ISSN: 0976-3104

REGULAR ISSUE:
Singh.

THE IIOAB JOURNAL

RESEARCH ARTICLE OPEN ACCESS

STRAIGHT VEGETABLE OIL: AN ALTERNATIVE FUEL FOR COOKING, LIGHTING AND IRRIGATION PUMP

R. N. Singh*

School of Energy & Environmental studies, Devi Ahilya Vishwavidayala, Takshashila Campus, Khandwa Road, Indor (MP) – 452017, INDIA

ABSTRACT

SVO (Straight Vegetable oil) of Jatropha was de-waxed and de-gummed as per the standard procedure, and was tested in irrigation pump set, kerosene cook stove and kerosene lamp. It was found that Jatropha oil could be successfully used as irrigation pump fuel, however at interval of every 25 - 30 hours of operation, fuel injection nozzle and head needs to be cleaned in spite of maintaining the Jatropha oil temperature between 80 to 90 °C. Out put of the irrigation pump is almost similar to diesel fuelled irrigation pump set, however fuel consumption rate in case of Jatropha oil was more compared to diesel. Recorded air pollutants were found to be higher in case of Jatropha oil as compared to diesel, except NOx. No significant, wear and tear in the engine component such as liner, piston, and piston rings, except bore gauge was observed. Trials taken with kerosene stove and kerosene lamp also reveals that Jatropha oil could be used as cooking fuel in pressurized stoves with a blend of 30% Jatropha oil and 70% kerosene without any problems. However for kerosene lamp it can be used with a blending of 10 % Jatropha oil and 90% kerosene.

Received on: 20th-Nov-2010
Revised on: 10th-Dec-2010
Accepted on: 8th -Feb-2011
Published on: 25th-Oct-2011

KEY WORDS

Vegetable oil, application

***Corresponding author:** Email: rnsingh.seema@gmail.com; rnsingh7@yahoo.com ; Tel: +91-731-2460309; MO: 09893660149 Fax: +91-731-2467378

[I] INTRODUCTION

As per the Government of India report, published by planning commission, a large part of India's population, mostly in the rural areas which does not have access to commercial energy sources will have to be provided hydrocarbon fuels and power by December 2012. The country faces problems of effectively meeting the growing energy demand and at the same time curb the resulting environmental degradation. In this background bio-fuels offer an attractive alternative for providing energy with less pollution.

All properties of plant oils are close to diesel except the viscosity. High viscosity of the plant oils is considered to be the major constraint although high acid value and presence of wax/gums etc. also adversely affects the engine performance. To reduce the viscosity number of method has been tried by researcher such as; cracking of plant oil, blending of the plant oil with appropriate additives like alcohol, chemically transforming the plant oils to convert them into esters (bio-diesel) by alcoholysis and de-waxing, de-gumming and heating the plant oils before injecting them into the combustion chamber. Considering the economic constrain last option seems more effective. Moreover plant oils, straight has several advantages as combustion fuel. Due to relatively simple and low-cost technology for expelling and filtering, the plant oil can be processed on the farm itself, thus saving the transport cost, time and energy [5, 6, 7].

Literature indicates that up to 75 % of diesel requirement could be replaced by plant oils with satisfactory engine performance [1, 2, 3 10, 12]. As mentioned above, diesel are still required (25 to 30 % of the specific fuel consumption) to supplement plant oil. Short-term engine tests of less than 10 hour duration carried out by author itself indicate that plant oils performed quite well. Problems occur only after the engine is operated on plant oil for longer duration of time [7]. In this study, effort has been made to utilize 100 % Jatropha oil with minor treatment for different applications.

[II] MATERIALS AND METHOD

2.1. Characterization of fuels

Non-edible oil generally contains about 3-4 %wax and gum. De-waxing and de-gumming of plant oils is required not only for smooth running of the CI engine but also to prevent engine failure even if plant oils are blended with diesel [13, 14]. It is therefore necessary to remove wax and gum from the fresh oil before it could be used in CI engine.

ISSN: 0976-3104

Characterization of diesel and Jatropha oil was done as per the ASTM standards (ASTM, 1983. The results obtained are given in [Table–1].

2.2. Modification of characteristics of Jatropha oil

Jatropha oil procured from the local markets was de-waxed & de-gummed as per standard procedure [11].

