Non-Edible Karanja Biodiesel- A Sustainable Fuel for C.I. Engine

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Abstract

Biodiesel are becoming popular as alternative eco-friendly fuel now days. The petroleum product requirement is going on increasing day by day in India with limited resources in the oil pool. Crisis of petroleum fuel and import of fossil fuel is giving a high impact on the economy and development. Besides the economy and development, fossil fuel also leads to a major problem like global warming and climatic change. The emission of harmful gasses like CO, NO_x, CO_2, and smoke density causes acid rain, health hazard and also global warming. The high oil price, environmental concern **and supply instability put many researchers to go for alternative fuel i.e. biodiesel. Biodiesel is part of the solution which reduced many of the problems. The objectives of this study are the production process, fuel properties, oil content, engines testing and performance analysis of biodiesel from karanja oil which is known as Karanja oil methyl ester(KOME). Engine tests have been carried out in a water cooled four stroke diesel engine and experimental investigation have been carried out to examine properties, performance and emission of different blends of KOME.**

Key words: Biodiesel, karanja oil methyl ester, KOME, performance, emission

Introduction

Biodiesel is a clean burning alternative fuel produced from domestic, renewable resources such as plant oils, animal fats, used cooking oil and even from algae. Biodiesel contains no petroleum, but can be blended at any level with petroleum diesel to create a biodiesel blend. Biodiesel blends can be used in compression ignition engines with little or no modifications. Among the vegetable oils edible and non-edible oils are used to produce biodiesel. The use of edible is a great concern with food materials. So it is justified to use non edible for the production of biodiesel. Non edible trees can grow in inhospitable condition of heat, low water, rocky and sandy soils. So non-edible oil plants like karanja, jatropha, mahua, neem will be the best choice for the source of biodiesel production.

The use of Karanja biodiesel in conventional diesel engines when used alone or with blends with petroleum diesel substantially reduces exhaust emission such as the overall life cycle of carbon dioxide (CO_2), particulate matter (PM), carbon monoxide (CO), sulfur oxides (SO_x) and unburned hydrocarbons(HC) with reducing the green house emission also. Regarding the power is same to that of diesel engine. The specific fuel consumption is more or less the same. The brake thermal efficiency is slightly on higher side. The aim of the present study is to experimentally investigate the effect of different blends of KOME on the performance of diesel engine. The results were compared with petroleum diesel.

Literature Review

Nagarhalli M.V. *et al.*, [1] have tested KOME and found that HC emission decrease by 12.8% for B20 and 3% for B40 at full load. NO_x decreased by 39% for B20 and 20% for B40 at full load. BSEC increased by 7% for B20 and 1.9 % for B40 at full load. A B40 blend has been recommended by the author.

H.Raheman and A.G. Phadatare *et al.*,[2] Emissions and Performance of Diesel Engine from Blends of Karaja Oil Methyl Ester(KOME) and Diesel have used for test. They found the average BSFC was 3% lower than diesel in case of B20 and B40. Maximum BTE was found to be 26.79% for B20 which is 12% higher than diesel. They concluded that B40 could replace diesel.

Nitin Shrivastava *et al.*,[3] made the experiment on JOME and KOME indicated that the emission of both showed reduction in CO, HC and smoke emission where as NO_x emission was found higher compared to diesel.

Ramchandra S. Jahagidar *et al* [4] carried experiment on KOME found that for KOME the brake power of the engine was almost same for all the loads. For BTE of KOME were improved by 3.8%. Volumetric efficiency also improved. They concluded that B40 & B60 will have the optimum performance.

Karanja Oil:

It belongs to the family leguminaceae. Commonly known as *Pongamia Pinnata*. Other name of karanja oils are pongam oil or honge oil. Pongamia is widely distributed in tropical Asia. The tree is hardy, reasonably drought resistant and tolerant to salinity. It is attractive because it grows naturally through much of arid India, having very deep roots to reach water, and is one of the few crops well-suited to commercialization by India's large population of rural poor. [5]

The karanja tree is of medium size, reaching a height of 15-25 meters. The tree bears green pods which after some 10 months change to a tan color. The pods are flat to elliptic,5-7 cm long and contain 1 or 2 kidney shaped brownish red kernels. The yield of kernels per tree is reported between 8 and 24 kg. The composition of typical air dried kernels is : Moisture 19%, Oil 27.5%, Protein 17.4%. The oil content varies from 27%-39%.[6]

The most common method to extract oil involves in collecting the pods. The pods are kept in water for 2 to 3 hours followed by drying in hot atmospheric condition. The dried pods are stuck with hammers and sticks to open them after which the seeds are winnowed out. Oil extraction is carried out in Ghanis and small expellers. The oil is dark in color with a disagreeable odor.

