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Performance and Emission Characteristics of Preheating Corn Oil Methyl Ester in CI Engine

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1. Introduction

Energy resources are necessary for the technological development of a country. Rising rate of people and production has led to increase in energy required, which in twist has led to the quick consumption of present energy resources. Due to its superior demand, diesel becomes a great deal in short supply of each transient day. Reduction of reserves of fuel resources has triggered the required to discover alternative energy resources. Scientist for the period of the past two decades have obtained that vegetable oils are gifted alternatives [1]. Various countries use edible oils such as sunflower, linseed, palm, soybean, coconut, rapeseed, etc. for biodiesel production [2]. In India, Corn production has been increased year by year and 2017 total production of corn was 26880 (1000MT). The corn production was 14.75% rise during 2016 to 2017 and 3.78% rise during 2017 to 2018 [3]. Recently, quite a lot of fuels have been analyzed to provide as low emission compared to diesel [4-5]. The raw vegetable oils produced less performance due to high viscosity because of fuel nozzle choking and piston ring sticking [6]. While raw vegetable oils cannot be used straight fuel in diesel engine without bringing its properties nearer to diesel. Especially viscosity drop is essential to develop the fuel atomization and mixing with air. There are four essential techniques are available to reduce viscosity of vegetable oils such as Direct use and blending, Micro-emulsification, Pyrolysis or thermal cracking and transesterification [7-8]. Transesterification is the most effective and best technique to reduce the viscosity of raw vegetable oils and bring the properties nearer to diesel [9, 10].

The specific fuel consumption of B100 corn oil methyl ester blend is about 0.49 kg/kWh and it is 0.07 kg/kWh higher when compared to 100% diesel at no load. The reason for the increase in fuel consumption is due to lower heating valve [11, 12]. The brake thermal efficiency of B20 Castor oil is about 8.57% lower than that of 100% diesel at full load conditions due to the improper mixing of air-fuel to lead incomplete combustion [13, 14]. The hydrocarbon and carbon monoxide are reduced with biodiesel as compared with diesel due to low carbon-hydrogen ratio biodiesel. Biodiesel is a non-toxic, biodegradable and renewable fuel with the possibility to reduce IC engine exhaust emissions. Biodiesel is potential for availability and environmental friendly [15, 16]. Methyl ether acts as cetane improver which will reduce the ignition delay period and reduce the formation of NOx. Adding the cetane improver the engine will become complete combustion and emissions carbon dioxide, hydrocarbon and NOx are reduced [17]. The preheated biodiesel improves the brake thermal efficiency and reduces the carbon dioxide, Hydrocarbon and little increase in NOx as compared to petroleum diesel due slight increase in combustion temperature [18, 19]. Biodiesel fuel admixed with 10% of ethanol (v/v) determines higher BSFC rates and increased exhaust emission. For B30 the values are PM (–23%), NOx (+3%), CO (–16.5%), HC (–28%). And for B30+7%E: PM (–29%), NOx (neutral to D), CO (–21.5%), HC (–35.5%) [20].

2. Methodology

2.1. Preparation of biodiesel

Transesterification is a method of producing a reaction between a raw corn oil and methanol in the presence of a catalyst (KOH) to produce Corn oil methyl ester and glycerol.

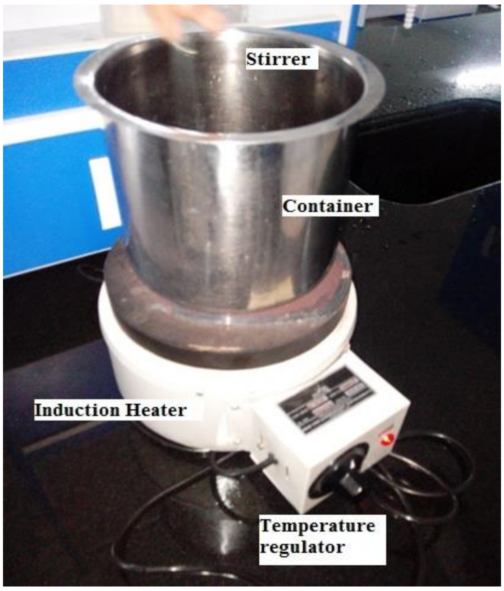

Fig. 1 Biodiesel production setup

Corn oil methyl ester (COME) from corn oil was prepared in Chemistry lab KNCET Trichy. Standard process was followed by using transesterification reaction was followed, using KOH as catalysts for reactions and methanol act as reagent respectively, to turn out biodiesel from corn oil. Figs. 1 and 2 shows the set up for biodiesel production. Separated biodiesel and glycerine was shown in Fig.3.

