Emission Analysis of a Compression Ignition Engine Fueled with Different Blends of Mahua Biodiesel

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Abstract

The consumption of fossil fuels is increasing day by day and the total utilization of fossil fuels globally is 10million tons on daily basis has been observed. These fuels are being exempted every day as they are present in limited quantity and it is anticipated that the future generation will face an intense energy supply collapse in the upcoming years. Again, the use of these fuels causes environmental problems as it emits harmful gases. The major problems due to fossil fuels occur due to the increased rate of consumption which produces many harmful pollutant emissions like Carbon Monoxide (CO), Carbon Dioxide (CO2), Oxides of Nitrogen (NOx), and Hydrocarbon (HC). The use of nonedible oils such as Karanja, Jatropha, Kusuma, Neem, etc., to produce biodiesel mainly in a tropical country like India is an added advantage due to their wide availability. Several research works are going on for use of the biodiesel to run a diesel engine. In the present work, a diesel engine was run by using Mahua biodiesel and engine emission was analyzed. The number of exhaust gases present in engine emission was found to be reduced significantly that supporting its use as an alternative fuel.

Keywords: *Mahua Oil, Transesterification, Biodiesel Blends, Emission Analysis, CI Engine.*

Introduction

Air Pollution has become a crucial problem due to rapid growth in population and industrialization. The combustion of fossil fuels produces many harmful gases like Carbon Monoxide (CO), Carbon Dioxide (CO2), Oxides of Nitrogen (NOx), and Hydrocarbon (HC) along with some traces of organic compounds like monocyclic aromatic hydrocarbons, polycyclic hydrocarbons, aldehydes, etc. [3]. Such poisonous compounds damage the temperature balance of the world, causing global warming, pollution, acid rain, etc. [4]. Due to changes in the environment, many human problems are seen such as cancers, respiration problems, heart disease, etc. Hence it is imperative to find an alternative source for fossil fuel that can be extracted by suitable processing of the biomasses (residuals & unsaturated fats from plants and animals). Now a day, to overcome all these problems biodiesel become one of the most interesting alternatives because biodiesel is biodegradable, non-polluting, and has very similar physical characteristics to biodiesel [5]. Biodiesel can be produced from non-comestible oils. The use of comestible oil to produce biodiesel in India is not workable because of its high cost and India is self-insufficient in comestible oils [11]. From the economical point of view, non-comestible oil can come up with the best source for biodiesel production. India is well capable for the production of biodiesel from non-combustible vegetable oil seeds [6]. Biodiesel produced from the vegetable oils is a favorable alternative fuel against diesel fuel because of its sustainability, better quality lighting, approximate energy fulfilment, and higher safety without the restriction of the energy. An overview of the production, properties, performance, and emission analysis of several biodiesels was provided by Madiwale and Bhojwani [1]. Ismail et al. [2] successfully produced biodiesel from crude castor oil through the transesterification method. Padhi and Singh [7] optimized the production of biodiesel from mahua oil. They haven't examined their emission characteristics, though. Rathore and Pandey [8] carried out experimental work on diesel engine performance and emission with mixed biofuel of Karanja and coconut. Arunkumar et al. [9] also studied the performance of diesel engine using castor biodiesel and obtained favourable results experimentally. Jena et al. [10] carried out their investigation on biodiesel preparation from mahua and Simarouba oil. Mahua is an indigenous plant in India and can easily be found all over India. An abundance of Mahua plants and awareness for its farming among the farmers in India has made Mahua oil the best source for Indian conditions. Mahua oil characteristics are preferably good over the other oils. Its characteristics are close to that of diesel. From a safety and storage perspective, Mahua biodiesel is good as its fire and flashpoints are higher. Hence Mahua oil was used as the raw material for biodiesel production. Transesterification is the common process to produce biodiesel from oils. However, sometimes esterification is also followed to get better and purified biodiesel. Esterification is the reaction between the oil and alcohol in the presence of an acidic catalyst by which glycerol and methyl ester is produced. The esterified oil we get here is pure than crude Mahua oil. Transesterification is the reaction between the esterified oil with alcohol in the presence of an alkali catalyst to produce glycerol and ester. The ester we get has a molecular weight one-third less than the crude Mahua oil ratio was taken to get low viscosity. Sometimes high alcohol to oil ratio was taken to get low viscous biodiesel. Different characteristics of castor oil and castor biodiesel are determined. In this work, prepared Mahua biodiesel was blended with conventional diesel. Three different blends B10, B20, and B30 were prepared by mixing 10%, 20%, and 30% of biodiesel with 90%, 80%, and 70% of conventional diesel respectively. The prepared Mahua biodiesel blends were then tested in a diesel engine and emission was observed and compared with the conventional diesel.