2.3. Experimental setup and measuring devices used

A 5 hp Field Marshal engine as per specifications given in Table–2 was used. Performance parameters planned to be studied include: Fuel consumption rate, operating efficiency at fixed level of suction height, engine exhaust temperature and emissions, lube oil contamination, smoke opacity, sound level, visible engine wear (bore diameter etc).

Table: 1. Characteristic of fuels

Fuel Type	Viscosity at 38 °C, cSt	Density at 38°C, g/cc	Cetane Index	Flash point, °C	Cloud point, °C	Carbon residues, %	Free fatty acid, %	Calorific value, kcal/kg	Wax & gum, %
Diesel	4.44	0.789	45	66	13	0.03	-	10404	-
DDJO	48.96	0.892	43 ± 2	242	16	0.22	1.14	8765	2.3

DDJO- De-waxed & de-gummed Jatropha oil 1 Kcal/kg ≈ 0.0041868 MJ/kg

Table: 2. Engine Details of 5 hp irrigation pump set

Name and Model of engine	Field Marshal, Gf 1
General Details	Constant speed, single cylinder, water cooled naturally aspirated, direct injection
Bore x Stroke	100 x 120 mm
Compression ratio	17: 1
Specific fuel consumption	236 g/kWh
Rated output	3.7 kW/5 bhp at 1500 rpm
Fuel injection opening pressure	175-180 kg/cm^2
Injection timing	26° BTDC
Engine conditions	New engine

The fuel flow rate was measured on volumetric basis. Efforts were made to use waste heat of engine exhaust to preheat the Jatropha oil to minimize operation and maintenance problem due to higher viscosity. A microprocessor based engine exhaust gas analyzer was used for the measurement of emissions levels. Smoke meter, sound pressure level meter and K type thermocouple and indicator were used to measure smoke intensity, sound pressure at a distance of 1 meter from the engine fly wheel, exhaust gas and oil temperature respectively.

Experiments were carried at a fixed suction head (5.2 m) of water column. A sampling port was provided in the exhaust pipe for measuring flue gas temperature and to collect flue gas samples. The test was conducted as per BIS Code No.13018 (1990), however due to limitation of sources/ facility all the parameters as mentioned in BIS Code No.13018 could not be measured.

2.4. Heating of Jatropha oil

A 20-litre capacity mild steel container (300 mm diameter & 350 mm height) was designed and developed to heat Jatropha oil through engine exhaust gas. Container consists of copper coil, temperature gauge and manual agitator [Figure–1]. The copper coil was made with 22 mm outer diameter and 20 mm inner diameter copper pipe having 7 rounds. One end of the copper coil was attached with exhaust gas pipe and the other end to the container releasing exhaust gas outlet. The mild steel container is supported using a proper stand. About 16-18 litres of Jatropha oil was poured in the container and it was observed that it took about 30 minutes to attain a temperature of 90 to100 °C from an ambient temperature of 30 °C.

It was also noted that although Jatropha oil temperature in the container was in the range of 90-100 °C, still when it reaches the nozzle, oil temperature drops down to room temperature due to capillary action. Later it was decided that the fuel pipe carrying Jatropha oil to the nozzle could be wrapped on the exhaust pipe. Number of rounds wrapped was decided by trial and error method with an objective to obtain about 80-90 °C oil temperature at the nozzle. The desire effect was achieved by wrapping 7 to 8 rounds of the fuel pipe on the exhaust pipe [Figure–2]. Both the exhaust pipe and the fuel pipe were insulated to maintain the desire temperature.

2.5. Test conditions and variables

Test conditions and variables involved in the trials have been listed in [Table–3]. The irrigation pump set was tested at original conditions as per the specifications provided by the manufacturer. However, minor changes in the engine variables during the test period due to environmental change, carbon deposition and wear of components were beyond control.

[III] RESULTS AND DISCUSSION

3.1. Performance of irrigation pump set

The performance of 5 hp irrigation pump set fuelled by de-waxed & de-gummed and heated Jatropha oil was determined at a constant engine speed of 1500 rpm which was controlled within a

THE IIOAB JOURNAL
ISSN: 0976-3104

Fig.1 Heating arrangement for JO

Fig 2 Modified heating arrangement for JO

range of ±15 rpm. Simulated condition was created by keeping the irrigation pump set at about 5.2 m height from ground level and a 1000 litre water tank was used to store and re-circulate water. The test was repeated three times to verify the out put and engine exhaust data. Specific energy consumption in diesel and Jatropha oil was calculated from the fuel consumption and calorific value of diesel and Jatropha oil. Calorific value of diesel and Jatropha oil was determined using bomb calorimeter.