Table -1 Characteristics of fatty acids in karanja oil [7]

Sl.No.	Fatty acid	Value (%)
1	Palmitic	3.7-7.9
2	Stearic	2.4-8.9
3	Oleic	44.5-71.3
4	Linoleic	10.8-18.3
5	Lignoceric	1.1-3.5

Material and Methods

Extraction of Karanja oil

Karanja seeds were collected from College of Forestry, under Orissa University of Agriculture and Technology (OUAT), Bhubaneswar, Odisha. For oil extraction from kernel of karanja two methods were implemented. First one was the mechanical extraction. The seeds were expelled in a mechanical expeller which was available in the Integrated Biodiesel Plant of OUAT. The oil recovery was calculated to be near about 27%. Second method used was Solvent extraction. Extraction was done with n-hexane using a Soxlet apparatus in the Renewable Energy Lab of OUAT. Process of solvent extraction was that in a nutshell, the extraction process consists of treating the raw material with hexane (solvent) and recovering the oil by distillation of the resulting solution of oil by distillation of the resulting solution of oil in hexane called miscella. Evaporation and condensation from the distillation of miscella recovers the hexane absorbed in the material. The hexane thus recovered was reused for extraction. The low boiling point of hexane (67^0C) and the high solubility of oils and fats in it were the properties exploited in the solvent extraction process. Under this process the oil content was found to be 35% which is more than that of mechanical expeller.[8]

For experiment purpose petroleum diesel was purchased from a nearby filling station. The above karanja oil contains free fatty acids, phospholipids, sterols, water odorants and other impurities. Above all the crude karanja oil was having high viscosity value. In order to use straight vegetable oil (SVO) in the engine, viscosity was to be reduced which can be done by heating the above oil. Other problems associated with using it directly in engine include carbon deposits, oil ring sticking, lubricating problem and also formation of deposits in the engine due to incomplete combustion.[9]

In order to reduce viscosity, four techniques were adopted like pyrolysis, dilution, micro emulsification and transesterification. Currently we adopt transesterification technique to convert high FFA and high viscous fluid to low FFA and low viscous fuel, namely karanja biodiesel. Since the crude karanja oil acid value was found to be more than 6, so acid esterification and transesterification techniques was adopted.[10] This conversion to biodiesel was conducted in Renewable Energy Lab of OUAT, Bhubaneswar. All the chemicals needed were available in the lab. The alcohol used is methanol, acid is sulfuric acid and KOH is used as an alkali.

Process Description

Acid Esterification

Oil feed stocks containing more than 6% free fatty acids go through an acid esterification process to increase the yield of biodiesel. Five liters of karanja oil were filtered and preprocessed to remove water and contaminations, and then fed to the acid esterification process. The acid catalyst i.e. H_2SO_4 (0.5% V/V), was dissolved in methanol (6% molar ratio of methanol/oil) and then mixed with the preheated oil. The mixture was heated up to 60^0C and stirred at a speed of 1600 r.p.m. for 2 hours resulting in decrease the acid value 8.42. As the acid value label was higher before going for trasesterification process once again acid esterification process was repeated to reduce the acid value. After 2^{nd} acid esterification the acid value reduced to 6.16. The top layer methanol was separated out by decantation process and the oil layer was taken for transesterification. Once the reaction was completed, it was dewatered by passing over a hydrous Na_2SO_4 and then fed to the transesterification process.

