Biodiesel production from jatropha oil and its characterization

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Abstract:

Biodiesel, a promising substitute as an alternative fuel has gained significant attention due to the predicted shortness of conventional fuels and environmental concern. The utilization of liquid fuels such as biodiesel produced from Jatropha oil by transesterification process represents one of the most promising options for the use of conventional fossil fuels. The Jatropha oil is converted into jatropha oil methyl ester known as biodiesel prepared in the presence of homogeneous acid catalyst. The physical properties such as density, flash point, Kinematic viscosity, Cloud point and Pour point were found out for Jatropha oil and Jatropha methyl ester. The same characteristics study was also carried out for the diesel fuel for obtaining the base line data for analysis. The values obtained from the Jatropha methyl ester is closely matched with the values of conventional diesel and can be used in the existing diesel engine without any modification.

Key words: jatropha oil, transesterification, biodiesel

Introduction:

Biodiesel is an alternative fuel made from renewable biological sources such as vegetable oils both (edible and non edible oil) and animal fats. Vegetable oils are usually esters of glycol with different chain length and degree of saturation. It may be seen that vegetable contains a substantial amount of oxygen in their molecules.

Practically the high viscosity of vegetable oils (30-200 Centistokes) as compared to that to Diesel (5.8-6.4 Centistokes) leads to unfavorable pumping, inefficient mixing of fuel with air contributes to incomplete combustion, high flash point result in increased carbon deposit formation and inferior coking. Due to these problems, vegetable oil needs to be modified to bring the combustion related properties closer to those of Diesel oil. The fuel modification is mainly aimed at reducing the viscosity and increasing the volatility.

One of the most promising processes to convert vegetable oil into methyl ester is the transesterification, in which alcohol reacts with triglycerides of fatty acids (vegetable oil) in the presence of catalyst. Jatropha vegetable oil is one of the prime non edible sources available in India. The vegetable oil used for biodiesel production might contain free fatty acids which will enhance saponification reaction as side reaction during the transesterification process.

All countries are at present heavily dependent on petroleum fuels for transportation and agricultural machinery. The fact that a few nations together produce the bulk of petroleum has led to high price fluctuation and uncertainties in supply for the consuming nations. This in turn has led them to look for alternative fuels that they themselves can produce. Among the alternatives being considered are methanol, ethanol, biogas and vegetable oils. Vegetable oils have certain features that make them attractive as substitute for Diesel fuels.

Vegetable oil has the characteristics compatible with the CI engine systems. Vegetable oils are also miscible with diesel fuel in any proportion and can be used as extenders. India highly depends on import of petroleum crude and nearly two third of its requirement is met through imports. Moreover the gases emitted by petrol, diesel driven vehicles have an adverse effect on the environment and human health.

Source of jatropha Oil: The plant that is generally cultivated for the purpose of extracting jatropha oil is Jatropha curcas. The seeds are the primary source from which the oil is extracted. Owing to the toxicity of jatropha seeds, they are not used by humans. The major goal of jatropha cultivation, therefore, is performed for the sake of extracting jatropha oil.

Analysis of jatropha curcus seed shows the following chemical compositions.
Moisture: 6.20%
Protein: 18.00%
Fat: 38.00%
Carbohydrates: 17.00%
Fiber: 15.50%
Ash: 5.30%

The oil content is 25-30% in the seed. The oil contains 21% saturated fatty acids and 79% unsaturated fatty acids. These are some of the chemical elements in the seed, cursin, which is poisonous and render the oil not appropriate for human consumption.

Oil has very high saponification value and being extensively used for making soap in some countries. Also oil is used as an illuminant in lamps as it burns without emitting smoke. It is also used as fuel in place of, or along with kerosene stoves.

Jatropha curcus oil cake is rich in Nitrogen, Phosphorous and Potassium and can be used as organic manure. By thermodynamic conversion process, pyrolysis, useful products can be obtained from the jatropha oil cake. The liquid, solid (char), and gaseous products can be obtained. The liquid can be used as fuel in furnace and boiler. It can be upgraded to higher grade fuel by transesterification process.

It is significant to point out that, the non edible vegetable oil of jatropha curcus has the requisite potential providing a promising and commercially viable alternative to diesel oil since it has desirable physical chemical and performance characteristics comparable to diesel. Cars could be run with jatropha curcus without requiring much change in design.

