BATCH TYPE SYNTHESIS OF HIGH FREE FATTY ACID JATROPHA CURCUS OIL BIODIESEL- INDIA AS SUPPLYING COUNTRY

Sanjay Gandhi Bojan[1], Sam Chelladurai[1] and Senthil Kumaran Durairaj[2]
[1]Department of Mechanical Engineering, CSI College of Engineering, Ooty, S. India
[2]KTVR Knowledge Park for Engineering and Technology, Coimbatore, S. India
E-Mail: sanjaygandhi_b@yahoo.com

ABSTRACT

The Jatropha Curcas oil grown and extracted in the rural belts of western ghat section of South India was tested for its physical and chemical properties to determine its suitability as a feedstock for biodiesel production. A compact, simple, 4-litre biodiesel processor was developed locally. The biodiesel processor was capable of producing biodiesel sufficient in quantity for formers in village level to run the commonly used farm engine for producing electricity for agricultural and other purposes. The properties like kinematic viscosity, acid number, specific gravity, Cetane number, etc of the biodiesel produced meet the ASTM standard but the yield quantity was comparatively low (80.50%) because of the high free fatty acid content in the raw Jatropha Curcas oil. The overall efficiency of the biodiesel produced as a fuel in a four stroke diesel engine coupled with a electric generator was high (24.38%) at maximum load conditions compare to raw Jatropha Curcas oil and petro diesel as fuels which gives only 19.6% and 20.11%, respectively shows the possibilities of using biodiesel produced as a fuel in diesel engine.

Keywords: biodiesel processor, jatropha curcas oil, biodiesel property, transesterification.

INTRODUCTION

The world at present mainly dependent on petroleum based fuels for power generation. Since these fuel sources are depleting fast, it is foremost important to find alternative sources of fuel for power generation. Moreover the capacity production of power is very less compared to the demand and due to problem in transmission; it is a greater task to electrify all parts, especially the rural parts of most of the developing countries. A promising way to electrify the rural areas in the developing countries is developing decentralized power generating units for various operations like pumping, lighting etc. At this scenario, it is foremost important to work at the scope of the fuel sources available at the native areas as input for decentralized power generating units because the benefits of such transition would go immediately to the local community in terms of economy, employment, etc.

Even though the non edible vegetable oil crops grown in the rural belts are promising factors, their high viscosity is the major limitation to use as fuel in existing diesel engines (Hanumantha Rao *et al*., 2009; Singh and Padhi, 2009; Kalbande *et al*., 2008). One possible method to overcome this problem is to convert these vegetable oils in to more compatible fuel for existing engines. Transesterification has emerged as the most viable and efficient method for this purpose (sanjay *et al*., 2010; Hanumantha Rao *et al*., 2009; Hanny and Shizuko, 2008; Venkateswara Rao *et al*., 2008). Even though the seeds of those oil crops are crushed and expelled to produce raw oil with locally available facilities, as the biodiesel production facilities especially the transesterification technology is not available in the rural areas, the raw oil and uncrushed seeds are sold and disposed for further processing and the benefit of growing these oil crops are not directly realized. Here the need for a simple, compact biodiesel processor using transesterification process is felt, as the formers themselves can produce biodiesel using the oil crops they grown. Keeping all these factors in mind, this study was undertaken to develop a simple, compact biodiesel processor so that the formers can produce biodiesel in their own farms and the same biodiesel can be used in their fields for various operations.

Since Jatropha is an experimentally proven non-edible vegetable oil for engine application (Forson *et al*., 2004; Verma and Gaur, 2009) and also available in most of the Indian rural belts, the same is a promising factor to produce biodiesel at Indian context. But India being a large country where rainfall, soil type, nutrition content of the soil, temperature and other factors vary from region to region. The physical and chemical properties of Jatropha Curcas oil are strongly influenced by processing, session e.g. climatic condition and geographical influences during the growth of the seed. This study focused on Jatropha Curcas oil extracted from the feed stock grown in the southern states of India especially the western ghat region for the production of biodiesel by alkali catalyst based transesterification process and the biodiesel produced was used as fuel in a single cylinder, diesel engine coupled with electric generator for power generation.

