POTENCY OF VEGETABLE OIL AS BIODIESEL FEEDSTOCK AND ITS PROCESSING IN INDONESIA

POTENSI MINYAK NABATI SEBAGAI BAHAN MENTAH BIODIESEL DAN PENGOLAHANNYA DI INDONESIA

Sudirman Habibie
Deputi Teknologi Industri Rancang Bangun dan Rekayasa
Badan Pengkajian dan Penerapan Teknologi
Gedung Teknologi 2 – TIRBR, Kawasan Puspiptek Serpong
Tangerang 15314, Banten
Telp. (021)75875944 Ext. 1123
Email : sudirmanhabibie@yahoo.com
Sudirman.habibie@bppt.go.id

Abstrak

Indonesia sejak tahun 2004 telah menjadi salah satu Negara pengimpor minyak fosil didunia yang setiap tahun meningkat. Saat ini produksi minyak Indonesia hanya berkisar 857.000 barrel per hari, sedangkan konsumsi telah mencapai 1,68 juta barrel per hari. Peningkatan subsidi minyak dan konsumsi minyak telah menekan kondisi ekonomi. Dilain pihak, Indonesia termasuk salah satu Negara penghasil beragam jenis tanaman penghasil minyak nabati sebagai bahan baku biofuel, seperti : sawit, kelapa dalam, jarak kapyar, jarak pagar, nyamplung, bunga matahari, jagung, zaitun, kacang tanah, kapas/kapok dan sumber lainnya seperti algae dan biomas. Untuk itu tidak ada pilihan lain, Indonesia harus segera mengembangkan tanaman penghasil minyak nabati sebagai pengganti minyak fosil. Disamping itu juga akan didiskusikan proses pembuatan biodiesel dari minyak nabati menggunakan metoda trans-esterifikasi untuk merubah trigliserida menjadi ester sebagai biodiesel.

Kata kunci : biofuel, minyak nabati, trigliserida, ester, biodiesel.

Abstract

Since 2004, Indonesia has become an importer of fossil oil in the world and it is increase steadily year by year. Currently its production of oil is only about 857,000 barrels per day, on the other hand its consumption has increased to 1,5 million barrels per day. The raising of oil subsidy and the increase of oil consumption has pressure Indonesian economy. On the other hand, Indonesia has a potency of production of various plants to produce vegetable oils as biofuel feedstock, such as : palm, coconut, jatropha, castor, calophyllum, sunflower, corn, olive, peanut, cotton/kapok and other sources like algae and biomass. Therefore, Indonesia has to develop soon plants to produce vegetable oils to replace fossil oil. Besides that, this study also reveals the processing of biofuel by using the trans-esterification method to convert triglyceride to ester namely biodiesel.

Keywords: biofuel, vegetable oils, triglyceride, ester, process technology

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INTRODUCTION

Indonesia has been recognized as an exporter country of fossil oil for almost 5 decades. In the 70s, Indonesian oil production was about 1.2 million barrels per day. But in the last five years, oil production has declined considerably and nowdays Indonesia is estimated to produce only about 857,000 barrels per day. However, the consumption increased steadily to 1.1 million barrel per day in 2007. The reduction of oil

production has led to Indonesia's status as exporter changing to an importer country. Inevitably, these changes affect the petrol price that forces the government to subsidize the price of oil. As the world price of oil reached about US$79 per barrel in July 2006 and then fluctuated for a long time, and was reduced again to US$65 in May 2007[1)]. This situation created uncertain conditions in business groups also in the communities. Although the world oil price reduced at that time, the future conditions were still unpredictable. Therefore Indonesia has to anticipate unstable oil price by increasing domestic oil prices. The consequences of this will trigger an increase of transportation costs and commodity prices in all sectors. This would contribute to social, economic and political instability.

