Performance and Emission Characteristics of Straight Vegetable Oil (Svo) as Alternate Transport Fuel for Sustainable Development

Dilip R. Pangavhane*, Sachin S. Harak, and Prashant B. Nehe

Abstract— *The technological development has resulted in unlimited exploitation of natural resources resulting in diminishing stocks of fossil fuels alongwith increase in number of transport vehicles, there is steep rise in energy demand. Alternative transport fuels have gained more importance in past few decades. Bio-diesel is better option for conventional fuels to protect environment for sustainable development. Though the various straight vegetable oils (SVO), edible and non-edible oils can be used for manufacturing biodiesel, out of which karanja oil is best suitable for biodiesel production. Multiple engine performance tests were conducted from obtained biodiesel on a four-stroke diesel engine. The blends upto 20% biodiesel can be used in all diesel engines and are compatible with most conventional storage and distribution equipments without any engine modifications resulting same payload capacity as that of petroleum diesel. The tests results have shown that the biodiesel is no different from petroleum diesel in terms of engine performance.*

Keywords— **Alternate Transport Fuels, Bio-diesel, CI Engines, Karanja, Sustainable Development, Transesterification.**

1. INTRODUCTION

Environmental pollution is an emerging threat and of great concern in present context pertaining to its effect on ecosystem. The technological development in industrial and automobile sector has resulted in unlimited exploitation of natural resources disturbing the delicate ecological balance between living and non-living components of the biosphere. The final destination of imbalance in environment will affect the human being, because of air, water and soil pollution.

For the fast technological developed world transport becomes the important part for its existence. Because of diminishing stocks of fossil fuels and increase in number of vehicles in transport sector there is steep rise in energy demand.

To maintain the tempo of high growth rate of world economy, it is necessary to maintain these inputs of energy resources. With the fast rate of depletion of crude oil deposits, alcohol blends on conventional fuels, LPG, CNG have come to the forefront and have been extensively studied and being implemented but are non renewable. These blended fuels are not the final solution to fuel crisis, as are only a compromise for marginal increase in fuel supply. These conventional fuels available in market are made environmental friendly by technical up gradation but still there are limitations in their sustainability. Alternate fuels are only promising hope of future, which has tremendous potential to energize fuel revolution in transport sector [1].

The dependence on fossil energy is unwise because of its cost, dwindling reserves and environment pollution. Therefore many countries have already initiated programmes to increase the use of alternative source of energy. The alternate fuels have large benefits beyond air quality and have gained more importance in past few decades owing to need for stronger energy security as well as to reduce green house gas emission. New fuels give new choices for consumers, which bring down our dependency on imported oil and will save millions of rupees on import bills. When the demand for imported oil peaks up, the production and use of alternate fuels like hydrogen, biodiesel etc. will definitely become more competitive in the market thus enabling use of such cleaner fuels for sustainable development which protects the environment [2]. In the world most of the countries has accorded priority to biodiesel technology for the protection of environment for sustainable development.

Biodiesel refers to any fuel substitute derived from renewable biomass. Vegetable oils or animal fats on treatment with alcohol (mostly methanol or ethanol) give alkyl esters or fatty acids. The alkyl esters of fatty acids are consigned with a general term, biodiesel when used as fuel. The name biodiesel was introduced by National Soydiesel Development board, US (now National Board of Biodiesel), which has pioneered the commercialization of biodiesel in the US. Likewise the petroleum diesel, the biodiesel operates the combustion ignition engines.

Biodiesel has some clear advantages over the straight vegetable oil (SVO).

*Dilip R. Pangavhane (corresponding author) is Principal, Nashik District Maratha Vidya Prasarak samaj College of Engineering, Udhoji Maratha Boarding Campus, Near Pumping station, Gangapur Road, Nashik-422013, Maharashtra, India. E-mail: drpangavhane@yahoo.co.in, ndmvpcoe_nsk@sancharnet.in. Phone: 91-0253-2571439, 2317016, (M) 9422769103.

Sachin S. Harak is Lecturer, Mechanical Engineering Depart., Nashik District Maratha Vidya Prasarak samaj College of Engineering, Gangapur Road, Nashik-422013, Maharashtra, India.

Prashant B. Nehe is Lecturer, Mechanical Engineering Depart., Nashik District Maratha Vidya Prasarak samaj College of Engineering, Gangapur Road, Nashik-422013, Maharashtra, India.

