Experimental Investigation of the Suitability of Orange Peel Oil, Neem Oil and Cotton Seed Oil as Alternate Fuel for Diesel Engines: A Review

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Abstract: ***In 1979 due to sudden increase in prices of the petroleum products by the supplying countries, attention was diverted to find out substitute indigenous vegetable oils as substitute fuel to diesel oil. Lot of work is going on different types of vegetable oils. The major advantage of vegetable oils as fuel is that they are non exhaustible and renewable. Since 10 years, researchers are studying on the effects of biodiesel on engine performance and emissions. The use of biodiesel leads to the substantial reduction in PM, HC and CO emissions accompanying with the imperceptible power loss, the increase in fuel consumption and the increase in NOx emission on conventional diesel engines with no or fewer modification. And it favors to reduce carbon deposit and wear of the key engine parts. Therefore, the blends of biodiesel with small content in place of petroleum diesel can help in controlling air pollution and easing the pressure on scarce resources without significantly sacrificing engine power and economy. However, many further researches about optimization and modification on engine, low temperature performances of engine, new instrumentation and methodology for measurements, etc., should be performed when petroleum diesel is substituted completely by biodiesel. This review has been taken up for identifying the effect of blending neem oil, orange peel oil and cotton seed oil with diesel on engine performance and emissions of CI engine.***

Keywords: biodiesel, Cotton seed oil, Neem oil, Orange peel oil, Performance, Emissions, alternative fuel

1. Introduction

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Diesel engine will be the major power source for automobiles in the twenty-first century. To reduce emissions and solve the energy crisis, designing diesel engines with low emission and less energy consumption has always be an objective for researchers across the globe. However, with the development of new technologies, today’s diesel engines have better emission characteristics and the less energy consumption compared with its predecessor. But, there is still lot to do on diesel engines aimed to achieve our goal of clean and effective diesel engine. Accordingly, research on a clean burning fuel instead of conventional fuel is advisable, which could not only decrease exhaust gas to a great extent, but, also provide more options of energy sources. The use of alternative fuels for internal combustion engines has attracted a great deal of attention due to fossil fuel crisis. Alternative fuels should be easily available, environment friendly, and techno-economically competitive. Successful alternative fuel should fulfill environmental and energy security needs without sacrificing engine operating performance. Renewable resources offer the opportunity to tap local resources and reduce dependency on fossil energy resources. Most biodiesel oils, particularly of the non-edible type can be used as fuel in diesel engines. One of the promising alternative fuels considered for diesel engine is biodiesel.

Biodiesel fuels are renewable, as the carbon released by the burning of biodiesel fuel is used when the oil crops undergo photosynthesis. Biodiesel also offers the advantage of being able to readily use in existing diesel engines without engine modifications. The alkyl monoester of fatty acids as bio-diesel which was obtained from renewable oil and fats materials by transesterification reaction is a good alternative. Biodiesel can be obtained from raw vegetable oil by transesterification with methanol or ethanol after chemical reactions. Vegetable oils present a very promising alternative to diesel oil since they are renewable and have similar properties as of diesel. Many researchers have studied the use of vegetable oils in diesel engines. This recommends the intensive studies on the use of alternative fuels especially renewable ones like vegetable oils and alcohols. Biodiesels such as Jatropha, Karanja, Sunflower and cottonseed are some of the popular biodiesels currently considered as substitute for diesel.

When biodiesel is used as a substitute for diesel, it is highly essential to understand the parameters that affect the combustion phenomenon which will in turn have direct impact on thermal efficiency and emission. In the present energy scenario lot of efforts is being focused on improving the thermal efficiency of IC engines with reduction in emissions. The problem of increasing demand for high brake power and the fast depletion of the fuels demand severe controls on power and a high level of fuel economy.

