

# Biodiesel Production from *Jatropha curcas* Linnaeus: A Review

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**Abstract:-** Since fossil fuels are getting depleted day by day, by virtue of which there exists an increasing urge for the past two decades to produce biodegradable, non-toxic fuel. With added advantage of 78.5 percent less carbon dioxide and carbon monoxide emission than petroleum diesel, biofuel could prove to be the future of aviation fuel. Also, industrial processing can extract biodiesel from both vegetable and animal fats. A multipurpose plant, *Jatropha curcas* Linnaeus which boasts of high content of oil in its seeds can be used to produce biodiesel with the help of different types of chemical processes. The emphasis of this review is to analyse production methods of biodiesel on large scale, relevant combustion properties of this fuel and have insights about *Jatropha curcas* Linnaeus plant.

**Keywords:** Biodiesel, Transesterification, Pyrolysis.

## INTRODUCTION

As fossil fuels are getting depleted day by day, by virtue of which there is a continuous research going on for the production of renewable sources of fuel from vegetable oils and animal fats. Comprised of mono-alkyl esters of long fatty acids, biofuels are derived from animal fats or vegetable oils. (Demirbas, 2000; Kinney and Clemente, 2005; Wilson et al., 2005). These fuels could be either in the form of animal fats or vegetable oils and they are converted into biodiesel using chemical or natural processes. With little modification, these wastes from animals and plants could be utilized as fuels. In fact, chemicals and fibers essential in daily life could also be produced with modification in these organic wastes. The comparison in the carbon content and its emission upon combustion lays the foundation stone for the difference between fossil fuels and biofuels. Modern engines that are manufactured today are made to operate on a vast variety of fuels, such as diesel, petrol, or gas as their primary source of fuel. Diesel engines running on biofuel almost provide same power output with slightly lower thermal efficiency, when compared to diesel engine running on fossil diesel. (Makkar et al., 1997; Pramanik, 2003; Agarwal and Agarwal, 2007; Tiwari et al., 2007). Also, there is a stark similarity between diesel fuel and biofuels in composition, hence this eliminates the need to modify engines to run on biofuels. Also, when compared to petrol engines, diesel engines produce the same amount of work with comparatively less consumption of fuel. Biodiesel is gaining popularity these days due to its carbon-neutral source of nature. This liquid fuel can be obtained by

processing vegetable oils chemically and then modifying its properties to match its performance with diesel. Biodiesel have similar characteristics like that of diesel (Agarwal, 2007). Africa and Asia being the net importers of vegetable oil, have identified *Jatropha curcas* as their latest crop for the nations to increase their own renewable source of energy. With the increase in interest in biofuels globally, the need for national governments to intervene and devise mechanisms to harness the value of the rapid paced industry and benefit from the increasing international trade in biofuels. Africa's initiative to utilise *Jatropha* to expedite the production of biofuels could place the continent as a global trader and distributor of biodiesel, hence increasing the political and economic leverage in the global society. Leading multinational corporations across the world, especially from China, India, Europe and Scandinavia have already started the hoard to acquire African land to start commercialise *Jatropha* productions. Telecom giants such as GSMA, Ericsson and MTN also don't want to leave this opportunity and have started their bids to invest in promoting the use of *Jatropha* biofuel to prove beneficial for the base stations of the cellular networks in this developing technical market across the globe (Katembo and Gray, 2007).

The plant family, Euphorbiaceae, infamous for hosting many plants which object with the Geneva Convention on chemical warfare, also hosts the origin of *Jatropha curcas* Linnaeus plant. This plant was first found in Mexico and was then introduced to Africa and Asia as a hedge plant Portuguese traders. The word *Jatropha* is extracted from the Greek word *Jatros* meaning doctor and *trophe* meaning food, which point towards medical applications, and that is why *Jatropha* finds traditional uses for medical purposes. Also, *Jatropha* is an ideal plant for small farmers since it is a grown as a shrub and can sustain itself on poor soils in the areas of less rainfall (250 mm annually) (Sarin et al., 2007; Foidl et al., 1996; Gressel, 2008). Owing to its ability to grow well in relatively less quality soil, it may also prove to help reclaim the already degraded land and preventing soil erosion. On an average, each *Jatropha* plantation is able to produce about five kilograms of seeds annually under optimal conditions. It has a long productive which lasts for a period of around 30 - 50 years (Banapurmath et al., 2008; Tamalampundi et al., 2008).

