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Performance Evaluation of a 3.5 kW Diesel Engine Fueled with Blended Biodiesel of Mustard Oil

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Abstract

In this investigation, methyl ester of Mustard oil was prepared by trans esterification using solid potassium hydro-oxide as catalyst and used in a 3.5kW single cylinder four stroke diesel engine. Tests were performed at different load conditions and the performance was analyzed for B5 to B30 blends of Mustard biodiesel and pure mineral diesel. It was concluded that the lower blends of biodiesel enhance the break thermal efficiency and reduce the fuel consumption. It is proved that the use of biodiesel (produced from Mustard oil) in compression ignition engine is a viable substitute to diesel.

Keywords

Mustard oil, Trans esterification, Engine performance

Nomenclature:

A	Cross sectional area of the Orifice (m2)	N	Engine Speed (rpm)
BP	Brake Power (kW)	N_r	Rated speed (rpm)
C.V	Calorific Value (kJ/Kg)	sfc	Specific fuel consumption (Kg/kW-hr)
C_d	Coefficient of discharge of Orifice	T	Torque
d_1	Diameter of rope (m)	V	Swept volume (m3/hr)
d	Bore diameter (mm)	W	Load on engine (kg)
FP	Friction Power (kW)	ρ	Density of the fuel used (gm/cc)
g	Acceleration due to gravity (m/sec2)	η_{bth}	Brake thermal efficiency (%)
H	Water head (mm of water)	η_{mech}	Mechanical efficiency (%)
h	Manometric air difference (mm)		
IP	Indicated Power (kW)		
L	Stroke length (mm)		
m_f	Mass of fuel consumption (Kg/hr)		

1. Introduction

The application of vegetable oil in internal combustion (IC) engines is not a novelty. Rudolf Diesel used peanut vegetable oil to demonstrate his invention of diesel engine in Paris, and he stated that, *"The use of vegetable oils as engine fuel may seem negligible today. Nevertheless, such oils may become, in the passing years, as important as oil and coal tar presently."* [1] After that the coal dust was used as a fuel in the same diesel fueled engine and achieved high performance. In later age the application of diesel engine increased by vertical growth as its demand increased in automobiles and industries. [2]. The availability of mineral diesel/crude oil is limited, that's why the whole world is searching for a new option of oil fuel. Biodiesel is biodegradable oil, and its demand can be fulfilled by increasing the production of crops.

Richard et al. [3] gave their experience and teardown analysis for engine operating on biodiesel blends (B20) and indicated the little difference in performance between biodiesel and pure diesel. A similar experiment on mahua (Madhuca indica) biodiesel for performance analysis on a compression ignition engine was carried out by Raheman and Ghadge [4]. The Performance Test of IC engine using Karanja biodiesel blending with diesel was established by Stalin and Prabhu [5] and found similar characteristic to conventional diesel for B20 Karanja blends. The feasibility of blending karanja vegetable oil in petro-diesel and utilization in a direct injection diesel engine was tested by S. Bajpai, P. K. Sahoo, and L. M. Das [6].

The depletion of world petroleum reserves and the increased environmental concerns have stimulated the search for alternative sources for petroleum-based fuel, including diesel fuels. For greening of the nation's fuel supply is advancing across the country as we use renewable, clean-burning biodiesel (BD) instead of petroleum diesel. In the whole world the research on biodiesel comes in revolutionary action [7]. So many experimental works were carried out by different researchers on various biodiesels like fish oil, fats, sunflower oil, canola oil, olive oil, waste oil, Karanja oil, Soyabean oil, Thumba oil, Cotton seed oil, and Algae oil [8-18].

India is ready for biodiesel revolution. As per the [19] government of India is working on nationalized biodiesel mission. India have been started the production of biodiesel at commercial stage before 2006; a biodiesel plant is also working to producing biodiesel at commercial scale which is situated at Nalgonda in Andhra Pradesh state. The aim of the Indian biodiesel mission was that the use of 20% blended biodiesel (B20 means 20% biodiesel and 80%diesel) started after 2011-12. It is estimated that the government will save the sum of Rs20, 000 crore and gives employment to at least 2 crore peoples with the biodiesel mission.