1.1 Biodiesel

Bio-diesel is fatty acid methyl or ethyl ester made from virgin or used vegetable oils (both edible & non-edible) and animal fats. The main commodity sources for bio- diesel in India can be non-edible oils obtained from plant species such as Jatropha Curcas, Karanj, Neem, Mahua etc. Bio-diesel contains no petroleum, but it can be blended at any level with petroleum diesel to create a bio-diesel blend or can be used in its pure form. Just like petroleum diesel, bio-diesel operates in compression ignition engine; which essentially require very little or no engine modifications because bio- diesel has properties similar to petroleum diesel fuels. It can be stored just like the petroleum diesel fuel and hence does not require separate infrastructure. The use of bio-diesel in conventional diesel engines results in substantial reduction of un-burnt hydrocarbons, carbon monoxide and particulate matters. Bio-diesel is considered clean fuel since it has almost no sulphur, no aromatics and has about 10% built-in oxygen, which helps it to burn fully. Its higher cetane number improves the ignition quality even when blended in the petroleum diesel. It provides significant lubricity improvement over petroleum diesel fuel. Lubricity results of bio-diesel and petroleum diesel using industry test methods indicate that there is a marked improvement in lubricity when bio-diesel is added to conventional diesel fuel. Even bio-diesel level as low as 1% can provide up to 65% increase in lubricity in distillate fuels.). HC and CO emissions were also reported to be lower. Non-regulated emissions were also found to be lower.

1.1.1 Neem Oil

A Neem tree can produce many thousands of flowers. In one flowering cycle, a mature tree may produce a large number of seeds. Neem trees start bearing harvestable seeds within 3-5 years, and full production may be started in 10 years, and this will continue up to 150-200 years of age. A mature Neem tree may produce 30-50 kg of fruit each year. By rough estimate India has nearly 20 million Neem trees. Indian Neem trees have a potentials to provide one million tonnes of fruits per year and 0.1 million tons of kernels per years (assuming 10% kernel yield). Neem seeds yield 40-60% oil. Neem is a golden tree that has gained world-wide importance owing to its multiple uses. Besides agro forestry, it is used in pest control, toiletries, cosmetics, pharmaceuticals, plant and animal nutrition and energy generation. Neem trees are considered to be a divine tree in India because of their numerous valuable uses. The commercial value of Neem has been known since Vedic times. Every part of Neem tree viz., leaf, flower, fruit, seed, kernel, seed oil, bark, wood, twig, root etc. has been in use and traded in various purpose.

Physical and chemical properties of neem oil, neem methylester and conventional diesel are presented in Table 1. The fuel properties of neem biodiesel were within the limits and comparable with the conventional diesel. Except calorific value, all other fuel properties of neem biodiesel were found to be higher as compared to diesel. Different properties of Neem oil and its esters are shown in table.1

1.1.2 Cotton seed oil

Cottonseed oil is extracted from cottonseed. Cotton has long been known as nature's unique food and fiber plant. It produces both food for man and feed for animals in addition to a highly versatile fiber for clothing, home furnishings and industrial uses. Cottonseed oil has a ratio of 2: 1 of poly n saturated to saturated fatty acids and generally consists of 65-70% unsaturated fatty acids including 18-24% monounsaturated (ole ic) and 42-52% polyunsaturated (linoleic) and 26-35% saturated (palmitic and stearic)6. The various properties of the above bio diesels are presented in table 1.

1.1.3 Orange peel oil

Orange fruits are largely produced in countries such as Brazil, USA, India, China etc. India is third largest country in producing oranges with annual production 6 million tones. Here the fruit flesh (carpel) is used and the peel is disposed as waste. Researchers have proved that the orange peel can be in used in production of methane as well as a quality fertilizer. The chemical constituents of orange peel are alkaloids, saponins, terpene s, resins, flavanoids, tannins, phenols and sugars but do not contain coumarins and steroids. It has also proved to be a very good anti-oxidant. The orange peel powder diesel solution is proved to be used as an alternative fuel for C.I engine. India has a huge potential of producing orange peel oil of 27,600 ton (based on 0.6% recovery of oil from 46 lakhs ton fruits by cold press process) from the orange fruits. Presently, 2–3 tons of orange oil is produced for food and cosmetic industries. There is no other demand for orange oil. As the demand increases for large quantity of orange oil for fuelling in internal combustion engines, the requirement for orange peel collection may be higher. Orange oil is a biomass-derived fuel obtained from orange skin, which has 90% D-limonene and can be used for many applications. It may be used as an agent or a source in surface cleaners, hand cleaners, furniture polish, soaps and shampoo production. In addition, orange oil can also be used as an alternative to gasoline either partially in the form of a blend or as a total replacement.