Materials and Methods

The Mahua trees are fast-growing and can grow easily in any kind of soil. Hence castor trees are shown all over India and easy to collect castor seeds and oil directly. All the properties like acid value, viscosity, the density of the crude Mahua oil were determined. In this study, the Mahua oil was transformed to castor-biodiesel with the aid of two-step transesterification process. In the first step, the free fatty acid (FFA) present in the Mahua oil was converted into methyl ester by acid-catalyzed esterification and the second step was the base-catalyzed transesterification using potassium hydroxide as the catalyst. The esterification was carried out to reduce the FFA of the oil. In the first step, the temperature was maintained at about 600-640C with 200ml methanol and 10gm of concentrated H2SO4. After heating it for 3 hours, the excess amount of alcohol with impurities was removed after pouring the product into a separating funnel. After removing the impurities from the bottom layer, the upper layer methyl ester was collected from the separating funnel for the base transesterification process. In the transesterification process, 10gm of KOH was dissolved in 200ml of methanol then poured into the flask. The mixture was heated at a constant temperature of about 620C and stirred continuously for 3hour. After heating it for 3 hours, the mixture was strained into a separating funnel for about 12 hours where two distinct layers were formed. The upper layer was comprised of methyl ester and the lower layer contained glycerol, excess amount of methanol, catalyst, and other by-products were irradicated. The upper layer of methyl ester or Mahua biodiesel was collected and rinsed several times with de-sterilized water until the washing water became neutral. Then the biodiesel layer was filtered to strain out the impurities and then was heated up to 1000C to remove any left-out moisture contents. The biodiesel was tightly sealed and kept for storage. The CI engine was run thrice using three different blends of Mahua biodiesel as a fuel. The blending percentages of biodiesel with diesel were 10%, 20%, 30%, and they were mentioned as B10, B20, and B30 respectively. The emission analysis was conducted by analyzing the exhaust gas of diesel with the help of an exhaust gas analyzer as shown in Figure 1.

Figure 1: Exhaust Gas Analyser

Result and Discussion

During testing of several Mahua biodiesel blends, the composition of exhaust gases, which mostly comprises of four primary pollutants such as CO, CO2, NOx, and HC, was noted. Table 1-4 displays the comparison of exhaust emissions.

Carbon Monoxide (CO) emission

Table 1 shows that Mahua biodiesel emits less carbon dioxide than regular diesel. It is because different Mahua biodiesel blends completely burn when compared to regular diesel.

Table 1: CO emission of conventional diesel and castor biodiesel at different load

Load(kg)	CO(%) Diesel	CO(%) B10	CO(%) B20	CO(%) B30
2	0.08	0.05	0.04	0.04
4	0.07	0.05	0.04	0.03
6	0.06	0.05	0.03	0.03
8	0.05	0.04	0.03	0.02

Figure 2: CO Vs load for conventional diesel and Mahua biodiesel blends

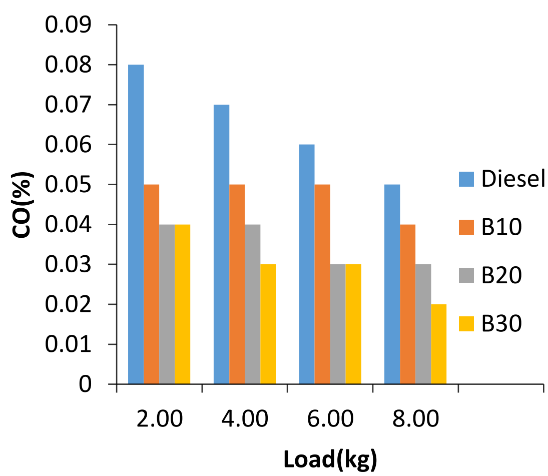


Figure 2 shows that the CO emission of Mahua biodiesel blends reduces as load increases with increasing biodiesel ratio. This is mostly because diesel did not undergo complete oxidation, which is what caused the problem. The production of CO2 during the combustion of biodiesel may be formed due to the presence of extra oxygen molecule in the biodiesel and this process aids in minimizing the CO emission.

Oxides of Nitrogen (NOX) emission

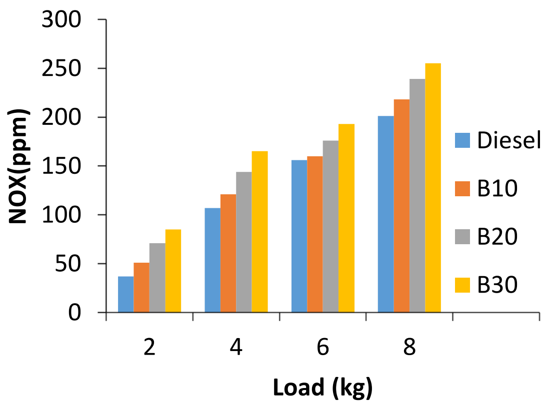
Table 2: NOX emission of conventional diesel and castor biodiesel at different loads.

Load(kg)	NO_X(ppm) Diesel	NO_X(ppm) B10	NO_X(ppm) B20	NO_X(ppm) B30
2	37	51	71	85
4	107	121	144	165
6	156	160	176	193
8	201	218	239	255

The NOX emission increases with the increase in percentage of biodiesel blends as shown in Table 2 and Figure 3. It is due to high oxygen content in the biodiesel which cause the formation of NOX in the emission chamber.