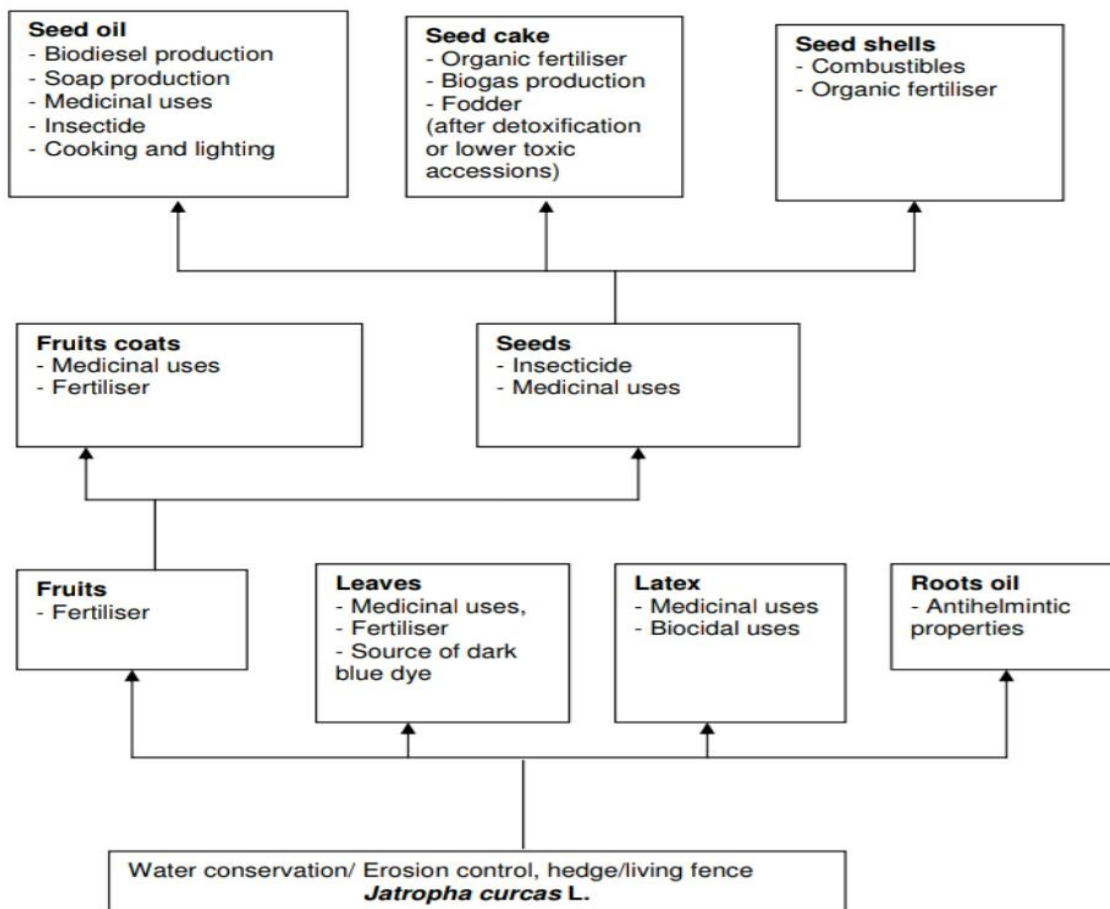


Figure 1. The various uses of *J. curcas* components (adapted from Jones and Miller, 1991).

Various benefits are also extracted from the frond, bark and the leaves of this plant, are illustrated in figure 1 above and Table 1 below tabulates major benefits and drawbacks of *J. curcas* production. Out of many agronomic claims about *Jatropha Curcas*, only a handful are scientifically sustained.

Table 1. The potential advantages and disadvantages of *J. curcas* L. plant.

The advantages of <i>Jatropha</i> plant
<b>Good agronomic traits</b>
1. Hardy shrub which grows in semi-arid conditions and poor soils
2. Can be intercropped with high value crops such as sugar, coconut palm, various fruits and vegetables, providing protection from grazing livestock and phyto-protection action against pests and pathogens
3. It is easy to establish and grows relatively quickly.
4. Yields around 4 tonnes of seed per hectare in unkept hedges are achievable
5. Has low nutrient requirements
6. Requires low labour inputs
<b>Multi-purpose plant</b>
1. Protective hedges around fields
2. Reclaims marginal soils
3. Non-edible and therefore does not compete with food supply when used for biodiesel production
4. Is energy crop that produce seeds with high oil yields
<b>The disadvantages of <i>Jatropha</i></b>
Seeds and leaves are toxic to human beings and animals
Toxicity is based on several components (phorbol esters, curcains, trypsin inhibitors and others) which make complete detoxification a complicated and difficulty process.
Competes with food production for land use

**Table 2.** Specifications of the seed of the seed oil of *J. curcas* (Foidl et al., 1996; Tamalampundi et al., 2008).

Variable	Variety Caboverde	Variety Nicaragua	Variety Nigeria
Colour	Light yellow	Light yellow	Light yellow
Saponification number (mg/g)	192	190	199
Viscosity at 30 °C (cSt)	39	37	17
Free fatty acids (% weight)	0.3-0.4	0.6-1.3	1.8
Unsaponifiable (% weight)	1.1	0.8	0.8
Iodine number	95	107	105
Acid value	–	–	3.5
Specific gravity (25 °C)	–	–	0.92

