Transesterification of Lard to Biodiesel using Two-step Microwave

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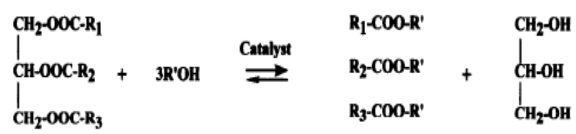
Abstract

A decreasing in a fossil fuel source and concerning in environmental problems have boosted a large consumption of alternative fuels. Biodiesel produced via a transesterification of vegetable oils and animal fats is a typical biofuel due to low toxic emission. In this present work, the transesterification of lard was performed in a batch system under two-step microwave using a homogeneous catalyst. This work aims to investigate the optimum reaction parameters such as methanol to fat ratio, reaction time and power consumption and to study some properties of product such as acid value, and viscosity. As a result, the best product was 98.1% of fatty acid methyl ester, 0.13 mgKOH/g and 40 0.41 cSt under methanol to fat ratio of 28%wt., 200 W for 3 min. Compared with a conventional heating system, the microwave-heating system consumes 13.8 times less energy than that of the conventional system.

Keywords: Biodiesel, Lard, Microwave

1. Introduction

Biofuels, nowadays, become attractive energy for many aspects, especially for transportation. One of them is biodiesel that is alkyl-ester obtained from the transesterification of vegetable oils or animal fat. Several studies have been done in order to obtain high biodiesel yield and less time consuming due to the high possibility of using biodiesel to replace a fuel oil in diesel engine. Compared to petroleum-based diesel, biodiesel is biodegradable and nontoxic [1-2]. The transesterification of triglyceride is shown in Fig. 1.



Triglyceride alcohol alkyl-ester glycerol

Fig. 1 Transesterification of triglyceride. R1, R2, R3, R' represent alkyl groups [3].

Transesterification of triglyceride by methanol to obtain fatty acid methyl esters is a popular reaction. In this process, either acidic or basic catalysts can be used such as sulfuric acid or potassium/sodium hydroxide. Generally, the mixture of oil/fat and methanol is heated and stirred at the desired condition with the catalyst. Then, the effluent is separated to have a high purity of methyl ester. However, the process requires a long time to obtain high yield of biodiesel. Recently, researchers pay more attention to an alternative process for biodiesel production that is the use of microwave radiation. Some advantages of this technique compared to the conventional heating technique are saving the energy consumption, easing to operation and decreasing contact time [4].

In Thailand, the cost of biodiesel mainly depends on the cost of the feed-vegetable oils, especially palm oil. This impacts cooking oil price. Therefore, the way to solve this problem is to find a new source that has a high potential to biodiesel production. In this work, we attempt to produce the biodiesel from lard by modifying the in-house microwave system.

2. Experimental

2.1 General procedures

Biodiesel product was analyzed by gas chromatography, thermogravimetric analyzer, Calorimeter and ASTM standard methods for viscosity and acid value. Gas chromatography analysis was carried out on a HP6890 equipped with a FID detector. The heating value of products was obtained from calorimeter model 1261. The profile of the weight changes in a product was measured by TGA-50, Shimadzu with a heating rate 10^{o}C/min for 70 min.

2.2 Activity test

The experiments were conducted in 2 steps: preheating step and reaction step. Lard was preheated in a microwave system - mono chromatic type with a different power for 5 min. Then, lard was mixed with methanol at a given amount of potassium hydroxide and heated to the desired temperature by using a microwave radiation. To obtain the highest yield, some parameters were studied as shown in Table 1. In addition, the reaction was also tested by a conventional heating system.

Table 1 Studied parameters for transesterification

Parameter	Value
Methanol/fat ratio	0.2-0.3
Reaction time for a microwave system, min.	1-10
Reaction time for a conventional heating system, min.	30-60
Power, W	200-500

3. Results and discussion

3.1 Preheating step

A preheating step was needed in order to keep fat in a liquid form before the reaction. To ensure that the properties of lard are not significantly changed during this step, some properties of samples before and after preheating step were observed as shown in Table 2. Samples were heated by microwave irradiation at different powers for 5 min. The results show a higher power, a higher temperature of sample. The heating value and acid value of samples after preheating are about the same as sample without heating. It is fair to conclude that the preheating step does not affect the properties of fat.

Table 2 Properties of lard before and after preheating step

	Final temperature (°C)	**Heating value (MJ/kg)**	**Acid value (mg KOH/g)**
Lard	-	39.5	0.50
Lard with preheating at 200 W	48	39.3	0.52
Lard with preheating at 400 W	62	36.3	0.54
Lard with preheating at 600 W	78	37.1	0.53
Lard with preheating at 800 W	108	36.2	0.60

3.2 Reaction step

The transesterification of lard was investigated under two types of heating system: a microwave radiation and a conventional heat. In this work, parameter variables affected the properties of products were studied such as the methanol to fat ratio, reaction time and power of the microwave system.

3.2.1 Reactions occurred under microwave system

The effect of reaction time on yield of biodiesel for a microwave system of 200 W and the methanol/fat ratio of 0.25 is presented in Fig. 2. At reaction time more than 5 min., yield of biodiesel drastically decreases.