MATERIALS AND METHODS

The objective of this study was to convert the locally available Jatropha Curcas oil, especially from the western ghat region of south India into methyl esters using alkali based transesterification. The raw Jatropha oil was obtained from Ms. Renulakshmi agro Industries India Private Limited, Coimbatore. South India. All the chemicals used were of analytical grade.

ARPN Journal of Engineering and Applied Sciences

Property analysis

The tests were conducted at Ace Test Labs and Consultancy (ATLaC), Cochin, South India, an approved testing laboratory of Government of Kerala, South India to measure the various physical and chemical properties of the Jatropha Curcas oil and Jatropha biodiesel.

Development of biodiesel processor

A batch type biodiesel processor of 4 litre capacity (Figure-1) was locally developed at C.S.I. College of Engineering, Ketti, South India, which mainly consists of:

1. SS reaction vessel (4 litre)
2. SS water bath (15 litre)

It was also provided with motorized stirrer and electrical heating arrangement. The water bath was heated by an Electrical heater of 1500 W. The stainless steel reaction vessel was covered with lid having provisions to fix the thermometer, stirrer and condenser which condenses the evaporated methanol during the process.

Figure-1. Biodiesel processor.

Transesterification process

Base catalyzed transesterification process was selected as it is simple process and requiring low temperature (Thiruvengadaravi *et al*., 2009; Palaniswamy *et al*., 2009). The transesterification process is the reaction of a tri - glyceride with an alcohol to form esters and glycerol. The alcohol reacts with the fatty acids to form the mono - alkyl esters or biodiesel and crude glycerol (Peterson *et al*., 1994). Since methanol was used in this process it is called methonolysis. Potassium hydroxide (KOH) was used as base catalyst.

$$\begin{array}{llllll} CH_2-OOC-R_1 & & & & R_1-COO-CH_3 & CH_2-OH \\ CH-OOC-R_2 & + & 3CH_3-OH & \xrightarrow[\text{60-70°C}]{\text{KOH}} & R_2-COO-CH_3 & +CH-OH \\ CH_2-OOC-R_3 & & & & R_3-COO-CH_3 & CH_2-OH \\ \text{(Triglyceride)} & + & \text{(methanol)} & & \text{(biodiesel)} & +\text{(glycerol)} \end{array}$$

Process parameters

The important factors that affects the conversion of vegetable oil into biodiesel are time of the reaction, alcohol quantity used, type of catalyst, quantity of catalyst used, temperature of the reaction (Demirbas, 2003; Vivek and Guptha, 2004; Vipan and Jatinder, 2008). Normally reaction is conducted at a temperature close to the boiling point of methanol; 60^0C to 70^0C at atmospheric pressure. Further increase in temperature was reported to have a negative effect on the conversion (Srivastava and Prasad, 2000). The amount of catalyst required is based on the amount of free fatty acid present in the oil. (Hanny and Shizuko, 2008; Naveen, 2008). Most of the researchers used 0.4 to1.5% KOH/NAOH by weight of oil for bio diesel production (Singh and Saroj, 2009; Tint and Mya, 2009; Surendra and Subhash 2008; Purnanand *et al*., 2009). The stoichiometry of transesterification reaction requires three mol of alcohol per mol of triglyceride to yield three mol fatty ester and one mol glycerol. Lower molar ratio of alcohol to oil required higher reaction time (Kalbande *et al*., 2008). With higher molar ratio, the conversion increased but the recovery decreased due to poor separation of glycerol (Srivastava and Prasad, 2000). Most researchers used molar ratio of 6:1(alcohol: oil). However an excess amount of alcohol is always used to shift the reaction in forward side. Based on the above discussion the process parameters as given in Table-1 were selected for biodiesel production.

ARPN Journal of Engineering and Applied Sciences

Table-1. Process parameters selected.

