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RESEARCH ARTICLE

Jatropha curcas AS A SUSTAINABLE SOURCE FOR BIODIESEL PRODUCTION AND ENVIRONMENTAL MANAGEMENT

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ABSTRACT

Biodiesel has attracted considerable attention during the past decade as a renewable, biodegradable and non-toxic fuel alternative to fossil fuels. *Jatropha curcas*, a multipurpose plant, contains high amount of oil in its seeds and can grow on marginal and wasteland. The availability and sustainability of sufficient supplies of less expensive feedstock in the form of vegetable oils like *J. curcas* and efficient processing technology to biodiesel will be crucial determinants of delivering a competitive biodiesel. *J. curcas* is the highly promoted oilseed crop at present in the world. The fuel properties of *Jatropha* biodiesel are comparable to those of fossil diesel and confirm to the American and European standards. This review highlights the specific features of the *Jatropha curcas* plant and its potential for the production of biodiesel and value-added products that could enhance the economic viability of *Jatropha* seed oil-based biodiesel production. This review also gives an update on the technological methods that can be used to produce biodiesel and the use of lipase as biotechnological solution to alkali and acid catalysis of transesterification.

INTRODUCTION

Energy is a basic requirement for economic development. 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). India declared its bio-fuel policy in which biodiesel, primarily from *Jatropha*, would meet 20% of the diesel demand beginning with 2011–2012. Biodiesel is an eco-friendly clean alternative diesel fuel produced from the plant and animals fats by process of transesterification. ASTM International (American Society for Testing and Materials) defines biodiesel as a mixture of long-chain mono-alkylic esters from fatty acids obtained from renewable resources, to be used in diesel engines. Biodiesel can be used in diesel engines, alone or blended with diesel oil. For instance, ''B5'' indicates a blend with 5% biodiesel and 95% diesel oil. Biodiesel is one of the most attractive bio-fuels because of its biodegradability, higher flash point, compatibility with the existing fuel distribution infrastructure and inherent lubricity (Knothe, 2008). The use of edible vegetable oils and animal fats for biodiesel production is great concern because this may cause imbalance in the food supply and demand so, it is impossible to justify the use of these oils for biodiesel production. Therefore, inedible vegetable oils can provide an alternative. Hence, the contribution of non-edible oils such as *Jatropha curcas* will be significant as an oil source for biodiesel production. Oil from *Jatropha* seeds extracted by cold pressing using an electric screw press (Maschinenfabrik Reinartz, 2011) and purified by a bag filtration system. Tapanes *et al*. (2008) reported that *Jatropha curcas* oil has tremendous potential for biodiesel production. *Jatropha* oil has low acidity and good oxidation stability compared to soybean oil, low viscosity compared to castor oil and better cold properties than palm oil. *Jatropha curcas* plant has been referred to as the second generation cropping solution for bio-fuel production with no competing food uses, (Gressel, 2008). *Jatropha curcas* can grow in tropical and subtropical climates across the world (Openshaw, 2000).

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Geographical distribution of jatropha

The name "*Jatropha*" is derived from the Greek word jatros (doctor) and trophe (food). *Jatropha curcas* is drought-resistant oil bearing multipurpose shrub/small tree which belongs to the family of *Euphorbiaceae* (Achten *et al*., 2006). *Jatropha* can grow in waste land, which makes it a more attractive feedstock for biodiesel production. There are two genotypes of *Jatropha curcas*, a toxic and a non-toxic one. The non-toxic genotype is found in Mexico only. It is a diploid species with 2n=22 chromosomes. *Jatropha* originates from Central America and was distributed by Portuguese sea farers to countries in Africa and Asia (Henning, 2000). *J. curcas* has been considered as one of the most promising potential oil sources for the production of bio-diesel in Asia, Europe and Africa (Chen, Y.H., *et al*., 2011). *Jatropha curcas* is a drought. Becker and Makkar (2008) reported 175 species of *Jatropha* around the world. *Jatropha* grows in arid and semi arid climates and in a wide range of rainfall regimes, from 200 to 1500 mm per annum (Achten *et al*., 2006). Optimum temperature range for *J. curcas* growth is 25–35^{0}C, but in some regions it may be found at higher altitudes with the risk of light frost. *J. curcas* has the potential to grow rain-fed in water scarce areas; irrigation may be applied for increased yields (Gerbens-Leenes *et al*., 2009).

