BIODIESEL PRODUCTION FROM PALM OIL TECHNOLOGY

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Abstract: *This study focuses on the production of biodiesel from palm oil technology which is applied in Indonesia. The concentration of palm biodiesel used in the test was ranged from B0 (pure petro-diesel), B10, B20, B30, B50 and B100 (pure biodiesel). The engine performance was evaluated through torque, power, and specific fuel consumption, while the emission was evaluated through carbon monoxide (CO), hydrocarbon (HC), and particulate matter (PM), carbon dioxide (CO2), and NOx pollutants. The result shows that higher content of palm biodiesel can reduce the emission of CO, HC, PM, and CO_2. It was found that the addition of biodiesel could increase the power and torque. Further more, NOx also decreased when the content of palm biodiesel increases, which is in contrast with those generally found in the previous non palm biodiesel studies.*

Keyword*: palm oil biodiesel, petro-diesel, CO), hydrocarbon (HC), particulate matter, O2, and NOx pollutants*

INTRODUCTION

Due to unstable oil price situation in the world market, many countries have been looking for alternative energy sources to substitute for petroleum. Vegetable oil is one of the alternatives which can be used as fuel in automotive engines either in the form of straight vegetable oil, or in the form of ethyl or methyl ester. Palm oil (*Elaeis guineensis*) has recently become a main feedstock for biodiesel production. There is a need to assess and compare the technical, environmental, and economic efficiency of biodiesel feedstock production.

The model of biodiesel production is divided into 3 stages: palm oil farming, palm oil production and transesterification into biodiesel. Relevant data for resource consumption and emissions to air, water and soil have to collect for all stages. Vegetable oil is one of the alternatives which can be used as fuel in automotive engines either in the form of straight vegetable oil, or in the form of ethyl or methyl ester. Palm oil (*Elaeis guineensis*) has recently become a main feedstock for biodiesel production. There is a need to assess and compare the technical, environmental, and economic efficiency of biodiesel feedstock production. The model of biodiesel production is divided into 3 stages: palm oil farming, palm oil production and transesterification into biodiesel.

Fresh fruit bunch of palm oil (FFB) - Milling is an integral part of the process to convert FFB into separated crude palm oil, palm kernel oil and by-products or waste. Power is required at several stages for various purposes. It may be used to produce steam for sterilization and processing, to drive the extraction and separation equipment, and to provide processing water (1.2 tons of water per ton FFB). Electricity is needed for ancillary farm and domestic purposes. The palm oil mill processes 40 t FFB per hour, which is equivalent to a mill processing about 120 000 – 150 000 t FFB per year (IOPRI, 2006).

For oil extraction there are two main sources of energy input: production waste for generating steam for mill machinery and kernel crushing, and diesel fuel for engine start-up. For the calculations regarding the CPO production stage, we considered for input FFB, water, steam produced from production waste, diesel fuel for on-site electricity generation, and for output fiber, shells, decanter cake, empty fruit bunches (EFB), ash, palm oil mill effluent (POME), emissions to air, crude palm oil (CPO) and kernel oil.

Transesterification - For the transesterification of palm oil the two components methanol and sodium hydroxide are required, as well as electricity for shaking the oil and the components to produce biodiesel. The reactor considered in our calculations for producing biodiesel from palm oil is a 20 000 liter batch-type reactor operating at a maximum of three batches per day with a reactor time of 8 hours per batch (PLEANJAI et al. 2004). The operating temperature is 50-60 $^{\circ}$C.

The biodiesel production rate is around 16 t per batch. Transesterification of the oil produces a mixture of methyl esters (biodiesel) and glycerol. The biodiesel is separated from the glycerol by gravity, then the remaining mixture is washed with water and acetic acid until the washing water is neutral. The methyl ester is then dried by heating. The biodiesel yield is around 87 % of the crude palm oil processed. The percentage of yield for biodiesel production can be calculated based on a stoichiometric material balance. Glycerol is a by-product that can be used to produce soap or other materials. For the transesterification stage we included the inputs of CPO, water, grid electricity, methanol and sodium hydroxide, and the outputs methyl ester, glycerol in our calculation.