Process parameters	Specification
Process selection	Alkali catalyzed transesterification
Reaction temperature	60^0C
Oil sample used	2000 ml of Jatropha Curcas oil
Methyl alcohol	6 mol /1 mol of oil
Catalyst used	2.09%w/w of oil (19 g/lit of oil)
Settling time	10-12 hrs
Speed of stirrer	400-500 rpm

Bio diesel production process

A known quantity (2000ml) of raw Jatropha Curcas oil was first filtered to remove the solid particles. The Jatropha Curcas oil was then heated up to 110^0 C for removal of moisture. Then the oil was cooled down up to 60^0C and taken in to the reaction vessel. The temperature was maintained throughout the process reaction with the help of water bath and temperature regulator. Required amount of KOH was weighed using electronic balancing machine and dissolved completely in the required amount of methanol. This alkali methoxide (MeOH) was added in to the oil in the reaction vessel and the mixture was stirred continuously using motorized stirrer arrangement throughout the reaction. During the reaction alcohol gets vaporized. To prevent any reaction loss a condenser was used to recover the alcohol vapour and reflux it back to reactor. The reaction was carried out for 90 minutes.

The products of the reaction were then transferred to a separating funnel and allowed to settle over night (12-15 hrs) by gravity separation into Jatropha methyl ester (biodiesel) at the top and the glycerol at the bottom by density difference. Next day the glycerol was drained out leaving the biodiesel at the top. This raw biodiesel was collected and water washed to remove the soapanified products and excess catalyst.

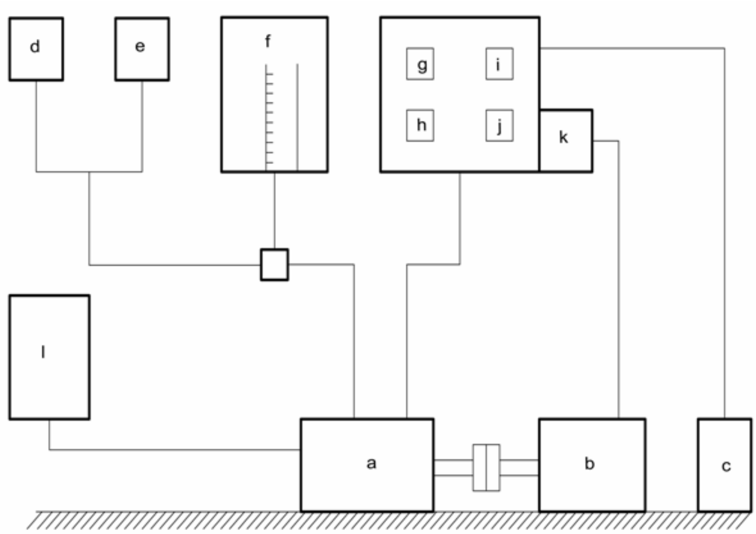
Experiments were designed and conducted by varying the catalyst amount, quantity of the methanol in order to investigate the effect of variables on the biodiesel yield. The reaction parameters selected for different experiment conditions were methanol to oil molar ratio (6:1, 6.75:1, and 7.5:1), catalyst concentrations (1.87, 2.09, 2.31 %w/w of oil) and all experiments were conducted at 60^oC. The reaction parameters for different experiment conditions are given in Table-2.

Table-2. Different experiment parameters.

Run no.	**Oil** (ml)	**Methanol to oil molar ratio**	**KOH % w/w of oil**
1	2000	7.5:1	1.87
2			2.09
3			2.31
4		6.75:1	1.87
5			2.09
6			2.31
7		6:1	1.87
8			2.09
9			2.31

Engine performance test

The biodiesel produced using biodiesel processor was used to run a four stroke diesel engine coupled with an electric generator (schematic is given in Figure-2). The performance test was conducted at different load conditions using neat biodiesel as fuel and also with the petro diesel and raw Jatropha Curcas oil as fuel.



a. Diesel engine b. Alternator c. Rheostat Arrangement d&e. Fuel Tanks f. Fuel Measuring burette g.Voltmeter h.Ammete i&j.Temprature Indicators k. Energy Meter l. Air Tank

Figure-2. Lay out of the engine test rig.

