroke length	110 mm
Comp. ratio	17.5 : 1
power output	5.2 KW
Speed	1500 rpm
Fuel type	Diesel
Cooling System	Water
Injection pressure	220 kgf/cm <sup>2</sup>
Ignition Timing	23°C Before TDC (rated)

Figure 2 Photographic view of the engine set-up

## VII TEST ENGINE DETAILS

The engine employed for the experimental work was a single cylinder, four stroke, water-cooled, vertical, naturally aspirated DI diesel engine developing power of 3.73 kW at 1500 rpm with compression ratio of 16.5:1.

- **DEE fumigation arrangement:**

DEE injector is fixed in the intake manifold for DEE injection and the electronic fuel pump was fixed for the purpose of DEE supply. In neat form DEE is injected into the intake manifold.

For DEE injection, DEE was supplied by a high-pressure pump at a pressure of 3 bar and injected near the intake valve, using a five-hole solenoid based electronic injector. The injector nozzle hole diameter was 0.126 mm each. The injector and pump were operated at 12 V power supply. A microcontroller (Atmega-328) was used to drive the fuel pump. The microcontroller was programmed to control the injection quantity of DEE, using a pulse width modulation (PWM). The duty cycle of PWM modulates the required injection quantity as set by the user. The excess fuel return system of the injector was modified, to send back the excess DEE, to the storage tank. An adapter (L293D) was used to supply the required current and voltage to the injector, pump, and a microcontroller.





Figure 3 DEE injection arrangement

• **Dynamometer**

The engine was coupled with range make Eddy current dynamometer as shown in figure and electronically operated control panel was used to vary the loads. The dynamometer can be operated in three different modes they are the constant current mode, the constant torque mode and the constant speed mode. in the constant torque mode the torque is kept constant and hence the overall power output will be proportional to the speed of the engine.

• **Computer Software:**

Software is based on ‘C’ & ‘Visual Basic’ languages. Software is Window based. The master controller in this system is the PC itself. Software is user friendly and allows the user to use Pointing device for selection of menus and parameters. To control the machine operations, software makes the use of I/O channels supplied with computer using I/O card. Input and output commands from computer are routed through the I/O card to the controller and then to machine.

**VIII RESULTS**

➤ **Brake Thermal Efficiency:**

From figure 1.3 shows the performance graph between BTE and brake power, here blended fuel WVOME is used with DEE fumigation techniques at different mass flow rate, in figure 1.3 brake thermal efficiency decreases with percentage of blended fuel, but as the mass flow rate of DEE increases the BTE of blended fuel also increases in the figure B20D50 has higher thermal efficiency due to higher oxygen content in DEE and Blended fuel. In figure 1.3 as the flow rate of DEE increases the BTE will also increase with blended fuel, here the BTE of diesel decreases because higher oxygen present in the fuel due to this complete combustion of fuel will occur and BTE increases.

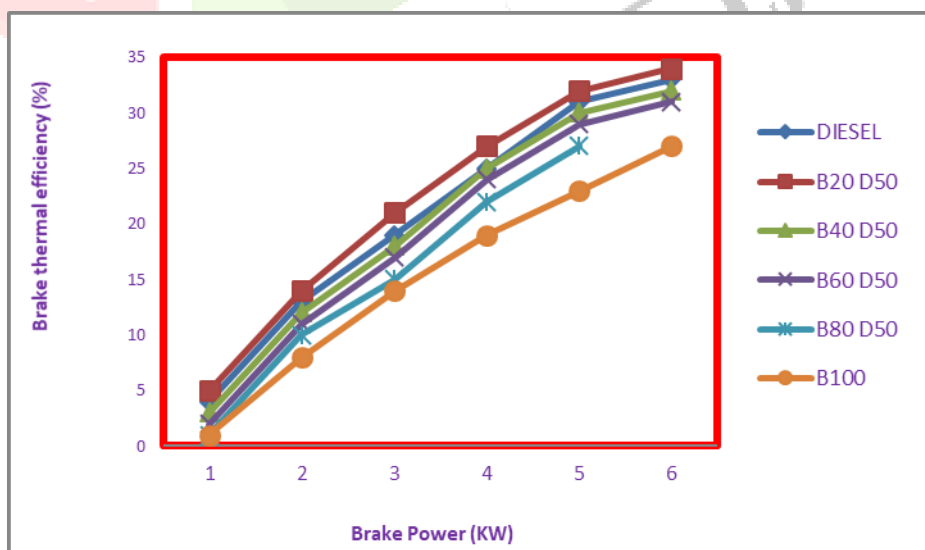


Figure 4 Variation of Brake thermal efficiency with Brake power for D50

➤ **Specific Fuel Consumption (BSFC):**

BSFC have inverse proportion to load, for biodiesel blends is higher at low load and it decreases with the increase in load. It is also finding out that, the consumption of fuel increase, as the amount of blending is increase in biodiesel. This is due to the lower heating or calorific value of biodiesel than fossil diesel also with different relationship between viscosity, density and specific fuel consumption. As a result, more amount of biodiesel blend is require to produce the same amount of energy due to its

