JATROPHA CURCAS PLANT AS A POTENTIAL BIODIESEL FEEDSTOCK IN INDONESIA

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ABSTRACT

One of the alternatives for biodiesel feedstock is oil from Jatropha curcas plant. The advantages of using this plant are due to its ability to grow in poor soils, different parts of the plant can also be used for different purposes, the by products of biodiesel productions have economic values, and biodiesel is more environmentally friendly when it is being produced and being used, compared to mineral derived oils. Although Indonesia has another alternative raw material for biodiesel production, i.e. palm oil, however the use of palm oil will affect its supply for the other sectors that have already established, e.g. for producing cooking oils. This situation will not happen to Jatropha curcas oil, due to its inedible characteristic.

Keywords: Biodiesel, Jatropha curcas, Indonesia

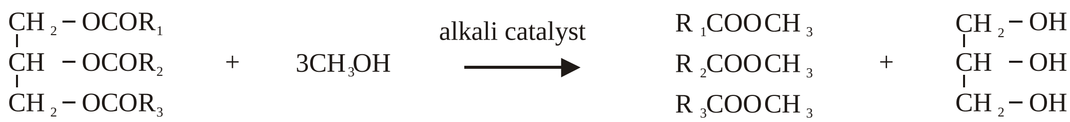
Salah satu alternatif untuk bahan baku biodiesel adalah minyak dari tanaman jarak. Keuntungan menggunakan tanaman ini adalah karena kemampuannya untuk tumbuh di tanah yang kurang subur, bagian lain dari tanaman ini juga dapat digunakan untuk tujuan yang berbeda, dengan hasil dari produksi biodiesel memiliki nilai ekonomi, dan biodiesel juga lebih ramah lingkungan ketika sedang diproduksi dan digunakan, dibandingkan dengan yang berasal dari minyak mineral. Meskipun Indonesia memiliki bahan baku alternatif lain untuk produksi biodiesel, yaitu minyak sawit, namun penggunaan minyak sawit akan mempengaruhi pasokan untuk sektor-sektor lain yang sudah mapan, misalnya untuk memproduksi minyak goreng. Situasi ini tak akan terjadi pada Jatropha curcas oil, karena tanamana ini tidak dapat dimakan.

Kata kunci: Biodiesel, Jatropha curcas, Indonesia

INTRODUCTION

Diesel engine was invented in 1885 by Rudolf Christian Karl Diesel (1858-1830), and was firstly displayed to public in 1900. Public was amazed by the ability of the engine to be run both by gasoline and peanut oil. In fact, the inventor stated in 1912 that "…the use of vegetable oils for engine fuels may seem insignificant today. But such oils may in the course of time become as important as petroleum and the coal tar products of present time".

Biodiesel is mono alkyl esters from fatty acid derived from plant oils, animal fats or used cooking oils, which is one of alternative fuels for petrodiesel. The most common biodiesel production process is by transesterification. Generally, chemical reaction formula of transesterification is as follows.



Triglyceride　　Methanol　　Fatty acid methyl esters (FAME)　　Glycerol

Although at present the use of mineral derived diesel fuel is the majority, however there is an increase concern on using biodiesel. This is due to the recent economic (i.e. high world price oils), and environmental (Global Warming) concerns. Biodiesel is a substitute for, or an additive to, the conventional diesel fuel. This alternative fuel can be derived from plantations, e.g. sunflower, rapeseed, canola, coconut palm, and *jatropha*.

From reaction formula (1), it can be seen that triglyceride, which is the main component in raw materials, is reacted with methanol with the help of alkali catalysts (commonly NaOH or KOH) to produce Fatty Acid Methyl Esters (FAME) that is biodiesel. Glycerol is a by-product from the transesterification reaction.