Fossil fuel is formed from the sediment of fossils that have been processed by a long period of time; oil is categorized as fossil energy or fossil fuel. Table 1 shows the composition of energy sources in Indonesia. Fossil fuel still dominates more than 50% of total energy consumption, and the oil consumption reached 158,900 kL per day[2)] in 2005. This table also shows that the composition of fossil fuel is much higher than the consumption of non fossil oils. This means that Indonesia is dependent on fossil oil as its main energy source.

The dependency on fossil oil has contributed to economic, social and environmental problems. From an economical point of view, the dependency on fossil fuel will affect the amount of government subsidization and the cost of products and goods using components of fossil oil. The increase of domestic consumption of fossil fuel, and the world price of oil are two things that may increase the government's spending. As long as the Government subsidizes oil consumption, Government spending will increase continuously alongside the increasing world oil price.

There are three ways to reduce dependence on fossil oil. Firstly, to find new technology that detects the locations of new sources of oil deposits, to optimize the production of domestic oil and conservation of energy sources. Secondly, a government program that reduces and optimizes energy consumption has to be socialized and optimized in society, resulting in more efficiency energy consumption. Thirdly, the development of alternative energies can be emphasized to reduce the use of fossil fuels.

Table 1.
The Composition of Energy Sources in Indonesia[3)]

Energy	Realization 1978/79 (%)	Realization 1983/84 (%)	Realization 1988/89 (%)	Projection 2005 (%)
Non Fossil Oil	18,01	22,09	37,57	37
Fossil Oil	81,99	77,91	62,43	63
Energy Total	100	100	100	100

Source: Blueprint Pengelolaan Energi Nasional oleh Departemen ESDM RI, 2004

Many sustainable alternative energies are available to subsidize fossil fuel. In Indonesia the potential of these sustainable energy sources are abundant, but they are not utilized optimally. The utilization of sustainable energy resources are divided into three categories. First, some sustainable energy resources are already developed commercially, such as biomass, geothermal and hydro-power. Second, other energy resources are developed in small amounts and in a few locations such as solar energy and wind energy. Thirdly, remaining energy resources are developed, but still under research such as marine energy[4)].

Vegetable oils are an example of sustainable energies that are found from biological resources both animal and vegetable. Biomass including wood, agriculture waste, plantations or forests, animal waste and organic components from industries and households are the product of photosynthesis. The granules of chlorophyll, which work as solar cells, absorb solar energy and convert carbon dioxide and water to carbon, hydrogen and oxygen compounds[5)]. These compounds are the process of energy absorbance that can be converted into other products. The result of the conversion process is such as compounds of charcoal or carbon, wood, alcohol, tar, etc[6)]. Solid biomass can be converted to form liquid, gas, heat and electricity. Conversion technology of biomass to form bio oil uses the pyrolise technology. This process technology is carried out by heating the raw material in a closed container without oxygen[7)]. Esterification technology is used to convert the biomass to become bio kerosene or biodiesel. However, fermentation technology is used to

make bioethanol and anaerobic digester technology is used to make biogas.

POTENCY OF PLANT TO PRODUCE VEGETABLE OILS

The Indonesian government has given a serious consideration to biofuel development by issuing President Instruction of No. 1, 2006 on 25 January 2006 about providing and using biofuel as an alternative energy.

Some Biofuels that can be developed are biodiesel and bioethanol. Indonesia has the great potential to produce biodiesel and bioethanol, considering that both biofuels are able to benefit from the geographical conditions as well as using resources that come from plants that grow in Indonesia. Based on the research of The Agency for Assessment and Application of Science and Technology (BPPT), Indonesia has more than 60 types of plants that have potencies as an energy alternative[8)].

For instance, coconut palm, coconut, castor oil plant, and the kapok tree can be used to make biodiesel to replace diesel fuel; and sugar cane, corn, cassava, sweet potato, and sago palm can be sources of bioethanol as a substitute for gasoline. Table 2 shows examples of plants that produce energy with potency of oil production in a litre per hectare and their energy equivalent.