The NOx emission is a function of the total oxygen inside the combustion chamber, temperature of combustion chamber, pressure, and compressibility of fuel. Again, the increase of NOx emission is due to the higher cetane number of biodiesel which will reduce the ignition delay. The increase of NOx emission is a result of the reduced ignition delay.

Figure 3: NOX Vs load for conventional diesel and Mahua biodiesel blends



HC emission

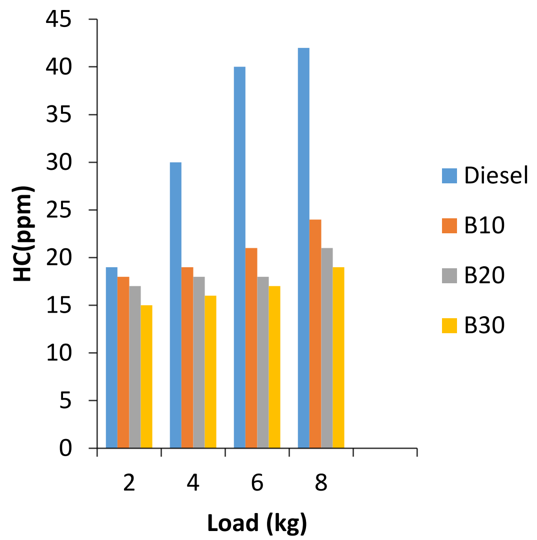
Table-3 shows that the HC emission of Mahua biodiesel is less as compare to conventional diesel. This may be due to effective combustion process inside the engine cylinder. When the load increases, the HC percentage also increases since amount of HC varies inversely with NOx.

Table 3: HC emission of conventional diesel and different biodiesel blends at different load.

Load(kg)	HC(ppm) Diesel	HC(ppm) B10	HC(ppm) B20	HC(ppm) B30
2	19	17	16	14
4	30	19	17	15
6	40	21	18	17
8	42	24	20	18

From Figure 4, it is observed that in B30 the HC emission is less as compare to B20, B10 and the conventional diesel because in B30 there is more biodiesel as compare to B20 and B10. As B30 contains more oxygen as compare to B20 and B10, it emits less HC.

Figure 4: HC Vs load for conventional diesel and Mahua biodiesel blends.



Carbon Dioxide (CO2) emission

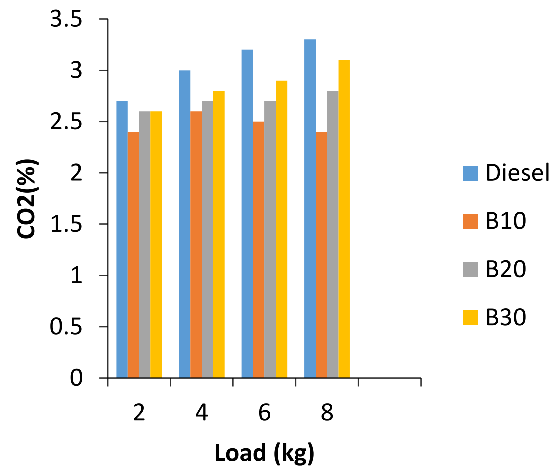
The CO2 emission in conventional diesel is more as it contain less oxygen. It is shown from Table-4 that the CO2 emission of B30 was more as compare to B20, B10. It is due to incomplete combustion process of higher blends of Mahua biodiesel in comparison lower blends.

Table 4: CO2 emission of conventional diesel and different biodiesel blends at different load.

LOAD	CO2 Diesel	CO2 B10	CO2 B20	CO2 B30
2	2.7	2.4	2.6	2.6
4	3	2.6	2.7	2.8
6	3.2	2.5	2.7	2.9
8	3.3	2.4	2.8	3.1

Figure 5 shows that the carbon dioxide emission increases with increasing biodiesel blends. However the emission is not so more than the diesel. Lower emission of biodiesel blends is due to high oxygen content than the diesel.

Figure 5: CO2 Vs load for conventional diesel and Mahua biodiesel blends.



Conclusions

The prepared biodiesel from Mahua oil has good enough inherent properties than conventional diesel and most of its properties have resemblance to that of diesel. From the above result, it can be concluded that biodiesel can be sustainable as an alternative fuel to diesel. The biodiesel contains more oxygen which promotes the complete & efficient combustion in diesel engines and it leads to lowered emissions. Due to high oxygen content, biodiesel emits lower CO and CO2 as compared to diesel. The NOX emission of biodiesel blends of Mahua oil has a scope to check the overall emission level of the blends by adapting engine modifications. As Mahua biodiesel has lower HC emission than conventional diesel, the biodiesel pollutes less as compared to diesel and can be regarded as a green fuel. Hence it is a sustainable fuel to be used as an alternative for diesel engine.

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