Three different blends B20 (20% Corn oil methyl ester+ 80% diesel v/v), B40 (40% Corn oil methyl ester + 60% diesel v/v), B60 (60% Corn oil methyl ester + 40% diesel v/v) were prepared. The properties of diesel and biodiesel blends have been calculated by volume fraction and are shown in Table 1

Fig.. 2 Biodiesel Seperation

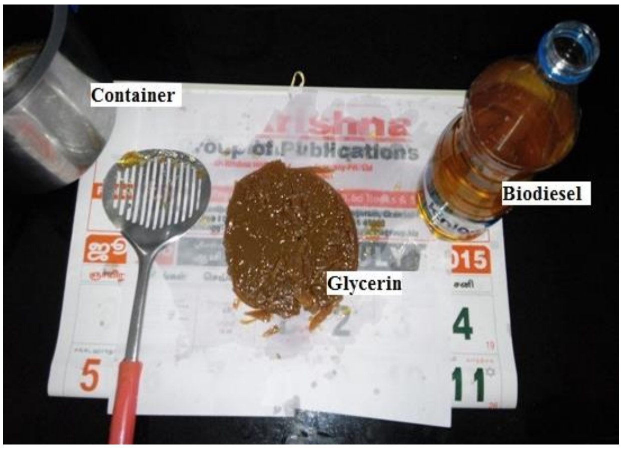

Fig. 3 Biodiesel and Glycerin

Table 1

Properties of various Fuels

Fuel Property	Unit	Diesel	B20	B40	B60
Density	Kg/m^3	832	834	848	862
Viscosity at 40°C	CST	5	5.6	6.4	7.1
Calorific value	MJ/kg	42	40.9	39.9	39.3
Flash Point	°C	62	76	95	111
Fire Point	°C	71	83	103	125

2.2. Experimental setup

Tests were conducted with the blends B20, B40 and B60 for two conditions with preheated fuel and unheated fuel over the entire range of engine operation. Results were compared with unheated diesel fuel. The engine used in this experiment is four stroke, constant speed, direct injection, single cylinder Compression ignition engine.

The mass flow rate of air is measured by using manometer, the temperature of inlet air and exhaust gas is measured by using a thermocouple and the consumption of fuel is measured by using burette. The engine specification is given in Table 2 and the schematic line diagram of IC engine setup and preheater is shown in Fig. 4. A counter flow pipe heat exchanger was attached in exhaust line of engine to preheat the corn oil by using waste heat energy from the engine exhaust gases. A flow control valve was used to adjusting the mass flow rate of exhaust gases to obtain the temperature of fuel to 80°C. Thermocouple was provided in fuel line to measure the temperature of fuel. The fuel temperature was maintained at 80°C for each load.

Table 2

Engine specification

S. No	Parameter	Unit	Description
1.	Make	-	Kirloskar
2.	Type	-	Four strokes, Single cylinder compression ignition engine
3.	No of Cylinder	No	1
4.	Stroke	mm	203
5.	Bore	mm	127
6.	Rated Power	kW	8
7.	Compression ratio	-	16.5:1
8.	Rated Speed	rpm	1500