1. It works in any diesel engine without any conversion or modification to the engine.
2. Viscosity is less than that of SVO.
3. It has better cold weather properties than SVO.
4. Biodiesel is clean, safe, and ready to use alternative fuel.
5. Biodiesel can be more expensive.

Though the various edible and non-edible oils can be used for manufacturing biodiesel, out of which karanja (Pongamia pinnata) is one of the best oil suitable for production of biodiesel. The Jatropha (Pongamia pinnata) is wild oilseed plant of medium sized tree that generally attains a height of about 8 m and a trunk diameter of more than 50 cm. The trunk is generally short with thick branches spreading into a dense hemispherical crown of dark green leaves. Jatropha plantation requires minimal rainfall, and it can be plant successfully on marginal, degraded, or even in deserted land. It is shrub, which can be grown on either side of railway tracks, thus preventing displacement of fertile land, which is used for food crops. Cultivation of Jatropha consists of ideal spacing for block plantations and paired row hedges 3.0m x 3.0m single rows can be planted at 2.0m spacing. The pit size of 1.5m x 1.5m x 1.5m, filled with topsoil with farmyard manure. A fertilizer mix (NPK) Nitrogen Phosphate and Potassium [15:15:15] should be applied at the rate of 250gm per plant during rainy season every year. It can be grown either from cuttings or seeds, its plants start bearing fruits from first years onwards. Each Jatropa tree can produce an average of 3.5kg of beans each year depending upon irrigation levels. Generally 2200 numbers of Jatropha trees are planted per hectare; this gives annual harvest of approximately 7 tonnes of beans or seeds, which will yield about 2.7 tonnes of karanja oil. The non-renewability of the present conventional fuels apart from deteriorating land, water and air quality has led to the look out for better alternatives. When the demand for imported oil peaks up, the production of alternate fuels like biodiesel [3] will definitely become more competitive in the markets thus enabling the use of such cleaner fuels in mere endeavor for the environment protection for sustainable development. This paper discusses the efforts made towards the production of biodiesel by Transesterification process and to compare its fuel characteristics with the petroleum diesel. The multiple performance tests were conducted from the obtained biodiesel on a four-stroke, two-cylinder water-cooled diesel engine producing 10HP, 1500 RPM, 10KV Dynamometer under different blend ratio.

2. MATERIALS AND METHOD

A. Experimentation

Though the various bio oils are used for production of biodiesel but the biodiesel obtained from karanja oil is used either as diesel fuel substitute or extender. In India there is great potential of karanja oil as compaired to the other non-edible oils. The comparative physical and chemical Properties of Karanja oil (Pongamia Pinnata) and Jatropha curcus oil is given in Table-1.

Table 1. Comparison of Physical and Chemical Properties of Karanja oil with Jatropha oil

Sr. No.	Properties	Karanja oil	jatropha oil
1	Viscosity (cSt)	15.10	52.76
2	Specific gravity	0.87	0.93
3	Flash point	197	240
4	Sulfur	13-16%	17%
5	Refractive Index	1.47	1.89

These oils cannot be directly used as fuels in the engines because of its high viscosity which may create problems in the engines. The advantage of using karanja oil is that the physical and chemical properties are far better than those Jatropha oil, hence processing becomes more simplified and economical. Apart from this Karanja tree can be grown on waste land and need not require more care for grow than that of Jatropha tree. Wood quality of karanja tree is also far better than jatropha tree which gives additional income. To reduce the viscosity of this oil, a chemical process called "transesterification" [4] is carried out for removing the triglycerides from this karanja oil. Generally four methods are adopted for converting the vegetable oil into biodiesel.

(i) Dilution (ii) Micro emulsion

(iii) Pyrolysis (iv) Transesterification

The transesterification process is best method of approach for converting vegetable oil into biodiesel. The processed oil obtained is "methyl esters" called as biodiesel, which was tested and the properties were compared with standards for diesel. As the fatty esters obtained by transesterification are very less viscous as due to less viscosity deposition of carbon gets reduced. The biodiesel obtained by transesterification has performed well in the long-term diesel engine test.

Karanja oil + Methanol = Biodiesel + Glycerol

B. Methodology

The experimental set up is prepared for biodiesel production; the brief methodology is given as below. By using constant temperature heating bath the reaction were carried out between the temperature range of 40^0C to 70^0C

C. Procedure

The karanja oil is purchased from the market and one kg karanja oil is taken as sample through filtering process and then it was heated up to 100^0C for removing any volatile matter and water, which may present in the karanja oil sample. Then the sodium methoxide is prepared for one kg karanja oil, by mixing Thirty-five gms of MeOH and six gms of NaOH in a separate container. Then the oil temperature is set at 65^0 for two hours, with carefully and slowly the sodium methoxide is added in the reactor then the colour was changed to dark brown [5].

