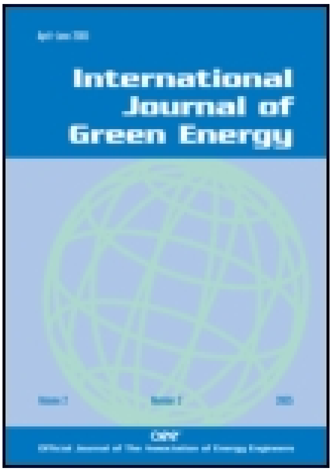

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THE PRODUCTION OF BIODIESEL FROM A BASTARD POOM FEEDSTOCK

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This study was conducted on the production of biodiesel from bastard poom via transesterification with potassium hydroxide as the catalyst. Certain experimental conditions were set for determining the maximum biodiesel produced. The most appropriate methanol solvent per bastard poom found was 1:4 by volume and 2 mass per unit volume of potassium hydroxide at 60°C for 30 min. The amount of biodiesel obtained was 88.56% by mass of crude oil. The following fuel properties were noted: the biodiesel had a golden yellow color without any residue. Its cloud point was at 2.4°C, the pour point at –1°C, the density at 15°C of $890\ \mathrm{kg/m^3}$, and the flash point at over 290°C. The acid value was 0.49 mgKOH−g, the water content was 610 mg−kg, combustion heating value was roughly 38,590 kJ−kg, the viscosity was 5.68 mm^2−s at 40°C, and copper corrosion was at 1A level. The analysis of water property of biodiesel from bastard poom showed its properties within Thai biodiesel standards. This indicates that bastard poom is suitable for developing as an alternative fuel.

Keywords: ***Bastard poom; Biodiesel; Alternative fuel***

INTRODUCTION

Biodiesel is now considered as an alternative fuel. The raw materials for producing biodiesel could be from plants and animals. A variety of plants exist and are available all year round in different parts of the world depending on respective climates, e.g., bastard poom, Jatropha, castor bean, rape seed, sunflower, etc. Each of these crops yields different amount of oil, and the components and fatty acid are also different. Thus, the production process for each requires different proportion of base material depending on the type and breed of the plant used. The comparison of physical properities of different sources of biodiesel is shown in Table 1. In India, Panchal et al. (in press) studied biodiesel production from Thespesia populnea seed oil by adding methanol at a ratio of 6:1, mixing intensity of 250 rpm, and reaction temperature of 60°C. Concentrated sodium hydroxide added was 1.5% by weight as the catalyst. This proportion was proved to yield maximum

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Table 1 Comparison of Physical Properties of Different Sources of Biodiesel (Meng et al. 2008[1]; Ong et al. 2011[2]; Patil and Deng 2009[3]; Biodiesel standards 2006[4], M. Satyanarayana and C. Muraleedharan[5])

			Biodiesel from various sources					
			Bastard poom					
Fuel properties	Testing method ASTM D2500	Standard biodiesel ASTM D6751[4]	Crude oil	Biodiesel	Palm[2]	Used vegetable oil[1]	jathropha[3]	Rubber Seed[5]
Cloud point (°C)	ASTM D2500	−3 to 12	−6.90	2.40	15	2.40	6	5
Pour point (°C)	ASTM D97	−5 to 10	−10.00	−1	14	−1	2	−8
Density (kg/m^3)	ASTM D4052	870–890	929.60	890	879.30	890	862	871
Flash point (°C)	ASTM D93	>130	>270	>290	181	171	135	164
Acidity number (mg KOH/g)	ASTM D664	<0.5	5.46	0.49	0.33	0.48	0.40	–
Water content (mg/kg)	ASTM D6304	<500	831.30	610	300	150	250	–
Viscosity	ASTM D445	1.90–6.00	44.61	5.68	4.90	4.23	4.80	4.98
Heating value (kJ/kg)	ASTM D240	–	39,64	38,590.40	–	32,900	39,230	35,780
Copper corrosion	ASTM D130	Class 3	1A	1A	1A	1A	1A	