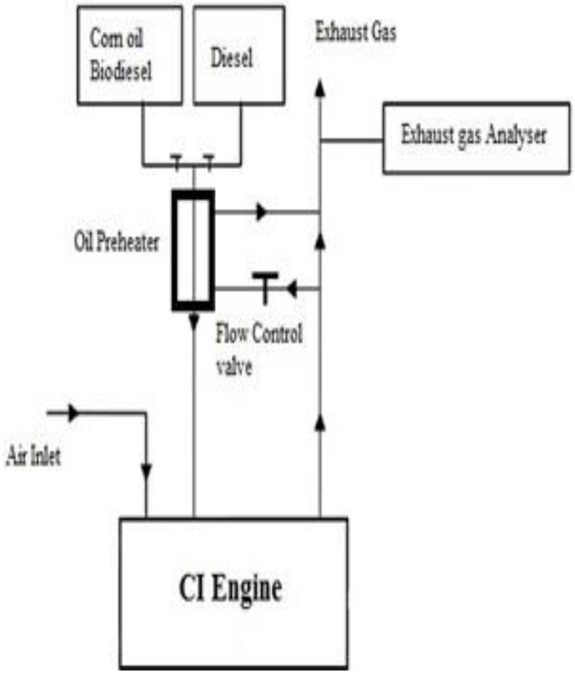

Fig. 4 Line diagram of CI engine setup and preheater

Table 3

Exhaust gas analyzer

Parameter	Resolution	Accuracy	Range
Carbon Monoxide	0.01%	+/-5% of reading +/-0.5% Volume	0-10% Over-range 20%
Oxygen	0.01%	+/-5% of reading +/-0.1% Volume	0-21% Over-range 48%
Hydrocarbon	1ppm	+/-5% of reading +/-12ppm Volume	0-5000ppm Over-range:10,000ppm
Carbon Dioxide	0.1%	+/-5% of reading +/-0.5% Volume	0-16% Over-range 25%
Nitric Oxide	1ppm	0-4000ppm+/-4% or 25ppm; 4000-5000ppm+/-5%	0-5000ppm
Carbon monoxide	0.01%	Calculated	0-15%
Sensor response	15 seconds		
Warm up	Less than 3 minutes		

The exhaust emission like HC, NOX and CO2 has been taken for each load at a constant speed by using Kane Automotive Gas Analyzer. It can measure carbon monoxide (CO), unburned hydrocarbons (HC), Oxygen (O2), Carbon dioxide (CO2) and Nitric oxide (NOx).

3. Result and discussion

3.1. Brake thermal efficiency

Brake thermal efficiency of an engine depends on Calorific value of fuels and load applied on the engine. Comparison of break thermal efficiency Vs brake power for unheated diesel, B20, B40 and B60 has been shown in Fig. 5. It was noted from Fig. 5 that brake thermal efficiency increases with increase in load for all fuels and decreases with increase in concentration of biodiesel. Brake thermal efficiency of Diesel, B20, B40 and B60 at 70% brake power was 31.80%, 29.00%, 26.50% and 24.30% respectively. BTE of B20 was 2.8% lesser than diesel fuel due less calorific value and high viscosity leads to poor atomization.

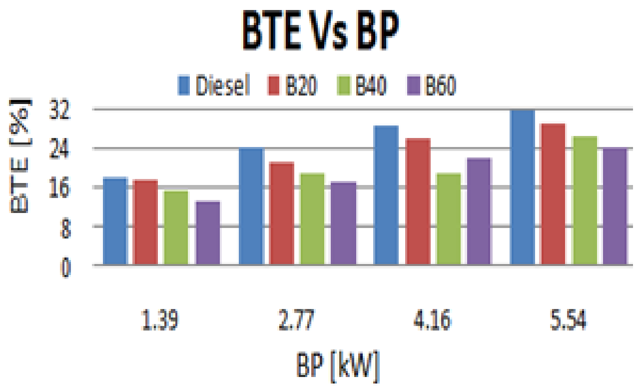

Fig. 5 Brake thermal efficiency of various unheated corn oil blend v/s load

Comparison of break thermal efficiency Vs brake power for preheated B20, B40 and B60 has been shown in Fig. 6. It was found from Fig 6 that brake thermal efficiency increases with increase in fuel temperature. Brake thermal efficiency of B20, B40 and B60 at 70% brake power was 32.00%, 29.00%, and 26.70% respectively. BTE of preheated B20 blend is very close to unheated diesel. The preheated B20 was 3% more than unheated B20 blend due to higher heating value and less viscosity.

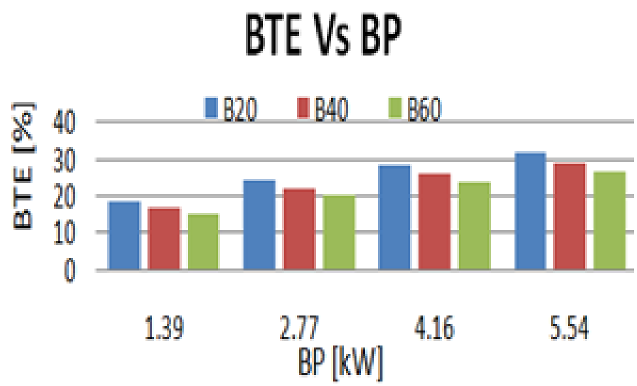

Fig. 6 Break thermal efficiency of various preheated corn oil blend v/s load

3.2. Brake specific fuel consumption

Brake specific fuel consumption Vs brake power for unheated diesel, B20, B40 and B60 has been shown in Fig. 7. It was noted that brake specific fuel consumption decreases with increase in load for all fuels and increases with increase in concentration of biodiesel due to higher mass flow rate of fuel to meet the engine loads. BSFC of Diesel, B20, B40 and B60 at 70% brake power was 0.16kg/kWh, 0.19kg/kWh, 0.22kg/kWh and 0.24kg/kWh respectively. BSFC of B20 was 0.03kg/kWh more than diesel fuel due lower heating valve and poor atomization of fuel.