The bio-oils cause operational and durability problems for long term storage when it is used without mixing in diesel. These problems are endorsed to low volatility, high viscosity and polyunsaturated characteristics of bio-oils. The process of trans esterification is an effective method of reducing bio-oil viscosity and eliminating operational and durability problems.[20]. Several researchers [21-29] have been using biodiesel as an alternate fuel in the existing CI engines without any modification.

In the present communication, Authors evaluated the performance and emission characteristics of a 5 hp single cylinder diesel engine at constant speed and variable loads using Mustard biodiesel which produced in the laboratory and pure diesel.

2. Material and Methods

2.1. Esterification of Mustard oil

The Crude Mustard oil is first heated to 60°C in a vessel. Then the oil is reacted with Methanol in presence of Catalyst KOH. The Molar Ration for esterification of oil & Methanol for Mustard oil is 4:1. The sequential production process is represented in Figure 1. The various properties of diesel and Mustard bio diesel are measured in the laboratory which is shown in table 2. The viscosity, kinematic viscosity and flash point of Mustard oil is differ than pure diesel so pure Mustard biodiesel can't be used in diesel engine. Only blended biodiesel can be used for internal combustion engines. The blending as per volume is filled in bottles and shown in Figure 2. The details of blending for B5 to B30 are explained in table 3.