ester amount of 92.6% by weight. Paridaet al. (2012) studied biodiesel production from vegetable oil using ultrasonic to accelerate reaction of solvents. The experiment showed maximum ester obtained at 98% with the reaction temperature of 55°C under a sonication frequency of 20 kHz for 5 min. The ratio of ethanol per vegetable oil was 5:1 and sodium hydroxide was used 1% as the catalyst. Rutto and Enweremadu (2011) also conducted biodiesel production from manketti nut with amount of methanol in the oil of 32 wt% and reaction temperature of 55°C. It was found that at the reaction time of 53 min and amount of catalyst of 1.02 wt%, the maximum yielded ester was 98.3%. Canakci (2007) studied the use of used vegetable oil and lard from restaurants in the US to produce biodiesel, since the US is the country where these oils are in sufficient amount for industrial production. They found that direct transesterification is not possible from the oil and lard discarded from restaurants due to high amount of free fatty acid, i.e., from 0.70.7 to 41.8. However, this problem could be solved by reducing the free fatty acid by mild acid catalyst before transesterification. Shazia Sultana et al. (2013) worked on production from *Sinapis alba* L. oil (commonly known as white mustard) via transesterification process at a ratio of 6:1 methanol per oil, with 0.5 g of sodium hydroxide as catalyst at 65°C for reaction time 75 min. The result yielded a maximum of 92% biodiesel. Sanjay Gandhi Bojan, Chelladurai, and Durairaj (2011) optimized reaction parameters of biodiesel production from high free fatty acid Jatropha curcas oil by alkali catalyst-based transesterification. The optimized conditions found were methanol to oil molar ratio of 7.28:1 with alkali catalyst of 2.06% w−w of oil, reaction temperature 61°C. The result yielded a maximum of 81.93%. Abdelrahman (2013) produced biodiesel from melon seed oil with a methanol to oil molar ratio of 6:1 with KOH concentration 0.75% w−w of oil, reaction temperature of 60°C. The results showed that biodiesel had slight influence on the original properties of petro diesel. Anastopoulos (2013) produced biodiesel from four vegetable oils (oils: sunflower, cotton seed, olive oil, and used frying oil) using calcium ethoxide as a heterogeneous solid base catalyst. The ester preparation involved a two-step transesterification reaction. The optimal condition for the first stage was an ethanol to oil molar ratio 12:1, catalyst amount of 3.5%, reaction temperature 80°C, whereas the maximum yield of ethyl esters of 80.5%. In the second stage, the yield of ethyl esters showed signs of improvement of 16% in relation with the one-stage transesterification, which was obtained under optimal conditions:catalyst concentration 0.75% and ethanol−oil molar ratio 6:1. Mofijur et al. (2012) criticized biodiesel produced from Jatropha via the transesterification process, saying that it yielded higher property than the biodiesel standards ASTM D 6751 and EN14214. The biodiesel from Jatropha was tested in real engine and compared to studies in Malaysia, Indonesia, India, Bangladesh, and Thailand. The result showed that in Malaysia, the engine consumed the least biodiesel. Parawira (2010) reviewed to give an update on the *Jatropha curcas Linnaeus* plant, the production of biodiesel from the seed oil and research attempts to improve the technology of converting vegetable oil to biodiesel and the fuel properties of the *Jatropha* biodiesel. The technological methods that can be used to produce biodiesel are presented together with their advantages and disadvantages. Transesterification is the most famous method since production is simple and the cost is low. Researches on catalysts showed that acidic and enzyme catalysts yield biodiesel of high purity and in great amount. However, enzyme is very expensive. Alkaline catalyst, on the other hand, allows shortest time to produce biodiesel until it is widely accepted in industrial production. Berchmans and Hirata (2008) from Indonesia studied production of biodiesel from Jatropha using double-stage action. In the first stage, methanol solvent was added at a ratio of 0.60 by weight using 1% of sulfuric acid by weight as the catalyst. The temperature was set at 50°C for 1 hr before leaving it another 2 hr for separation. Then, the mixture of water and methanol on top was removed. During stage 2, the separated oil was mixed with methanol solvent at a ratio of 0.24 by weight, with sodium hydroxide of 1.4% by weight as the catalyst at the temperature of 65°C for 2 hr. The yield of 90% biodiesel was obtained, which was the maximum amount from the experiment.

