Comparative Analysis of CI Engine Fuelled with Mahua oil & Jatropha oil derived Single & Dual Biodiesel Blends

Milind Balkrishna Patil[1], Prof. Arun M. Kulkarni[2], Prof. Amol S. Dayma[3], Dr. Mrs. S. N. Bobade[4]

[1 & 3]Department of Mechanical Engineering, SSJCOET, Asangaon, University of Mumbai, Maharashtra, India
[2]Department of Mechanical Engineering, SSJCOE, Dombivli, University of Mumbai, Maharashtra, India
[4]Research Head, Indian Biodiesel Corporation, Baramati, Maharashtra, India

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Abstract - *Biodiesel is becoming a significant substitute for petroleum-based automotive fuels. Biodiesel is produced from vegetable oils (edible or inedible), animal fats or used cooking oils. Edible vegetable oils are mainly used for human consumption; can lead to an increase in the price of biodiesel. Available quantities of used oils and animal fats are not sufficient to meet current biodiesel demands. For these reasons, the uses of inexpensive inedible vegetable oils are preferred for the production of biodiesel. The actual raw material supply of any vegetable oil is not sufficient to meet current demand. Competition for biodiesel is mainly related to the cost of raw materials, which is high since the production process uses only a favorable raw material for the oils. The cost of producing biodiesel can be reduced by mixing two different biodiesels. To meet the current demand for adequate alternative fuels with a reasonable market price, biodiesel must be derived by blending two or more biodiesels from different feed stocks. The properties of the different biodiesels vary in a very small proportion, which gives more possibilities to combine different biodiesels between them. In the dual blend of biodiesel, we blended two different biodiesels that combine 50% Mahua oil and 50% biodiesel derived from Jatropha oil. Biodiesel has been blended with additives in various proportions to prepare a series of test fuels that are tested in a diesel engine to study various parameters. In this research, we study the performance characteristics of the CI engine fueled with Mahua oil and single and double biodiesel blends derived from Jatropha oil.*

Key words: Mahua, Jatropha, Single, Dual, Biodiesel, Blends

1. INTRODUCTION

Energy is a major contribution to economic growth and sustainable development in both industrialized and developing countries. The global energy requirement for transport is covered by non-renewable fossil fuels. As fossil fuels are limited sources of energy, the growing demand for energy has led to the search for alternative energy sources economically efficient, socially just and ecologically. It has been established that these energy sources have limited quantities and that they should be used to exhaust resources. Fuel is an essential energy source for industrial and daily transport activities. It is important to meet the demand for fuel to reach the development around the world. Globalization is growing rapidly, which is difficult to satisfy. In view of the decline in supply and rising demand, oil prices are likely to rise further. In addition, growing concern about climate change caused by humans as a result of rising temperatures and pollution of the environment are other sources of clean energy driving. Alternative options for conventional fossil fuels are urgently required for sustainable development. One such source is ethanol from biomass / cereal crops and biodiesel processing of edible oils and non-edible plant. Biodiesel is a better option to meet the demand for diesel.

India's energy supply is mainly covered by non-renewable energy sources such as coal, natural gas and oil. These will continue to play a dominant role in their energy scenario over the coming decades. The strongest energy demand comes from the industry, followed by the transport sector. The car population in India is expected to grow by 10 to 12% per annum. The current diesel consumption in India accounts for about 40% of the total oil consumption in India. While the domestic production of oil and natural gas will be lower than demand. There is a large gap between supply and demand, which is currently imported, resulting in a heavy burden on the foreign currency of the country. Therefore, ensure long-term supply of energy sources and development is important to set priorities to ensure that the future energy needs are met. The country is currently looking for alternative energy options from biofuels to meet the requirements of the transport sector. To promote biofuels as an alternative source of energy, the Indian government foresees compulsory biofuels fuel requirements, with incentives policy, the development and optimal use of raw materials of domestic biomass to facilitate production of biofuels. [1-17]

1.1 Biodiesel

Biodiesel is the only alternative fuel that can be used directly in any unchanged diesel engine. Since it has properties similar to diesel fuel, biodiesel can be mixed with diesel fuel in any ratio. Biodiesel is a relatively new product in India. Vegetable oils have long been used as new fuel engines. In 1912 the use of vegetable oils for fuels appears to be insignificant. Plant oil as an optimistic alternative presents because of its various advantages: it is renewable, environmentally friendly and occurs easily in rural areas in urgent need for new energy forms. Scientists have found that the viscosity of vegetable oil could be reduced by a simple chemical process in 1970 and could function well as a diesel fuel in a modern engine. The fuel generated by simple transversal of vegetable oil is called biodiesel. It is an alternative fuel that can be used in diesel engines and provides a performance similar to conventional diesel fuel. It reduces the dependency of the countries on foreign oil imports.

