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Biodiesel production from used frying oil in Phnom Penh

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Abstract: *Biodiesel is a renewable green fuel obtained through the transformation of animal and vegetable fats, as well as used oil. This biodiesel can replace fossil diesel. The production of biodiesel from recycled oils is comparable in quality to that virgin vegetable oil biodiesel with an added attractive advantage of being lower in price. The current research was therefore to study the production of biodiesel from used frying oil for fried banana in Phnom Penh by reducing the viscosity of this oil by trans-esterification. In this process, there are two main steps. The first step is the esterification by adding a small amount of H_2SO_4 as a catalyst. The second step is the trans-esterification by using NaOH as a catalyst. The yield of biodiesel obtained from the experimentation was 88% compared to the quantity of used frying oil as a raw material. By transforming the used frying oil to biodiesel, the viscosity decreased from 39.32 mm^2/s to 7.93 mm^2/s. The other parameters are also improved such as apparence, color, flash point, water content, ash content, acid value and iodine value. In conclusion, the process of trans-esterification can reduce the viscosity of used frying oil that is applicable for biodiesel.*

Keywords: Used frying oil; Biodiesel; Esterification; Trans-esterification; Catalyzer.

1. INTRODUCTION

In Cambodia, there are many food sellers who use the frying oil again and again for many times until the oil turns black. They are mostly the sellers who sells the food on the street or at the markets. They focused only on the income, not the customers' health. In addition, the fast food restaurants are now increasing in numbers, especially in Phnom Penh and the vegetable oil is usually used for cooking and frying. This used frying or cooking oil should not be used to fry or cook for many times as it is harmful for the health of customers. For KFC comapny, about 200 litres of used oil were discarded per month after utilization. It should be therefore converted into other valuable sources including biodiesel. Biodiesel has become more attractive recently because of its environmental benefits and the fact that it is made from renewable resources. Biodiesel is a renewable fuel manufactured from methanol and vegetable oil, animal fats, and recycled cooking fats (U.S. Department of Energy, 2006). There are four primary ways to make biodiesel including direct use and blending, microemulsions, thermal cracking (pyrolysis) and trans-esterification. The most common method to produce biodiesel is through a process called "trans-esterification," which involves altering the chemical properties of the oil by using methanol. Using the used cooking/frying oils as raw material is a primary option to be considered to lower the cost of biodiesel for commercialization (Fangrui and Hanna, 1999).

The objective of this research was therefore to transform the waste frying oil in Phnom Penh into biodiesel by trans-esterification and to evaluate the quality of biodiesel produced.

2. METHODOLOGY

2.1 Collection of used frying oil for biodiesel production

In this study, 3 L of the used frying oil was obtained from the seller who sold the fried bananas in Phnom Penh and kept at room temperature. The experiments were conducted as soon as possible within 1 week. In addition, the characteristics of used frying oil such as appearance, color, viscosity, density, acid index, ash content and water content were determined before trans-esterification.

2.2 Biodiesel production by trans-esterification

Biodiesel production is based on trans-esterification of vegetable oils and fats through the addition of methanol (or other alcohols) and a catalyst, giving glycerol as a co-product (IEA, 2007). A catalyst is usually used to improve the reaction rate and yield (Fangrui and Hanna, 1999). The trans-esterification process is shown in Figure 1.

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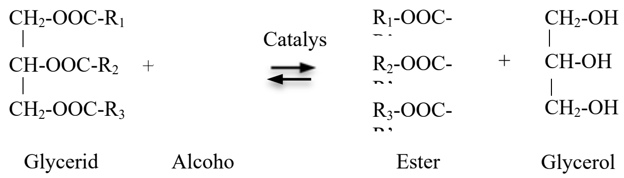

Fig. 1. Trans-esterification of triglyceride with alcohol

Trans-esterification for biodiesel production from used frying oil was performed at Institute of Technology of Cambodia (ITC). The used oil was first filtered to remove the precipitate and pre-heated at 60 ºC for 15 min to remove some water. It was then agitated for 5 min and 8% of pure methanol was added. It was agitated for another 5 min and 0.1% of 95-97% H_2SO_4 was added for esterification with agitation at 35 ºC for 2 h. Agitation for another 1 h without heating and then kept at room temperature for more than 8 h. Sodium methoxide solution was first prepared by dissolving 2.55 g of NaOH (catalyst) in 60 mL of methanol. The oil sample was mixed with half volume of this solution and heated with agitation at 55 ºC for 10 min. for trans-esterification. Another 30 mL of sodium methoxide solution was added and heated at 55 ºC for another 2.5 h. The sample was then left at room temperature for sediments (glycerol) to settle down. After 1 h, methyl esters were separated from glycerol and washed with the mixture of hot water (60 ºC) and phosphoric acid (10%) with the ratio of 1: 1/3 (methyl ester: mixture) to remove the excess of alcohol and catalyzer. During washing, the sample was agitated for at least 24 h and then left for 1.5 h to separate the biodiesel and water. Finally, the biodiesel was dried to remove all the water and its quality was analyzed.