Orange oil has been used as a fuel for spark ignition engines, since most of its properties are closer to gasoline. The high-octane value of these fuels can enhance the octane value of the blend when it is blended with low-octane gasoline. As a result, the knock limited compression ratio (CR) can be increased further. Results indicate that gasoline– orange oil blend with catalytic coating performs better when compared to the normal lean burn engine. Different properties of orange peel oil and its esters are shown in table.1

1.2 Bio-Diesel in India

About 400 wild species found in India produce non edible oils that can be converted to bio-diesel. A salient feature of India's bio fuel program is to only utilize wastelands, degraded forest, and non-forest lands for cultivation of oil seed plants. Of about 55 million ha of wastelands in India, about 32 million ha are suitable for biodiesel production. The available information about wasteland suitability for oil seed plantations is incomplete, and a proper wasteland mapping exercise should precede any major bio-diesel development program in India. The demand of diesel (H.S.D) is projected to grow from 39.81 Million Metric Tonne in 2001-02 to 52.32 MMT in 2006-07 @ 5.6% per annum. Our crude oil production as per the Tenth Plan working Group is estimated to hover around 33-34 MMT per annum even though there will be increase in gas production from 86 MMSCMD (2002-03) to 103 MMSCMD in (2006-07).

Table 1: properties of diesel, cotton seed oil, neem oil, orange peel oil and its esters

Properties	Diesel	Cotton Seed Biodiesel	Cotton Seed Oil	Neem oil	Neem biodiesel	Orange Peel oil biodiesel
Flp (^{0}C)	60	120	260	214	120	74
Fp (^{o}C)	62	153	230	222	128	82
ϱ (g/cm3)	830	868	911	912–965	820–940	816.2
µK (CS) at 300^{0}c	3.15	9.155	25.03	20.5–48.5	3.2–10.7	3.52
S.G.	0.83	0.876	0.911	0.912-0.965	0.820-0.940	0.8162
Cv (KJ/Kg)	42500	39162	38062	32000–40000	39600–40200	34650
CN	45	49-50	43	31–51	48–53	47

Flp-Flash point, Fp-Fire Point, **ϱ -density, µK- Kinematic Viscosity, S.G.-specific Gravity, C_v- Calorific Value, CN-Cetane Number**

2. Related Work

a) Work on cotton seed oil and its blends

A number of researchers have experimentally investigated the combustion, performance and emission characteristics of vegetable oils and their esters in diesel engines.

1. S. Kirankumar [1] He conducted experiment on the four stroke single cylinder water cooled diesel engine at constant speed (1500 rpm) with varying loads by using cotton seed oil blends of C10, C20 and C30 by varying the injection pressures from 165 bar to 210 bar. The performance characteristics like brake thermal efficiency, brake specific fuel consumption and exhaust gas temperatures were investigated. Based on investigations, a comparison was drawn on engine performance with pure diesel operation and with different blends. Their Experimental results demonstrated that at 195 bar fuel injection pressure, the performance characteristics were observed better with blends when compared to the pure diesel operation. Maximum brake thermal efficiency observed was 34.01% with 30% blend at an injection pressure of 195 bar and lower specific fuel consumption observed was 0.258 kg/kw-hr with 30% blend at an injection pressure of 195bar.

2. R. Senthil Kumar and R. Manimaran[2] They conducted performance test on horizontal single cylinder variable speed Greaves engine with various blends of cottonseed oil (B5, B10, B15, B20, B40 & B100) and compared the performance of cottonseed oil with diesel. Based on their observations of this experiment, They concluded that TFC and SFC were found to be the function of load and brake power. The performance test done on various blends of biodiesel showed that its characteristics followed the same trend as that of the bio-diesel. The emission test conducted showed that emission levels for biodiesel were lower than diesel. On comparing the performance test graphs of B5, B10, B15, B20, B40,They concluded that TFC and SFC of B100 and B40 is very high compared to that of diesel . So the usage of these blends will be uneconomic but the TFC and SFC of B20 remains very stable on various loading conditions.