Engine exhaust temperature was always higher in case of Jatropha oil compared to diesel. The increase in exhaust gas temperature may be due to delayed combustion because of slower combustion characteristics of Jatropha oil. Moreover almost all plant oils have slow burning characteristic compared to diesel. The increase in exhaust gas temperature may be responsible for reducing the brake thermal efficiency. Batt et al., 2001[4] also have reported similar result while working with karanja oil in a single cylinder engine. Engine was also run at 1200 rpm maintaining other engine parameter constant, however no improvement in the engine performance was observed. Similarly fuel injection pressure was also increased from 175-180 kg/cm^2 to 190 kg/cm^2, again no improvement in the engine performance was observed. Performance of irrigation pump set using both fuels is shown in **Table–3**. The effect on pollutants using diesel as well Jatropha oil are shown in **Figures–4, 6**.

3.1.1. Fuel consumption rate

Fuel consumption rate increased by almost 15-20% compared to diesel at the 5.2 m suction height of water. **[Figure–3]** shows a comparison of the fuel consumption rate obtained for diesel and de-waxed & de-gummed and heated Jatropha oil.

3.1.2. Wear and tear in the engine component

Since the engine was run on pure Jatropha oil heated to about 70-80°C, it was considered desirable to study the effect of Jatropha oil on the wear and tear of various engine components. The effect was studied in terms changes that took place in different components (e.g. change in shape, diameter, thickness, weight and length etc) after 100 hours cumulative operation of irrigation pump set with heated Jatropha oil. No significant change was observed in the liner diameter, piston diameter, and thickness of piston ring, except bore gauge, however about 2.985 g carbon deposition on different components of the engine was recorded.

3.1.3. Effect on engine oil

Engine oil used in irrigation pump set was characterised for viscosity, flash point, TBNE, sediment and water content before putting into the engine and after 100 hours running for pumping of water. Study reveals that Kinematics Viscosity, TBNE value and sediments increased after 100 hours running for pumping water. It may be due to dilution of engine oil by Jatropha oil.

Table: 3. Effect on specific energy consumption and efficiency with change of fuel in irrigation pump set

Fuel	Fuel consumption rate, Kg/hr	SFC, g/kWh	SEC, MJ/kWh	Brake thermal Efficiency, %
Diesel	0.644	302	13.18	7.59
DDJO	0.8678	407	14.87	6.72

DDJO- De-waxed & de-gummed Jatropha oil; Specific Fuel Consumption; SEC- Specific Energy Consumption