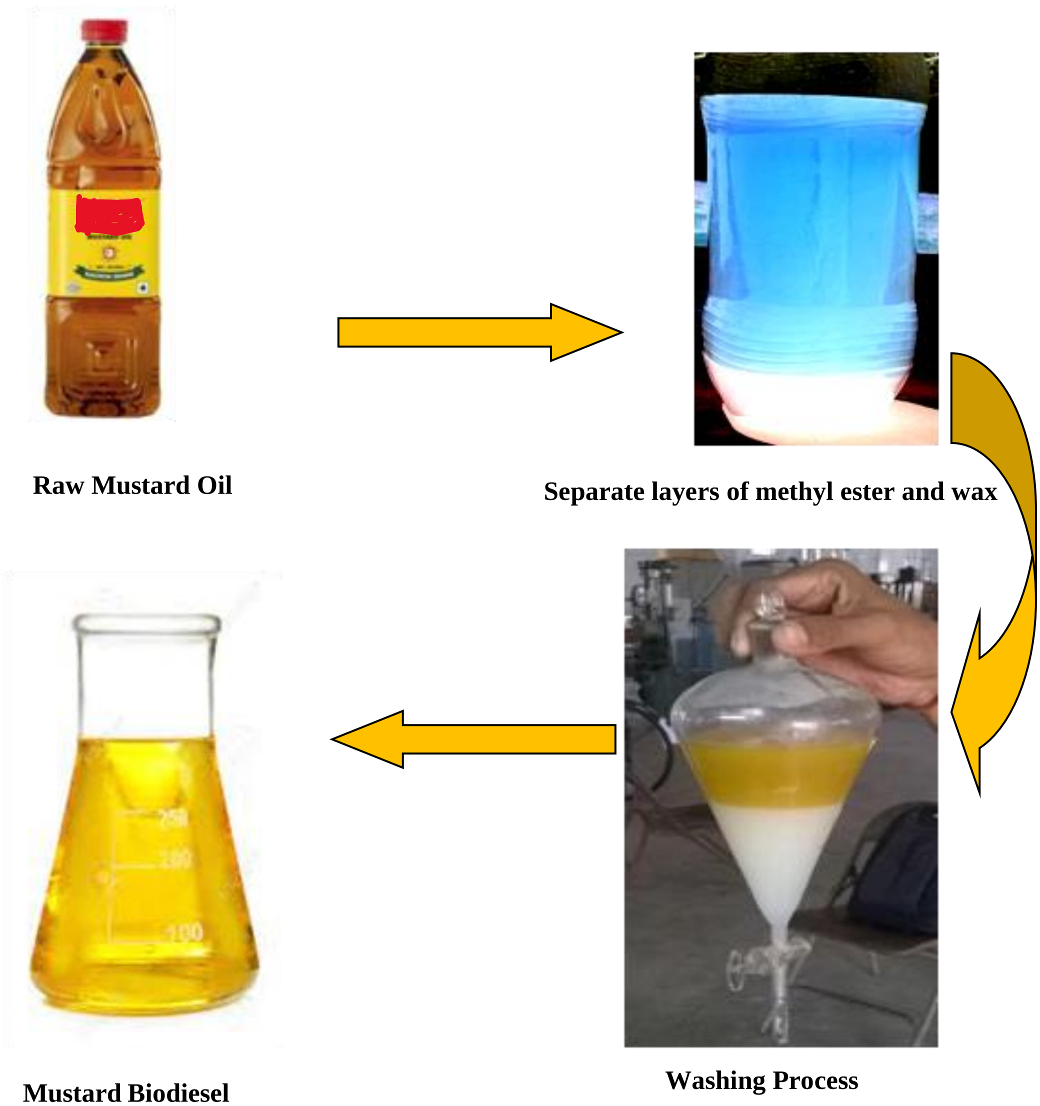


Figure1. Stages of Mustard biodiesel producing

Table 1. Measured Physiochemical Properties of Mustard Biodiesel

Properties	Diesel	Mustard Biodiesel	ASTM 6751 standard	EN 14214 Standard
Density (gm/cm3)	0.82	0.895		0.86-0.9
Dynamic Viscosity (cSt) at 40°C	2.85	2.8		
Kinematic viscosity (cSt)	2.8	3.5		3.5-5.0
Flash Point (°C)	61	105	Min. 130	Min 101
Fire Point (°C)	75	200		
Calorific Value, kJ/kg	42000	39857		
Pour Point (°C)	-6	-12		
Cloud Point (°C)	1	-6		
Cetane no.	49	50	Min. 47	Min 51

Figure 2. Sampling of Mustard Biodiesel blending with diesel

Table 2. Details of Different Blends of Mustard Biodiesel

Sr. No.	Blends	Composition
1	B5	95% Diesel + 5% Biodiesel
2	B10	90% Diesel + 10% Biodiesel
3	B15	85% Diesel + 15% Biodiesel
4	B20	80% Diesel + 20% Biodiesel
5	B25	75% Diesel + 25% Biodiesel
6	B30	70% Diesel + 30% Biodiesel