Table 2.
Types of plant as an energy maker[9)]

	Oil Production (litre per hectare)	Energy Equivalent (kWh per hectare)
Elaeis guineensis (coconut palm)	3.600 – 4.000	33.900 – 37.700
Jatropha curcas (jarak pagar)	2.100 – 2.800	19.800 – 26.400
Aleurites fordii (kemiri seed)	1.800 – 2.700	17.000 – 25.500
Saccharum officinarum (sugarcane)	2.450	16.000
Ricinus communis (jarak kepyar)	1.200 – 2.000	11.300 – 18.900
Manihot esculenta (cassava)	1.020	6.600

Source: Business Week 15 Maret 2006 edition

Several species of plants that require 4 to 12 months to be cultivated generally are plants producing seeds containing oil, such as castor, sesame, sunflower, peanut, soybean, hemp plant, etc[10)]. Vegetable fuel can be gained from animals, such as cow tallow, goat tallow, pig tallow, etc. Beside that, the waste of used frying oil can be utilized as vegetable fuel. However, the plants that contain the largest percentage of oil, such as coconut palm, coconut and kemiri, which are well known in Indonesia, are prerennial crops that will produce seeds optimally after 5 years. These plants need fertile land, high rainfall, and intensive maintenance. This will affect the running costs and will therefore affect to the selling price of the product, and several years are needed to become financially viable.

Biodiesel is a bright yellow or dark yellow liquid, with a high boiling point and low gas pressure. The viscosity is lower than water, at 0.86 g/cm^3. Biodiesel has viscosity like solar (diesel fuel produced from petroleum), and can be used as an alternative fuel for diesel machines or as an additive or additional compound to make ultra-low sulfur diesel (ULSD) smooth. However, the sulfur content in biodiesel cannot be more than 15 ppm.

BIODIESEL

Biodiesel is a fuel generated from bio-oil that has similar characteristics to diesel oil. The biofuel is environmental friendly because it produces better emission compared to diesel oil, and also free of sulphur, has a low smoke number and a high cetane number resulting in clear burning, has a lubricating characteristic on engine pistons, and is also biodegradable so that it becomes a non toxic energy.

According to BPPT research, biodiesel can be used directly as fuel for engine diesel without the need of any engine modifications, or as a mixture with diesel fuel in any concentration started at 5%[8)].

The biodiesel development needs a bio-oil raw material which can be formed from plants containing fatty acid such as crude palm oil, Jatropha curcas, coconut, soursop, annona, and kapok [9)]. The Indonesian land is rich in natural resources that can be used as

raw materials for biodiesel. Crude Palm oil is one of the prospective sources for bio-oil raw materials in Indonesia considering that Indonesia produces CPO in a great volume and that increases in every year.

Biodiesel characteristics are similar to those of diesel fuel, so biodiesel can be used alone or mixed with diesel fuel to replace some amounts of diesel fuel. Biodiesel can be used in diesel machinary without modification of the machinary. This separates biodiesel with other vegetable oils such as straight vegetable oil (SVO) or waste vegetable oil (WVO)[10,11]. Biodiesel uses the letter "B" to identify that this biodiesel is mixed with diesel fuel. For example, B20 is a biodiesel fuel mixed with 80% of diesel fuel; B100 is a pure biodiesel fuel.

If compared with diesel fuel, biodiesel has advantages such as[12]:

- Has a lubricant characteristic on piston machinery because it is a non-drying oil.
- Able to eliminate the green house effect
- Is a renewable energy (sustainable energy) because it is made from natural materials that can be renewed, so the continuity of raw material is safe;
- Increases the independency of oil supply because it can be produced locally.

The other advantages of biodiesel are[13]:

- It is environmental friendly because its gas emission has good qualities, such as sulphur free, low smoke number and high cetane number (>60), and as a result burning efficiency is good;
- Biodiesel consists of low hydrocarbon aroma: benzolfluoranthene is reduced 56% and benzopyrenes is reduced 71%.
- Biodiesel reduces CO emission about 50% and CO_2 about 78% in netto lifecycle because the emissions of biodiesel in the formation of carbon will be recycled.
- Clean burning, and as a result it does not produce toxins and easily falls apart[14].