3. M. Martin and D. Prithviraj[3] In their experimental investigation, the viscosity of cottonseed oil (CSO), which is considered a potential alternate fuel, was reduced by blending it in different proportions with diesel, and its viscosity at various temperatures was analyzed and used as a fuel in a compression ignition (CI) engine. Performance, combustion and emission parameters at various loads were calculated using a single cylinder CI engine and compared with neat diesel and cottonseed oil. A remarkable improvement in the performance of the engine is noticed as the viscosity of the oil is reduced. Brake thermal and volumetric efficiencies of the engine increased with a significant reduction in the exhaust gas temperature. Reductions in smoke, CO and HC emissions are also noticed. Their results show that a blend containing 60% of cottonseed oil with diesel, which is heated to a temperature of 70°C, can be used as an alternate fuel without any engine modification.

4. Shyam Kumar Ranganathan*et al.*[4] They investigated the comparative performance of single cylinder diesel engine with direct use of cotton seed oil methyl ester and preheated condition at variable temperature such as 50, 70 and 90°C.The properties such as viscosity, flash point, pour point were experimentally measured of COME, thus obtained are comparable with ASM biodiesel standards. The COME has been tested in single cylinder four stroke diesel engines coupled with rope brake dynamometer. They carried out experiment for varying load at constant speed. Their results revealed that preheating COME up to 90°C at higher load lead to increase in brake thermal efficiency is 2 % as compared to diesel fuel and brake specific fuel consumption increases at higher load as compared to diesel fuel. There was no significant change found in brake power where as exhaust gas temperature of all preheated biodiesel COME was high and break specific energy consumption required to preheat COME was high as compared to diesel.

5. S.Naga Sarada*et al.*(2010)[5] They conducted test with cotton seed oil and diesel. To improve the combustion characteristics of cotton seed oil in an unmodified engine, effect of increase in injection pressure was studied. The injection pressure was increased from 180 bar to 240 bar (in steps of 15 bar). The investigation of their experiment revealed that the optimum pressure for cottonseed oil as 210 bar and comparison of the performance of the engine was studied in terms of brake specific fuel consumption, brake thermal efficiency, indicated thermal efficiency, mechanical efficiency and exhaust emissions. Increased injection pressure has a significant effect on enhancing engine performance and lowering emissions. Increase in the injection pressure from 180 bar to 240 bar with cotton seed oil as fuel lead to: Quieter operation of the engine was observed when cotton seed oil was used as fuel. Performance of engine with cotton seed oil as fuel was better at an IP of 210 bar. An increase in the Brake thermal efficiency from 25.02% to 28.02% was observed with increase in injection pressure from 180bar to 210 bar; due to better atomization and improved combustion of the fuel lowering of the HC emissions from 1720 ppm to 1480 ppm. According to their investigation the Performance of engine with cotton seed oil as fuel at an IP of 210 bar was approximately similar to the operation of engine with diesel.

b) Work on cotton seed, neem oil and its blends cotton seed oil, orange peel oil and its blends

1. K.Dilip Kumar and P.Ravindra Kumar [6] They carried out experimental investigations on C.I.engine with Bio Diesel blends of cotton seed Methyl Esters and Neem Oil Methyl Esters. The engine used for their experiment was single cylinder Four Stroke water cooled, constant speed diesel engine with cotton seed Methyl ester (CSOME) and Neem oil methyl ester (NOME) which were derived through transesterification process and parameters of transesterification were optimized. The blends of various proportions of the CSOME & NOME with diesel were prepared, analyzed and compared with diesel fuel, and comparison was made to suggest the better option among the bio diesel. Various Tests have been carried out to examine properties, performance of different blends (C05, C10, C15, and C20) of CSOME and NOME in comparison to diesel. From their experimental Results it was indicated that C20 have closer performance to diesel. However, its diesel blends showed reasonable efficiencies. They were also observed that cotton seed methyl ester gives better performance compared to Neem methyl esters and also the emissions and smoke for these diesel blends were less as compare to the pure diesel.