OBJECTIVES

Purpose the study is to review and evaluate oil palm plantation, property of palm oil, conversion process to biodiesel, suitable available land, biodiesel quality, environmental impacts, engine test performance, and benefit to the country from using biodiesel.

MATERIAL AND METHODS

In this study, there are several journal of biodiesel production from palm oil is presented are used for reviewing the palm oil biodiesel production and its application for the engine performance.

Test Vehicle - The performance and emission tests were conducted at the Thermodynamics and Propulsion Engine Research Center, which focuses its work on diesel engine bench and non-stationary operation tests for performance and emissions of fuels, including biodiesel. The facility consists of 3 rooms, namely the control and data management room, vehicle test room and the emission analysis room. The control and data management room is used for controlling all testing activities including collecting testing data, ventilation system, Constant Volume Sampling (CVS) System, hydrocarbon and particulate sampling system and emission analysis facilities. The test vehicle was a 2004 built passenger car with direct injection, automatic transmission, and a 2500 cc capacity diesel engine. The engine was as it is with slight modification in its fuel delivery system for convenience of fuels changing between test runs. The chassis dynamometer (CD) which is located in the vehicle test room consists of a pair of 48 inch in diameter steel roll. The roll was connected to a DC motor. The specification of CD is as follows:

- Maximum speed: 200 km/h
- Maximum power: 150 kW
- Inertia could be tested: 454 – 2722 kg
- Room testing temperature: 5 – 40^{o} C

BIODIESEL TECHNOLOGY

Palm Oil processing - Currently, Indonesia is known as the largest producer of palm oil in the world with a total CPO production of 15 ton per year. Domestic consumption of CPO is about half of the total production leaving the rest for export. With the price fluctuation of

CPO in the last few years, and the increase production in the near future, it is important too find other uses of CPO such as for palm oil biodiesel. Substitution of petroleum diesel with palm oil biodiesel should be done gradually by producing a blend of bio-petrodiesel.

Palm oil biodiesel technology - Biodiesel is chemically defined as a methyl ester derived from natural oils such as vegetable oils, animal fats or used frying oils. Biodiesel is a clean-burning, renewable, non-toxic and bio-degradable fuel that can be used alone or in blends with petroleum-derived diesel. Chemically, biodiesel is a mono alkyl ester or methyl ester with C chain between 12 to 20. The length of the C chain differentiates biodiesel from petrodiesel. Biodiesel has similar physical properties to petrodiesel so that it can be either mixed with petrodiesel or directly used for diesel engines. Although it is similar to petrodiesel, biodiesel has a higher flash point that makes it less flammable, contains no sulfur and benzene which are carcinogenic that makes biodiesel cleaner, saver and easier to handle than petrodiesel. Basically biodiesel is made through transesterifation of palm oil with methanol. Such process is accomplished in batch or continuer at 50-70 ^{o}C. The products are biodiesel and glycerine.

***Biodiesel Quality and Standard**

Because of the fact that biodiesel is produced in quite differently scaled plants from vegetable oils of varying origin and quality, it was necessary to install a standardization of fuel quality to guarantee engine performance without any difficulties. Generally, the parameters which are selected and established to define the quality of biodiesel can be classified into two groups.

Table 1

German biodiesel standard E DIN 51606 (KNOTHE AND DUNN, 2001)

Fuel properties	**Unit**	**Test method**	**Limit (min)**	**Limit (max)**
Density	g/ml	DIN EN ISO 3675	0.875	0.900
Kinematic viscosity	mm^2/s	DIN EN ISO 3104	3.5	5.0
Flash point	^{o}C	DIN EN ISO 22719	110	
Cetane number		DIN 51773	49	
Carbon residue	wt.%	DIN EN ISO 10370		0.05
Sulfur content	wt.%	DIN EN ISO 24260		0.01