There are some advantages of biodiesel utilization, i.e.:

- Biodiesel can be produced from renewable resources (Janaun and Ellis, 2010);
- Biodiesel can be used directly on diesel engines, without the need for any modifications. It can be used individually or as a blend with petrodiesel (Lapuerta *et al*., 2008);
- The use of biodiesel can reduce CO_2 emission up to 78%, as compared to the use of petrodiesel (Agarwal, 2007);
- Emission reduction of most air pollutants, i.e., carbon monoxide, hydrocarbon, particulate matter and smoke (Mittelbach *et al.*, 1985; Haas *et al.*, 2001; Sahoo *et al.*, 2009; Tan *et al.*, 2012; Ozsezen *et al.*, 2009);
- Other advantages as compared to petrodiesel: more biodegradable (Sendzikiene *et al.*, 2007), lower toxicity (USEPA, 2002), much lower sulfur content (Mittelbach *et al.*, 1985), lubricating effect on engine and higher flash point thereby safer for storing and transporting (Labeckas and Slavinskas, 2006).

ABOUT *JATROPHA CURCAS* PLANT

Jatropha curcas plant is originally from the American continent. This plant is usually available in all tropical and sub tropical areas, and has over 200 names worldwide and various uses. Some of the names are physic nut (English), *pugernoot* (Dutch), *pignon d'Inde* (French), *sabudam* (Thai), *kadam* (Nepalese), and *tubing-bakod* (Filipino). Usually people use this plant to fence their crop lands, because this plant is not consumed by animals. The bark is grey and exudes whitish coloured, watery latex when cut. *Jatropha curcas* plant sheds their leaves once a year and grows very fast that can attain a height of around 4 metres in 4 – 5 years, although in some cases can reach up to eight or ten meters under favourable conditions. After two years of plantation, it starts to produce fruits. The fruit of *Jatropha curcas* plant is capsule shaped which initially green coloured, but turns yellow and finally becomes black after ripening. Each fruit consists of 3 to 4 seeds that can be produced by the plant up to 50 years. From 1 kg of fruit there are 1,200 to 1,500 seeds.

According to Tickell (2000), actually there are some other plants beside *Jatropha curcas plant* that can also produce vegetable oils. The following table shows various types of the plant together with the amount of possible extracted oil per hectare of the plants.

Table 1. Potential of Vegetable Oil Productions from Different Plants

Plant	Latin Name	kg oil per hectare	Plant	Latin Name	kg oil per hectare
Corn	*Zea mays*	145	Rapeseed	*Brassica napus*	1,000
Oat	*Avena sativa*	183	Olive	*Olea europaea*	1,019
Cotton	*Gossypium hirsutum*	273	Physic nut	*Jatropha curcas*	1,590
Soybean	*Glycine max*	375	Coconut	*Cocos nucifera*	2,260
Peanut	*Arachis hypogaea*	890	Oil palm	*Elaies guineensis*	5,000

Source: Tickell, 2000

Although there are some plantations that produce more oils than *Jatropha curcas*, however those oils are edible. This means that there will be a competition in using those oils if their availability is less than their demands. In this situation, *Jatropha curcas* oil which contain trace of toxins thus makes it inedible is better for producing biodiesel.

Furthermore, *Jatropha curcas* is not only known for its potential to produce oil. Although many people focus on using the oil of this plant, however almost all parts of the plant are usable. Following are the specific utilizations of *Jatropha curcas* plant.

JATROPHA CURCAS PLANTATION

The *Jatropha curcas* plant grows almost everywhere, even on gravely, sandy, and saline soils. This plant can be grown in a nursery by its stems or seeds, and it can be planted in marginal/poor soil areas because it is one of drought resistant plants. It has been successfully grown in dry regions with annual rainfall of 300 – 1,000 mm. The plant sheds most of its leaves to reduce transpiration loss, thus making it drought resistant. Suitable altitudes are from 0 – 500 m and preferred temperature is above 20^0C,