The selection of non-edible vegetable oils as a raw material for biodiesel production requires a review of existing work. Extensive recent research into the production of biodiesel from various raw materials shows the advantages of inedible oils compared to edible oils. The production of biodiesel from inedible petroleum raw materials can solve the problems of food, the environment and economic issues related to edible vegetables. The development of inedible biodiesel could be an important program to combat poverty for the poor in rural areas, and to ensure energy security in general and in particular rural areas and to improve rural agriculture. All these problems have a major impact on the sustainability of biodiesel production. The complete replacement of oil imports for the transport and agricultural sectors is the biggest and most difficult challenge for India and other parts of the world. By modifying existing facilities to conduct comprehensive biodiesel research studies and their feasibility for compression ignition engines, this research will serve as a model for such a design. [1-17]

1.2 Present work

The development of the biodiesel industry and the use of biodiesel in developing countries such as India is a low priority sector. The present work is a small step towards minimize dependency on individual biodiesel & to promote production of dual hybrid biodiesel of two different vegetable oils. The sustainable development can be achieved by mixing a combination of renewable and alternative fuels such as biodiesel from various vegetable oils and hybridize biofuels to improve efficiency of vehicles. The search for an alternative fuel for diesel fuel is crucial for the economy and safety of every nation. The main goal of this research is to synthesize biodiesel from non-food feed stocks such as Jatropha & Mahua and then compare their different variants. This study is a step towards the sustainable development of biodiesel through the use of inedible raw materials, which are available and have outstanding properties.

The choice of Mahua and Jatropha for the hybridization of tropical raw materials to improve their quality parameters is of interest to research. The underlying motivation of this research is to develop new biodiesel production routes through the hybridization process. The hybridization of the raw material biodiesel is a new development process presented in this study. Researchers around the world have not tested this process as an option. It is therefore a new focus on biodiesel developments. Another motivation is that in the production, evaluation and testing of biodiesel from inedible raw materials mahua oil and jatropha, creates a way for the expansion of trade and the adaptation of the technology.

2. MATERIALS AND METHODS

Among the nonedible oil sources, Mahua and Jatropha seeds have been identified as potential biodiesel sources and comparing with other sources, they have added advantages such as rapid growth, higher seed productivity, suitable for tropical and subtropical regions of the India.

2.1 Materials

2.1.1 Mahua oil

Madhuca indica is found mainly in India, commonly known as Mahua. It belongs to the family of the Sapotaceae and grows rapidly up to about 20 m high, has perennial or semi-annual foliage and adapts to arid environments. In some countries, Mahua oil is considered edible as it is only used for the production of ghee. In our country, however, it is considered unpalatable oil. Madhuca indica is one of the inedible, non-edible tree-based oils with a high production potential of around 60 million tonnes per year in India. This type of tree has a slow growth because the average height at the end of the fourth year is about 0.9 to 1.2 m. It also has resistance to drought. Trees have a large root system that stretches, but many roots are flat. The leaf falls between February and April and begins to bloom at the same time. The fruit matures in May-July. Mahua is spread by seeds. Grain is about 70% of the seed and contains 50% of oil. Each tree produces about 20 to 40 kg of seeds per year depending on the age and size of the tree and the total oil yield per hectare is 2.7 t per year. Its seed contains about 35-40% Madhuca indica. It is an important tree for the poor; is very popular for its flowers and seeds. The tree has a religious and aesthetic value in tribal culture. [3-7]