As BPPT research, apart from CPO, there are more than 60 types of bio-oil in Indonesia that can potentially be used as raw materials for biodiesel, such as castor oil, coconut oil, soybean oil, and kapok oil.

Recently, there are at least three plants that can be used as biodiesel feedstock; jatropha, sunflower and coconut palm[15].

1. Jatropha curcas Linneaus

Jatropha has the advantages of a long life time (more than 50 years), and it does not need much water for growing. Rainfall needed is low compared to other plants. Although its product is lower than the result of coconut palm, jatropha is able to survive in the worst conditions without water in the critical land. However its seed residue is a good organic fertilizer for the reclamation of critical lands. On the other hand, jatropha is also disadvantaged because of its cultivation time compared with the selling price, but it is tolerable because of its many advantages.

Compared with Lanilla species known as Ricinus communis, jatropha has a few advantages as follows[11]:

- Oil production of jatropha is much higher than of castor.
- Ricinus communis (castor) has seeds that are covered by hard skin. These need to be preheated by steam to soften the hard skin seed. This uses additional energy. On the other hand, a jatropha seed is soft like a peanut, so it can be pressed by simple equipment.

Amongst those raw materials, the jatropha plant is a superior plant for biodiesel development. This plant is a prospective as a biodiesel raw material because it can grow in critical land and its oil characteristics are suitable for biodiesel. Operational costs for developing a castor oil plantation is more economical than palm oil. For comparison purposes, the development and maintenance cost of jatropha plant needs only 20% to 25% of total production cost, whereas palm oil requires 40% to 50%.

2. Sunflower (Heliantus annus)

Sunflower oil has a lower production per hectar compared to jatropha or coconut palm. The advantage of sunflowers is the short cultivation time; only 90 days or 3 months from planting. If it grows in level, wide land, the cultivation can use a mechanization process. This equipment is named "Combine"[15]. This machinery, which is fitted in front of a tractor, shaves stems, and at the same time separates stems from seeds or fruits. This method can be applied only in level and wide land. Cultivation of sunflowers by hand will result in less productivity than jatropha.

Oil from seeds can be used as frying oil, as can coconut or palm oils, however jatropha oil cannot be used as frying oil. The waste of sunflower seeds can be used as organic fertilizer for reclamation of critical land. Waste and fresh seeds can be used as animal food with a high nutrient content. This is the superiority of sunflower compared to the waste of jatropha seeds, which cannot be used as fodder because it contains the toxin curcaine.

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3. Coconut Palm (Elaeis guineensis)

Coconut palm has a higher commercial economic value than jatropha plants and sunflowers. But this plant needs intensive maintenance for chemicals and processing technology for cultivation and processing. Coconut palm plants also need wide areas of land for growing. This can result in companies clearing forests to plant coconut palms, as has happened in some regions such as Asahan region in North Sumatera, and Sanggau in West Kalimantan.

The idea of combining the development of these three plants (coconut palm, jatropha and sunflowers) is interesting[8)]. Jatropha and sunflowers can be used to reclaim critical land. After a few years, the land will be fertiled by natural fertilizer from the waste of jatropha and sunflowers. After that the land can be planted with long-term plants such as coconut palms.

PROCESS TECHNOLOGY FOR MAKING BIODIESEL

In Indonesia there are more than 60 plants species that can produce vegetable oil both for food and non food[8,9)]. But only a few can be processed as biodiesel feedstock. From several plants found in Indonesia, crude palm oil is the most feasible to be processed as biodiesel according to its production amounts. However other plants need to be researched and focused on the cultivation of seedlings and plantations.

Biodiesel is made by a chemical process named “trans-esterification” of vegetable oils. The trans-esterification process is the reaction process between triglyceride and alcohol (methanol and ethanol) to form ester and glycerol[15)]. This process results in two products, metil or ethyl esters (biodiesel), and glicerin as a side product. This side product may be separated from the oil through gravitation or other methods. The raw material for biodiesel could be vegetable oils, animal tallow and waste frying oil. All these raw materials may consist of triglyceride, fatty acids and other impurities that are present during the pre treatment process.