THE IIOAB JOURNAL
ISSN: 0976-3104

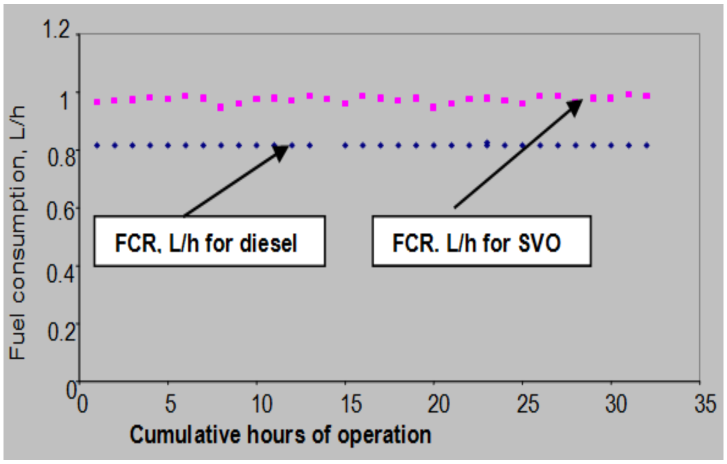

Fig: 3. Effect on fuel consumption rate with respect to time

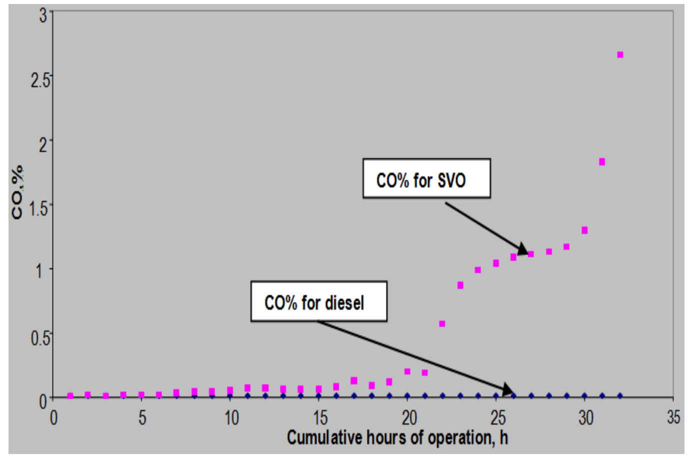

Fig: 4. Effect on CO with respect to time

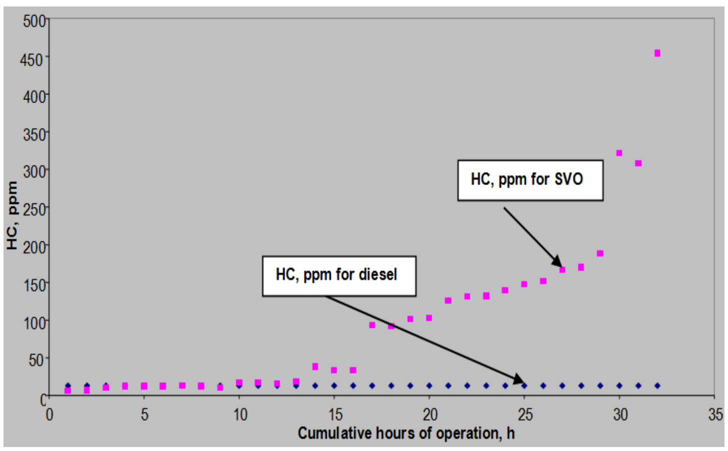

Fig: 5. Effect on HC with respect to time

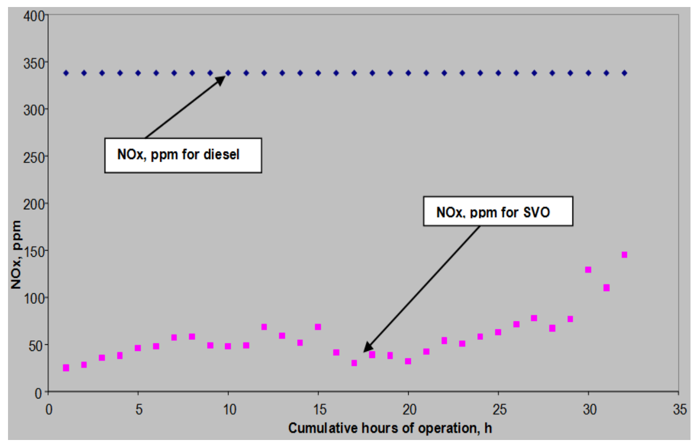

Fig: 6. Effect on NOx with respect to time

3. 2. Jatropha oil for cooking

3.2.1. Cooking

To check the maximum possible blending of Jatropha oil with Kerosene, without sacrificing stove performance, blends of Jatropha oil and Kerosene in the ratio of 10:90, 20: 80, 30:40, 40:60, and 50:50 on volumetric basis were prepared. These blends were tested using commercially available pressure stoves [Figure–7]. The stove performance was found to be satisfactory up to 30 % of Jatropha oil blends with 70 % kerosene; however after 25 - 30 minutes interval soot deposited on the nozzle has to be removed. With the blends having mixture ratio of more than 30:70 Jatropha oil and kerosene following observations were made:

1) Although at the blend ratio of 50:50, Jatropha oil & Kerosene stove was working smoothly, however frequent pulses with higher flame length was observed at intervals of 20-30 seconds.

2) Flame temperature was more than 954 °C.

3) From the nozzle of stove burner dripping of Jatropha oil was observed

4) Viscosity of freshly prepared 50: 50 (Jatropha oil & kerosene) blend was compared with used 50: 50 (Jatropha oil & kerosene) blend and was observed as 17.2 and 18.3 cS respectively.