ARPN Journal of Engineering and Applied Sciences

RESULT AND DISCUSSIONS

Physical and chemical properties of raw Jatropha Curcas oil

The physical and chemical properties of raw Jatropha Curcas oil were determined. The values are given in Table-3. It was observed that the kinematic viscosity of the raw Jatropha oil was very high (40.28mm^2/sec). High viscosity affects the flow characteristics of the oil causes improper atomization of the fuel and incomplete combustion. (Emil *et al*., 2009; Yogendra *et al*., 2008). The high acid value (13.7 mg KOH/g oil) of the Jatropha oil indicates that the free fatty acid content of the oil was high which is not a desirable value. Normally conversion of oil into biodiesel by transesterification is complicated if it contains higher amount of FFA (more than 4 mg KOH/g) content in the oil (Thiruvengadaravi *et al*., 2009) and the amount of catalyst required will also be high to neutralize the free fatty acids.

Table-3. Physical and chemical properties of raw Jatropha Curcas oil.

Property	Value
Specific gravity	0.9107
Calorific value	9002 kcal/kg
Acid no	13.76 mg KOH/g oil
Kinematic viscosity	40.28 mm^2/sec
Flash point	220^{0}C
Cetane no	51
Iodine value	110.5
Soaponification value	192
Moisture content	0.06%w/w
Peroxide value	1.93
Sulphur content	0.02%w/w
Refractive index	1.46

Physical and chemical properties of biodiesel prepared

The properties of biodiesel produced from Jatropha Curcas oil was measured and compared with ASTM specifications and the results are presented in the Table-4.

The acid value of the raw Jatropha oil (13.7 mg KOH/g oil) was reduced to 0.14 mg KOH/g of oil. Cetane Number of the biodiesel was considerably increased and well within the ASTM specified limit which indicates the better combustion quality of the fuel (Tint and Mya, 2009). The flash point of the biodiesel from Jatropha oil was 105^{0}C and it was lower than the ASTM specification and indicates it is safer than petro diesel to handle and store because it has a little bit higher flash point than petro diesel. The decrease in kinematic viscosity from 40.28 mm^2/sec to 4.2 mm^2/sec was an important fuel property of transesterified Jatropha Curcas oil. This indicates that the flow capability of raw Jatropha Curcas oil has been increased to a significant extent by transesterification. This increase in fuel's ability to flow would increase complete burning of the fuel without any ignition delay. The specific gravity of the biodiesel was 0.887 and it was also reduced to a significant extent when compared to specific gravity of the raw Jatropha Curcas oil which was 0.9107.

Table-4. Analysis of physical and chemical properties of biodiesel produced.

Property	Value	ASTM standard
Specific gravity	0.887	-
Calorific value	9486 kcal/kg	-
Acid No. mg KOH/g oil	0.14	0.50 maximum
K. viscosity mm^2/sec	4.2	1.9 - 6.0 mm^2/sec
Flash point	105^{0}C	130^{0}C min
Cetane No.	52.3	47 min
Iodine value	109	-
Soaponification value	186	-
Moisture content	0.03%w/w	0.05% v/v max
Peroxide value	1.72	-
Sulphur content	NIL	15ppm max
Refractive index	1.43	-

The yield quantity of biodiesel production

The biodiesel yield of transesterification process for different variable conditions of KOH and methanol are shown in Figure-3 and it is evident that the biodiesel processor is capable of producing biodiesel sufficient enough to run the farm engines on day today basis for agricultural applications on a small scale. But the yield was affected by the amount of catalyst and methanol used. The maximum yield of biodiesel (80.5%) was obtained at catalyst concentration 2.09% w/w of oil and methanol to oil ratio 7.5:1.