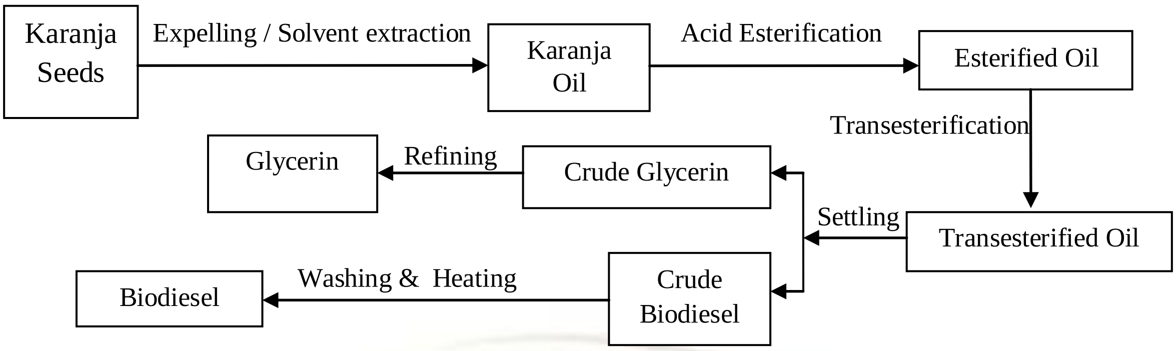

Fig-1 Line Diagram of Karanja Biodiesel Process

Trasesterification

Oil feed stocks containing less than 4% free fatty acids are filtered and preprocessed to remove water and contaminants and then fed directly to the transesterification process along with any products of the acid esterification process. The catalyst KOH is dissolved in methanol and then mixed with the pretreated (65^0C) oil. Once the reaction is complete, the major co-products, biodiesel and glycerin are separated into two layers.

The product is allowed to stand overnight to separate the biodiesel and glycerol layer. The upper biodiesel layer is separated from the glycerol layer and washed with hot distilled water to remove the excess methanol, catalyst and traces of glycerol. The washed ester layer is dried under the vacuum to remove the moisture and methanol and again passed over a hydrous Na_2SO_4. The biodiesel obtained is termed as Karanja oil methyl ester(KOME).[11]

Table-2. Acid value of Karanga oil.

KARANJA OIL	ACID VALUES
Before esterification	25.76
After 1st esterification	8.42
After 2nd esterification	6.16
After transesterification	1.12

Table-3 Fuel properties of Karanja oil, KOME and Diesel

FUEL	A	B	C	D	E	F
Diesel	0.84	45.34	-12	68	63	2.44
Karanja Oil	0.91	34	7	250	240	32.1
KOME	0.88	36.12	6	225	218	6.88

Where A → Specific Gravity
B → Calorific Value (Mj / Kg)
C → Cloud Point (^{0}C)
D → Fire Point (^{0}C)
E → Flash Point (^{0}C)
F → Kinematic Viscosity at 40^0C(cSt)

The Fuel properties of different blends of KOME are mentioned in Table-4

Table-4.Property of KOME and its blends

Blends Of KOME	Calorific Value (Mj/Kg)	Specific gravity	Kinematic Viscosity at 40^0C (cSt)	Flash Point (^{0}C)
B20	39.00	0.843	3.25	75
B40	37.95	0.856	4.40	83
B60	37.25	0.867	5.65	86
B80	36.25	0.876	6.55	92
B100	36.12	0.88	6.88	218

Engine Experimental Set up

Experiments were performed at the Department of Firm Machinery and Power, OUAT, Bhubaneswar for different blends of KOME. A single cylinder four stroke, constant speed, liquid cooled, direct injection diesel engine was used to investigate the performance and emission characteristic. The engine was coupled with a single phase 230 V AC alternator with electrical loading of different watts. A multi gas analyzer was used for analysis of CO, CO_2, O_2, NO_x and smoke meter for smoke intensity. Lubricating oil used is 20W40 for the engine. Engine detailed specification is shown in Table-5

Table-5 Engine Specifications

Engine parameters	Specifications
Manufacturer	Kirloskar
Engine Model	DM 8.5
Bore x Stroke (mm)	95 x 110
Compression ratio	17.5:1
Rotation	Clockwise
Starting	H.S
Speed(rpm)	1500
Power rating (Kw)	6.2
Horse Power(HP)	8.5
Fuel tank capacity(L)	11.5
Oil .Sump Capacity (L)	3.75
SFC(gm/bhp/hr)	185