3.2.2. Fuel consumption rate (FCR)

The stove was filled with the blended fuel up to three-fourth of its capacity. The stove was lighted and brought up to a working pressure of 140 kN/m2 (1.4 kgf/cm^2) within 5 minutes. Immediately the lighted stove was kept on a sensitive balance with an accuracy of 1 g for recording the fuel consumption rate. The stove was allowed to burn for 1 hour with an aluminium pan having sufficient water in it. At the end of 1 hour, weight of the burning stove was noted and weight of stove without aluminium pan was recorded. The difference in the initial and final weight of the burning stoves divided by time gave the fuel consumption rate. Table 4 shows the performance of pressure stove at different blending of Jatropha oil with kerosene. For cooking application wick (thread) stove was also tried, however it could not work even at 10 % blending of Jatropha oil with 90 % kerosene.

Fig: 7. Kerosene pressure stove

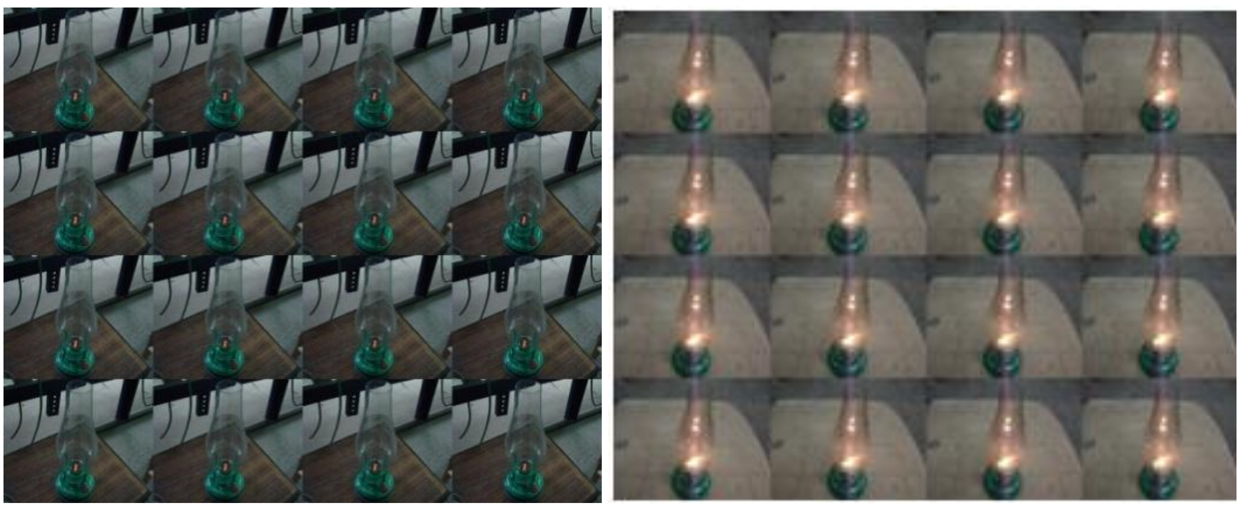

Fig: 8. Performance of Kerosene lamp with blended Jatropha oil

3.3. Jatropha oil for lighting

To check maximum possible blending of Jatropha oil with Kerosene, without sacrificing the performance of kerosene lamp, blends of Jatropha oil and Kerosene in the ratio of 10:90, 20: 80, 30:40, 40:60, and 50:50 on volumetric basis were prepared. These blends were tested at commercially available Kerosene lamp **[Figure–8]**. It was observed that with less than or equal to 25% blending of Jatropha oil with kerosene worked satisfactorily only for a period of one hour, due to very poor capillary action of Jatropha oil, however 10% blending of Jatropha oil with kerosene worked satisfactorily for more than 4 hours continuously without any problems. Air pollution, which include % CO, % CO_2, % O_2, ppm HC, ppm NOx and smoke intensity were also measured and found to be within limits.

