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Sustainable Energy Production from *Jatropha* Bio-Diesel

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ABSTRACT

The demand for petroleum has risen rapidly due to increasing industrialization and modernization of the world. This economic development has led to a huge demand for energy, where the major part of that energy is derived from fossil sources such as petroleum, coal and natural gas. Continued use of petroleum sourced fuels is now widely recognized as unsustainable because of depleting supplies. There is a growing interest in using Jatropha curcas L. oil as the feedstock for biodiesel production because it is non-edible and thus does not compromise the edible oils, which are mainly used for food consumption. Further, J. curcas L. seed has a high content of free fatty acids that is converted in to biodiesel by trans esterification with alcohol in the presence of a catalyst. The biodiesel produced has similar properties to that of petroleum-based diesel. Biodiesel fuel has better properties than petro diesel fuel; it is renewable, biodegradable, non-toxic, and essentially free of sulfur and aromatics. Biodiesel seems to be a realistic fuel for future. Biodiesel has the potential to economically, socially, and environmentally benefit communities as well as countries, and to contribute toward their sustainable development.

Keywords : Biodiesel; Jatropha Curcas; Trans Esterification; Free Fatty Acids; Sustainable Development.

1 INTRODUCTION

ENERGY is a basic requirement for economic development. Every sector of Indian economy agriculture, industry transport, commercial and domestic needs input of energy. The economic development plans implemented since independence have necessarily required increasing amount of energy. As a result consumption of energy in all forms has been steadily rising all over the country. This growing consumption of energy has also resulted in the country becoming increasingly dependent on fossil fuels such as coal, oil and gas. Rising prices of oil and gas and potential shortage in future lead to concern about the security of energy supply needed to sustain our economic growth. Increased use of fossil fuels also causes environmental problems both locally and globally (Jain and Sharma 2010). Sustainable energy refers to the “meeting the energy presents without the compromising the ability of future generation to meet their own needs”. In India, the consumption of crude oil was about 184.68 MT for the year 2007–2008, but 80% of this production was met by import (TEDDY, 2007). The share of high-speed diesel was about 36% in the above production. The rate of energy consumption is increasing at the rate of 6.5% per annum while reserves for petroleum oil are decreasing day by day. India’s share of crude oil production is about 1% of total world crude oil production while in consumption; its share is about 3.1% of total world consumption (Energy Statistics 2003-2004). The import of crude oil has increased from 63% in 1971 to 80% in 2007–2008. The demand of high-speed diesel (HSD) is projected to grow from 39.81 MT in 2001–2001 to52.32 MT in 2007–2008 at the rate of 5.6% per annum (Subramanian et al. 2008). The scarcity of conventional fossil fuels, growing emissions of combustion-generated pollutants, and their increasing costs will make biomass sources more attractive (Sensoz, S. et al. 2000). Petroleum-based fuels are limited reserves concentrated in certain regions of the world. These sources are on the verge of reaching their peak production (Ayhan Demirbas. 2009). The fossil fuel resources are shortening day by day. The scarcity of known petroleum reserves will make renewable energy sources more attractive (Sheehan, J.et al. 1998).

2 BIOFUEL

Biofuels, particularly liquid ones like ethanol and biodiesel, has been felt by most of the countries and their governments have been trying to promote these fuels. The advantages of biofuel are manifold, as derived from renewable sources it will not be depleted (unlike fossil fuels) and thus provides energy security to a country over a much longer time horizon; it has a greater employment generating effect at the stages of agricultural production and processing into fuel, and it also saves the country from the leakage of foreign exchange required for buying fossil fuel. Since the use of biofuels was not in practice in most of the countries, there has been the need to promote institutions involving cultivation of energy crops, biofuel production, market, consumption, distribution, etc., which usually take time. Different countries have adopted different policies and strategies, ranging from mandating the blending ratio of biofuel in fossil fuel to direct and indirect subsidies in order to create market demand and indigenous supply, to facilitate vehicle manufacturers to modify engines suitable for the use of biofuel, to convince the consumers of the benefits of biofuels and to habituate them to biofuels. India declared its biofuel policy in which biodiesel, primarily from jatropha, would meet 20% of the diesel demand beginning with 2011–2012. The focus in India is primarily on biodiesel as diesel is presently the most important vehicle fuel and its demand is growing at rapid rate. In spite of the efforts made by the state, production of biodiesel, however, has not picked up at all. Doubt arises as to whether the country will be able to meet the target. Looking at the potential resources one may find no reason why it should not be achieved, but the government policy, particularly regarding land utilization, organizing cultivation of jatropha and pricing of jatropha seeds, needs to be more clear (Bishwas et al. 2010).