Even though alternative energy may bring hope to us, the proportion is still meager when compared to the needs that are met at present by energy from fossil fuels. Planning and setting a goal for the future are vital and a good beginning with many countries seeing the importance of alternative energy and are supporting research on it, especially energy from green plants. This research was a study of “production of biodiesel from bastard poom,” which has a possibility as an alternative plant energy. In this study, bastard poom seeds were extracted for oil which was reacted with methyl alcohol using alkaline as the catalyst. This reaction is called transesterification or alcoholysis. The product obtained was biodiesel of the ester type derived from plant oil. In order to know if this biodiesel is suitable for use, we performed an experiment and compared its property with the United States accepted standard biodiesel ASTM D6751. Besides, we also studied the fuel properties and the rate of chemical use compared to the production of biodiesel from such oil. Most importantly, indigenous plants could be more beneficially utilized.

MATERIALS AND EXPERIMENT METHODS

Bastard Poom (*Sterculia foetida* L.) Tree and Crude Oil Compositions

Sterculia foetida L. (Figure 1) is scientific name of Bastard Poom and belongs to the Sterculiaceae family, which has about 2000 types of species. They are able to grow in hot and arid areas, which distributed in areas of 100–600 m above sea level from eastern Africa, India, Sri Lanka, Myanmar (vernacular name is Letpan-shaw), Indo-china, Thailand (vernacular name is Samrong), throughout Malaysia (vernacular name is Kelumpang jari).

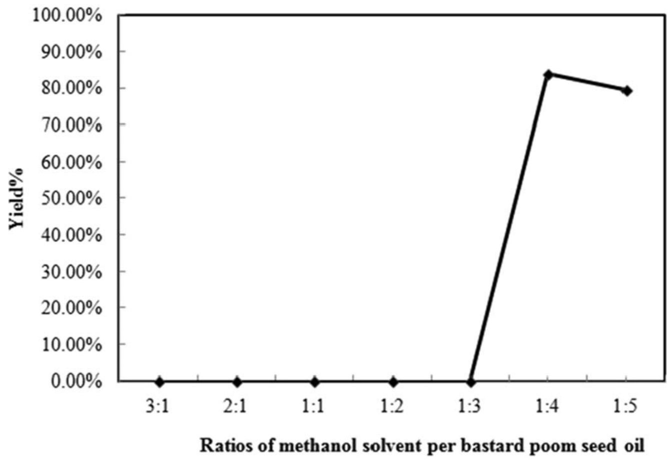

Figure 1 Finding the most suitable KOH to oil ratio.

They are a type of softwood tree with a brown bark, large, straight, deciduous tree and growing up to 30 m in height. Bastard poom is a common perennial having good resistance to drought and so can grow anywhere. Bastard poom wood is soft, the tree is deciduous, stands straight with smooth gray barks and red-color flowers. The fruits are borne in bunches of 1–32 fruits. Each fruit has about 8–32 seeds. Young fruits are green in color and turn red when mature and black when dry. The seeds are cylindrical and round in shape. Studies have shown that bastard poom barks can be used to treat intestine diseases. The red fruits can be extracted for dye, while seed oil can be used for cooking.

The composition of the crude Bastard Poom oil is Palmitic (40.16%), cis-9-Oleic (15.12%), cis-9, 12-Linoleic (15.04%), and cis-11, 14-Eicosadienoic acids (15.67%). These fatty acids are unsaturated fats with 1 or 2 double chemical bonds which are commonly found in plants and animals oils. Based on the oxidation index (Knothe and Dunn 2003), the oxidation stability of these unsaturated oils is not good and should be further investigated.