Jatropha oil expelled from seeds and filtered through filter press can replace kerosene or oil lamp. Jatropha oil can be used as liquid fuel for lighting and cooking. It will also be used in big Diesel engine based electricity generating sets, pump sets, heavy farm machinery, where the viscosity of oil is not an issue.

The seeds of jatropha contain (50% by weight) viscous oil which can be used for manufacture of candles and soap, in the cosmetic industry, for cooking and lighting by itself or as a Diesel /paraffin substitute or extender. The latter use has important implications for meeting the demand for rural energy services and also exploring practical substitute for fossil fuels to counter green house gas accumulation in the atmosphere.

Jatropha curcus as an energy source: Oil from jatropha curcus: There are number of variety of jatropha. Best among these are jatropha curcus. Jatropha oil is an important product from the plant for meeting the cooking and lighting needs of the rural population, boiler fuel for industrial purpose or as a viable substitute for Diesel. About one- third of the energy in the fruit of jatropha can be extracted as oil that has a similar energy value to Diesel fuel. Jatropha oil can be used directly in Diesel engines added to Diesel fuel as an extender or transesterified to a bio-diesel fuel. There are some technical problems to using jatropha oil directly in Diesel engines that have yet to be completely overcome. Moreover, the cost of producing jatropha oil as a Diesel substitute is currently higher than the cost of Diesel itself.

Other products of Jatropha curcus: The jatropha oil can be used for soap production and cosmetics production in rural areas. The oil is a strong purgative, widely used as an antiseptic for cough, skin diseases and as a pain reliever from rheumatism. Jatropha oil has been used commercially as a raw material for soap manufacture for decades, both by large and small industrial producers.

When jatropha seeds are crushed, the resulting jatropha oil can be processed to produce a high-quality biodiesel that can be used in a standard diesel car, while the residue (press cake) can also be processed and used as biomass feedstock to power electricity plants or used as fertilizer (it contains nitrogen, phosphorous and potassium).

Use as jet fuel: Aviation fuels may be more widely substituted with biofuels such as jatropha oil than fuels for other forms of transportation. On December 30, 2008, Air New Zealand flew the first successful test flight with a Boeing 747 running one of its four Rolls-Royce engines on a 50:50 blend of jatropha oil and jet A-1 fuel. Subsequently, Air New Zealand and Houston based Continental Airlines have run tests in Jan. 2009, further demonstrating the viability of jatropha oil as a jet fuel.

Variations in the Yield of Jatropha Oil: It is often considered that a more effective extraction technique would yield greater quantities of oil. This is partly inaccurate, since an effective extraction method would only yield the optimum quantity and not more than that. The optimum oil content in jatropha plants varies between species and genetic variants.

Climatic and soil conditions generally affect the yield of the oil as well. However, improper processing techniques such as prolonged exposure of the harvested seeds to direct sunlight can impair the oil yield considerably. The maximum oil content that has been reported in jatropha seeds has been close to 47%. However, the accepted average is 40%, and the fraction that can be extracted is taken to be around 91%.

Methods and Devices for Jatropha Oil Extraction

Some of the methods that are usually employed for the extraction of jatropha oil are as follows

Oil Presses: Oil presses have been used for the purpose of oil extraction as simple mechanical devices - either powered or manually driven. Among the different oil presses that are used for jatropha oil extraction, the most commonly used presses include the Bielenberg ram press.

The Bielenberg ram press involves the traditional press method to extract oil and prepares oil cakes as well as soaps. It is a simple device that yields around 3 liters of oil per 12 kg of seed input. Since the recognition of jatropha as an alternative energy sources (namely, biofuel), jatropha oil extraction methods have also gained due importance in the market. Since jatropha oil is the primary ingredient required in the production of biofuels, the development of oil extraction methods and the optimization of existing methods of extracting the oil have become significant.

Oil Expellers: Different kinds of oil expellers are used for the purpose of jatropha oil extraction. The most commonly used ones are the Sayari oil expeller (also called the Sundhara oil expeller) and the Komet Expeller. The Sayari expeller is a diesel-operated oil extraction device that was originally developed in Nepal. It is now being developed for use in Tanzania and Zimbabwe for the purpose of jatropha oil extraction and oil cake preparation. The prototype included heavy parts made of cast iron. The lighter version has the cast iron replaced with iron sheets. A model driven by electricity is also available. The Komet expeller is a single-screw oil expeller that is often used for extracting jatropha oil from the seeds and also for the preparation of oil cakes.