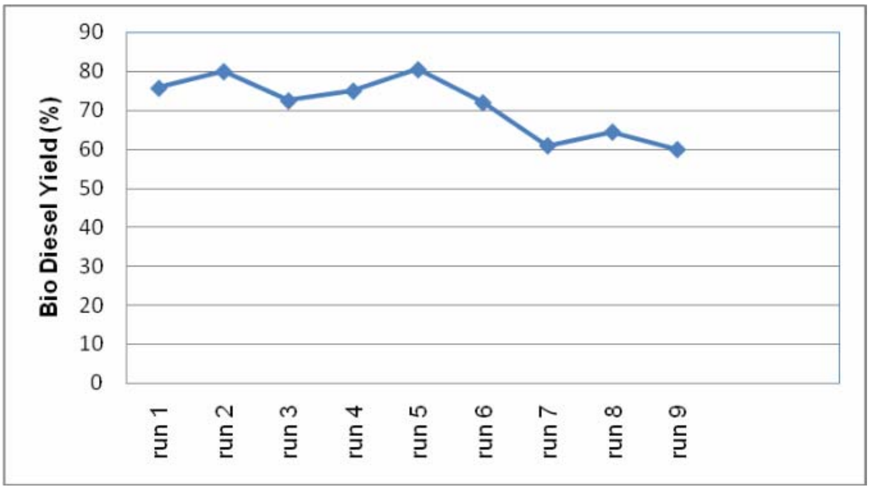


Figure-3. Biodiesel yield at different variable conditions.

Determination of engine performance

The biodiesel produced by biodiesel processor using transesterification process was used to run a four stroke diesel engine coupled with an electric generator. The engine was also run using petro diesel and 100% raw Jatropha Curcas oil as fuel and comparisons are made with the performance of the biodiesel produced. The overall efficiency of the engine coupled electric generator at different load conditions were measured and given in Figure-4. It is evident that the overall efficiency using biodiesel as fuel was more than the overall efficiency of the engine using petro diesel and raw Jatropha oil as fuels at all load conditions. This is mainly because of the oxygen content available in the biodiesel which improves the combustion process.

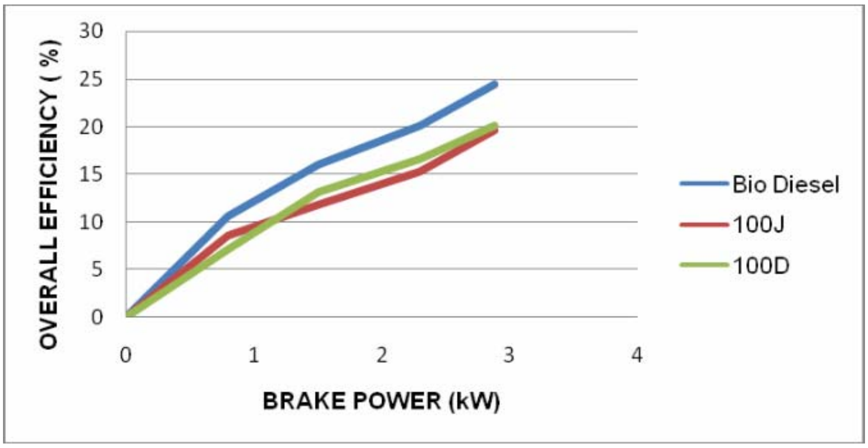


Figure-4. Overall efficiency at different load conditions.

CONCLUSIONS

Jatropha Curcas oil from western ghat region of south India was selected as a feed stock for biodiesel production as it is locally available. The biodiesel processor developed was capable of producing biodiesel from Jatropha Curcas oil by alkali catalyst based transesterification and produced a maximum of 80.5% biodiesel under optimum conditions. The physical and chemical properties of biodiesel produced meet the ASTM specifications, especially the kinematic viscosity and acid value were reduced to the significant extent and the cetane number was increased as compared to raw Jatropha Curcas oil. The reason for the lower yield was the high Free Fatty acid content of the raw Jatropha oil.

ACKNOWLEDGEMENTS

The author expresses their thanks to the Management of CSI College of Engineering, Ketti, South India for their support in developing the biodiesel processor and to Ms. Renulakshmi of Agro Industries India Private Limited, Coimbatore, South India for their support by providing raw Jatropha Curcas oil.

REFERENCES

Hanumantha Rao Y.V., Ram sudheer Voleti, HariharanV. S., Sitharama Raju A.V. and Nageswara Reddy P. 2009. Use of Jatropha oil methyl ester and its blends as an alternative fuel in diesel engine. Journal of the Brazilian society of Mechanical sciences and Engineering. 31(3): 253-260.