Experimental Design

Three experiments were performed to find the influence of different ratios of methanol solvent to crude oil, catalysts, and temperature in the reaction on the result product from transesterification. The first stage was preparation of base substances. Methanol solvent was prepared in seven different ratios of potassium hydroxide per methanol, namely 3:1, 2:1, 1:1, 1:2, 1:3, 1:4, and 1:5 in order to find the best ratio. In Experiment 1, potassium hydroxide concentration was 2% by mass per volume of solvent. The experiment was performed at 60°C and reaction lasted 30 min. The test tube was observed for complete reaction by looking at the separation between of biodiesel and glycerin, and then the ratio of methanol and bastard poom was applied in the next experiment. In Experiment 2, the most suitable amount of potassium hydroxide was determined by using the ratio of methanol and bastard poom from Experiment 1 and controlling the amount of potassium hydroxide at 0.5%, 1.0%, 1.5%, 2.0%, and 2.5% by mass per volume at 60°C for 30 min. Again, complete reaction in the test tube was observed from stratification of biodiesel and glycerin. The amount of potassium hydroxide with the most suitable mass per volume of solvents was taken to apply in the next experiment. Experiment 3 applied the most suitable ratios of alcohol per crude oil from Experiments 1 and 2, respectively, with reaction temperatures of 50, 55, 60, and 65°C for 30 min. Completion of reaction was compared by measuring ester obtained at the end in order to find the conditions of the three variables in transesterification. The yield of biodiesel can be simply determined by

$$\text{Percent yield (\%)} = [\text{mass of methyl ester (g)}/\text{mass of crude oil (g)}] \times 100\%.$$

Analyzing Biodiesel Properties

The biodiesel made from bastard poom seeds was measured for nine biodiesel properties in the biofuel testing laboratory of the Energy Technology Development Research Group, the National Metal and Materials Technology, namely: acid number, cloud point, density, pour point, flash point, viscosity, amount of water, heating value, and copper corrosion according to the ASTM standard. Then, the results were compared with biodiesel produced from other raw materials.

RESULTS AND DISCUSSION

The study of influence of different ratios of methanol and bastard poom on transesterification in the biodiesel production, namely 3:1, 2:1, 1:1, 1:2, 1:3, 1:4, and 1:5, was conducted in this research with other variables at constant amount. Potassium hydroxide was 2% by mass per volume, the temperature was 60°C and transesterification lasted 30 min. When the transeserification process ended, glycerin was removed and the remaining biodiesel was brought to measure the amount against the condition that yielded most complete reaction. This was compared to the amount of biodiesel obtained from correlation of the ratio of methanol solvent and oil with the greatest amount of product at one point as shown in Figure 1. If the catalyst was of excessive amount, glycerin would be higher and biodiesel obtained would be less as shown in Figure 2.

From Figure 1, the experiment covered seven conditions of the ratios of methanol solvent per bastard poom seed oil. It was found that at the ratio 1:4, temperature of 60°C, and the period of reaction of 30 min, after reaction ended 83.77% of biodiesel could be

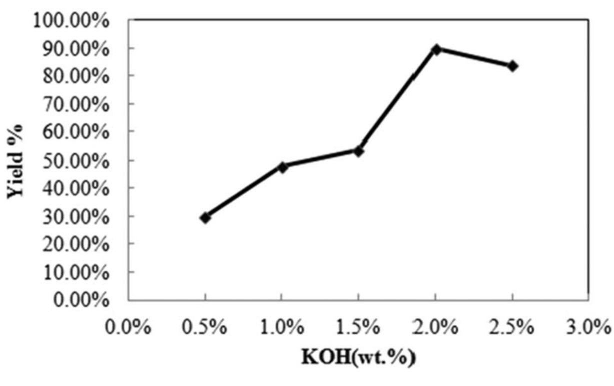

Figure 2 Finding the most suitable catalyst.

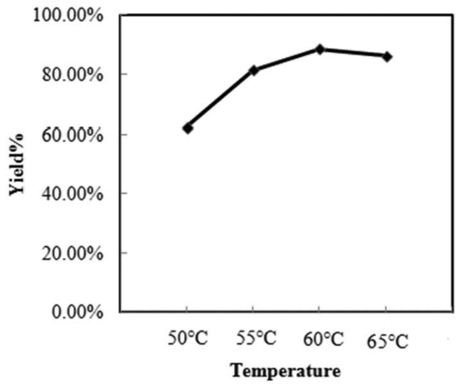

Figure 3 Result of study on reaction temperature.

separated from glycerin by crude oil weight. We found that with the ratios of 3:1, 2:1, 1:1, 1:2, and 1:3 there was no stratification of glycerin and biodiesel owing to incomplete reaction. At the ratios 1:4, 1:5, there was stratification, but the ratio 1:4 yielded greater amount of biodiesel; therefore, 1:4 was the most suitable ratio.