Table 2. Utilization of *Jatropha curcas* Plant

Whole Plant	Root	Leaf	Latex	Seed	Barks	Twig
- Prevent erosion - Fence land - Decoration - Green manure - Prevent desertificati on	- Medicine	- Medincine (piles, malaria)	- Medicine (cancer) - For making: varnish, ink	- Oil extraction (up to 37%) For: lighting or diesel fuel, lubricant or hydraulic oil, making: insecticide, soaps, candles, cosmetics. - Cake for fertilizer	- Tanning and dyeing material s	- Medicine - Herbal tooth brush

Source: http://www.jatrophabiodiesel.org/jatrophaPlantation.php?_divid=menu2

although it also can grow in higher altitude with an ability to withstand a light frost. After two to five years, the plantation will produce seeds that annually yields from 2 to 12 tonnes per hectare depend on soil quality and rainfall (http://www.jatrophabiodiesel.org/jatrophaPlantation.php?_divid=menu2). Following are some key factors that influence the oil yield of *Jatropha curcas*.

Table 3. Influencing Factors on *Jatropha curcas* Plantation

No	Key Factor	Explanation
1	Climate	Able to deal with severe heat, doing well in warmer areas. When cold it drops its leaves. Can withstand light frost but not for long period of time.
2	Quality of the Soil	Best in sandy well-drained soils. Can cope with very poor soils and grow in saline conditions.
3	Irrigation	Can handle dryness very well and possible to live almost entirely on humidity in the air. Optimum rainfall for high yields from 600 to around 1,400 mm.
4	Weeding	With four times a year weeding, proper fertilization, surface ploughing and pruning can yield around 15 – 20 kg of fruit per tree.
5	Use of fertilizer	For poor quality soils fertilizer containing small amount of calcium, magnesium, and sulphur can increase yields. Can also use pressed cake from oil extraction.
6	Crop density	Wider spacing can increase yields. However, 2 x 2 metres spacing should be used for commercial plantation
7	Inter-cropping	No specific intolerance with other crops has been detected, thus can be inter-cropped with various types of plant.

Source: http://www.jatrophabiodiesel.org/

OIL EXTRACTION FROM *JATROPHA CURCAS* SEEDS

Oil is very easily extracted from *Jatropha curcas* seeds by using a presser-expeller. There are various types of the presser-expeller, from the simplest ones that are hand driven expellers, to more sophisticated engine driven expellers which are shown in the following figure.