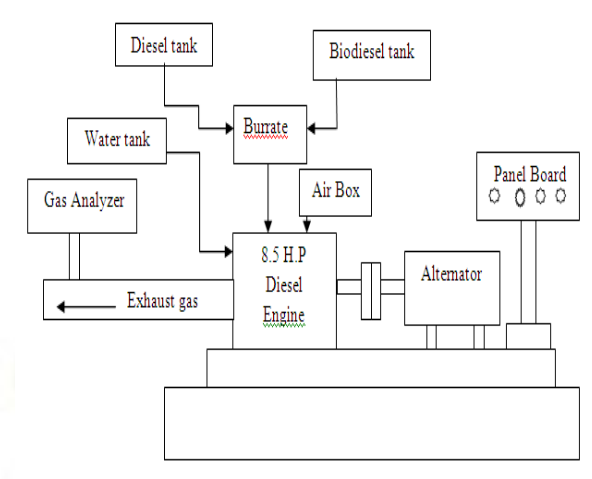

Fig.-2. Schematic Layout of Experimental Set up

Result and Discussion

All sort of experiments were conducted by using the above engine and the performance, and emission results obtained were analyzed and discussed. Also the performance and characteristics of different blends of KOME were compared with fossil fuel diesel.

Calorific Value

It is the heat produced by the fuel within the engine that enables the engine to do the useful work.[12]

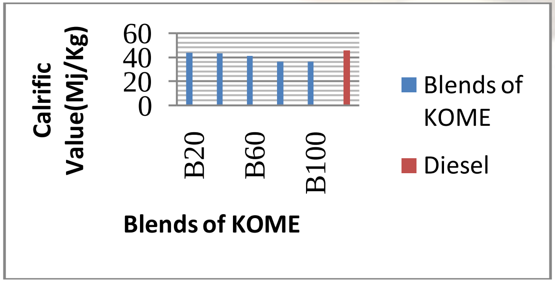

Fig.3. Calorific values of Blends of KOME and diesel

Fig.3 shows the variation of gross heat of combustion of different blends of KOME with diesel. The graph indicates as the blend increases the calorific value decreases. It implies more amount of biodiesel to be injected to get the useful work. B20 was the better choice among other blends.

Specific gravity

The specific gravity of a liquid is the ratio of its specific weight to that of pure water at a standard temperature. Specific gravity of vegetable oil is greater than 0.90 and that of biodiesel is less than 0.90.[13]

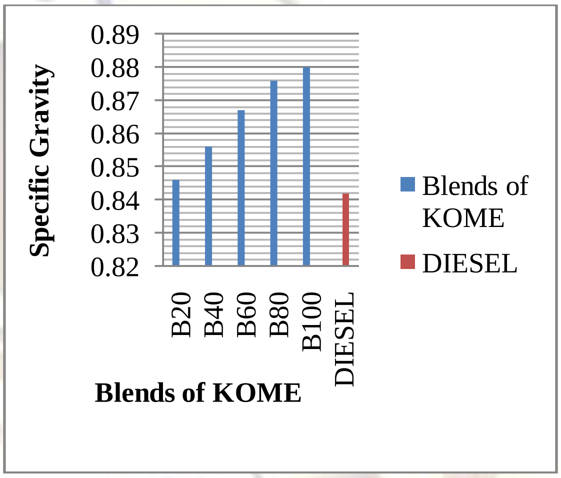

Fig.4. Specific gravity of Blends of KOME and biodiesel

The graph of Fig.4 indicates that specific gravity reduced with increase in diesel amount in the blend.