2.2. Properties Analysis

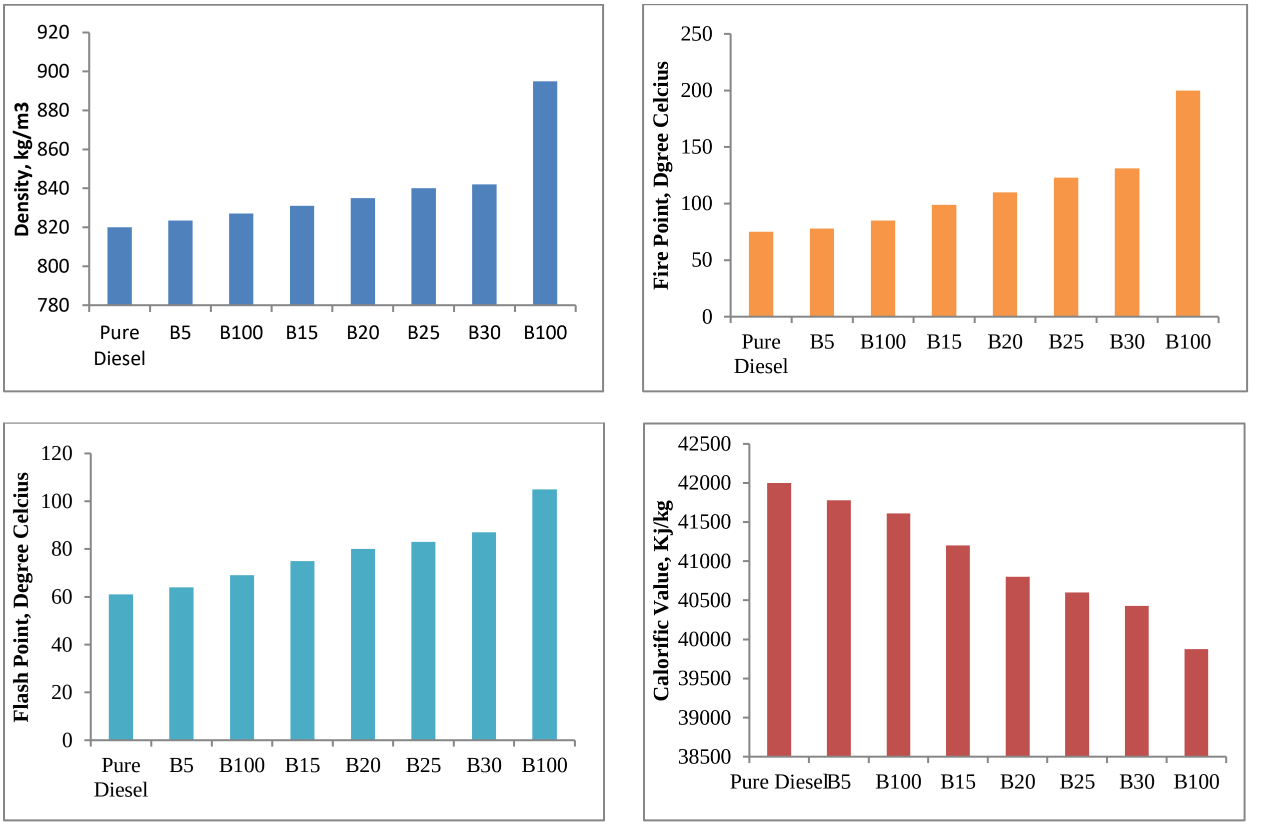


Figure 3. Insitu measured properties of pure diesel and bend Mustard biodiesel

The properties of the pure diesel and Mustard Biodiesel are measured in the laboratory and also measured all properties Mustard biodiesel shown in Table 2 and the properties of blended biodiesel from B5 to B30 also measured and presented in Figure 3. These properties are measured in the laboratory whereas the Viscosity is measured through Red Wood viscometer of 90 mm height and 46 mm diameter with silver plated brass material. The Flash point determines the temperature at which the sample will flash when a test flame is applied under the conditions specified for the test. Fire Point: Fire Point determines the temperature at which the sample will continue to burn for at least 5 seconds. The fire and flash point Pensky-Martens apparatus made by Aimil was used to measure the fire and flash point of the diesel and blended fuel with Mustard biodiesel from B5 to B30. The Aimil make equipment is used to measure the cloud and pour point properties of the fuel which are available in the chemistry lab, the equipment is followed by IS: 1448 (Part10), ASTM D 2500 and BS:4452. The density of the fuel is measured by a hydrometer which is made of glass material. Aimil photochem bomb calorimeter is used to measure the calorific values of pure diesel and blended diesel fuel.

2.3. Experimental Setup Specification and description

The specifications of the experimental engine are given in table 4. A Belt type brake drum dynamometer is used for loading the engine. A digital speedometer is used to measure the shaft speed of the I. C. engine. Chromel-alumel thermocouples in conjunction with a digital temperature indicator are used for measuring the inlet and exhaust gas temperature. The experimental setup is shown in figure 4(a). The line diagram of set-up is shown in figure 4(b). In which 1-2-3-12 is air circuit.

Table 3. Engine Specifications

Particular	:	Specification
Engine	:	Four stroke single cylinder CI engine
Make	:	Prabhat
BHP	:	5 hp/3.5kW
RPM	:	1500
Fuel	:	Diesel
No. of cylinders	:	one
Bore	:	87.5 mm
Stroke length	:	110 mm
Starting	:	Manual cranking
Dynamometer	:	Brake Drum Type (Belt Type)
Drum Diameter	:	0.155 m
Max. Load Capacity	:	20kg
Coefficient of discharge	:	0.64
Working cycle	:	Four- stroke
Method of cooling	:	Water-cooled
Method of ignition	:	Compression ignition
Lubrication oil	:	SAE – 40 / equivalent

In this circuit air passed through air filter (2) and supplied to the engine through engine inlet valve. A U-tube manometer (4) is used for measurement of air supply to the engine. Air compressed by the piston in compression stroke at the end of compression combustion will starts and after completing the combustion in power stroke combust gases goes through the filter in the atmosphere and the sampling for emission has been taken before 12. The second circuit 10-8-7-11-6 is fuel circuit for bio-diesel supply. Whereas 10 is a fuel tank, 9 is a graduated burette (transparent glass tube) which is used to measure the fuel consumption in engine per second, 8 is a fuel filter, 7 is a fuel pump and 6 is multi-point injector. For measuring brake power, a brake drum type dynamometer is used at the engine which shows in figure by 15 (drum) and 16 (belt and weight spring). Another most important circuit is the cooling circuit in which 14 is the source or sink of water supply to the engine where 13, 19, are the pump and three-way valve respectively. There are some tubes which play an important role in supply of air are 1 and 3, for fuel 11, for water 17 and 18.