2.1.2 Jatropha oil

Jatropha oil is inedible oil for the production of biodiesel. The jatropha plant has a scientific name like Jatropha curcas from the family Euphorbiaceae. It is a small tree or a large shrub, up to 5-7 m tall. It is a drought-resistant plant that can survive on abandoned farmland and Brachland. It is a tropical plant that can thrive in a series of climatic zones with precipitation of 250 to 1200 mm. The plant comes from Mexico, Central America, Africa, India, Brazil, Bolivia, Peru, Argentina and Paraguay. It is well adapted to arid and semi-arid conditions and has low fertility and moisture requirements. It can also grow in moderately calcined, salty, degraded and eroded soils. The ideal plant density per hectare is 2500. It produces seeds after 12 months and reaches its maximum productivity in five years and can live between 30 and 50 years. Depending on the variety of soil conditions, jatropha seeds contain 43-59% of oil. [8-11]

2.1.3 Catalyst

The catalysts are used to accelerate a chemical reaction by reducing the activation energy, which is the energy required to initiate the reaction. There are two types of catalyst systems, heterogeneous and homogeneous systems. Nowadays, heterogeneous catalysts are not very popular because of the high cost or incapacity to achieve the degree of reaction required by the ASTM specification standard. The homogeneous system includes acids and bases. However, acid catalysts are not preferred due to a much slower Transesterification process of triglycerides in fatty acid methyl ester versus basic catalysts. The catalyst provides very high yields but the reaction rate is very slow and requires more time and higher temperatures to complete the reaction. Thus, acid catalysts are commonly used to pre-treat raw materials with high levels of free fatty acids. During this pretreatment, the fatty acids are converted into the fatty acid ester.

Alkali metal alkoxides are the most effective transesterification catalyst compared to the acidic catalyst. The most common alkaline catalysts are sodium hydroxide (NaOH) and potassium hydroxide (KOH). Sodium hydroxide (NaOH) is most efficient catalyst used for this purpose. The catalyst concentration in the range of 0.5 to 1% by weight yields 90 to 94% conversion of vegetable oil into esters. Further increase in catalyst concentration does not increase in conversion yields. Although there are different types of Transesterification processes for basic and acidic catalysts, virtually all commercial biodiesel manufacturers use basic catalysts. [12-15]

2.2 Methodology

2.2.1 Transesterification reaction:

Transesterification of vegetable oils with simple alcohol has long been the preferred method for producing biodiesel. Transesterification is a reversible reaction between triglyceride and alcohol in the presence of a catalyst for producing glycerol, and a monoalkyl ester is known as biodiesel. The weight of the monoalkyl ester is one third of the typical oil and therefore has a lower viscosity.

The chemical reaction that the biodiesel preparation describes is:

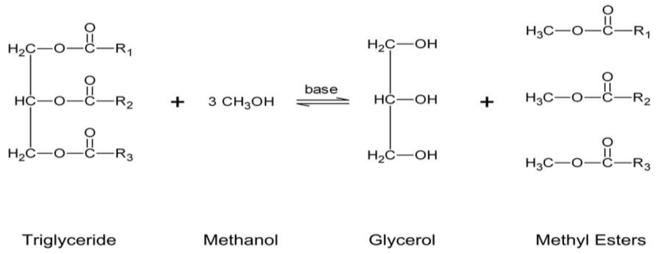

Fig-1: Transesterification reaction process of Biodiesel production

In this figure, R_1, R_2, R_3 represent long carbon chains. This reaction is occurred by alkali (NaOH, KOH), acid (H_2SO_4, HCl) or enzymes (lipase). In the transesterification process, methanol and ethanol are more frequent. Methanol is most prevalent due to its low cost and physico-chemical advantages associated with the dissolution of triglycerides and alkalis.The first step is the conversion of triglycerides to diglycerides, followed by the conversion of diglycerides to monoglycerides, and of monoglycerides to glycerol, yielding one methyl ester molecule from each glyceride at each step. In most cases, biodiesel is produced by a catalyzed transesterification process based on oil and is more economical.

2.2.2 Properties of Biodiesel

Some of the desirable fuel properties of biodiesel derived from various vegetable oils are shown in Table-1.