2. A.V. Krishna Reddy *et al.*[7] They conducted experiments on 5.2 BHP single cylinder four stroke water-cooled variable compression diesel engine. Methyl ester of cottonseed oil is blended with the commercially available Xtramile diesel. Cottonseed oil methyl ester (CSOME) is blended in four different compositions from 10% to 40% in steps of 10 vol%. They use these four blends and Xtramile diesel brake thermal efficiency (BTE) and brake specific fuel consumption (BSFC) were determined at 17.5 compression ratio. They concluded that Properties of the 10% and 20% blends of CSOME are nearer to the diesel fuel. The performance of the cottonseed oil methyl ester fuelled engine is comparable with diesel engine. Engine could be run without any difficulty using cottonseed oil methyl ester blends. These blends of cottonseed oil can be recommended for present diesel engines without any modification. Thus the above investigations of their experiment suggest that esterified vegetable oils can be effectively employed in emergency as a suitable alternative fuel in existing diesel engine.

3. M. Harinath Reddy *et al.*[8]They investigated the performance of a diesel engine using diesel fuel and cottonseed oil (CSO) biodiesel in terms of brake thermal efficiency and indicated thermal efficiency for conventional diesel, cottonseed oil, as well as for Jatropha oil. A Single Cylinder, 4-stroke vertical, water-cooled, self-governed diesel engine developing 5 HP at 1500 rpm engine was selected for the testing with diesel fuel and neat bio-dieselat full load conditions. The evaluation of theoretical data of their experiment showed that the brake thermal efficiency and indicated thermal efficiency of CSO biodiesel was slightly higher than that of diesel fuel and Jatropha oil. Their study reveals that the use of cottonseed oil biodiesel improves the performance parameters of CI engine compared to conventional diesel fuel.

4. Bhojraj N. Kale, Dr.S.V.Prayagi[9]
They investigated the performance of a diesel engine using diesel fuel and cottonseed oil (CSO) biodiesel in terms of brake thermal efficiency and indicated thermal efficiency for conventional diesel, cottonseed oil, as well as for jatropha oil. For this aim, A Single Cylinder, 4-stroke vertical, water- cooled, self-governed diesel engine developing 5 HP at 1500 rpm (Rope brake dynamometer with spring balances and loading screw. Brake drum diameter = 0.400 m.) Engine is selected for the testing with diesel fuel and neat biodiesel, which is cottonseed oil methyl ester, at full load conditions. The evaluation of theoretical data showed that the brake thermal efficiency and indicated thermal efficiency of CSO biodiesel was slightly higher than that of diesel fuel and jatropha oil.
They conclude that at constant speed of 1500 rpm it is observed that brake thermal efficiency (η_{bth}) with use of CSO methyl ester is slightly greater in comparison with jatropha biodiesel and petroleum diesel. It is also observed that indicated thermal efficiency (η_{ith}) with use of CSO methyl ester is considerably greater (i.e. 20.70%) in comparison with jatropha biodiesel and petroleum diesel.

5. Leenus Jesu Martin. M, Edwin Geo. V, Prithviraj. D[10]
They conducted experimentation on cso and opo. Cottonseed oil, which is considered, is not suitable as a fuel for diesel engines straight because of its high viscosity. Addition of a small quantity of another light vegetable oil, Orange Peel oil reduces the viscosity and improves the performance of the engine largely. Blends of varying proportions of cottonseed oil and orange peel oil were prepared, analyzed and their properties were calculated. The performance of the engine using diesel, the blends and cottonseed oil were evaluated using a single cylinder, four stroke, and direct injection compression ignition engine. The results obtained were compared with baseline data generated with raw cottonseed oil and diesel. 15% of Orange peel oil by volume addition to cottonseed oil exhibited the best performance and smooth engine operation without any problem.

The diesel engine was successfully operated using OPO and CSO blends and compared with diesel as fuel. Based upon the results the following conclusions are made.