After two hours of completion the reaction mixture was placed in separating funnel and the system was kept in 40^0C for at least 5 Hours. During this two layers were observed out of which upper one is of Bio diesel and the bottom contains Glycerin and unreacted reactants, this process is known as settling and separation process. Then by draining out the bottom and giving out water wash to upper layer for removing any soap present in the product. Then heating the sample up to 100^0C, for removing the unreacted methanol and water remained during water wash. The obtained product is pure Bio diesel ready to use as a fuel.

Table 2. Comparative properties of Bio diesel obtained from karanja oil and Jatropha oil.

Sr No	Properties	Biodiesel from	
		Karanja oil	jatropha oil
1	Density, (40^OC) g/cm^3	0.88	0.918
2	Viscosity, (40^OC) cSt	4.84	5.51
3	Calorific Value, Kcal/kg	9792	9470
4	Flash Point, ^{O}C	109	240-110
5	Pour Point, ^{O}C	-14.00	8
6	Sulpher contents (%)	0.1	0.13
7	Carbon Residue (%)	0.24	0.64

The bio diesel obtained from karanja oil is tested for checking its physical and chemical properties i.e. the fuel properties as a fuel and compared with bio diesel obtained from Jatropha oil, are shown in the Table-2. From this table it is observed that the Properties of obtained biodiesel form Karanja oil is far better than that of Jatropha oil. The Comparison of biodiesel sample obtained from karanja oil was made with B.U. standards and is given in Table-3. From this table, it is observed that the obtained biodiesel has almost the similar values as that of B.U. standards.

Similarly the Comparison of biodiesel sample obtained from the karanja oil was made with petroleum Diesel and given in Table-4. From this table it is observed that the pollution content parameters affecting on environment are very low as compared to that of the petroleum diesel.

Table 3. Comparison of bio-diesel sample obtained from karanja oil with B.U. standards.

Sr No	Specification	Unit	(Obtained Sample) biodiesel	B.U. Standards for biodiesel
1	Density at 30^0C	G/ml	0.88	>0.8
2	Combustion point	^{0}C	192	>55
3	Kinetic viscosity	Cst	4.84	5
4	Calorific potential	MJ/Kg	41	Undefined
5	Cetane number	----	48	>48
6	Ester content	%	>99	>99
7	Sulfur content	%	0	<0.55
8	Carbon residues	%	0.024	<0.1
9	Specific gravity	^{0}C	0.895	0.87 to 0.89
10	Cloud point	^{0}C	-11	-11 to 16
11	Pour point	^{0}C	-14	-15 to 13

D. Testing as a Fuel

The multiple performance tests were conducted from the obtained biodiesel on a four-stroke, two-cylinder water-cooled diesel engine producing 10 HP at 1500 RPM with 10 KV, Dynamometer. The experimental set up is as shown in Figure: 1 with all necessary instrumentation and engine without making any modification of the present system [6-7].

The various engine performance tests were conducted with obtained biodiesel from karanja oil, as 50%, 100% and with diesel as a complete fuel.

The results obtained during the various engine trials are given in Tables 5, 6 and 7, for different combinations of biodiesel with petroleum diesel. From the obtained results it is concluded that the biodiesel also gives the more comparable engine performance as a complete fuel or its blend with diesel as that of the petroleum diesel.

Table 4. Comparison of biodiesel sample obtained from karanja oil with petroleum Diesel

Sr No	Specification	Units	(Obtained sample) Biodiesel	Diesel
1	Density at 30^0C	G/ml	0.88	0.85
2	Combustion point	^0C	192	55
3	Kinetic viscosity	Cst	4.84	2-8
4	Calorific potential	MJ/Kg	41	45
5	Cetane number		48	47.5
6	Ester content	%	>99	0
7	Sulfur content	%	0	<0.5
8	Carbon residues	%	0.024	<0.35
9	Cloud point	^0C	-11	--
10	Pour point	^0C	-14	--
11	Boiling point range	^0C	--	188-333