Traditional Methods: Traditional methods by which the oil is extracted from the seeds by hand using simple implements are still practiced in rural and less developed areas.

Modern Concepts: Methods like ultrasonication have been discovered to be effective in increasing the percentage of jatropha oil that can be extracted using chemical methods like aqueous enzymatic treatment. The optimum yield for such methods has been discovered to be around 74%. Jatropha oil extraction methods are still being researched. The goal of such researches is to discover methods to extract a greater percentage of jatropha oil from the seeds than the current procedures allow.

Oil Extraction:
Oil Extraction may be done:
Mechanically (by pressing the kernels)
Chemically; and
Enzymatically

Production Process
Transesterification: Is the process of chemically reacting a fat or oil with an alcohol in a presence of a catalyst. Alcohol used is usually methanol or ethanol Catalyst is usually sodium hydroxide or potassium hydroxide. The main product of transesterification is biodiesel and the co-product is glycerin

Separation: After transesterification, the biodiesel phase is separated from the glycerin phase; both undergo purification .The chemical properties of jatropha oil are given below.

Item	Value
Acid Value	38.2
Saponification value	195.0
Iodine Value	101.7
Viscosity (at 31°C), Centistokes	40.4
Density (g/cm³)	0.92

Fatty acid composition

Palmitic acid (%)	4.2
Stearic acid (%)	6.9
Oleic acid (%)	43.1
Linoleic acid (%)	34.3
Other acids (%)	1.4

Jatropha curcas seed

Jatropha curcas plant

Experimental procedure

Neutralization: The vegetable oil contains about 14-19.5 % free fatty acids in nature, it must be freed before taken into actual conversion process. The presence of about 14% of free fatty acid makes Jatropha oil inappropriate for industrial biodiesel production.

The dehydrated oil is agitated with 4 % HCl solution for 25 minutes and 0.82 gram of NaOH was added per 100 ml of oil to neutralize the free fatty acids and to coagulate by the following reaction.
$RCOOH + NaOH \rightarrow RCOONa + H_2O$

The coagulated free fatty acid (soap) is removed by filtration. This process brings the free fatty acid content to below 2 % and is perfect source for biodiesel production.

Biodiesel production: In this study, the base catalyzed transesterification is selected as the process to make biodiesel from Jatropha oil. Transesterification-ion reaction is carried out in a batch reactor.

For transesterification process 500 ml of Jatropha oil is heated up to 70°C in a round bottom flask to drive off moisture and stirred vigorously. Methanol of 99.5 % purity having density0.791 g/cm³ is used. 2.5 gram of catalyst NaOH is dissolved in Methanol in bi molar ratio, in a separate vessel and was poured into round bottom flask while stirring the mixture continuously. The mixture was maintained at atmospheric pressure and 60°C for 60 minutes.

After completion of transesterification process, the mixture is allowed to settle under gravity for 24 hours in a separating funnel. The products formed during transesterification were Jatropha oil methyl ester and Glycerin. The bottom layer consists of Glycerin, excess alcohol, catalyst, impurities and traces of unreacted oil. The upper layer consists of biodiesel, alcohol and some soap. The evaporation of water and alcohol gives 80-88 %pure glycerin, which can be sold as crude glycerin is distilled by simple distillation.

Jatropha methyl ester (biodiesel) is mixed, washed with hot distilled water to remove the unreacted alcohol; oil and catalyst and allowed to settle under gravity for 25 hours. The separated biodiesel is taken for characterization.

Biodiesel Characterization

The specific gravity reduces after transesterification, viscosity from 57 to 4.73 centistokes, which is acceptable as per ASTM norms for Biodiesel.

Flash point and fire point are important temperatures specified for safety during transport, storage and handling. The flash point and fire point of biodiesel was found to be 128°C and 136°C respectively. Flash point of Jatropha oil decreases after transesterification, which shows that its volatile characteristics had improved and it is also safe to handle.

Higher density means more mass of fuel per unit volume for vegetable compared to diesel oil. The higher mass of fuel would give higher energy available for work output per unit volume.