Productivity of *Jatropha* Plantation

Jatropha plant bears fruits from 2nd year of its plantation and the economic yield starts from 4th or 5th year on-wards. *Jatropha* gives about 2 kg of seed per plant in relatively poor soils such as in Kutch (Gujarat). The economic seed 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 conditions and agriculture practices. Jain and Sharma (2010), reported that the estimated cost of plantation has been 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.

Properties of crude *Jatropha curcas* L. Oil

The measured acid value in *Jatropha* oil is 22.7mKOH/mol and saponification value is 194.7mKOH/mol, average molecular weight of CJCO (crude *Jatropha curcas* oil) 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 considered as a suitable feedstock for the production of biodiesel.

Table 1. Properties of crude *Jatropha curcas* L. oil

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

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

Processing techniques

The processing techniques that are mainly used to convert vegetable oils into fuel form are direct use and blending, pyrolysis, microemulsification and transesterification (Nwafor, 2003).

Direct use and blending

Pramanik *et al*. (2003) found that 50% blend of *Jatropha* oil could be used in diesel engine without any major operational difficulties but further study is needed on the long term effect on engine. However, direct use of vegetable oils and their blends have generally been considered to be unsatisfactory and difficult to use in both direct and indirect diesel engines. The main problems in use of vegetable oils are the high viscosity, acid composition, free fatty acid content, as well as gum formation due to oxidation, polymerisation during storage and combustion etc. (Agarwal, 2007, Meher *et al*., 2006).

Micro-emulsion

A micro-emulsion is defined as a colloidal equilibrium dispersion of optically isotropic fluid microstructures with dimensions generally in the 1-150 nm range formed spontaneously from two normally immiscible liquids and one or more ionic or non-ionic amphiphiles (Ma and Hanna, 1999). Agarwal (2007) found that the problem of the high viscosity of vegetable oils can be solved by micro-emulsions with solvents such as methanol, ethanol and 1-butanol. In micro-emulsion, alcohols such as methanol and ethanol are used as viscosity lowering additives, higher alcohols are used as surfactants and alkyl nitrates are used as cetane improvers. Microemulsions can improve spray properties by explosive vaporisation of the low boiling constituents in the micelles and also results in reduction in viscosity increase in cetane number and good spray characters in the biodiesel.

Pyrolysis (thermal cracking)

The conversion of one substance into another by means of heat in the absence of oxygen or by heat in the presence of a catalyst which result in cleavage of bonds and formation of a variety of small molecules is known as pyrolysis. The pyrolysis of *Jatropha* oil produce alkanes, alkenes, alkadienes, aromatics and carboxylic acids in various proportions (Ma and Hanna, 1999). The equipment used for thermal cracking and pyrolysis is expensive. Furthermore, the removal of oxygen during the thermal processing also removes any environmental benefits of using an oxygenated fuel (Ma and Hanna, 1999). Another disadvantage of pyrolysis is the need of separate distillation equipment for separation of the various fractions and the product obtained was similar to gasoline containing sulphur which makes it less eco-friendly (Ranganathan *et al*., 2008).

Transesterification (alcoholysis)

Transesterification is the reaction of a fat or oil with an alcohol to form fatty acid alkyl esters, methyl and ethyl esters and glycerol. It is usually carried out by heating an excess of the alcohol with vegetable oils under different reaction conditions in the presence of an inorganic catalyst. The alcohols that can be used in the transesterification process are methanol, ethanol, propanol, butanol and amyl alcohol. The reactions are often catalysed by an acid, a base or enzyme to improve the reaction rate and yield. Alkali-catalysed transesterification is much faster than acid-catalysed transesterification and is most often used commercially (Ranganathan *et al*., 2008, Agarwal and Agarwal, 2007). The alkalis which commonly used are sodium hydroxide and potassium hydroxide. Sulphuric acid, sulfonic acids, and hydrochloric acids are the usual acid catalysts. After transesterification of trigylcerides, the products are a mixture of esters, glycerol, alcohol, catalyst and tri-, di- and monogylcerides which are then separated in the downstream (Demirbas, 2005). Transesterification removed the high viscosity component. Hence, the product has low viscosity like the fossil fuels. Flash point of the biodiesel is lowered after transesterification and the cetane number is improved. The yield of biodiesel in the process of transesterification is affected by several process parameters which include; presence of moisture and free fatty acids (FFA), reaction time, reaction temperature, catalyst and molar ratio of alcohol and oil.