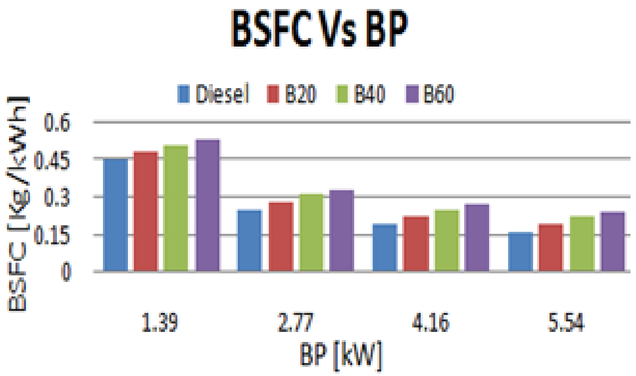

Fig. 7 Brake specific fuel consumption of various unheated corn oil blend v/s load

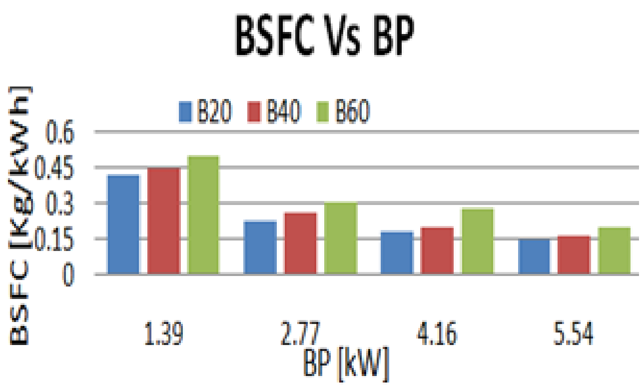

Fig. 8 Brake specific fuel consumption of various preheated corn oil blend v/s load

Comparison of break thermal efficiency Vs brake power for preheated B20, B40 and B60 has been shown in Fig. 8. BSFC of preheated B20, B40 and B60 at 70% brake power was 0.15kg/kWh, 0.17kg/kWh and 0.20kg/kWh respectively. BSFC of preheated B20 blend is very close to unheated diesel. The preheated B20 was 0.04kg/kWh less than unheated B20 blend due to improve atomization and mixing of fuel.

3.3. Carbon dioxide

CO_2 emissions for unheated diesel, B20, B40 and B60 are shown Fig. 9. The corn oil fuel blends contain lower carbon content due to more amount of oxygen present. Hence CO_2 formation with corn oil methyl ester will be less compared to diesel. It was observed that carbon dioxide increase with increase in load for all fuels and decreases with increase in concentration of biodiesel. CO_2 of Diesel, B20, B40 and B60 at 70% brake power was

4.80%Vol, 4.46%Vol, 4.30%Vol and 4.12%Vol respectively. CO_2 of B20 was 0.34% Vol less than diesel fuel. Variation of CO_2 Vs brake power for preheated B20, B40 and B60 has been shown in Fig. 10. Carbon dioxide of preheated B20, B40 and B60 at 70% brake power was 4.40%Vol, 4.25%Vol and 4.00%Vol respectively. CO_2 of preheated B20 blend was 0.40%Vol and 0.02%Vol less than unheated diesel and unheated B20 blend due the hydrogen to carbon ratio of biodiesel blend was more than that of diesel fuel which causes the lesser percent of CO_2 formation.