3 BIO- DIESEL

Biodiesel (Greek, bio, life + diesel from Rudolf Diesel) refers to a diesel-equivalent, processed fuel derived from biological sources. Biodiesel fuels are attracting increasing attention worldwide as a blending component or a direct replacement for diesel fuel in vehicle engines. (Ayhan Demirbas. 2009). Biodiesel is a diesel fuel alternative produced from vegetable oils and animal fats (Alleman, 2006). It is defined as ‘‘the mono alkyl esters of long chain fatty acids derived from renewable lipid feedstock, such as vegetable oils and animal fats, for use in compression ignition (diesel) engines”. The fatty acids from these sources are transformed via trans-esterification with methanol to the corresponding methyl esters that can be used as fuel (Tang, et al. 2008). Biodiesel as an alternative fuel for diesel engines is becoming increasingly important due to diminishing petroleum reserves and the environmental consequences of exhaust gases from petroleum-fuelled engines. Biodiesel, which is made from renewable sources, consists of the simple alkyl esters of fatty acids. As a future prospective fuel, biodiesel has to compete economically with petroleum diesel fuels (Berchmans and Hirta, 2008). One way of reducing the biodiesel production costs is to use the less expensive feedstock containing fatty acids such as inedible oils, animal fats, waste food oil and byproducts of the refining vegetables oils (Veljkovic et al., 2006). The availability and sustainability of sufficient supplies of less expensive feedstock will be a crucial determinant delivering a competitive biodiesel to the commercials filling stations. Fortunately, inedible vegetable oils, mostly produced by seed-bearing trees and shrubs can provide an alternative. With no competing food uses, this characteristic turns attention to Jatropha curcas, which grows in tropical and subtropical climates across the developing world (Openshaw, 2000). Biodiesel is a clean-burning fuel currently being produced from grease, vegetable oils, or animal fats. Its chemical structure is that of fatty acid alkyl esters. Biodiesel is produced by trans esterification of oils with short-chain alcohols or by the esterification of fatty acids. The trans esterification reaction consists of transforming triglycerides into fatty acid alkyl ester, in the presence of an alcohol, such as methanol or ethanol, and a catalyst, such as an alkali or acid, with glycerol as a by-product (Hoydoncx, et al. 2004).

3.1 *Jatropha* as an option of Bio-Diesel

Jatropha curcas Linn is a flowering plant species in the spurge family, Euphorbiaceous, which is native to the northern and southern Americas, mainly Mexico and Brazil .It is a non-edible oil bearing plant that is widespread in arid, semi-arid, and tropical regions of the world. J. curcas grows in areas with between 250 and 3000 mm annual rainfall and is found from sea-level up to 1800min altitude. It grows in all soils except vertisols, but it prefers light sandy soils . J. curcas can be used to prevent and/or control erosion; to reclaim land; to grow as a live fence, especially to contain or exclude farm animals; and to be a commercial crop. Thus J. curcas can help with land reclamation, erosion control, protection, and improving the microclimate. J. curcas is easy to establish, grows quickly and is hardy, because it is drought tolerant The seeds contain about 27e40% oil, with an average value of 34.4% based on the dry mass .Recently, J. curcas has been considered as one of the most promising potential oil sources for the production of biodiesel in Asia, Europe, and Africa (Chen, Yi-Hung, et al. 2011). Jatropha curcas is a drought-resistant perennial, growing well in marginal/poor soil. It is easy to establish, grows relatively quickly and lives, producing seeds for 50 years. Jatropha the wonder plant produces seeds with an oil content of 37%. The oil can be combusted as fuel without being refined. It burns with clear smoke-free flame, tested successfully as fuel for simple diesel engine. It is found to be growing in many parts of the country, rugged in nature and can survive with minimum inputs and easy to propagate (Mittlelbach, 1996). Jatropha curcas is becoming the future source of biodiesel for India. The planning commission, Government of India, has initiated an ambitious program of growing Jatropha curcas on waste land for biodiesel production. Among the various oil seeds, Jatropha curcas has been found more suitable for biodiesel production on the basis of various characteristics. The cultivation of jatropha is possible under stress condition and the oil of these species having various characteristics is more suitable for biodiesel production. Jatropha curcas has been scientifically developed to give better yield and productivity of oil. Jatropha oil has higher cetane no. (51) Compared to other oils, which is compared to diesel (46–50) and make it an ideal alternative fuel and requires no modification in the engine. A study has been done on biodiesel from Jatropha oil as a transport fuel for UP state and found that this will save foreign exchange and reduce CO2 emission (Chauhan et al. 2007).