Singh R.K. and Saroj K Padhi. 2009. Characterization of Jatropha oil for the preparation of biodiesel. Natural product radiance. 8(2): 127-132.

Kalbande S.R., More G.R. and Nadre R.G. 2008. Biodiesel production from Non - edible oils of Jatropha and Karanja for utilization in Electrical Generator. Bioenergy research. 1: 170-178.

Hanny Johanes, Berchmans and Shizuko Hirata. 2008. Biodiesel production from crude *Jatropha curcus* L. seed oil with a high content of free fatty acids. Bioresource technology. 99: 1716-1721.

Venkateswara Rao T., Prabhakar Rao G. and Hema Chandra Reddy K. 2008. Experimental Investigation of Pongamia, Jatropha and Neem Methyl Esters as Biodiesel on C.I. Engine. Jordan Journal of Mechanical and Industrial Engineering. 2: 117-122.

Forson F.K., Oduro E.K. and Hammond-Donkoh E. 2004. Performance of Jatropha oil blends in diesel engine. Renewable Energy. 29(7): 1135-1145.

Verma K.C. and Gaur A.K. 2009. *Jatropha Curcas* L. Substitute for Conventional Energy. World Journal of Agricultural Sciences. 5(5): 552-556.

Thiruvengadaravi K.V., Nandhagopal J., Sathya Selva Bala, V., Dinesh Kirupha, S., Vijayalakshmi P. and Sivanesan S. 2009. Kinetic study of the estrification of free fatty acids in non-edible Pongammia pinnata oil using acid catalyst. Indian Journal of Science and Technology. 2(12): 20-24.

Palaniswamy E., Manjula and Manoharan N. 2008. Effective Methods for Converting Non-edible Vegetable Oil In to Methyl Esters. Institute of Engineers (India) Journal. 89: 11-13.

Peterson C.L., Korus R.A., Mora P G and Madson J.P. 1991. Fumigation with propane and transesterification effect on injector choking with vegetable oil fuels. Trans. of the ASAE. 30(1): 28-35.

Demirbas A. 2003. Biodiesel fuels from vegetable oils via catalytic and non-catalytic supercritical alcohol transesterification and other methods; a survey. Energy conservation and management. 44: 2093-2109.

Vivek and Guptha A.K. 2004. Biodiesel production from Karanja oil. Journal of Scientific and Industrial research. 63: 39-47.

Vipan Kumar and Jatinder Kumar. 2008. Kinetics of *Jatropha Curcas* transesterification in batch reactor. Proceedings of the world congress on Engineering and Copmputerscience. San Francisco.

Srivastava A. and Prasad R. 2000. Triglycerides based diesel fuels. Renewable and Sustainable Energy Reviews. 4: 111-133.

Naveen Kumar. 2007. Production of biodiesel from high FFA rice brain oil and its utilization in a small capacity diesel engine. Journal of scientific Industrial research. 66: 399-402.

Tint Tint Kywe and Mya Mya Oo. 2009. Production of biodiesel from Jatropha Oil (*Jatropha Curcas*) in pilot plant. World academy of Science, Engineering and Technology. 50: 477-483.

Surendra R Kalbande and Subhash D Vikhe. 2008. Jatropha and Karanja Bio fuel: An alternate fuel for diesel engine. ARPN Journal of Engineering and Applied Sciences. 3(1): 7-13.

Emil Akbar, Zahira Yaakob, Siti Kartom Kamarudin, Manal Ismail and Jumat Salimon. 2009. Characteristic and Composition of Jatropha Curcas Oil seed from Malaysia and its potential as biodiesel feedstock. European Journal of Scientific Research. 29(3): 396-403.

Yogendra S. Kushwah, Mahantha P. and Subash C. Mishra. 2008. Some studies on fuel characteristics of Mesua Ferrea. Heat transfer Engineering. 29(4):1-5.

Sanjay Gandhi Bojan, Senthil Kumaran Durairaj and Sam Chelladurai. 2010. Response Surface Methodology for Optimization of Biodiesel Production from high FFA *Jatropha Curcas* Oil. International Journal of Green Energy. Article in press.