Table-1: Properties of diesel and biodiesel fuels

Properties	Diesel	Mahua oil Biodiesel (100% MB)	Jatropha oil Bio-diesel (100% JB)	Dual Biodiesel (50% MB + 50% JB)
Density (gm./cc)	0.840	0.870	0.880	0. 873
Calorific value (kJ/kg)	42490	38450	39050	38850
Cetane number	45	51.2	51.6	51.5
Viscosity@ 40 ^{0}C	3.05	5.8	4.84	5.4
Flash point ^{0}C	58	129	162	149

Biodiesel is a better fuel than diesel in terms of sulfur content, firing point and aromatics content. The properties of biodiesel fuel are close to diesel fuels, and biodiesel is thus a solid alternative to diesel fuels. The conversion of triglycerides to methyl or ethyl esters by the transesterification process reduces the molecular weight to one third of the triglyceride, reduces the viscosity by a factor of about eight, and easily increases volatility. These methyl esters of different biodiesel have a higher denudation than diesel. The calorific value of these biodiesel is about 10% less than diesel. These methyl esters of various biodiesel containing 10 to 11% by weight of oxygen can improve the combustion as compared to the hydrocarbon diesel fuel in an engine. The cetane biodiesel index is 50, which is higher than diesel. The use of tertiary amines and amides can be effective to improve the ignition quality of diesel fuel without adversely affecting the cold-flow characteristics. If the volatility increases slightly, the boot problem persists when it is cold.

3. EXPERIMENTATION

3.1 Test Engine

Fig-2: 4-stroke compression ignition engine

A single stage cylinder, constant speed, 4-stroke water cooled diesel engine was used for the engine test. Different blends of biofuel with diesel are tested for different parameters.

The specification of diesel engine in which experiment is performed is as follows:

Table-2: Specification of engine

FUEL	DIESEL
TYPE OF IGNITION	COMPRESSION
RATED POWER	5.2 kW @ 1500 rpm
NO. OF CYLINDER	ONE
COMPRESSION RATIO	16.5:1
BORE	80 mm
STROKE	110 mm
ORIFICE DIAMETER	22 mm
METHOD OF LOADING	ROPE BREAKE
METHOD OF STARTING	CRANK START

3.2 Blends

The blending of pure diesel with single & dual biodiesels is done in different proportion which to be tested. In Single biodiesel blends diesel is blended with any one biodiesel derived from only one vegetable oil. In dual biodiesel blending, we are blended two different biodiesels i.e. combination of 50% Mahua oil & 50% Jatropha oil derived biodiesel with diesel fuel. The dual blending contains equal blending quantity of two different biodiesels.

The different variants with their proportions are as follows:

3.2.1 Fuel I: Mahua biodiesel Variants

i. MB5: (95% Diesel + 5% Mahua Biodiesel)
ii. MB10: (90% Diesel + 10% Mahua Biodiesel)
iii. MB15: (85% Diesel + 15% Mahua Biodiesel)
iv. MB20: (80% Diesel + 20% Mahua Biodiesel)

3.2.2 Fuel II: Jatropha biodiesel Variants

i. JB5: (95% Diesel + 5% Jatropha Biodiesel)
ii. JB10: (90% Diesel + 10% Jatropha Biodiesel)
iii. JB15: (85% Diesel + 15% Jatropha Biodiesel)
iv. JB20: (80% Diesel + 20% Jatropha Biodiesel)

3.2.3 Fuel III: Dual biodiesel Variants

i. DuB5: (95% Diesel + 5% Dual Biodiesel)
ii. DuB10: (90% Diesel + 10% Dual Biodiesel)
iii. DuB15: (85% Diesel + 15% Dual Biodiesel)
iv. DuB20: (80% Diesel + 20% Dual Biodiesel)

4. RESULTS AND DISCUSSIONS

4.1 Engine performance

Biodiesel was mixed with additives in various proportions to produce a series of test fuels tested in a diesel engine to examine various parameters. The engine power is measured with 100% diesel, 5%, 10%, 15% and 20% blends of Mahua, Jatropha and Dual Biodiesel.

4.1.1 Brake Power

The comparison of B.P. (kW) for different biodiesel blends is shown in chart-1.