Table 2

Selected fuel properties for diesel and biodiesel fuels (TYSON, 2001)

Fuel properties	**Unit**	**Diesel**	**Biodiesel**
Fuel Standard		**ASTM D975**	**ASTM PS 121**
Fuel composition		C10-C21 HC	C12-C22 FAME
Pour point	^{o}C	- 35 to -15	-15 to 10
Cetane number		40-55	46-65
Flash point	^{o}C	60-80	100-170
Boiling point	^{o}C	188-343	182-338
Water content	(%)		0.05
Density	gr/l	7.079	7.328
Special gravity	kg/l	0.85	0.88
Viscosity	(mm^2s^{-1})	1.3 – 1.4	1.9 – 6.0
Carbon	wt %	87	77
Cloud point	^{o}C	-15 to 5	-3 to 12
Sulfure	wt %	0.05 max	0 – 0.0024

One group contains general parameters, which are also used for mineral-oil based fuels, and the other group especially described the chemical composition and purity of fatty acid methyl esters. According to METTELBACHM (1996); Knothe and Dunn, (2001) and TYSON, (2001), such countries, such France and Germany used code of DIN E 51606, Austria (O-NORM C1190/1911), and Sweden (SS 155436); while USA used ASTM (American Standard for Testing Materials) as the standard to ensure good fuel quality for both pure biodiesel (B100) and blended 20% (B20). These can be seen in Table 1 & 2 below.

***Biodiesel properties vegetables biodiesel**

Table 3

Biodiesel properties palm oil, jatropha, rapeseed and soybeans (MEHER et al., 2006 and RANGANATHAN, 2008)

Property	Palm Oil	Jatropa curcas	Rapeseed	Soybean	Fossil fuel	Biodiesel standard	
	Sources:	Sources: Parawira (2010)				Value	Metode
Calorific value (MJkg-1)		39.23	36.90		42	38.3	
Pour point (^oC)		20				> 18	ASTM D 2500
Flash point (^oC)	190	135	175	174	> 68	> 100	ASTM D 93
Density (kgm-3)		880	920		840	850 – 900	ASTM D1298
Viscosity (mm2s-1)		4.8	4.5		2.6	2.3 - 6	ASTM D 445
Cetane number	42		46	37.9		< 51	ASTM D 613
Ash content (%)		0.20	0.01		0.17	< 0.02	ASTM D 874
Water content (%)		0.073	0.075		< 0.02	< 0.05	ASTM D 2709
Acid value (mgKOHg-1)		0.40			< 0.80	< 0.80	AOCS Ca12-55
Carbon residue (%)		0.20			0.17	< 0.30	

REMARK:

1. **Calorific Value, Heat of Combustion** – Heating Value or Heat of Combustion, is the amount of heating energy released by the combustion of a unit value of fuels
2. **Pour (melt) Point** - Melt or pour point refers to the temperature at which the oil in solid form starts to melt or pour. In cases where the temperatures fall below the melt point, the entire fuel system including all fuel lines and fuel tank will need to be heated
3. **Flash Point (FP)** - The flash point temperature of diesel fuel is the minimum temperature at which the fuel will ignite (flash) on application of an ignition source. Flash point varies inversely with the fuel's volatility. Minimum flash point temperatures are required for proper safety and handling of diesel fuel

4. **Density** – Is the weight per unit volume. Oils that are denser contain more *energy*. For example, petrol and diesel fuels give comparable energy by weight, but diesel is denser and hence gives more energy per litre.
5. **Viscosity** – Viscosity refers to the thickness of the oil, and is determined by measuring the amount of time taken for a given measure of oil to pass through an orifice of a specified size. Viscosity affects injector lubrication and fuel atomization. Fuels with low viscosity may not provide sufficient lubrication for the precision fit of fuel injection pumps, resulting in leakage or increased wear.
6. **Cetane Number (CN)** - Is a relative measure of the interval between the beginning of injection and auto-ignition of the fuel. Just as octane numbers determine the quality and value of gasoline (petrol).The higher the cetane number, the shorter the delay interval and the greater its combustibility. Fuels with low Cetane Numbers will result in difficult starting, noise and exhaust smoke. In general, diesel engines will operate better on fuels with Cetane Numbers above 50.
7. **Ash Percentage -** Ash is a measure of the amount of metals contained in the fuel. High concentrations of these materials can cause injector tip plugging, combustion deposits and injection system wear. The ash content is important for the heating value, as heating value decreases with increasing ash content.
8. **Sulfur Percentage -** The percentage by weight, of sulfur in the fuel Sulfur content is limited by law to very small percentages for diesel fuel used in on-road applications.