In the biodiesel production, alcohol is needed to convert glyceride to ester, and the excess alcohol is needed to keep the reaction permanent. A catalyst is necessary to speed up the reaction of methyl or ethyl ester. Vegetable oils consist of fatty acids lower than animal tallow/fat. Vegetable oils also consist of phospholipids. These two compounds of fatty acids and phospholipids can be removed during refining and degumming respectively.

Generally, alcohol used in the process of vegetable oils is methanol, but ethanol, isopropanol or butanol can also be used, but the problem with these options is the presence of water in the alcohol[16)]. If the water content is high, the quality of oil will be lower because the presence of soap, fatty acids and triglyceride is also high.

Biodiesel quality is also influenced by the temperature of the esterification process and time used for mixing or the speed of the alcohol mixture. A catalyst is needed to increase the solubility power during the occurance of reaction. Generally catalysts used are from strong base catalysts such as NaOH and KOH, but many researchers also use acid catalyst for trans-esterification process. The catalyst used will depend on the content of fatty acids in the oil. If the fatty acid content is less than 2%, it will reduce to form soap. Normally catalysts are very hygroscopy and will react to form chemical solutions that can be destroyed by alcohol.

If a catalyst absorbs more water, it is not effective in speeding up the reaction of esters. So biodiesel product is not optimal. After a reaction occurs, catalysts have to be neutralized by adding strong mineral acids. After the neutralization process, the washing process may continue with distilled water until neutral. Hydrochloric acid can also be used to neutralize base catalysts. If phosphate acid is used, it will form phosphate fertilizer with potassium (K_3PO_4)[17)]. The base process for biodiesel can be seen in figure 1.

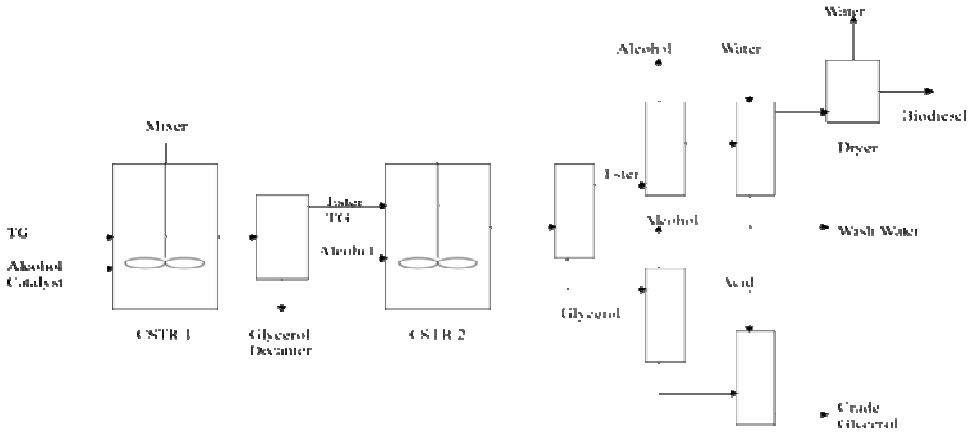

Figure 1.
Hybrid Batch/Continuous (Base Catalyzed Process)[18)]

In general, there are three methods of transesterification processes to make biodiesel from vegetable oils (bio lipids);

- Transesterification process using base catalysts
- Transesterification process using acid catalysts
- Conversion of vegetable oil to fatty acids then processed into biodiesel.

Almost all biodiesels are processed by a transesterification method using base catalysts because this method is more economical and only needs low temperatures and low pressure for the process. The conversion of biodiesel through this method may attain 98%. Vegetable oil consists of free fatty acids less than 1% will produce high yields of biodiesel, but if higher than 1%, it will need pretreatment process because the involvement of high fatty acids content are reduced efficiency for production. The world trade standard on fatty acid content is 5%, so it will need de-acidification with metanolitic or hard glicerol. A simple reaction of transesterification can be as follows;

100 lbs of vegetable oils + 10 lbs of methanol → 100 lbs biodiesel + 10 lbs of glycerol.