At full load (5kW) condition

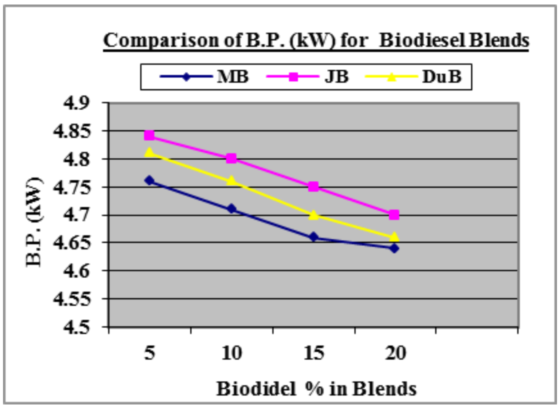

Chart-1: Comparison of B.P. (kW) for Biodiesel Blends

The braking performance can be called pure power, useful power or power required to move the wheels. It has been observed that by increasing the amount of biodiesel contained in the fuel, the braking performance is reduced. This is mainly due to the lower calorific value, the higher flash point, the higher viscosity and the delayed combustion process. It can also be seen that the brake power decreased gradually with increasing percentage of biodiesel. It has been observed that Mahua biodiesel variants have a lower BP value than two other mixtures due to its higher viscosity.

4.1.2 Brake Specific Fuel Consumption

The comparison of BSFC (Kg/kWh) for different biodiesel blends is shown in chart-2.

At full load (5kW) condition

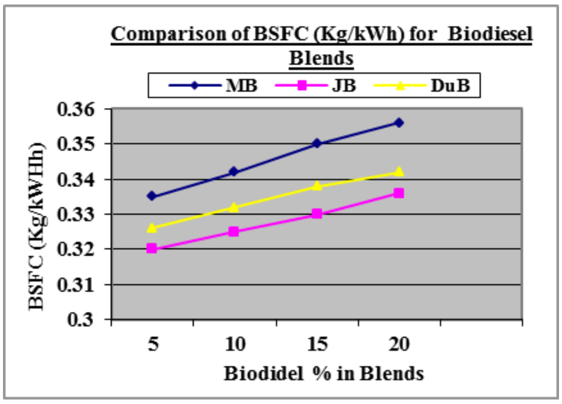

Chart-2: Comparison of BSFC (Kg/kWh) for Biodiesel Blends

Specific Fuel Consumption (SFC) is a measure of the efficiency of the engine in using the fuel supplied to produce work. It can be observed that the BSFC values are higher when biodiesel blends are used due to the higher density and lower calorific value of biodiesel blends. From the graph it was observed that the brake specific fuel consumption of the Mahua biodiesel among these three fuels is higher. It has also been observed that dual biodiesel blends have an intermediate value for all fuels variants. As seen in the graph by increasing the biodiesel content in the fuel, the value of BSFC increases in ascending order for all these fuels.

4.1.3 Brake Thermal Efficiency

The comparison of B.T.E. (%) for different biodiesel blends is shown in chart-3.

At full load (5kW) conditions

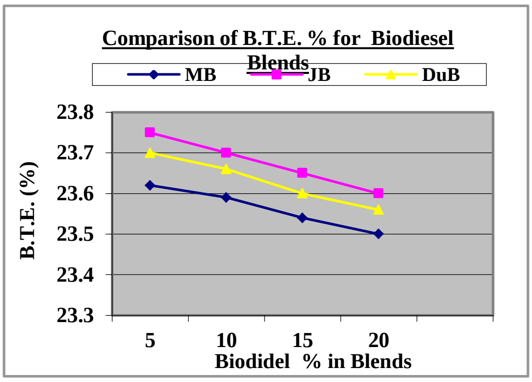

Chart-3: Comparison of B.T.E. % for Biodiesel Blends

The brake thermal efficiency is defined as the ratio of brake horse power to the heat energy of the fuel supplied during the same interval of time. From the graph it was observed that with the increase of the biodiesel share a decrease of the BTE is recorded. The dual biodiesel variants show a middle nature between Mahua biodiesel and Jatropha biodiesel mixtures.

4.1.4 Exhaust Gas Temperature

The comparison of E.G.T. (^{0}C) for different biodiesel blends is shown in chart-4.