3.2 Productivity of *Jatropha* Plantation

Jatropha plant bears fruits from 2nd year of its plantation and the economic yield stabilizers from 4th or 5th year onwards. The plant has an average life with effective yield up to 50 years. Jatropha gives about 2 kg of seed per plant in relatively poor soils such as in kutch (Gujarat). The seed yields have been reported as 0.75–1.00 kg per plants thus the economic yield can be considered to range between 0.75 and 2.00 kg/plant and 4.00 and 6.00 MT per hectare per year depending on agro-climatic zone and agriculture practices. The cost of plantation has been estimated as Rs. 20,000/- per hectare inclusive of plant material, maintenance for 1 year, training overheads, etc., includes elements such as site preparation, planting management, fertilizers, irrigation, deseeding and plant protection seed collection, seed processing, etc., for 1 year, i.e., the stage when it will start bearing fruits (Jain and Sharma 2008).

3.3 Advantages of cultivation of *Jatropha Curcas*

1. *Jatropha* can be grown in arid zones (20 cm rainfall) as well as in higher rainfall zones and even on land with their soil cover.
2. It is a quick yielding species even in adverse land situations, viz., degraded and barren lands under forest and non-forest use, dry and drought prone area, marginal lands even an alkaline soils and also as agro forestry crops.
3. *Jatropha* can be a good plant material for eco-restoration in all types of wasteland.
4. *Jatropha* grows readily from plant cuttings or seeds up to the left of 3–5 m.
5. *Jatropha* is not considered good forage material.
6. The plant is highly pest and disease resistant.
7. *Jatropha* removes carbon from the atmosphere stores it in the woody tissues and assists in the buildup of soil carbon.

3.4 Properties of crude *Jatropha Curcas* L. Oil

Table 1 shows the properties for CJCO. On the basis that the measured acid value is 22.7mKOH/moil and saponification value is 194.7mKOH/moil, average molecular weight of CJCO was calculated as 872.0 g/mol. The saponification value of CJCO was found to be small, indicating high concentration of triglycerides, and therefore CJCO can be a suitable feedstock for the production of FAME (biodiesel). Nevertheless the high content of free fatty acids (11.4% w/w) shows that conventional biodiesel production technology using homogeneous base catalytic system is not suitable for CJCO.

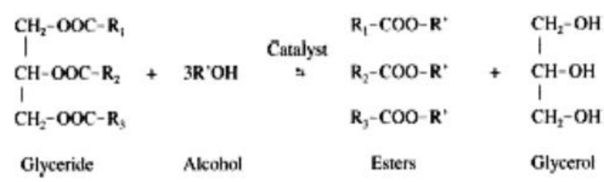
Table1: Properties of crude *Jatropha curcas* L. oil.