During the esterification process, triglyceride reacts with alcohol to form ester and glycerol. This reaction occurs with the involvement of a strong base catalyst such as sodium hydroxide, potassium hydroxide or sodium silicate. The amount of the catalyst is important in affecting the reaction of triglyceride and alcohol. Researchers have said that the concentration of NaOH about 6.25 gr/L is suitable to reach the optimum reaction[17)]. Because the reaction between triglyceride and alcohol is reversible, the excess of alcohol needs to push the reaction to the right so the conversion of ester is completed.

In the transesterification reaction, R1, R2 and R3 are a long chain of carbon and hydrogen mentioned as fatty acid, as shown in figure 2.

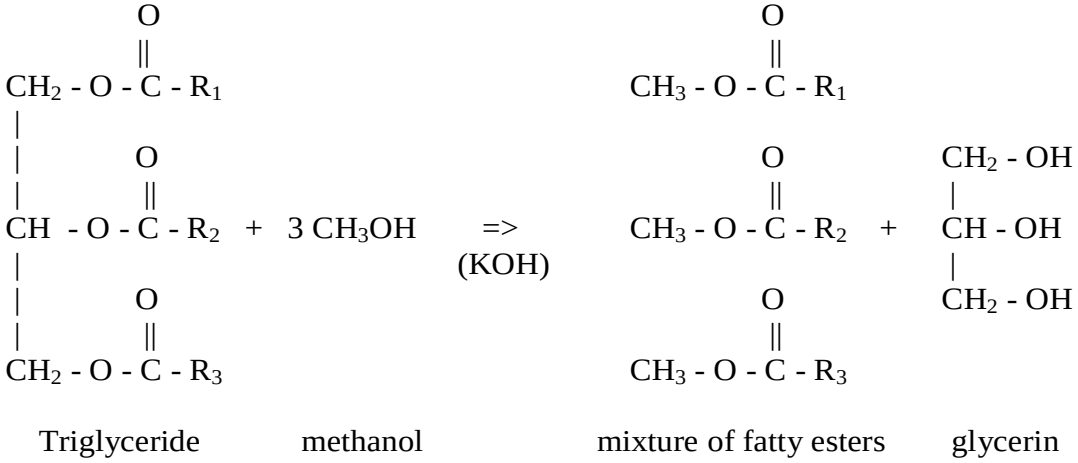

Figure 2.
Transesterification reaction[19)]

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CONCLUSION

The production of Indonesian oil reduces continuously, in contrast to the domestic consumption of oil, which increases day by day. This triggers the domestic oil price to depend on world oil prices because the lack of domestic oils have been substituted by oil imports. This dependency will affect all fields such as price of goods, transportation cost, energy cost, etc.

By considering the effects of fossil oils on social, economic and environmental problems, the use of biofuel to subsidize the fossil oil may be the best solution. In the long term, it will support the aims of achieving sustainable development.

In Indonesia there are more than 60 plants species that can produce vegetable oils. These oils may produce biofuel depending on the supply amount of oil. Therefore only a few of them have been identified to have potency for conversion to biodiesel; namely jatropha oil, sunflower and crude palm oil.

Assuming the supply of jatropha seeds is constant and having a long-term economic prospect, the reduction of biodiesel selling price may be projected in 2015. As a result the biodiesel subsidies will also be reduced.

The transesterification process is the primary process of biodiesel production because it is the key of forming methyl oleate, labeled biodiesel. The catalyst used may be an acid or base catalyst, but based catalysts such as NaOH and KOH are cheaper and more effective.

The prime consideration in the oil sample is the presence of free fatty acid (FFA). The concentration of FFA in the oil is less than 1% much more productive for biodiesel. If FFA content in the oil is more than 1%, the oil needs to be pre treated through degumming or refined processes before being used.

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