- The use of the neat CSO results in inferior performance and high emissions as compared to diesel because of its high viscosity, poor atomization and mixing.
- Engine operation with the blend of orange oil with CSO results in better performance than neat CSO. At full load, the brake thermal efficiency with neat CSO is 28% and for the optimum blend of 15% orange oil, it is 30.5 % while that of diesel is 32.3%.
- There is a reduction in smoke level with CSO-OPO blend in comparison to neat CSO due to better mixture formation with the blend resulting in improved combustion. The smoke level with
- 15% OPO blend is 3.5 BSU, for neat CSO it is 3.9 BSU and for diesel it is 3.4 BSU.
- Both HC and CO emission are found to be high for CSO under normal operating conditions. The CSO-OPO blend results in lower CO and HC emissions at high load. This may be because of its reduced viscosity at high operating temperatures. The HC and CO emission for the optimum blend quantity of 15% OPO is 55 ppm and 0.22% respectively.
- The cylinder peak pressure is 72.2 bar and maximum rate of pressure rise is 4.5 bar/°CAwith 15% OPO**,** which is higher compared with neat CSO. This is mainly due to increased premixed combustion with OPO.
- Heat release with neat CSO indicates higher diffusion burning and lower premixed burning rates as compared to diesel. Blending of OPO with CSO increases the premixed combustion phase which leads to increase in the brake thermal efficiency.
- Overall, it is concluded that an optimum blend of 15% OPO with CSO can be used as a CI engine fuel.

6. Dr.V. Naga Prasad Naidu, Prof. V. Pandu Rangadu[11]

This study focuses on Evaluation of performance and emission characteristics of a single cylinder four stroke diesel engine with two different biodiesels namely Neem oil and Cotton seed oil separately. The performance is compared on the basis of brake specific fuel consumption, brake thermal efficiency, exhaust gas temperature and emissions of hydrocarbons and oxides of nitrogen. This study reveals that the performance of the engine with these biodiesels differ marginally from diesel and hydrocarbon emissions are less than diesel. It is also observed that the cotton seed oil showing better performance and emission characteristics as compared with Neem oil. They concluded that,

- the brake thermal efficiency of the engine depends majorly on the heating value and viscosity. The cotton seed oil is having brake thermal efficiency nearer to diesel.
- with the higher combustion rate, the temperature inside the engine and in turn in the exhaust increases
- The Hydrocarbon emissions are less than diesel fuel
- The CO emissions depends on the combustion chamber temperature and it is less with bio diesels
- The NOx emissions increase with the higher temperatures in the chamber. With the bio diesels due to its lower heating values and higher viscosity the temperature in the chamber is less and in turn emissions are less than diesel fuel.

It is concluded that out of the two bio diesels cotton seed oil is best oil and the efficiency is also nearer to the diesel. So the cotton seed oil can be used as alternative to diesel.

c) Recent work

7. Miss. J.M.Phate, Prof. A.V.Kulkarni [12]

They are working on performance evaluation of CI engine by using orange peel oil and cotton seed oil and its blends with diesel.

8. S.D. Bhopale, A.V. Kulkarni[13]

They are working on performance evaluation of CI engine by using Neem oil and cotton seed oil and its blends with diesel.

d) Work on orange peel oil

1. D. Subramaniam, A. Murugesan and A. Avinash[14]

Performance, emission, and combustion characteristics of methyl esters of Punnai, Neem, Waste Cooking Oil and their diesel blends in a C.I. engine was experimentally examined. For their study, Punnai oil methyl esters (POME), neem oil methyl esters (NOME), and Waste Cooking Oil Methyl Esters (WCOME) were prepared by tranesterification process. The Bio diesel-diesel blends were prepared by mixing 10%, 30%, 50%, and 70% of bio diesel with diesel. The effects of three methyl esters and their diesel blends on engine performance, combustion, and exhaust emissions were examined at different engine loads. Experimental results concluded that up to 30% of methyl esters did not affect the performance, combustion, and emissions characteristics. On the other hand, above B30 (30% Biodiesel with 70% diesel) a reduction in performance, combustion, and emission characteristics were clear from the study.

It was evident in the study that for all test fuels the brake thermal efficiency increased with increase in brake power. Among B10, B30, B50, B70, and B100 bio diesel, bio diesel blends up to B30 has a maximum brake thermal efficiency. With an increase in bio diesel blends the value of BSFC also increased.