higher density and lower calorific value in comparison as compare to Conventional diesel fuel. Again due to higher viscosity of bio diesel blend than diesel fuel, so biodiesel causes poor atomization and mixture formation and thus increases the fuel consumption rate to maintain the equal power output. In figure 1.4 shows the variation between SFC with brake power, here the fuel consumption of B20D50 blend is lower than that of other blends like B40D50, B60D50, and B80D50, the neat diesel has lowest fuel consumption and neat WVOME has highest fuel consumption.

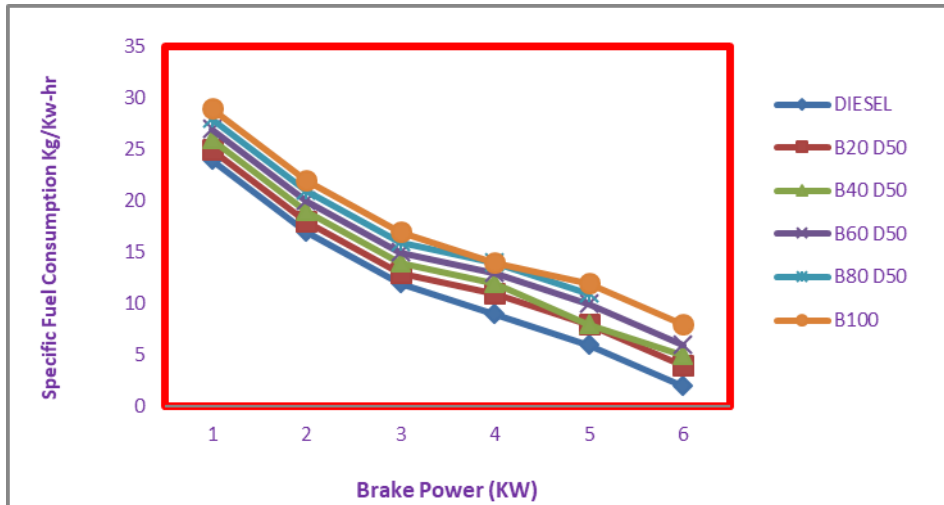


Figure 5 Variation of Specific fuel consumption with brake power for D50

**Percentage of energy share by diethyl ether:**

The Di-ethyl ether (DEE) was aspirated into the engine at the rate of 50 g/hr, for all engine brake power. The variation of DEE energy share for different DEE flow rates with BP is shown in Figure. It can be observed that, when the load increased the energy share of diethyl ether decreased. This may be due to the higher cylinder temperature at higher engine loads as reported by Murayama (1992). Thus, as the amount of energy needed increases, the fraction of the energy provided by the DEE decreases.

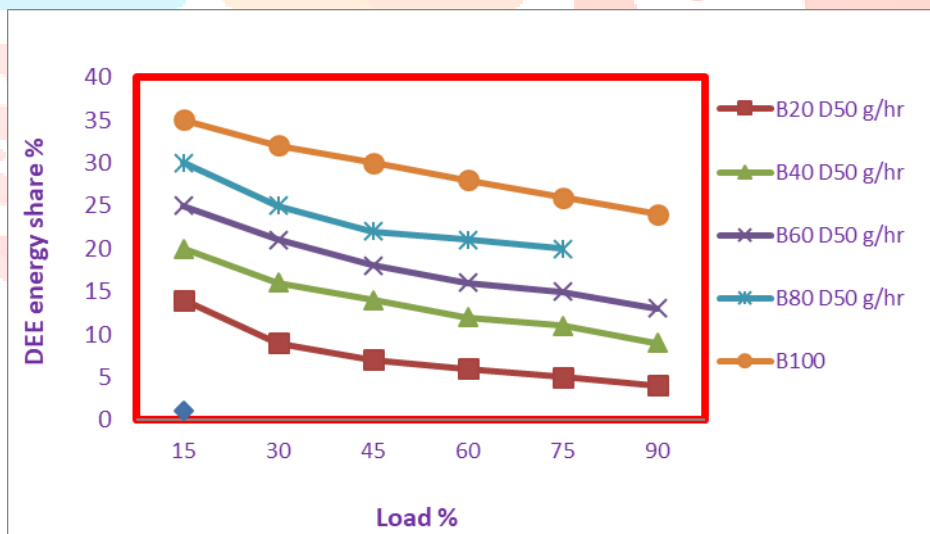


Figure 6 Variation of DEE energy share with load for D50.