Kinematic Viscosity

Viscosity is the resistance to flow of liquid due to internal friction between the liquid and surface. Low viscosity results in an excessive wear and power loss while high viscosity result in filter blockage, high pressure and coarse atomization and fuel delivery rates. [12]. The preheated fuel lowered the viscosity to tolerable values. [7]

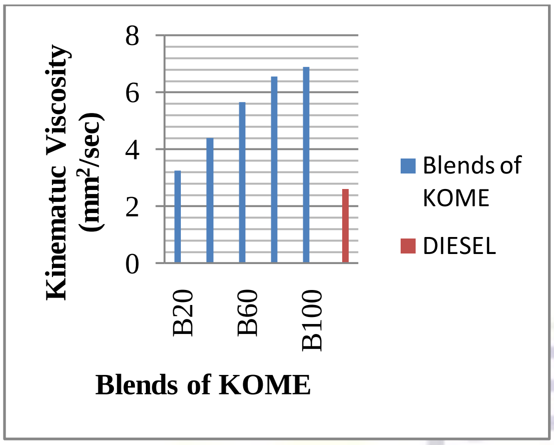

Fig.5. Kinematic Viscosity of Blends of KOME and diesel

Fig -5 indicates the Kinematic viscosity of B20 biodiesel was found to be close to that of diesel, which results in better atomization without preheating.

Brake Power

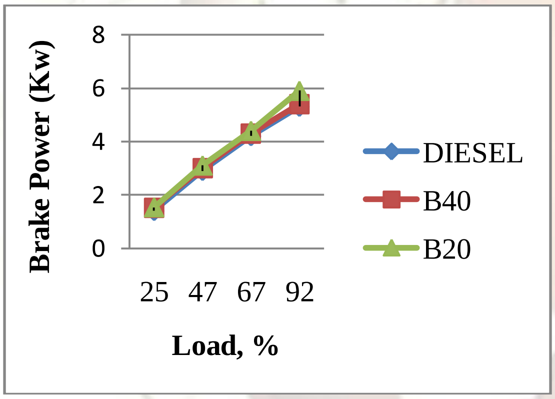

Fig.-6 Brake Power for different Loads

Referring to Fig. 6, it is observed that brake power increase with load in all cases. Brake power is more or less equal with diesel at lower loads for B20 and B40 blends. Maximum brake power is observed for B20 oil.

Brake specific fuel consumption:

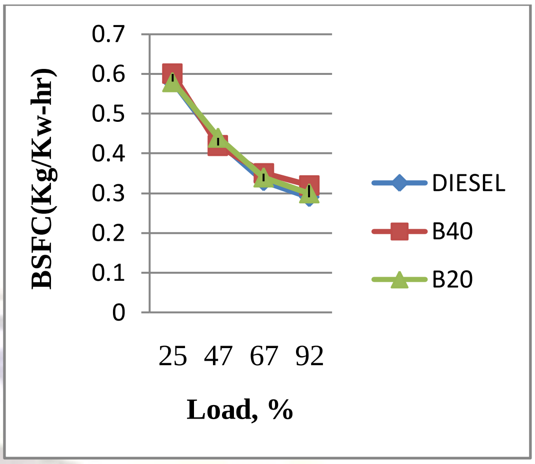

Fig.7. Variations of Brake specific fuel consumption with load

Fig.7. shows the comparison of fuel consumption of B20 and B40 KOME with diesel. Graph indicates BSFC reduces with increase in load in all cases. This may be due to change in the combustion timing, higher viscosity and lower calorific value of KOME biodiesel. Both the blend gives better result up to 50% load.

Brake Thermal Efficiency

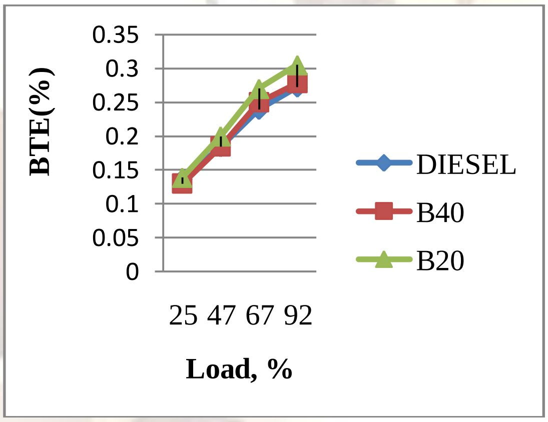

Fig.8. Variations of Brake Thermal Efficiency with load

Fig. 8 shows that the Brake Thermal Efficiency for B20 and B40 at lower load is more or less equal to that of diesel. At higher load the Brake Thermal Efficiency increases for B20 and B40 blends.