Table: 4. Performance of pressure stove at different blending of Jatropha oil with kerosene

Sr. No.	Blend Ratio (JO:K)	Initial weight of stove+ kerosene	Final weight of stove+ kerosene	Duration, minutes	Fuel consumption rate (FCR), kg/h
1	0:100	1.367 kg	1.312 kg	20	0.165
2	30:70	1.549 kg	1.493 kg	20	0.168
3	40:60	1.678	1.853	20	0.175
4	50:50	1.678 kg	1.587 kg	20	0.30

THE IIOAB JOURNAL
ISSN: 0976-3104

[V] CONCLUSION

Following conclusions were drawn from the study:

- Jatropha oil could be used as irrigation pump fuel, however for every 25 - 30 hours of operation the fuel injection nozzle and head have to be cleaned even though Jatropha oil temperature was maintained between 80 to 90 °C.
- Discharge of water was about 24658 L/hr for diesel as well heated Jatropha oil.
- Out put of the irrigation pump is similar for both diesel & Jatropha oil; however fuel consumption rate in case of Jatropha oil is more compared to diesel.
- All the pollutants released by using Jatropha oil are higher as compared to diesel, except NOx.
- No significant, wear and tear in the engine components such as liner, piston, and piston ring, except bore gauge was observed after 100 cumulative hours of operation, however about 3 g carbon deposition was found on different engine components.
- Jatropha oil could be used as fuel in cooking pressure stove with a blend of 30% Jatropha oil and 70% kerosene without any problems.
- Jatropha oil could be used as lighting fuel with blend of 10% Jatropha oil and 90% kerosene without any problems.

REFERENCES

[1] Bari Slim TH, Yu CW. (2002) Effect of preheating of crude palm oil (CPO) on injection system, performance and emission of a diesel engine. *Renewable Energy* 27: 339−351.

[2] Bhattacharya S, Reddy CS. (1994) Vegetable oil as fuel for internal combustion engine: A Review. *J Agric Engg Res* 57: 157−166.

[3] Bhatt YC, Murthy NS, Datta RK. (2001) Karanja (*Pongamia Glabra*) oil as a fuel for diesel engines. Agril Engg Today 25(5−6): 45−57.

[4] Batt YC, Murthy NS, Datta RK. (2003) Fuel properties of five non−edible vegetable oils and their blends with diesel. *SESI Journal* 13(192): 31−40.

[5] Final Report. [2007] Final Report on "Replacement of hydrocarbon fuel by Jatropha oil and bio−diesel in stationary engine" of work done at SPRERI, Vallabh Vidyanagar Report submitted to the Industries Commissionerate, Government of Gujarat, Udyog Bhavan Gandhinagar, Gujarat.

[6] Forson FK, Oduro EK, Donkoh EH. (2004) Performance of Jatropha oil blends in a diesel engine. *Renewable Energy* 29: 1135–1145.

[7] Karaosmanoglu F, Kurt G, Ozaktas T. (2000) Long term CI engine test of sunflower oil. *Renewable energy* 19: 219–221.

[8] Kumar MS, Ramesh A, Nagalingum. (2001) Investigations on the use of Jatropha oil and its methyl ester as a fuel in a compression ignition engine. *J of Institute of energy* 74: 24–28.

[9] Pramanik K. (2003) Properties and use of Jatropha Curcas oil and diesel blends in compression ignition engine. *Renewable Energy* 250: 239–248.

[10] Shyam M, Verma SR, Pathak BS. (1984) Performance of 5 hp diesel engine with various blends of plant oil and diesel/kerosene oils. *J Agril Engg ISAE* 21(3): 113.

[11] Sharma BK. (1986) Industrial Chemistry – Oils, Fats, Waxes and Soaps. Goal Publishing House, Subhash Bazar, Meerut, India.

[12] Singh RN. (2007) Investigations on operation of IC engine using producer gas and non−edible plant oils and their esters in duel fuel mode. PhD thesis submitted to Devi Ahilya University, Indore (M P).

[13] Van der walt AN, Hugo FJ. (1981) Diesel engine test with sunflower oil as an alternative fuel. Beyond the Energy Crisis− Opportunity and Challenges Volume II. Third International Conference on Energy Use Management. Berline (West). Eds. RA Fazzolare and C R Smith 1927−33. Pergamon Press, Oxford.

[14] Yarbrough CM, Lepori WA, Engler CR. (1981) Compression Ignition performance using sunflower seed oil. *ASDAE* Paper Number 81−3576. St. Joseph, MI: ASAE.