At full load (5kW) condition

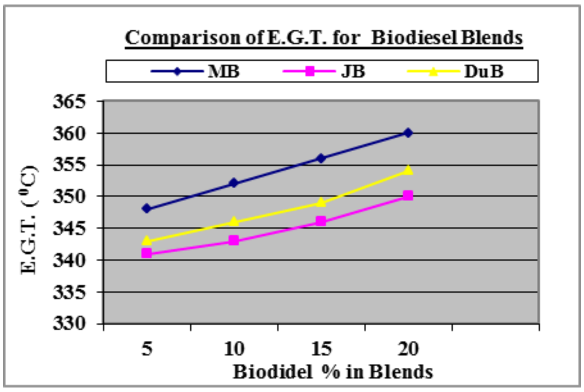

Chart-4: Comparison of E.G.T. ^{0}C for Biodiesel Blends

The observation was made by EGT measurements with increasing biodiesel%. EGT will also increase for all three mixtures. The reason for a higher temperature of the exhaust gas was an incomplete combustion in the high load cylinder, resulting in an increase in the temperature of the exhaust gas. Also a poor atomization of vegetable oil due to a higher viscosity to cause a slow combustion of the supplied oil can burn at the end of the cycle.

4.2 Engine Emissions

4.2.1 Hydrocarbons Emissions

The comparison of HC Emission (ppm) for different biodiesel blends is shown in chart-5.

At full load (5kW) condition

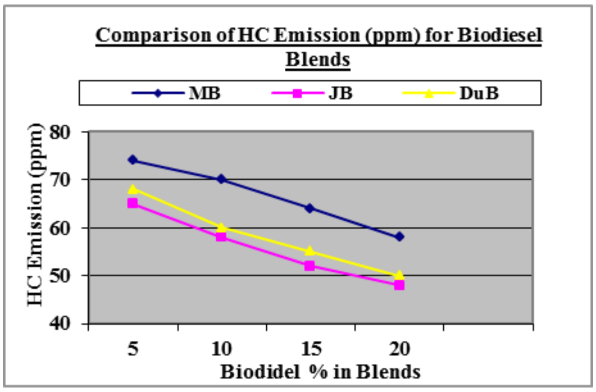

Chart-5: Comparison of HC Emission (ppm) for Biodiesel Blends

It has been observed that by increasing the amount of biodiesel, the HC emissions for all three variants are also reduced. Because of the higher viscosity, all the hydrocarbons present in the Mahua biodiesel do not completely burn, leaving behind the particulate carbon of the engine exhaust so that the Mahua biodiesel has maximum HC emissions. With the increase in the biodiesel share in the mixtures, the HC emissions have consequently followed a decreasing trend.

4.2.2 CO_2 Emissions

The comparison of CO_2 Emission (ppm) for different biodiesel blends is shown in chart-6.

At full load (5kW) condition

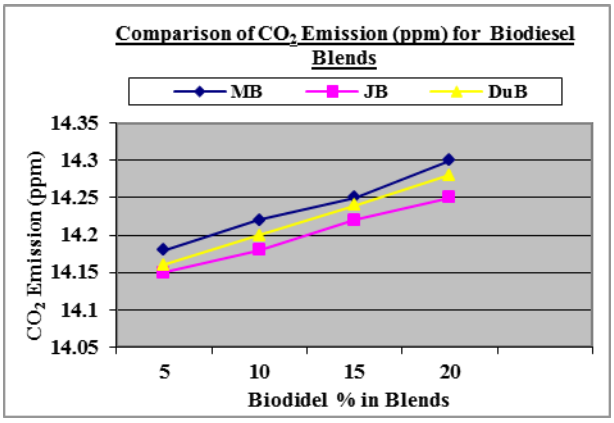

Chart-6: Comparison of CO_2 Emission (ppm) for Biodiesel Blends

It has been observed that among these three biodiesel Jatropha biodiesel blends show lowest value of the CO_2 emissions and higher value of % CO_2 emissions with a larger amount of biodiesel in Mahua biodiesel. MB has a value that is slightly larger than the other two types of biodiesel mixtures. A higher proportion CO_2 emission from all biodiesel blends is due to the increased viscosity of biodiesel.

4.2.3 CO Emissions

The comparison of CO Emission (ppm) for different biodiesel blends is shown in chart-7.