RESULTS AND DISCUSSION

The implication to the engine performance including fuel consumption, heat, emission and overall performance of the engine after using biodiesel. Implication to the engine performance including fuel consumption, heat, emission and overall performance of the engine after using biodiesel.

It is clear that the higher power of the blending fuel compare to the power of pure petro-diesel fuel in this study could be affected by the lower viscosity value of tested pure biodiesel B100 than viscosity value of tested pure petro-diesel fuel. Fuel viscosity has impacts on injection and combustion. If fuel viscosity is high, the injection pump will be unable to supply sufficient fuel to fill the pumping chamber, which will effect to a power loss for the engine (KNOTHE et. al., 2004).

A fuel consumption of B100 (0.69 L/10 km) was higher than a fuel consumption of B0 (2) (0.65 L/10 km), but lower than B0 (1) (1.03 L/10 km). Although the CO and HC emission of B0 (2) was higher than B100, B0 (2) released lower CO2 emission than B100, which gives significant effect to the reduction of fuel consumption. The reduction of fuel consumption as a function of biodiesel blend composition B10, B20, B30, B50 and B100 were 6%, 9%, 16%, 22% and 33% respectively. Those result were clearly shows a close relationship between fuel viscosity and atomization. Higher viscosity of the fuel tends to reduce the quality of fuel atomization, which could potentially give impacts to the higher emission and fuel consumption.

The distinct influence of sulphur content in diesel fuel on particulate emissions has been investigated by MERKISZ, et.al., (2002). As expected, their result showed that the highest PM emission was obtained at the highest sulphur content in diesel fuel. The reduction of PM emission is depending on the value of sulphur content in the fuel. For fuel with lower sulphur (350 and 50 ppm) content almost the same PM emission level, but for fuel with higher sulphur (2000 ppm) content about 20% higher PM emission than lower sulphur diesel fuel. B0 (2) has higher sulfur content (1479 ppm) than B0 (1) (335 ppm), but as showed on figure 5, PM emission of B0 (2) was lower than B0 (1). This slightly contradictive result demonstrated that the lower viscosity value of B0 (2) (4.425 cSt) than the viscosity value of B0 (1) (5.436 cSt) is more effective to the reduction of PM emission compare to the effect of lower sulphur content value. CO and NOx emissions were also reduced although not as sharp as the reduction of particle and HC emission. Lower NOx emission at higher biodiesel blend concentration is contradictive with those generally found in previous non palm biodiesel studies.

The formation of NOx depends on the combustion temperature and oxygen content in the mixing combustion product. Biodiesel blend fuel has a faster ignition ability, increase the combustion room temperature and pressure, which would finally stimulate the NOx formation. Nearly all cited studies report that biodiesel-fuelled engine has a slight increase of NOx emission (MITTELBACH AND REMSCHMIDT, 2004)

CONCLUSION

The emission of CO, HC and particle decreased considerably with the increase in biodiesel blend. The reduction in particle emission was very sharp at 10% blend (B10), while the sharp reduction in HC emission started at 20% blend (B20). The results also shows lower NOx emission as well as higher torque and power for biodiesel blend compare to that of pure petro-diesel fuel. This result could be as a consequence of the properties of tested palm biodiesel, which has higher cetane number and lower viscosity value compared to the petrodiesel fuel sample.

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