In Figure 2, five conditions were experimented with different amount of potassium hydroxide as the catalyst. At 2% by mass per solvent volume when reaction ended, 89.76% of biodiesel could be separated from glycerin. So this was the condition that yielded the highest amount of biodiesel. If potassium hydroxide concentration was increased to 2.5%, glycerin would increase and biodiesel produced from the reaction would decrease.

Figure 3 shows transesterification using 2% by mass per solvent volume of potassium hydroxide, potassium methoxide to bastard poom of 1:4 in order to find the most suitable temperature range. The temperatures were set at the order of 50, 55, 60, and 65°C. At 60°C, we obtained highest amount of biodiesel at 88.56% by mass of crude oil of all solvent inputs. When the temperature was increased to 65°C, however, amount of biodiesel decreased. It is noted that an error of ±3°C occurred in controlling the temperature of water basin.

The analysis of nine properties of biodiesel from bastard poom against the standard biodiesel showed that the cloud point, pour point, density, acidity, and copper corrosion are under the standards. However, the flash point is much higher than the standard when compared to other types of biodiesel. Water is also found remaining at a greater amount than in other types. This indicates correlation between water content and flash point, i.e., when water content is high, the flash point may be high too.

The experiment we conducted on biodiesel production from bastard poom also indicated that the 1:4 ratio of methanol solvent to oil used was lower than palm oil. Soybean (Gomes et al. 2011) used oil (Meng, Chen, and Wang 2008) and Jatropha oil (Biodiesel standards 2006) which were at 15:1, 9:1, 9:1, and 9:1, respectively. The amount of biodiesel obtained from bastard poom was 88.56% by mass of crude oil, which was less than biodiesel from palm oil, soybean, used oil, and Jatropha oil which were 91.1%, 98.7, 85.8%, and 95%, respectively. This could perhaps result from the different production process components and devices. However, biodiesel produced from bastard poom met the standard criteria of biodiesel. What should be further investigated is removal of water content from the oil, for the amount of water could result in good flash point. The biodiesel produced from bastard poom should be tested with diesel engines in order to find its efficiency. Development of bastard poom breed which can grow in all regions of Thailand should be done to utilize the tree and plan at least domestic or household use of the biodiesel and an alternative energy source in the future.

CONCLUSION

This research studied production of biodiesel from bastard poom. A 12-year old bastard poom tree in Khon Kaen province, Thailand, was selected. The seeds were squeezed on a screw press to obtain crude oil with low triglyceride. The crude oil cannot be directly used in any engine. It has to undergo transesterification with potassium hydroxide as catalyst in order to find the maximum amount of biodiesel produced. It was found that the ratio of methanol solvent per bastard seed oil was 1:4 by volume. Potassium hydroxide of 2% by mass per total volume was used at 60°C and reaction time of 30 min. The amount of biodiesel obtained was 88.56% by mass of crude oil. The experiment in biodiesel production using bastard poom in transesterification showed that the bastard poom oil, used oil, and Jatropha oil had different mixture ratio of methanol and oil, but biodiesel obtained from bastard poom was slightly less than the others. The step of study that followed showed the oil had a golden yellow color and no residue was found. The cloud point was at 2.4°C, the pour point at –1°C, the density at 15°C was 890 g−m^3, the flash point was at over 290°C, the acid number was 0.49 mgKOH−g, the water content was 610 mg−kg, the heating value for combustion approximately 38,590 kJ−kg, the viscosity at 40°C was 5.68 mm^2−s, and the copper corrosion was found at the 1 A level. The analysis of these nine properties proved that biodiesel produced from bastard poom met the Thai biodiesel standards. This biodiesel will be further tested in agricultural diesel engines in order to find the standard as a replacement for other fuels or as an alternative fuel for farmers and communities.

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