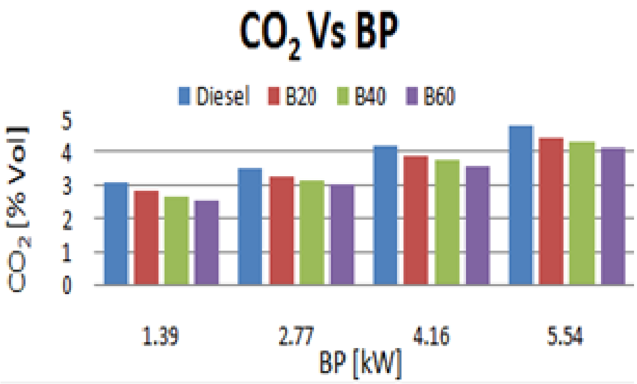

Fig. 9 Carbon dioxide of various unheated corn oil blend v/s load

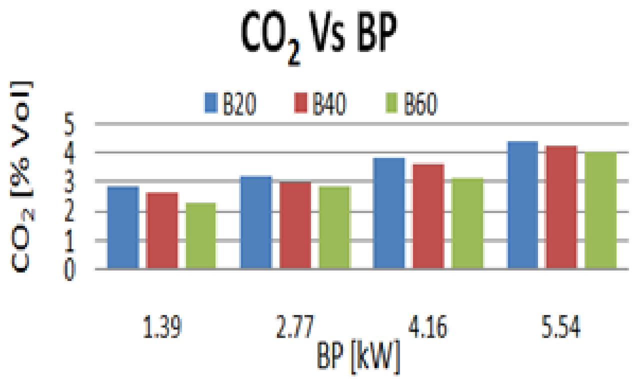

Fig. 10 Carbon dioxide of various preheated corn oil blend v/s load

3.4. Oxides of nitrogen

Fig. 11 shows NOx emissions for all the blend ratios under different loads. The important factors that cause NOx formation are high combustion temperatures and availability of oxygen. It was found that NOx increase with increase in load for all fuels and decreases with increase in concentration of biodiesel. NOx of Diesel, B20, B40 and B60 at 70% brake power was 188ppm, 177ppm, 167ppm and 156ppm respectively. NOx of B20 was 11ppm less than diesel fuel due to lower caloric value causes lesser gas temperatures in the combustion chamber.

The effect of NOx for preheated B20, B40 and B60 are shown in Fig. 12. NOx of preheated B20, B40 and B60 at 70% brake power was 186ppm, 191ppm and 194ppm respectively. NOx of B20 was similar to unheated diesel. However, the NOx is increased with increase in concentration of preheated corn oil fuel due to higher combustion temperature.

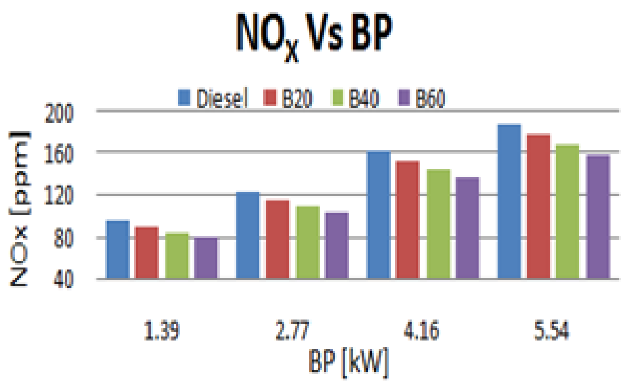

Fig. 11 NOx of various unheated corn oil blend v/s load

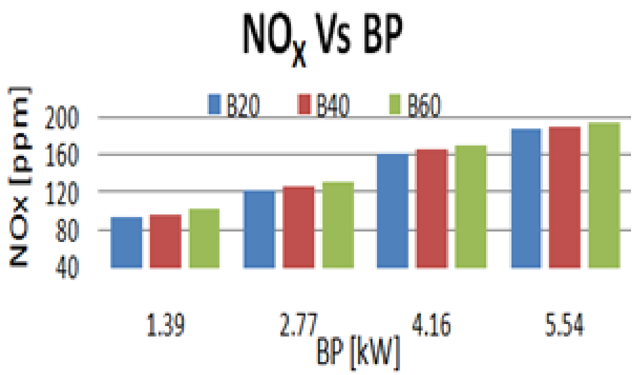

Fig. 12 NOx of various preheated corn oil blend v/s load

3.5. Hydro carbons

Fig. 13 shows HC emissions for all the blend ratios under different loads. The important factors that cause HC formation are poor combustion due to poor atomization and mixing of fuel and air. It was found that HC increase with increase in load for all fuels and decreases with increase in concentration of biodiesel. HC of Diesel, B20, B40 and B60 at 70% brake power was 51ppm, 46ppm, 42ppm and 37ppm respectively. HC of B20 was 5ppm less than diesel fuel due to better mixing of biodiesel and air.