Moisture content	0.159% w/w	MPOB p 2.1
Free fatty acid	11.41% w/w	MPOB p 2.5
Acid value	22.7 mKOH/moil	MPOB p 2.5
Saponification value	194.7 mKOH/moil	MPOB p 3.1
Density	0.9220 g/ml	MPOB p 4.5
Free fatty acid composition		
Palmitic acid,	C16:0 14.4%	MPOB p 3.5
Palmitoleic acid,	C16:1 0.1%	MPOB p 3.5
Stearic acid,	C18:0 3.6%	MPOB p 3.5
Oleic acid,	C18:1 43.2%	MPOB p 3.5
Linolenic acid,	C18:2 38.7%	MPOB p 3.5

*MPOB ¼ Malaysian Palm Oil Board (Yee, KF et.al 2011).

4. Chemistry of Biodiesel Production

Conventional production of biodiesel from *J. curcas* L. seeds involve two main processing steps; extraction of oil and subsequent esterification/trans esterification to fatty acid methyl esters (FAME). In this study, the feasibility of in situ extraction, esterification and trans esterification of J. curcas L. seeds to biodiesel was investigated. It was found that the size of the seed and reaction period effect the yield of FAME and amount of oil extracted significantly. Using seed with size less than 0.355 mm and n-hexane as co-solvent with the following reaction conditions; reaction temperature of 60 ‘C, reaction period of 24 h, methanol to seed ratio of 7.5 ml/g and 15 wt% of H2SO4, the oil extraction efficiency and FAME yield can reached 91.2% and 99.8%, respectively. This single step of reactive extraction process therefore can be a potential route for biodiesel production that reduces processing steps and cost (Shuit, S H et al. 2010). Biodiesel is produced by trans esterification of large, branched triglycerides in to smaller, straight chain molecules of methyl esters, using an alkali or acid or enzyme as catalyst. There are three stepwise reactions with intermediate formation of diglycerides and monoglycerides resulting in the production of three moles of methyl esters and one mole of glycerol from triglycerides. The overall reaction is:



Alcohols such as methanol, ethanol, propanol, butanol and amyl alcohol are used in the trans esterification process. Methanol and ethanol are used most frequently, especially methanol because of its low cost, and physical and chemical advantages. They can quickly react with triglycerides and sodium hydroxide is easily dissolved in these alcohols. Stoichiometric molar ratio of alcohol to triglycerides required for trans esterification reaction is 3:1. In practice, the ratio needs to be higher to drive the equilibrium to a maximum ester yield.

4.1 The *Jatropha curcas* plant and oil

The oil yielding plant *Jatropha curcas* L. is a multipurpose and drought resistant large shrub, which is widely cultivated in the tropics as a live fence. The Jatropha plant can reach a height up to 5 m and its seed yield ranges from 7.5 to 12 tons per hectare per year, after five years of growth. The oil content of whole *Jatropha* seed is 30-35 % by weight basis.

4.2 Biodiesel Pilot Plant

The biodiesel pilot plant consists of a trans esterification reactor with heater, a stirrer, chemical mixing tank, three glycerol settling tanks and washing tank. The capacity of pilot biodiesel plant is 250 liters/day. The cost of the pilot plant is Rs. 2.5 lakhs. The process flowchart for biodiesel production and pilot biodiesel plant are shown in figure 1.

4.3 Pilot Biodiesel Plant Operation

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In the pilot biodiesel plant, jatropha oil is blended with alcohol and catalyst mixture in trans esterification reactor. The reactor is kept at reaction temperature for specific duration with vigorous agitation. After reaction, the biodiesel and glycerol mixture is sent to the glycerol settling tank. The crude biodiesel is collected and washed to get pure biodiesel. Depending upon the need, the size of the unit can be scaled up to get higher production capacity. The fuel properties of jatropha biodiesel produced in the pilot plant are given in the table (Ramesh, et al.).

$$\text{Jatropha oil +Alcohol} \xrightarrow{\text{Catalyst}} \text{Jatropha biodiesel+ Glycerol}$$

Table2: Fuel Properties of *Jatropha* Oil and its Biodiesel

Properties	Jatropha Oil	Jatropha biodiesel	Diesel
Density, g/ml	0.920	0.865	0.841
Viscosity @ 40oC, Cst	3.5	5.2	4.5
Calorific value, MJ/kg	39.7	39.2	42.0
Flash point, oC	240	175	50.0
Cloud point, oC	16	13	9.0