Higher viscosity is a major problem in using vegetable oil as fuel for diesel engines. Cloud and pour point are criterion used for low temperature performance of fuel. The cloud point for Diesel is 4°C which is very low and the fuel performs satisfactorily even in cold climatic conditions. The higher cloud point can affect the engine performance and emission adversely under cold climatic conditions. The pour point for Diesel is -4°C. In general higher pour point often limits their use as fuels for Diesel engines in cold climatic conditions. When the ambient temperature is below the pour point of the oil, wax precipitates in the vegetable oils and they loose their flow characteristics, wax can block the filters and fuel supply line. Under these conditions fuel cannot be pumped through the injector. In India, ambient temperatures can go down to 0°C in winters.

Fuels with flash point above 66°C are considered as safe fuel.

Conclusion

In the current investigation, it has confirmed that Jatropha oil may be used as resource to obtain biodiesel. The experimental result shows that alkaline catalyzed transesterification is a promising area of research for the production of biodiesel in large scale.

Effects of different parameters such as temperature, time, reactant ratio and catalyst concentration on the biodiesel yield were analyzed. The best combination of the parameters was found as 6:1 molar ratio of

Methanol to oil, 0.92% NaOH catalyst, 60°C reaction temperature and 60 minutes of reaction time The viscosity of Jatropha oil reduces substantially after transesterification and is comparable to diesel. Biodiesel characteristics like density, viscosity, flash point, cloud point and pour point are comparable to diesel.

References

1. Gubitz G.M. et al edition, Biofuels and Industrial products from jatropha curcas, proceedings from a symposium held in Mamagua, Nicaragua, Technical University of Graz, Uhlandgasse, Austria **(1997)**

2. Henning R., The Jatropha project in Mali, Rothkreuz 11, D-88138, weissens-berg, Germany **(1997)**

3. Maauwa B., Economic feasibility study plant oil fuel project, 6 msasa Avenue, Norton, Zimbabwe **(1995)**

4. Zimbabwe Biomass News Plant oil Zimbabwe sustainable fuel for the future, BUN-Zimbabwe, P/Bas 7768, Causeway, Zimbabwe **1(2), (1996)**

5. Heller J., Physic nut, Jatropha carcass promoting the conservation and use of underutilized and neglected crops. International Plant Genetic Resources Institute (IPGRI), Rome, Italy, **(1996)**

6. Barn Wall B.K. and Shama M.P., Prospects of Biodiesel Production from Vegetable oils in India, I, **9**, 363-378, **(2005)**

7. Morrison R.T., Boyd R.N., Organic Chemistry, 6th edition, 771-778 **(2002)**

8. Igwe I.O., The effect of temperature on the viscosity of vegetable oils in solution, *Industrial crops and products,* **19**, 189-190, **(2004)**

9. Hass M.J., Scott K.M., Marmer W.N. and Foliga T.A., In situ alkaline transesterification; an effective method for the production of fatty acid esters from vegetable oils, *J. A.M. oil chem.*, SOC **81**, 81-89 **(2004)**

10. Lim D.G., Soares V.C.D., Ribeiro E.B., Carvalho D.A., Cardoss E.C.V., Rassi F.C., Mundim K.C., Rubin J.C., and Suarez P.A.Z., Diesel-like fuel obtained by Pyrolysis of Vegetable oil, *Journal of Analytical and Applied Pyrolysis*, **71**, 987-998 **(2004)**

11. Altin R., Cetinkaya S. and yucesu H.S., The Potential of using Vegetable oil fuels as fuel in Diesel engines, *Energy Conservation an Management*, **42,** 529-538 **(2001)**

12. Demiras A., A Direct Route to the calculation of the Heating values of liquid fuels by using their density and viscosity measurement, *Energy Conservation and Management*, **41,** 1609-1614 **(2000)**

13. Ramadhas A.S., Jayaraj S. and Muraleedharan, C., Use of Vegetable in I.C. Engines- Review, *Renewable energy,* **29,** 727-742, **(2004)**

14. Demirbas, A., Fuel properties and calculation of higher heating values of vegetable oils, *Fuel,* **77 (9/10)**, 1117-1120 **(1998)**

Table-1: The properties, Diesel, Jatropha oil and biodiesel

Property	Diesel	Jatropha oil	Biodiesel
Flash point ^oC	65	214	128
Fire point ^oC	78	256	136
Pour point ^oC	-6	6	-2
Cloud point ^oC	5	11	8
Viscosity at 40^oC	2.86	36.92	4.82
Viscosity index	98	181	154
Specific gravity (29^oC)	0.792	0.944	0.84
Refractive index at 40^oC	1.32	1.61	1.46
Calorific value (MJ/kg)	44.34	39.76	42.80