Role of catalysts

To make the transesterification process possible a catalyst in the form of an alkali, acid or lipase enzyme is required. Alkali-catalysed transesterification is much faster than acid-catalysed transesterification and is less corrosive to industrial equipment and therefore it is the most often used commercially (Ranganathan *et al*., 2008, Marchetti *et al*., 2007). Sodium hydroxide or potassium hydroxide is used as basic catalyst with methanol or ethanol. The second conversional way of making the biodiesel is to use an acid as catalyst. Sulphuric acid, sulfonic acids, and hydrochloric acids are the usual acid catalysts but the most commonly used is sulphuric acid. Acid catalysts are used if the triglyceride has a higher free fatty acid content and more water. Recently, enzymatic transesterification has attracted much attention for biodiesel production as it produces high purity product (esters) and enables easy separation from the by-product, glycerol (Devanesan *et al*., 2007, Ranganathan *et al*., 2008). The efficiency of transesterifcation process using lipase can be significantly increased by using intracellular lipase (whole cell immobilisation) instead of extracellular lipase which demands complex purification stages before immobilisation. Tamalampudi *et al*. (2008) recently reported that whole cell *R. oryzae* immobilised onto bio-mass support particles which catalysed the methanolysis of *Jatropha* oil more efficiently than Novozym 435. The production of biodiesel using a biocatalyst eliminates the disadvantages of the alkali process by producing product of very high purity with less or no downstream operations (Meher *et al*., 2006).

Fuel properties of *Jatropha* Biodiesel

Jatropha biodiesel has comparable properties with those of fossil biodiesel and conforms to the latest standards for biodiesel. The fuel properties of *Jatropha* biodiesel are summarized in Table-2.

Table 2. The comparable properties of diesel oil and *Jatropha* seed oil.

Parameters	Jatropha seed oil	Diesel oil
Density at 15^0c	0.92	0.841
Viscocity at 30^0c	52	11.75
Cetane number	51	50
Flash point (^{0}c)	240	50
Sulphar (ppm)	0.13	1.2
Calorific value (MJ/Kg)	40.70	42.71

Reference - Akintyo, 2004.

Jatropha cultivation and chemical aspects

Propagation by seeds and cutting

Heller (1996) reported that *Jatropha* can be raised easily by seeds or cuttings, although the trees propagated by cutting possess a lower drought resistance because the plant propagated by cutting produces adventitious root system and the plant propagated by seeds produces tap root system.

Propagation by tissue culture

Poor seed germination, scanty and delayed rooting of seedlings and vegetative cuttings paved way for the necessity of micropropagation of *Jatropha*. These techniques also reduced the space requirement and produce disease free and high yielding plant (Purkayastha et al., 2010).

Phytoconstituents in *Jatropha*

Openshaw (2000) reported that decorticated *Jatropha* seeds contain 40-60% oil. As reported by Akintayo (2004) the *Jatropha* oil contains approximately 24.6% crude protein, 47.25% of crude fat and 5.54% moisture. Phytoconstituents of *Jatropha* shown below in Table-3:

Table 3. Phytoconstituents in *Jatropha*

Various parts	Chemical composition	References
Leaves	Cyclic triterpenes stigmasterol, stigmas-5-en-3β, 7β-diol, 7α-diol, cholest-5-en-3fl, campesterole, β-sitosterole, flavonoids, dimer triterpene alcohol and two flavonoidal glycosides.	Hufford and Oguntimein (1987)
Seeds	Curcin and phorbolesters	Adolf et al., (1984)
	Steroids, alkaloids, saponins	Aiyelaagbe et al. (2007)
Stem bark	Saponins, steroids, tannins, glycosides, alkaloids and flavonoids	Igbinosa et al. (2009)
Roots	β-sitosterole, marmasin, propacin, curculatheranes A&B and curcusones A&D, diterpinoid jatrophol and jatropholone A&B, cumarin tometin etc.	Naengchomnog et al., (1994)