**➤ Exhaust Gas Temperature:**

The EGT of biodiesel is higher than that of diesel. The heavier molecules of biodiesel lead to continuous burning even during exhaust which causes higher exhaust gas temperature or DEE blended biodiesel also, the exhaust gas temperatures are found to be lesser than that of biodiesel in full load. The higher latent heat of evaporation of DEE (356 kJ kg<sup>-1</sup>) reduces the combustion temperature and hence the reduction in EGT. Secondly the higher cetane number of DEE (>125) (Jothi *et al.*, 2008) creates shorter ignition delay period, reducing the chance of burning being extended to exhaust stroke and hence reduces the EGT as shown in In Figure 1.5 shows the variation of the exhaust gas temperature with brake power for different blending of WVOME with DEE flow rate of 50 g/hr, here the EGT of B20D50 and B40D50 decreases as compared to diesel and WVOME, because DEE reduce combustion temperature hence the reduction of EGT.

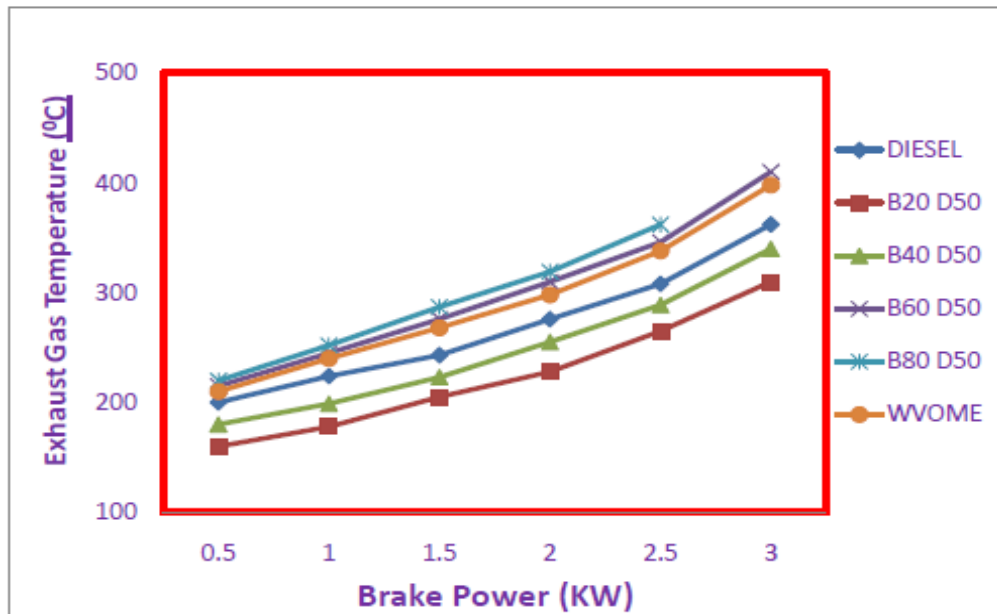


Figure 7 Variation of exhaust gas temperature with brake power for D50.

## IX CONCLUSION

The experimental investigations and performance carried out indicate that it is possible to operate a compression ignition engine with neat WVOME with certain modifications depending on the technique.

- **Brake thermal efficiency:** - The highest thermal energy obtained for diesel and B20 WVOME blends are closer to diesel, as percentage of WVOME increases as the BTE decreases. For neat WVOME the BTE is lower.
- **Specific Fuel Consumption (SFC):**- The SFC for WVOME are highest than diesel due to calorific value of diesel is higher than biodiesel, the SFC decreases with load.
- **Exhaust Gas Temperature:** exhaust gas temperature decreases with percentage of biodiesel decreases.
- **Energy Share by Diethyl Ether:** minimum energy share obtained in B20D50 and high energy share obtained in B80D50.

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