## PROCESSING TECHNIQUES

### Pyrolysis (Thermal Cracking)

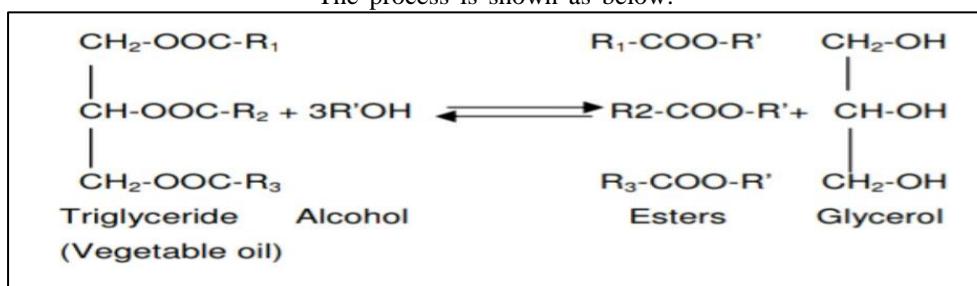
The process of converting one substance into another in the presence of heat without air (Oxygen), or with heat along with a catalyst, which leads to the formation of a wide range of small molecules, is termed as pyrolysis.

Extensive studies have been carried out upon the pyrolysis of *Jatropha* seed oil has led to the conclusion that it leads to the production of alkenes, alkanes, alkadienes, carboxylic acids and aromatics in varying proportions (Ma and Hanna, 1999; Alencar et al., 1983; Peterson, 1986).

### Transesterification (Alcoholysis)

The synthesis of an oil (triglyceride) or a fat with an alcohol to produce fatty acid alkyl esters, glycerol and methyl and ethyl esters is known as transesterification.

The process is shown as below:



In industries, vegetable oils are heated with excess alcohol under varying conditions in the presence of catalysts such as Sodium Hydroxide to produce the biofuel in large quantity. Excess of alcohol is used in order to shift the reaction's equilibrium to the products side because the reaction is reversible. Most widely used alcohols in the transesterification process are ethanol, methanol, butanol, propanol and amyl alcohol. Such reactions are mostly catalysed by an enzyme, either acidic or basic in order to increase the rate of reaction and improve the yield. Commercially, alkali based catalysts are used more commonly since they make the transesterification process much faster than acid catalysed reactions (Ma and Hanna, 1999; Ranganathan et al., 2008; Agarwal and Agarwal, 2007). Due to the drastic changes in viscosity of vegetable oils due to transesterification, the glycerol has to be removed and thus brings the viscosity of the remaining product similar to that of fossil fuels.

## EFFECT OF CATALYST

A catalyst is a chemical reagent which helps to accelerate a chemical reaction and make it feasible. In case of the process of transesterification, an alkali/acid makes the reaction faster and is thus used as a catalyst in the reaction.

### Alkali Catalyst

It has been observed experimentally that often the transesterification reactions which are catalysed by alkalis are more faster than those catalysed by acid catalysts. (Ma and Hanna, 1999; Ranganathan et al., 2008; Agarwal, 2007; Marchetti et al., 2007). Sodium hydroxide or potassium hydroxide is used as alkaline catalyst with ethanol or methanol as well as the vegetable oil. The basic catalyst concentration in the range of 0.5 - 1% by weight yield 94 -99% conversion of most vegetable oils into esters. . The process is energy intensive, as the alkaline catalyst needs to be separated from the final product, the recovery of glycerol becomes difficult. Also, the wastewater produced requires treatment and the level of water and free fatty acids interfere with the reaction. Soap formation takes place due to free acid and water contamination and due to the same reason, the process of separation becomes a challenging process to complete (Fukuda et al., 2001; Barnwal and Sharma, 2005).

### Acid Catalyst

The alternate method to engender biodiesel is to use alcohol with the animal fats and an acid. The most commonly used acidic catalyst in this process is Sulphuric Acid. If higher free fatty acid or water is present in the animal fat then, acid catalyst is used. Despite of the high yields, another risk always looms in the industrial process, which is the time taking nature of the reaction due to the corrosive nature of the acid (Freedman et al., 1984). Some authors has enunciated that the reactions are slow, needing typically temperatures above 373°F and more than 3 hours to fully complete the conversion.(Meheret al., 2006).

### PROPERTIES OF JATROPHA BIOFUEL

Table 3: Juxtaposition of the different technologies to produce biodiesel.