CO, CO_2, HC, NOx, and smoke are considered to be the major exhaust emissions from C.I. engines. The diesel engine produces lesser amount of CO and HC emissions than spark ignition engines. Moreover, in case of bio diesel fueled engines, presence of airborne oxygen as well as its presence in the molecules of bio-diesel aids nearly complete combustion of fuel. The NOx emission of diesel at maximum load was noted to be 960 ppm, whereas for B100 NOME it was noted to 890 ppm. This reduced NOx emission for B100 bio diesel when compared to diesel may be due to the reduced premixed combustion rate leading to lower NOx emissions for B100 bio diesel operation.

The experimental results proved that up to B30 blend of bio diesel-diesel blends, the performance and emission characteristics were not much affected. When the blend ratio increased, incomplete combustion takes place because of less time available for mixture formation, which leads to a reduction in the brake thermal efficiency of the engine as well as an increase in the emission level.

The combustion analysis revealed that the overall combustion characteristics of B30 bio diesel blends were closer to diesel than pure bio diesel. Overall, the methyl esters of waste cooking oil proved improvements in performance and emission characteristics than the methyl esters of Punnai and Neem due to its closer physical and thermo-chemical properties to neat diesel.

2. Yogesh Tamboli, Dr. G. R. Selokar, Amitesh Paul and Jehan Zala [15]

The brake thermal efficiency was found reduced about 5% for Neem oil ester when compared to diesel. The brake specific fuel consumption is increased about Neem oil ester it is increased about 11% to 13% when compared to diesel fuel. The brake power is reduced about 12% for neem oil ester when compared to that of diesel. The carbon monoxide is reduced for Neem oil ester it is reduced about 16 % when compared to that of diesel. It is concluded that the carbon monoxide for vegetable oil ester is less when compared to diesel fuel. The concentration of hydrocarbon is decreased. 15 % for Neem oil ester when compared to diesel fuel. The formation of nitric oxides is decreased about 3 % for Neem oil ester when compared to that of diesel fuel. The smoke level is decreased about ester 10 % for Neem oil ester when compared to diesel fuel. Thus multizone combustion model can be an efficient tool to calculate the effect of design and operating parameter.

Hence it is concluded that in terms of performance characteristics and emission vegetable oil esters can be regarded as a potential substitute for diesel fuel.

- Neem based methyl esters (biodiesel) can be directly used in diesel engines without any engine modifications.
- Brake thermal efficiency of B10, B20 blends are better than B100 but still inferior to diesel.
- Properties of different blends of biodiesel are very close to the diesel and B20 is giving good results.
- It is not advisable to use B100 in CI engines unless its properties are comparable with diesel fuel.
- Smoke, HC, CO emissions at different loads were found to be higher for diesel, compared to B10, B20 blends.

3. Conclusion

1) Good mixture formation and lower smoke emission are the key factors for good CI engine performance. These factors are highly influenced by viscosity, density, and volatility of the fuel. For bio-diesels, these factors are mainly decided by the effectiveness of the transesterification process. With properties close to diesel fuel, bio-diesel from Jatropha, pongamia pinnata cotton seed oil, orange peel and Neem seed oil can provide a useful substitute for diesel thereby promoting our economy. Biodiesel and diesel fuel blends may prove an alternative option as diesel fuel in the future because they are renewable resources and less polluting.
2) Based on the observations of the different experiments conducted by various researchers, it can be concluded that, the performance test done on various blends of biodiesel shows that its characteristics follow the same trend as that of the diesel.
3) The emission test conducted shows that emission levels for biodiesel are lower than diesel.
4) Indicated thermal efficiency, brake thermal efficiency, brake power, volumetric efficiency can be increased by using different biodiesels such as CSOME, OPOME and NOME and its blends with diesel as an alternative fuel for diesel.
5) Exhaust emissions like CO, PM, UHC, smoke capacity can be reduced considerably by using different biodiesels such as CSOME, OPOME and NOME and its blends with diesel as an alternative fuel for diesel.
6) Only NOx emission increases at any type of blend as compared to diesel.
7) Specific fuel consumption increases at any type of blend as compared to diesel
8) Thus the usage CSO, OPO and NO as biodiesel and its blends with diesel will be more optimum compared to diesel.

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