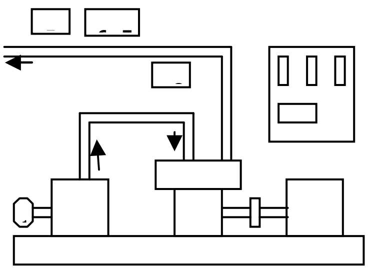

Fig. 1. Experimental Setup

1. Air flow meter
2. Air vessel
3. C.I. Engine
4. Dynamometer
5. Smoke meter
6. CO, HC analyzers
7. NO analyzer
8. Thermocouple

Table 5. Test on diesel engine with Diesel fuel

Sr. No	Break Power (KW)	Fuel Consumption (Kg/hr)	Mechanical efficiency (%)	Indicated thermal efficiency (%)
1	2.62	4.05	64.88	24.94
2	3.42	4.85	70.64	28.46
3	4.81	6.2	77.18	29.3
4.	6.28	7.1	81.52	28.93
5.	6.75	8.92	84.03	31.87

Table 6. Test on diesel engine with 50% biodiesel and 50% Diesel as a fuel

Sr No	Break Power (KW)	Fuel Consumption (Kg/hr)	Mechanical efficiency (%)	Indicated Thermal efficiency (%)
1	1.62	4.12	39.8	13.0
2	3.71	5.61	55.0	16.3
3	4.62	7.12	64.2	18.29
4	6.0	8.5	70.58	20.29
5	6.78	9.28	73	21.58

Table 7 Test on diesel engine with 100% Biodiesel as a fuel

SrNo	Break Power (KW)	Fuel Consumption (Kg/hr)	Mechanical efficiency (%)	Indicated Thermal efficiency (%)
1	1.62	4.12	46.2	12
2	3.21	5.11	55.0	14.32
3	4.67	6.57	64.2	16.50
4	6.0	7.90	70.58	18.56
5	6.96	8.86	73.00	21.58

3. RESULTS AND DISCUSSION

A. Emissions reductions with biodiesel

As the Biodiesel is made entirely from vegetable oil, it does not contain any sulfur, aromatic hydrocarbons, metals or crude oil residues. The absence of sulfur means a reduction in the formation of SO_2. Figure-2 shows the biodiesel percentage reduction of emissions as compared with the petrodiesel. The various parameters related to emission are as given below.

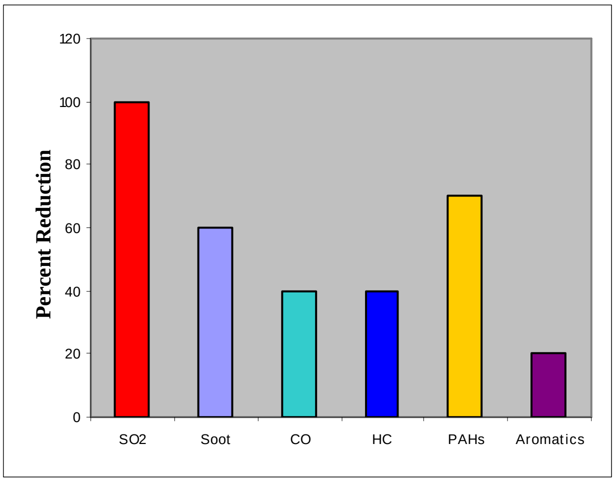

Fig. 2. The Biodiesel emissions compared with Petrodiesel

B. Lower Hydrocarbon Emissions

The Biodiesel itself burns cleanly, but it also improves the efficiency of combustion in blends with petroleum fuel. As a result of cleaner emission though our engine was older one still we notice less soot under load and less carbon during startup compared to diesel.

C. Smoke and Soot Reductions

The smoke (particulate material) and soot (unburned fuel and carbon residues) are of increasing concern to urban air quality problems that are causing a wide range of adverse health effect for the citizens, especially in terms of respiratory impairment and related illness. With necked eyes we easily noticed that there was considerable reduction in black smoke from exhaust.

D. Carbon Monoxide Emissions

Carbon monoxide gas is a toxic byproduct of all hydrocarbon combustion that is also reduced by increasing the oxygen content of the fuel. More complete oxidation of the fuel results in more complete combustion to carbon dioxide rather to leading to the formation of carbon monoxide. When the fuel was switched from lower sulfur petroleum diesel to clean biodiesel, there was a 28-37% drop in carbon monoxide emissions. During third test (i.e.100% biodiesel) CO% shown by gas analyzer was 30% less than that of Government guidelines which is advantageous for the biodiesel.