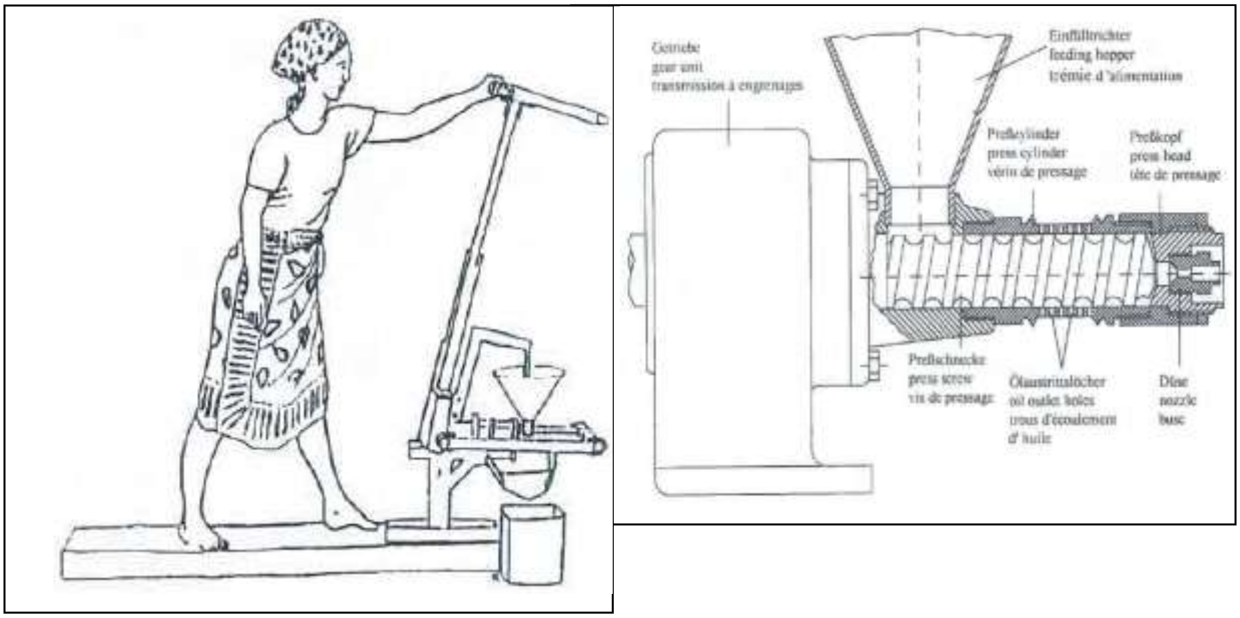


Figure 1. Presser-Expeller Equipments
Source: Kurki & Bachmann (2006)

The availability of the two types of equipment can make poor people to produce their own source of income. Moreover, the hand driven driven expellers are also suitable for areas where electricity are not yet available. On the other hand, for those who are expecting commercialization of the products, the engine driven equipment can help them to reduce the production time thereby increasing their production capacities. The price of the hand driven presser-expeller equipment varies, for example it is around US$265 in Tanzania (http://journeytoforever.org/biofuel_supply.html#Oilpress).

From every 3 kg of seeds there is around 1 liter of extracted oil (http://herbal-medicine.philsite.net/tuba-tuba.htm). The pressed cake from the presser-expeller machine can be used as fertilizer due to its nutrient content, i.e. 6% Nitrogen (N), 2.75% Phosphor (P), and 0.94% Potassium (K), which is similar to chicken manure (http://www.jatrophacurcasindia.com/).

Furthermore, the cake can also be used as animal feedstock after being introduced to heat and chemical treatment to detoxify its toxins contents (Aregheore et. al, 2003).

ECONOMIC BENEFITS FROM *JATROPHA CURCAS* PLANTATION

An example of economic benefits from *Jatropha curcas* plantation is taken from the experience of India that has started to cultivate the plant several years ago. The following table shows the summary of expenditure and revenue per one hectare of land that comparing the plantation with and without intercropping systems. The calculation is for the land that is already owned by farmers (i.e. no cost for acquiring the land).

Table 4. Potential Income from *Jatropha curcas* Plantation

Year	US $ per hectare per year					
	Without Intercropping			With Intercropping		
	Expenditure	Revenue	Income	Expenditure	Revenue	Income
Year 1	545.19	33.56	-511.63	545.19	1,152.13	606.94
Year 2	111.86	100.67	-11.19	111.86	1,286.36	1,174.50
Year 3	111.86	559.29	447.43	111.86	1,677.86	1,566.00
Year 4	111.86	894.86	783.00	111.86	2,013.43	1,901.57
Year 5	111.86	1,398.21	1,286.36	111.86	2,516.78	2,404.93

Source: Modified from http://www.jatrophabiodiesel.org/economics.php?_divid=menu4

The table shows that by using intercropping system, the income is started to be gained in the first year. Examples of intercropping system are plantation of *Jatropha curcas* with red and green peppers, tomatoes, water melons, vanilla, mulberry etc. Furthermore, the intercropping has some other advantages as follows.

- Avoid dependency on one crop.
- Reduction the use of fertilizers.
- Possible to recover investment in shorter time.
- Flexibility in the distribution of labours.
- Produce a large variety of useful products.
- Availability of harvest over a longer period of time.

BIODIESEL PRODUCTION FROM *JATROPHA CURCAS* OIL

The seeds of *Jatropha curcas* content from 31% to 37% oil that can be used as fuel both in unrefined and refined states. The unrefined oil (straight vegetable oil) has too high viscosity to be used in current diesel engine, therefore there is a need for modifying the engine to cope with the high viscosity. However, there are many chemical processes available to reduce the viscosity. Two scientists, E. Duffy and J. Patrick, discovered in 1853 a simple chemical process to reduce the oil viscosity called transesterification. After the chemical process, the oil is called biodiesel that can be used or blended directly without any diesel engine modifications.