Ecological and industrial uses of jatropha

1. Soil conservation Potentials of *Jatropha*

Jatropha can grow in different soils climatic conditions, therefore it seems to be ideal on land that is otherwise not usable anymore. *Jatropha* can be established in gravelly, sandy, degraded or acidic soil (Openshaw, 2000). It has the possibility for reclaiming marginal soils by re-anchoring the soil. Francis *et al.* (2005) reported the improvement of soil structure after 18 months of *Jatropha* plantations in India.

2. Jatropha as green manure and fertilizer

Jatropha seed cake has potential as good organic manure (Gubitz et al., 1999), because of its high nitrogen content ranging from 3.2 to 3.8 % (Kumar and Sharma, 2008) similar to that of neem oil cake and cow dung manure.

3. Use in soap industry

Jatropha oil has high saponification value and glycerine is obtained as a by-product of *Jatropha* bio-diesel which can also be used for making soap. *Jatropha* soap can be produced by boiling the oil with a soda solution (Henning *et al.,* 1994). *Jatropha* oil has high saponification value and glycerine is obtained as a by-product of *Jatropha* bio-diesel which can also be used for making soap. *Jatropha* soap can be produced by boiling the oil with a soda solution (Henning *et al*., 1994).

4. Jatropha as food

Martinez *et al*. (2006) reported that the boiled and rosted seeds of *Jatropha* are eaten in certain regions of Mexico. A non toxic variety of *Jatropha* is reported in Mexico and Central America which do not contain toxic phorbol esters (Duke, 1985). Rahma (2013) studied that detoxified *Jatropha* seed flour had high quality protein comparable to chick pea and soybean which increase its potential uses as a protein supplement in several food items

5. Medicinal uses of *Jatropha*

A phytoconstituent known as Curcacycline-A show anti-tumor activities as reported by Van den Berg *et al*. 1995. Heller (1996) reported that *Jatropha* oil can be used to treat skin diseases and soothe rheumatic pain. Latex has antimicrobial properties against *Straphylococcus aureus, Escherichia coli* etc. (Thomas, 1989). Parveen *et al*. (2007) reported that rural communities use the juice from leaves to cure diseases such as dysentery and colic. Ethanolic root extract of *J. curcas* was found to have antibiotic effect on *Escherichia coli, Neisseria gonorrhoea* and *Staphylococcus aureus*, with a minimum inhibitory quantity of 0.5ml (Arekemase, 2011).

Jatropha Toxicity

A toxic protein known as curcin has been isolated from the seed and leaves. As per the findings of Adolf *et al*. (1984), high concentration of phorbol esters present in *Jatropha* seed has been identified as main toxic agent responsible for *Jatropha* toxicity. The toxicity of phorbol esters is mainly due to their action on biological cell membranes (Goel *et al*., 2007). Phorbol esters in *J. curcas* kernel meal can be reduced to undetectable levels (< 5mg/g) by using organic solvents (alkaline methanol) (Kumar, 2013). Phengnuam and Suntornsuck, (2013), performed submerged fermentation experiments of *J. curcas* seed cake with *Bacillus licheniformis*, in distilled water, for 5 days and observed a reduction in phorbol esters by 62%.

Conclusion

Jatropha is a non-edible plant which can grow on wasteland or on marginal land. Jatropha seeds have high oil content and it can grow under stress condition, therefore, it is considered as best alternative source for biodiesel production. Biodiesel produced from *Jatropha* is clean, eco-friendly and economic due to its low production cost. *Jatropha* oil has higher cetane no. compared to other oils, which make it an ideal alternative fuel and requires no modification in the engine. *Jatropha* has also many industrial and ecological benefits which makes biodiesel production economic. The *Jatropha cultivation* as an industry is in the initial stage of development and systematic and considered efforts are being made for its promotion. At present the farmers are unable to obtain optimum economic benefits from this plant. Therefore, new technologies and more research work is required to gets optimum benefits from this *Jatropha* by using by-products more efficiently in sustainable manner for environmental management.

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