Figure 4. (a) Photo of experimental setup

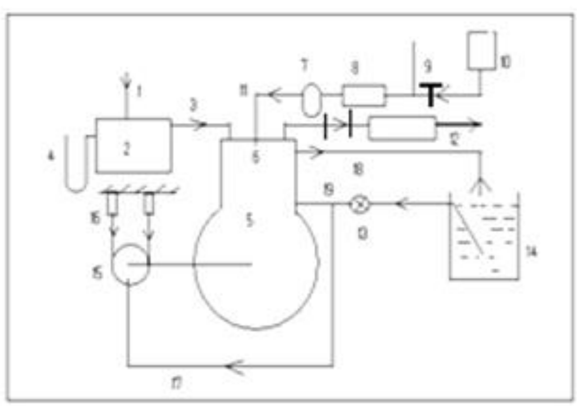


Figure 4. (b) Line diagram of IC engine circuit

2.4. Performance Evaluation

The Brake Power (bp), specific fuel consumption (sfc), thermal efficiency and mechanical efficiency (η_{mech}) have been calculated to determine the performance of the compression ignition engine based on Mustard biodiesel as fuel by using the following equations.[30]

$$BP = \frac{2\pi NT}{60\times 1000}\ kW \quad [1]$$

Where Torque can be calculated by

$$T=(F1-F2)\times R_{eff} \quad [2]$$

The T is torque, N is revolution per minute (R.P.M.), F1 is the tension on the tight side and F2 is the tension on the slack side. The R_{eff} is the effective radius of the dynamometer (Drum radius +Belt Thickness),

The mass flow rate can be calculated by-

$$m = \rho v/t \quad [3]$$

Where, ρ is the density of fuel, v is the volume flow (Consumption of fuel in m^3) consumption within a certain time interval, t is the time interval for which consumption of fuel is to be measured.

The indicated power can be calculated by

$$IP=BP+FP \quad [4]$$

Where, IP is Indicated power, BP is brake power and FP is friction power. The friction power (FP) can be evaluated by willian's line method.

The Mechanical efficiency can be evaluated by

$$\eta_{mech} = \frac{BP\times 100}{IP}\ \% \quad [5]$$

The brake thermal efficiency can be evaluated by-

$$\eta_{bth} = \frac{BP\times 3600\times 100}{M_f\times C.V}\ \% \quad [6]$$

The brake specific fuel consumption (BSFC) can be calculated by-

$$BSFC = (m_f.CV)/BP \quad [7]$$

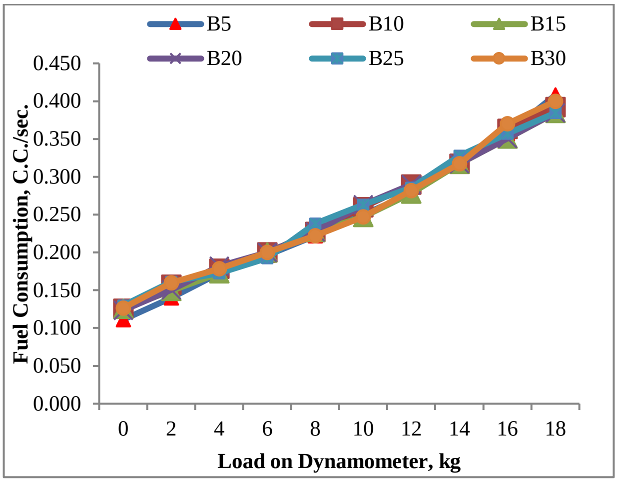
The Brake mean effective pressure may be evaluated by-