Based on reaction formula (1) that is shown previously, the oils that are extracted from *Jatropha curcas* seeds react with methanol with the aid of catalyst NaOH to form methyl ester (biodiesel) and glycerine. The chemical process ends when the glycerine is left on the bottom and the methyl ester is on the top which can be filtered. The standard for biodiesel specification in Indonesia is SNI 04-7182-2006.

There are some existing technologies developed for producing biodiesel. The list of the technologies and their installation costs based on the capacities is presented in the following table.

Table 5. Biodiesel Production Technology

Technology	Capacity (Tons/year)	Installation Cost (US$)
Bandung Institute of Technology	5,000	2,000,000
Campa	5,000	3,000,000
Lurgi	50,000	13,000,000
Biodiesel International (BDI)	50,000	15,000,000
Conneman	50,000	15,000,000

Source: Ministry of Industry of Indonesia (2006)

To show the process that occurs in a biodiesel production, following figure shows the flow diagram of the Lurgi Process. The flow diagram shows that in the production of biodiesel, there will be a by product that can has economic value, i.e. glycerine. Glycerine can be purified to be used in pharmaceuticals, cosmetics, and toiletries industries.

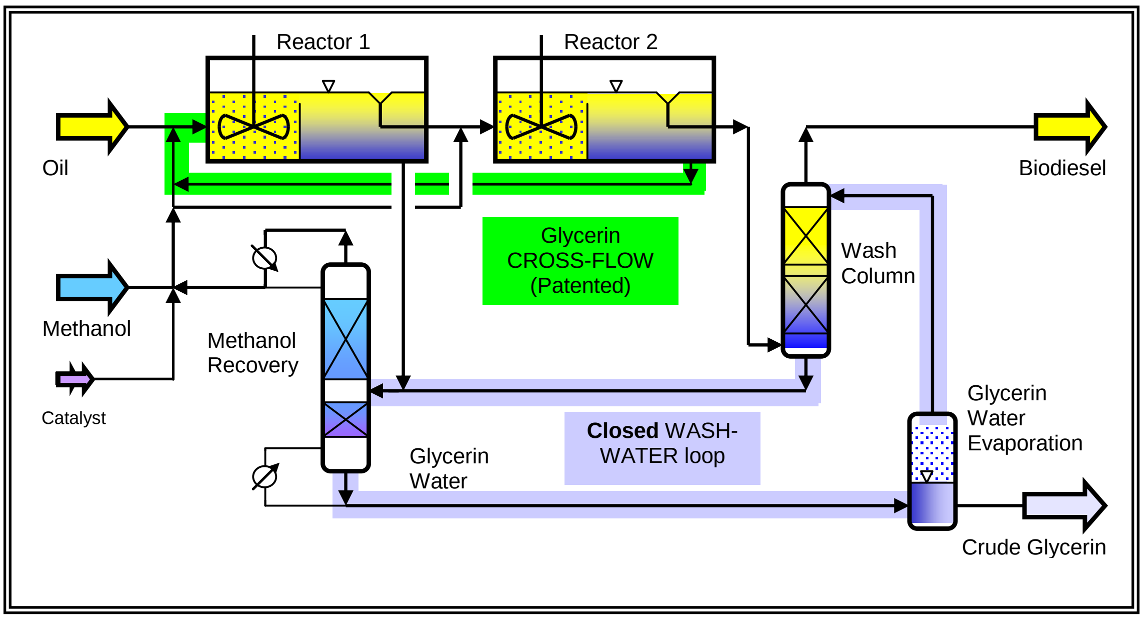


Figure 2. Lurgi Process in Biodiesel Production
Source: Kleber (2003)