E. Nitrogen Oxides

The gas analyzer monitor report shows that there is slight increase (several percent) in NOx emissions with Biodiesel that are attributable, in part to the higher oxygen content of fuel mixture. More oxygen and better combustion of the fuel is the indication of more formation of NOx emission with Biodiesel as a fuel.

F. Noise Reductions

During the experimental trials it is observed that there is considerable reduction in engine noise and vibration as engine was working very smoothly. This will give the added life to the engine and security to its parts.

G. Energy Security Benefits

With agricultural commodity prices approaching record lows and petroleum prices approaching record high, it is clear that more can be done to utilize domestic surpluses of vegetable oils while enhancing our energy security. Biodiesel can be manufactured as per existing industrial production capacity, and used with conventional equipments; it provides substantial opportunity for immediately addressing our energy security issues.

H. Biodiesel helps to reduce greenhouse gases

Unlike other “clean fuels” such as compressed natural gas (CNG), Biodiesel and other biofuels are produced from renewable agricultural crops that assimilate carbon dioxide from the atmosphere. The carbon dioxide released during the year from burning vegetable oil, biodiesel in effect, it will be recaptured next year by growing crops in the fields to produce more vegetable oil from the biomass.

I. Social Aspects

India ranks sixth in world for energy demand accounting 3.5% of world commercial energy demand in 2003. The energy demand is expected to grow at 4.8%. The demand of diesel component is estimated around 40 million tones. The current annual import bill of crude oil in terms of foreign exchange is around Rs. 6,04,000 Crores. Diesel is mainly consumed by Industrial and transport sector, as road transport consumes almost 75%, while the railways accounts for the rest. Biodiesel can replace diesel and other fuels. It is produced from renewable materials, biodiesel considerably reduce soot emission, and it has zero sulfur content. The CO_2 emitted is also gets absorbed by trees under growth (CO_2 recycle) and similarly biodiesel is easily decomposes biologically and so there is no harm to the human being and environment which will be more helpful for sustainable development.

The main advantages of using biodiesel are:

(i) This project will develop and utilizes wastelands by growing kranja trees and will protect the environment.

(ii) Along the rail tracks and national highways karanja trees can be planted, which will protect the environment by producing the karanja oil.

(iii) There will be creations of employment opportunities in rural areas, especially to the women, which will helps to improve the economical status of rural peoples.

(iv) This biodiesel project will indirectly promotes the organic farming by marketing the de-oiled cake, which will be available to the farmers as a fertilizer for different cropping patterns.

(v) It will restore the degraded lands and generate income opportunity for rural public.

There will be reduction in import quantity of petroleum oil because of production of biodiesel, ultimately the foreign exchange will be saved.

4. CONCLUSION

From the experimental results obtained it is concluded that the karanja oil (SVO) cannot be used directly as a fuel in the CI engine because of higher specific gravity, higher viscosity and low volatility as compared to petrodiesel. Similarly the biodiesel is more compitable with diesel and more suitable as fuel for the CI engines without any modification. There is also reduction in % of CO and HC in the exhaust gases. The non-renewability of conventional fuels apart from deteriorating land, water and air quality has led to the look out for better alternatives and the biodiesel is a substitute for the above problem. When the demand for imported oil peaks up the production of alternate fuels, like biodiesel will definitely become more competitive in the market thus enabling the use of such cleaner fuels in mere endeavor.

ACKNOWLEDGMENT

Authors acknowledge to the Managements and Directors of NDMVPS College of Engineering, Nashik, for providing the basic facilities required for conducting this experimentations.

REFERENCES

[1] Mashelkar, R.A. 2002. Report of expert committee on Auto fuel policy.

[2] Bhagavath, R. 2004. Fueling the future- The changing scenario, March-May 2004. Environment Science and Engineering 2(1): 1-8.

[3] Bio-Fuel, Report of the committee on development of bio-fuel, Planning Commission, Govt. of India, 2003.

[4] Green, D.W. and Moloney, J.O. 1998. Perry's Chemical Engg. Handbook, 7th Edition, McGraw Hill publication Co.

[5] Smith, J.M.; Van Ness, H.C. and Abott, M.C. 1999. "Introduction to chemical Engineering Thermodynamics", 5th Edition, McGraw Hill Publication Co.

[6] Senthil Kumar, M.; Ramesh, A. and Nagalingam, B. 2003. An experimental comparison of methods to use methanol and Jatropha curcus oil in a compression ignition engine. International Journal of Biomass and energy 25: 309-318.

[7] Green rating project, Environmental rating of Indian Automobile Sector. 2003. Centre for Science and Environment, New Delhi.