$$BMEP = (BP \times 60 \times 1000)/LAN \quad [8]$$

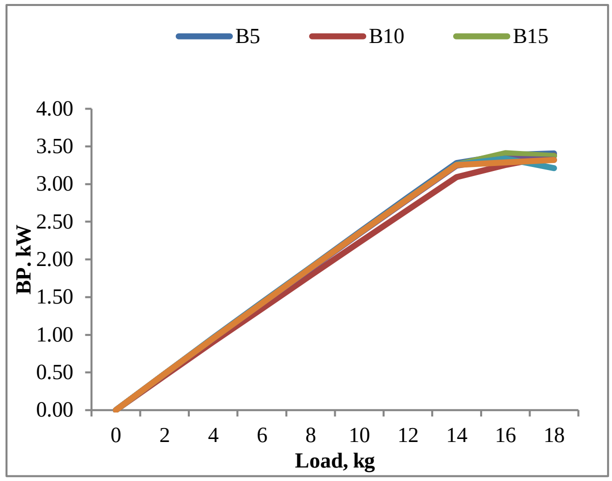
Where, L is the stroke length (Swept length in the cylinder), A is the cross-section area of piston/cylinder and N is R.P.M.

3. Results and Discussion

The numerical results of the performance of the compression ignition (CI) engine based on the 0 to 30% blended Mustard biodiesel with mineral biodiesel is shown in figure 4. The Brake power developed by the engine is presented in figures from 0 kg load to 18 kg load conditions on belt type dynamometer. The load increases with an increase in brake power as well as fuel consumption. The 20% blend is satisfied with all the blending conditions because of low specific fuel consumption and better brake thermal efficiency as compared to other blends. The brake thermal efficiency firstly increases and afterwards it will decrease the similar characteristics have been observed for mechanical efficiency for same load conditions. It is observed that below 20% Mustard biodiesel can be blended with diesel fuel without any change in the CI engine. Some researchers also found that some changes are required for more % of blending because the vegetable oils (Mustard oil) are more fatty acids than pure mineral diesel fuel.



(a)



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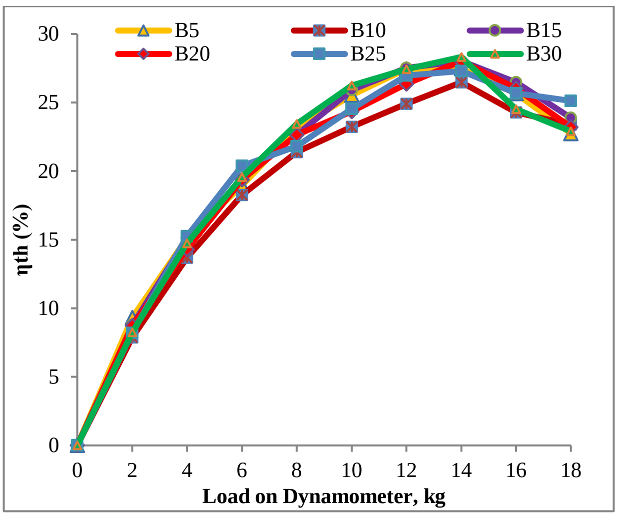

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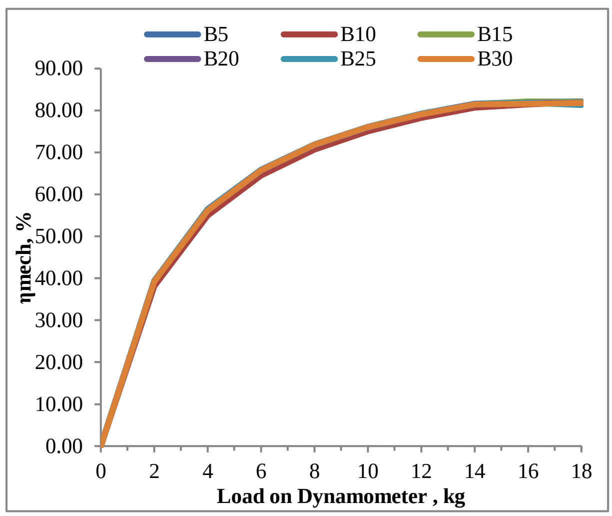

(d)

Figure 5. Performance Curves for Mustard Biodiesel blended fueled 5 hp engine

4. Conclusions

The Mustard biodiesel blends performance offered close to diesel. Therefore, Mustard biodiesel can be used in CI engines in rural areas. The maximum limit of the blending is 30% but the most feasible blending is B20. It gives better performance like high break thermal efficiency and low specific fuel consumption. High power is also reported by many other researchers, and it may be due to better lubricity which reduces friction loss and better combustion of blends.

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