At full load (5kW) condition

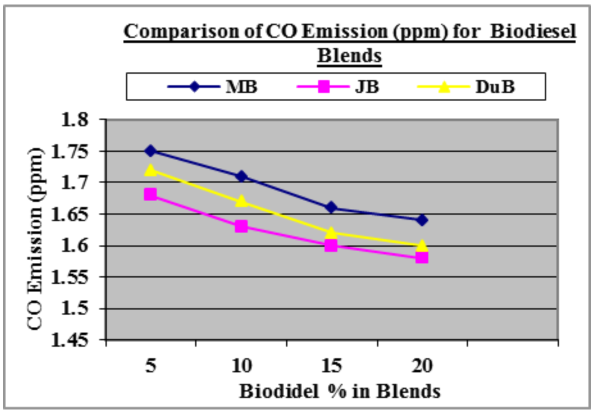

Chart-7: Comparison of CO Emission (ppm) for Biodiesel Blends

From the graph it is observed that the CO emission is decreases due to sufficient fuel combustion. The air-fuel ratio decreases with increasing load as all typical combustion engines due to the cleaner combustion of the mixture. As the percentage of biodiesel increased in the blend, the higher oxygen contents of biodiesel allow more carbon molecules to burn and combustion becomes completed. Moreover, low aromatics in the blends may be an additional reason for reducing CO emission.

4.2.4 NO_x Emissions

The comparison of NO_X Emission (ppm) for different biodiesel blends is shown in chart-8.

At full load (5kW) condition

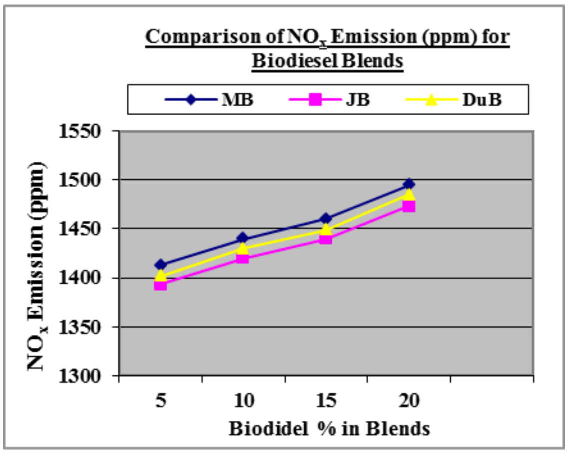

Chart-8: Comparison of NO_x Emission (ppm) for Biodiesel Blends

From the graph it is observed that the NOx emission increases with the increase of the biodiesel content (%). It was found that the NOx emission was a maximum of 20% for the three different fuels. With the rise of biodiesel in pure diesel, NOx emissions will rise. In addition, the density has an effect on the emission of NOx, that is, biodiesel has a higher density that causes more fuel jet into the combustion chamber, resulting in a rise in NOx. NOx occurs in areas of cylinders in which high temperature peaks occurred during uncontrolled combustion. NOx emission for these biodiesel variants is more than diesel in all loading conditions. This is mainly due to the presence of oxygen and more cetane of the biodiesel variants.

5. CONCLUSION

In the present study, it is observed that the qualities of biodiesel produced from non-edible oil are comparable with diesel fuel. As they are slightly heavier than diesel fuel hence their viscosities are also little higher than that of diesel fuel. The heating values of these methyl esters are slightly lower as compared to diesel fuel.

Further the performance and emission characteristics of MB & JB methyl ester and their various dual blends with diesel have been studied at full loads and constant speed of 1500 rpm.

Over the entire range of speed, all fuel variants give average reduction in brake power (BP) and increased brake specific fuel consumption (BSFC). In case of engine emission, the fuel blends give an average reduction in carbon monoxide (CO) and hydrocarbon (HC) emissions. However, all fuel blends increased nitrous oxides (NO_x) emission. The overall results suggest that the dual biodiesel variants have intermediate results for all the parameters. Dual variants are preferable due to very less output difference than higher variants for engine performance and better in emissions over the same variants.

The performance of DuB is found to be very close to two other fuel variants. This study suggests that the Dual blends can be preferred over single biodiesel blends.

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