2.3 Physico-chemical analysis of used frying oil and biodiesel

Some parameters such as viscosity, density, flash point and color were measured at TELA company at Prek Pnov (Kampong Speu province) by using Koehler machine (ASTM D445), Density/specific gravity meter (DA-645 model), Satastill and Lovibond, respectively. Other parameters including water content, ash content, acid value and iodine value were analyzed at ITC using oven at 105 ºC, oven at 550 ºC, titration with KOH and titration with iodine solution, respectively.

3. RESULTS AND DISCUSSION

3.1 Characteristics of used frying oil before trans-esterification

Before trans-esterification, the used frying oil was characterized as shown in Table 1. By comparing with Jatropha oil and palm oil, the appearance of used frying oil was the same as that of palm oil. The turbidity of used frying oil indicated that the impurities were high because of frying many times. Therefore, the yield of biodiesel production might not be high because of these impurities and refining of the used oil is needed. The color of used frying oil was also the same as that of palm oil. During the frying process, the oil is exposed to high temperatures in the presence of air and moisture. Under these conditions, it may undergo important changes due to hydrolytic, oxidative and thermal reactions (Refaat, 2010). The viscosity of used frying oil was also comparable with that of palm oil. The viscosity of the oil depends on the high quantity of fatty acids, alcohol groups, saturated materials, mono-, di-, and triglyceride, and increasing the quantity of polymers in frying oil. When the composition of oil is different, the viscosity is also different. According to Table 1, the density of used frying oil is similar with that of jatropha oil and palm oil. The acid value of used frying oil was two times higher than that of jatropha oil. Normally, the acid number is in function with the duration of storage as the triglycerides are converted into fatty acids and glycerol, and the type of oil used for biodiesel production (Mittelbach and Remschmidt, 2004). The increase in acid value indicated that the oil is rancidified during storage as the triglycerides are converted into fatty acids and glycerol. The ash content of used frying oil was only 0.04%, which was very much smaller than that of jatropha oil and palm oil. The water content of 0.04% was detected only in used frying oil. This might be due to the water content in bananas releasing into the oil during frying. The iodine value of used frying oil was found to be high, approximately 146.66 g I_2/100g of oil.

Table 1. Characteristics of used frying oil, jatropha oil and palm oil

Parameters	Frying oil	Jatropha oil	Palm oil
Appearance	Turbid	Clear	Turbid
Color	Red	Yellow	Red
Viscosity at 40 ºC (mm^2/s)	39.32	35.00	38.56
Density at 15 ºC (kg/m^3)	0.9191	0.9189	0.9141
Acid value (mg KOH/g)	3.82	1.89	4.80
Ash content (%)	0.04	5.80	10.00
Water content (%)	0.04	–	–

3.2 Characteristics of biodiesel produced from used frying oil

After trans-esterification, the yield of biodiesel produced from the used frying oil was 88%. This yield was lower compared to that of biodiesel producted from jatropha oil (92%) and palm oil (93%). The characteristics of biodiesel obtained from the used frying oil were also compared with those of jatropha oil, palm oil and standard as indicated in Table 2. The properties of biodiesel differ depending on the source of plant oil/fat source. This is mainly related to their chemical structure, such as the number of carbons and the number of double bonds in the hydrocarbon chain. From used frying oil to biodiesel, the appearance and color were changed from turbid to clear and from red to yellow, respectively. And the density, the flash point, the ash content and acid value of biodiesel of frying oil were similar with those of other oils and ranged in the standard of PIT Public Company Limited. However, its viscosity and iodine value were higer than those of other oils and standard.

Table 2. Characteristics of biodiesel from different oils

Parameters	**Used frying oil**	**Jatropha oil**	**Palm oil**	**Standard**
Appearance	Clear	Clear	Clear	Clear & bright
Color	Yellow	Yellow	Red	Yellow
Viscosity (mm^2/s)	7.93	5.84	7.28	3.5–5.0
Density (kg/m^3)	0.8913	0.8923	0.8850	0.860–0.900
Flash point (ºC)	186	186	176	Min 120
Ash content (%)	0.015	–	–	Max 0.2
Water content (%)	0.040	–	–	–
Acid value (mg KOH/g)	0.38	–	–	Max 0.50
Iodine value (g I_2/100g)	140.00	–	–	Max 120

4. CONCLUSIONS

In conclusion, the biodiesel can be produced from used frying oil by trans-esterification with some acceptable characteristics including appearance, color, viscosity, density, flash point, acid value and ash content. In addition, trans-esterification can reduce the viscosity of used frying oil from 39.32 mm^2/s to 7.39 mm^2/s. For further studies, the comparison about characteristics of oil before and after using many times, the optimization of methanol to oil ratio, the mineral content of biodiesel (phosphorus, sulfate and copper), the influence of used oil oxidation on the yield of biodiesel and the effect of fatty acid composition on the quality of biodiesel should be investigated.

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