Variable	Alkali catalysis	Acid catalysis
Reaction temp (°C)	60-70	55-80
Free fatty acid in raw materials	Saponified products	Esters
Water in raw materials	Interference with reaction	Interference with reaction
Yields of methyl esters	Normal	Normal
Recovery of glycerol	Difficult	Difficult
Purification of methyl esters	Repeated washing	Repeated washing
Production cost of catalyst	Cheap	Cheap

Table 4: Properties of jatropha oil, jatropha biodiesel and fossil diesel Fuel (Kamman and Phillip, 1985; Matsumoto et al.,2001; Ban et al., 2001).

Property	J. oil	J. biodiesel	Diesel	Biodiesel standards	
				AST D 6751-02	DIN EN 14214
Density (15°C, kgm <sup>-3</sup> )	940	880	850	-	860-900
Viscosity (mm <sup>2</sup> s <sup>-1</sup> )	24.5	4.8	2.6	1.9-6.0	3.5-5.0
Flash point (°C)	225	135	68	>130	>120
Pour point (°C)	4	2	-20	-	-
Water content (%)	1.4	0.025	0.02	<0.03	<0.05
Ash content (%)	0.8	0.012	0.01	<0.02	<0.02
Carbon residue (%)	1.0	0.20	0.17	-	<0.30
Acid value (mgKOHg <sup>-1</sup> )	28.0	0.40	-	<0.80	<0.50
Calorific value (MJkg <sup>-1</sup> )	38.65	39.23	42	-	-

### APPLICATION OF BODIESEL IN COMBUSTION ENGINES

Since vegetable oils have high viscosity,so this property of jatropha oil creates a problem in pumping and spraying characteristics when it is used in combustion engines. For compression ignition engines, biodiesel can be blended with fossil diesel in order to create a new bled of biodiesel or it can also be used in its purest composition. Since the biodiesel has very similar attributes when compared to mineral diesel, because of which compression ignition engines require very minute modification or no modifications. The various advantages and disadvantages of biodiesel are given in table 5.Without detoxification jatropha curcas oil cannot be used for comestible purposes, making its use as a energy source for fuel production very usefuel. During second world war, biodiesel extracted from jatropha curcas oil was used as a substitute for diesel fuel in madagascar, cape verde and benin. Early engine tests were done in thailand with jatropha curcas oil which depicted satisfactory performance of the engine. (Gubitz et al., 1999; Recep et al.,2000).

Table 5: Advantages and Disadvantages of biodiesel fuel.

Advantages of biodiesel
1. Provides a domestic, renewable energy supply.
2. Biodiesel is carbon neutral because the balance between the amount of CO <sub>2</sub> emissions and the amount of CO <sub>2</sub> absorbed by the plants producing vegetable oil is equal.
3. Biodiesel can be used directly in compression ignition engines with no substantial modifications of the engine.
4. Blending of biodiesel with diesel fuel increases engine efficiency.
5. The higher flash point of biodiesel makes its storage safer.
6. Biodiesel is non-toxic.
7. Biodiesel degrades four times faster than diesel.
8. CO, CO <sub>2</sub> and UBHC, PAH, soot and aromatics emissions are reduced in biodiesel and its blends than in fossil diesel because biodiesel is oxygen in structure and it burns clearly all the fuels.
9. It is biodegradable.

Disadvantages of biodiesel
1. More expensive due to less production of vegetable oil.
2. Blends of biodiesel above 20% can cause engine maintenance problems and even sometimes damage the engine in the long term.

### CONCLUSION

From being used traditionally for medicinal uses to being used to prevent soil erosion, *Jatropha Curcas* Linnaeus is also used as a source of an oil that has the potential to be converted into biodiesel. Also, *Jatropha* is also said to be beneficial against the use of omnipresent greenhouse effect, creating auxiliary earnings for the rural individuals, and provide a vital source of renewable energy globally. Researchers enunciated that biodiesel contains lower aromatics and extra oxygen molecules when compared to base fuel diesel. (Arunkumar et al., 2019; Kavitha et al., 2019). The presence of lower sulphur content in biodiesel leads to soot production in fuel which ultimately results into lower smoke emission (Monirul et al., 2016; Arunkumar et al., 2019; Kandasamy et al., 2019). The lower carbon molecule in biodiesel is another reason for this (Khan et al., 2018; Dhamodaran et al., 2017; Kandasamy et al., 2019). Biodiesel has the properties which can make it an alternative to fossil diesel owing to its environmental benefits such as fewer carbon emission and due to the gospel that it is extracted from renewable resources, *Jatropha* is a auspicious source of biodiesel since its seeds can hold considerable amount of oil and the species has good attribute. In India, there are enormous potentiality for the extraction of biofuels from *Jatropha Curcas* as they are found in wastelands across India.

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