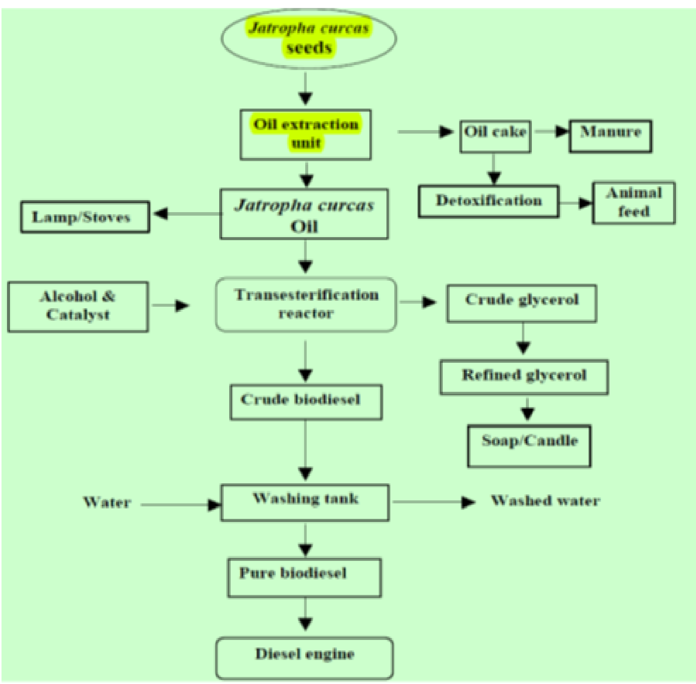

Fig. 1. Process flowchart for biodiesel production from jatropha seeds and by products

4.4 Advantages of Biodiesel

1. Biodiesel is a green liquid fuel free from environmental problem as it emits emissions compared to diesel.
2. Biodiesel may not require engine modification up to B20. However, higher blends may need some minor modification
3. Biodiesel is cheaper than diesel and can be a on farm fuel where the farmer can grow the seed oil crops, produced biodiesel and can use in the field itself.
4. Biodiesel can make the vehicle perform better as it has a cetane number of over 100 which is a measure of the quality of the fuel's ignition.
5. Owing to the clarity and the purity of biodiesel it can be used without adding additional lubricant unlike diesel engine.
6. Biodiesel reduces the environmental effect of a waste product. Because biodiesel is made out of waste products itself, it does not contribute to nature's garbage at all. Biodiesel can be made out of used cooking oils and lards. So instead of throwing these substances away, the ability to turn them into biodiesel becomes more than welcome.
7. Biodiesel is energy efficient. If the production of biodiesel is compared with the production of the regular type, producing the latter consumes more energy. Biodiesel does not need to be drilled, transported, or refined like petroleum diesel. Producing biodiesel is easier and is less time consuming.
8. Biodiesel is produced locally. A locally produced fuel will be more cost efficient. There is no need to pay tariffs or similar taxes to the countries from which oil and petroleum diesel is sourced. Every country has the ability to produce biodiesel.

4.5 Disadvantages of Biodiesel

1. Low calorific value than diesel.
2. Higher pour and cloud point.
3. Higher NOx emission.
4. Corrosive nature against copper and brass.
5. Low volatility.

5 Conclusions

Biodiesel is a clean-burning fuel that is renewable and biodegradable. *Jatropha curcas* is becoming the future source of biodiesel for India. Biodiesel production from *Jatropha curcas* with a high content of FFA has been investigated. In alkali base catalyzed trans esterification process, the presence of high concentration of FFA reduced the yield of methyl esters of fatty acids significantly. The planning commission, Government of India, has initiated an ambitious program of growing *jatropha curcas* on waste land for biodiesel production. Among the various oil seeds, *jatropha curcas* has been found more suitable for biodiesel production on the basis of various characteristics. The cultivation of *Jatropha* is possible under stress condition and the oil of these species having various characteristics is more suitable for biodiesel production. *Jatropha curcas* has been scientifically developed to give better yield and productivity of oil. *Jatropha* oil has higher cetane no. (51) Compared to other oils, which is compared to diesel (46–50) and make it an ideal alternative fuel and requires no modification in the engine.

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