Smoke Opacity

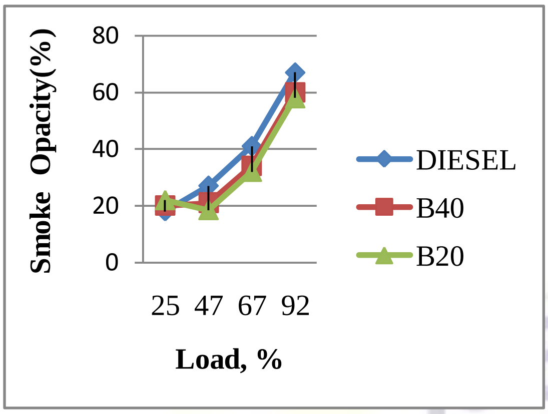

Fig.9. Variations of Smoke Opacity with engine load

Fig.9 represents the variation of smoke opacity of B20 and B40 blends with diesel. Due to incomplete combustion of fuel in the engine smoke is formed. The above graph indicates that incomplete combustion is much lower in case of B20 and B40 biodiesel compare to diesel.

Exhaust Gas Temperature

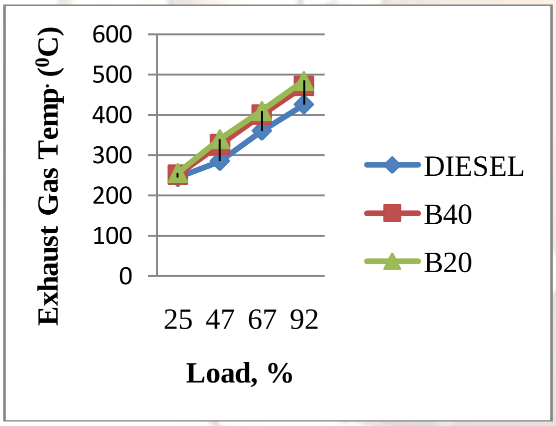

Fig.10. Variations of Exhaust Gas Temperature with engine load

Fig.10 indicates the variation of exhaust gas temp with load. Heat carried away by the exhaust gas can be calculated by multiplying this temp into mass of exhaust gases produced and the specific heat of exhaust gases. Graph indicates that minimum exhaust gas temp is obtained in case of diesel.

Engine Emissions

CO_2 Emission

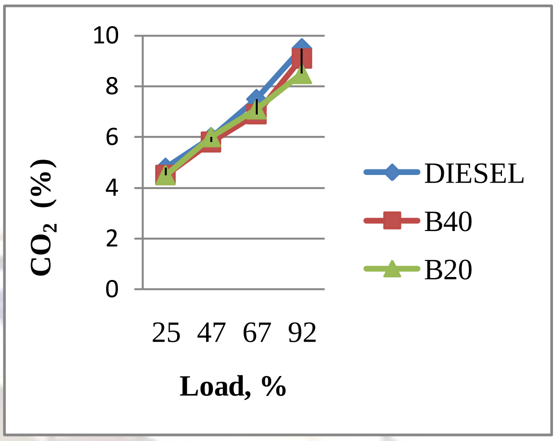

Fig.11. Variations of CO_2 concentration with engine load

The variation of CO_2 produced with diesel and diesel blends are presented in Fig. 11. Graph indicates the variation of CO_2 at higher load emission of CO_2 in B40 found to be higher than B20 by 7%. For all blends percentage of CO_2 increases with load.

O_2 Emission

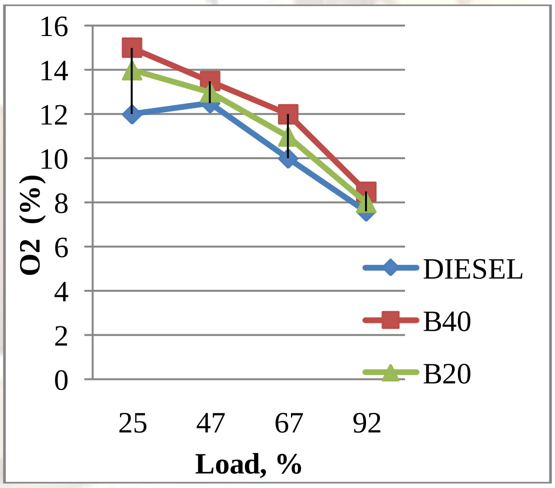

Fig.12. Variations of O_2 concentration with engine load

Variation of O_2 concentration with engine load is shown in Fig.12. The graph indicates that as the blends increases the percentage of O_2 also increases. It indicates that biodiesel is an oxygenated fuel as a result of better combustion.