As for the price of biodiesel, in India based on a pilot project report by Ramesh, D et al (2006), the price of one liter of biodiesel is US$0.72. This price has taken into account the potential selling of glycerine as a by product. However, another source in India mentioned that from a commercial scale plant the price is US$0.56, inclusive of taxes and duties (http://www.svlele.com/biodiesel_in_india.htm). For Indonesia, the price of conventional diesel fuel per liter is US$0.47, which is still subsidized around US$0.22 per liter. Therefore, assuming that the biodiesel price is the same as in India, if the Government of Indonesia wants to encourage people using biodiesel, the government has to set the price of the fuel at least the same as the price of conventional diesel fuel. This can only be done by reducing subsidy for the conventional biodiesel.

POTENTIAL OF BIODIESEL FROM *JATROPHA CURCAS* IN INDONESIA

Biodiesel potential is calculated by using the data related to biodiesel production from *Jatropha curcas* from above discussions.

The data used is the potential of seed production from 2 to 12.5 tons/year/hectare, the oil extracted is one liter per 3 kg of seeds, and information regarding the area of marginal lands in Indonesia that is around 22 million hectares in 2004. (http://siaphut.dephut.go.id/siaphut/reports/rlps/penyebaran_lahan_kritis.php).

The result of calculation is the potential of biodiesel from *Jatropha curcas* plant from 14.7 to 91.7 million kiloliters of biodiesel in 2004. Whereas the total national diesel fuel consumption for that year was around 27.5 million kiloliters (US Embassy – Jakarta, 2006).

ENVIRONMENTAL IMPACT OF USING BIODIESEL

There are some impacts of using biodiesel to the environment. First, the use of biodiesel can reduce the emission of some air pollutants. Based on information from US-EPA (2002), the following table shows the changes of some air pollutant emissions due to biodiesel use.

Table 6. Changes of Some Air Pollutant Emissions due to Biodiesel Use

Type of Biodiesel	Hydro carbon	CO	Particulate Matter	NOx
B20	-20%	-12%	-12%	-2% to +2%
B100	-67%	-48%	-47%	+10%

B20 = 20% blend of biodiesel on conventional diesel fuel
B100 = 100% diesel fuel use
Source: US-EPA (2002)

The table shows the changes in some air pollution parameters that are regulated in the United States of America. Almost all parameters show reductions in emissions. There is only one parameter that is not decreasing, i.e. Oxides of Nitrogen (NOx). However, due to the fact that using biodiesel is also reducing the amount of sulphur dioxide emission (US-EPA, 2002), there are some available technologies to deal with the NOx emissions, e.g. the use of catalytic converter. Vehicles with conventional diesel fuel cannot use the converter due to the sulphur dioxide emission that can reduce the effectiveness of the converter.

The second advantage of using biodiesel to the environment is the potential of carbon dioxide (CO_2) removal from the plantation of the plants for producing biodiesel. For one hectare of *Jatropha curcas* plantation, can contribute to the reduction of 10 tonnes of CO_2 per year. (http://www.tnau.ac.in/tech/swc/evjatropha.pdf). Moreover, Bugge (2000) calculated that the use of biofuels from rapeseed oil has a positive CO_2 balance, i.e. more CO_2 is absorbed by the plantation than is emitted from the plantation and processing. This is an opportunity for developing countries to gain as much as possible the carbon trade through the Clean Development Mechanisms (CDM). Based on an overview of biodiesel and petroleum diesel life cycles (Sheehan et al., 1998), biodiesel use reduces net CO_2 emissions by 78.45% for B100 and 15.66% for B20 compared to petroleum diesel.

The third environmental benefit of using biodiesel is energy balance related to the production of biodiesel. Sheehan et al (1998) concludes that biodiesel yields 3.2 units of fuel product energy for every unit of fossil energy consumed. In contrast, the report also states that conventional diesel fuel uses 1.2 units of fossil resources to produce 1 unit of the fuel, i.e. only yields 0.83 units of energy. This means that the production of biodiesel can also preserve un-renewable fossil fuels.

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