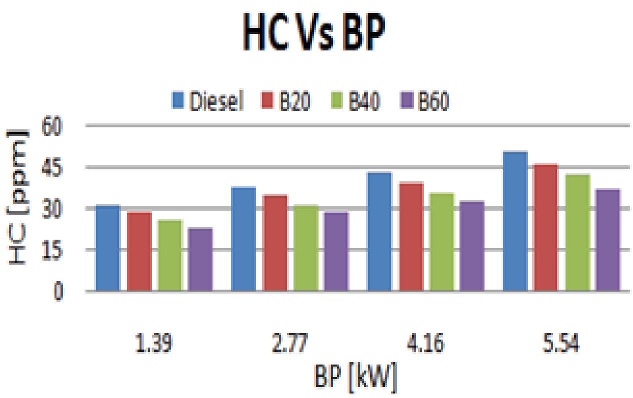

Fig. 13 HC of various unheated corn oil blend v/s load

The effect of HC for preheated B20, B40 and B60 are shown in Fig. 14. HC of preheated B20, B40 and B60 at 70% brake power was 49ppm, 45ppm and 40ppm respectively. However, the HC is decreased with increase in concentration of preheated corn oil fuel due to better atomization of the blended fuel and better combustion.

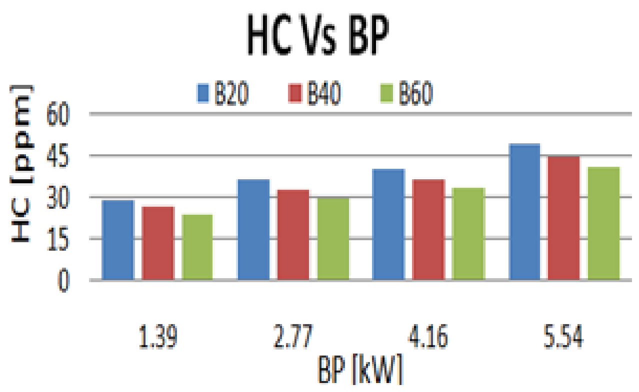

Fig. 14HC of various preheated corn oil blend v/s load

4. Conclusion

Use of a vegetable oil, namely corn oil, is considered as a new possible source of alternative fuel for CI engine. It was noted the engine was no difficulty at the time of starting and ran well over the corn oil blends. Higher the corn oil temperature will decrease the viscosity of oil which enhance the better atomization and combustion of fuel. The experimental results are below.

- The BTE of preheated B20 was 3% more than unheated B20 blend due to higher heating value and less viscosity.
- At the brake power of 5.54kW, the brake specific fuel consumption preheated B20 was 0.04kg/kWh less than unheated B20 blend due to preheating improves atomization and mixing of fuel.
- CO_2 of preheated B20 blend was 0.40%Vol and 0.02%Vol less than unheated diesel and unheated B20 blend.
- HC of preheated B20 blend was 2ppm less than unheated B20 blend.
- The NOx is increased with increase in concentration of preheated corn oil fuel due to higher combustion temperature.

From the result, it was found that preheated B20 corn oils could be used as the best alternate to diesel fuel without any engine modification.

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PERFORMANCE AND EMISSION CHARACTERISTICS OF PREHEATING CORN OIL METHYL ESTER IN CI ENGINE

S u m m a r y

In the present work on unheated Corn oil methyl ester and Preheated Corn oil methyl ester is used to prepare different concentration blends with diesel, B20, B40 and B60 were used as alternative fuels in a compression ignition engine. The properties like calorific value, flash point, fire point and viscosity of these oils were determined. The viscosity of corn oils has been reduced through transterification process. The waste heat energy from the exhaust gas was reused to preheat the corn oil around 80°C by adjusting the flow rate of exhaust gas. The performance and emission characteristics of a single cylinder, direct injection diesel engine were determined using unheated corn oil, Preheated Corn oil and diesel. Brake thermal efficiency of preheated B20 was more than other blends and unheated fuels but equal to diesel fuel. Brake specific fuel consumption, CO_2 and HC of preheated B20 were less than unheated fuels and diesel. However, the NOx emission of preheated B20 was little higher than unheated fuels and diesel due to high combustion temperature. By considering the result of all the factors, preheated B20 blend was found to be a suitable alternative for diesel fuel.

Keywords: corn oil, preheated, performance, exhaust emissions.

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