NO_X Emission

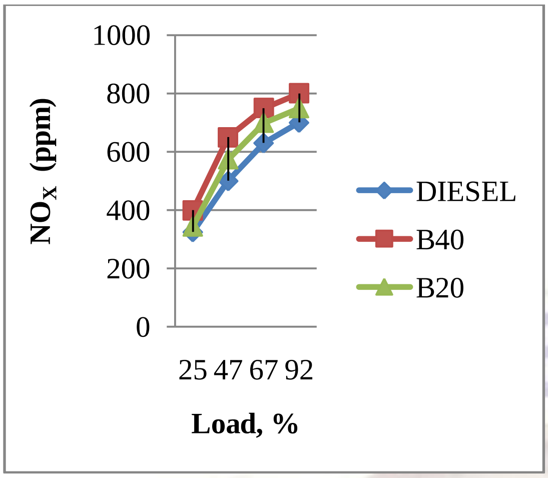

Fig.13. Variations of NO_X concentration with engine load

Fig.13 indicates the variations of NO_x concentration with engine load. It was observed that with the increase in load NO_x composition in exhaust gas of diesel increases. Emission of NO_X are found to be more for KOME blends compared to diesel. The presence of oxygen in KOME leads to raise the temp of combustion temp which is responsible of NO_x formation.

Unburned Hydrocarbon Emission

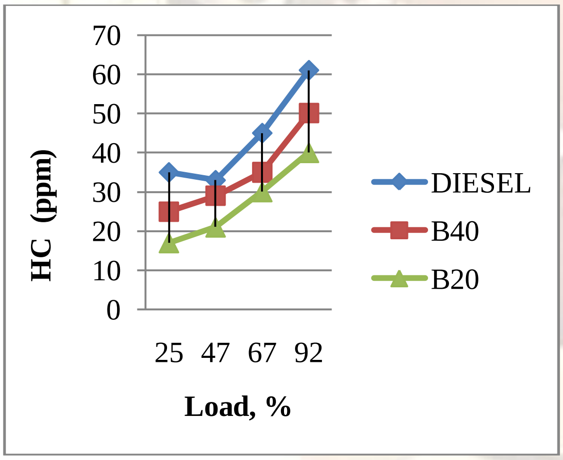

Fig.14. Variations of HC concentration with engine load

Graph indicates the un-burnt hydrocarbon at different engine load for different diesel blends as shown in Fig.14. The graph shows lower hydrocarbon as compared to diesel due to better combustion of biodiesel. At full load HC emission decreased by 35% B20 and 22% for B40.

Conclusion

By transesterification method karanja crude oil was converted to KOME. Major of the fuel properties were tested. Performance and emission tests were conducted by using a four stroke diesel engine. Respective graphs were plotted and results were analyzed and compared with diesel. The major conclusions were drawn based on the tests.

- The oil extraction was found 35% by n-hexane method.
- Lower calorific value indicates more oil consumption.
- The specific gravity, Kinematic viscosity of B20 and B40 blends is much closer to diesel.
- At higher load maximum brake power was observed for B20 blend.
- BSFC reduces with increase in load
- BTE shows better result than diesel.
- Incomplete combustion of KOME is much lower than diesel which was indicated in smoke opacity curve.
- Exhaust gas temp is more or less compare to diesel.
- NO_x emissions are found to be more for KOME blends while CO_2, HC and smoke emissions are lowered as compared to diesel.

From the above observation it can be concluded that besides considering the economy part blends of B20 and B40 of Karanja biodiesel can be considered as a sustainable fuel. It can be used as an environment friendly alternative fuel without major engine modification.

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