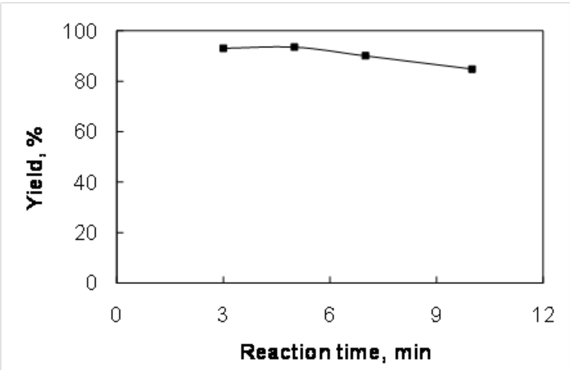


Fig. 2 Effect of reaction time on yield.

Figure 3 presents the effect of methanol to fat ratio on yield of biodiesel when using a power of 200 W for 5 min. The results show that yield of biodiesel increases with the ratio of methanol to fat increases.

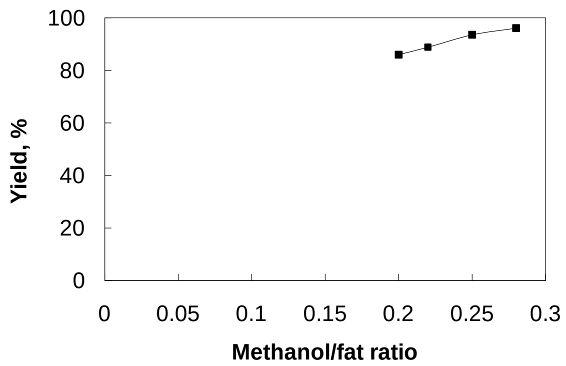


Fig. 3 Effect of the methanol to fat ratio on yield

At this point, we can conclude that transesterification of lard under a microwave system does not require a long reaction time, but prefers the high methanol/fat ratio.

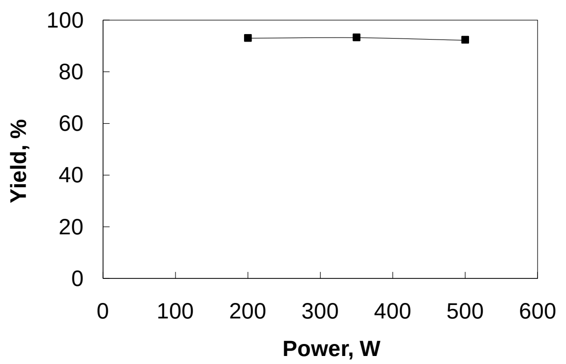


Fig. 4 Effect of the power on yield.

To investigate the effect of power on biodiesel yield, the experiments were conducted at the methanol/fat ratio of 0.25 and the reaction time of 3 min. The effect of power of microwave system on biodiesel yield obtained at methanol:fat ratio of 1:4 for 3 min is shown in Fig. 4. Yields obtained at 200 W, 300 W and 500 W are almost the same value. It can be said that the high level of heat or power in does not enhance the transesterification of lard. The system does not require a high power of microwave.

3.2.2 Reaction occurred under conventional heating system

The reactions were investigated under two different ratio of methanol/fat for 30 min, 45 min and 60 min. The reaction temperature was kept at a constant of 60°C. The result is shown in Fig. 5.

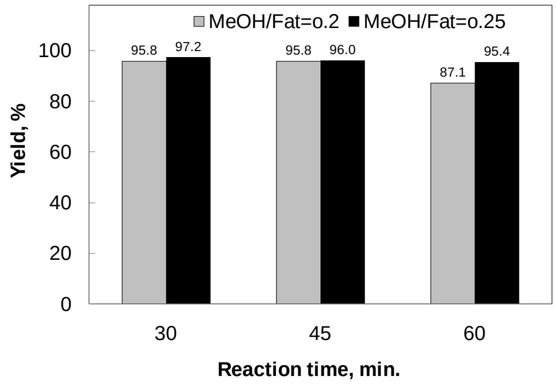


Fig. 5 Effect of the ratio of methanol/fat on biodiesel yield under 3 different reaction times

Similarly to a microwave system, at the same reaction time, the yield of biodiesel increases as a result of an increase the ratio of methanol/fat. However, the reaction time has slightly affected on biodiesel yield.

3.2.3 Comparison reactions between microwave and conventional heating systems

Table 3 represents the properties of biodiesel obtained under microwave and conventional heating systems. Properties of biodiesel obtained from both heating systems are similar. In addition, these properties agree upon the specification of biodiesel. The acid values of products are 0.05-0.16 mg KOH/g which less than 0.5 mg KOH/g defined in the specification. For viscosity of biodiesel should be in a range of 3.5-5 cSt.

Table 3 Properties of biodiesel obtained under two different heating systems

Entry	Heat method	Process variables			Yield	Properties	
		Power (W)	Methanol/Fat	Reaction time (min.)	(%)	Acid value (mg KOH/g)	Viscosity (cSt.)
1	microwave heat	200	0.20	5	85.9	0.112	4.502
2	microwave heat	200	0.20	7	89.3	0.112	4.397
3	microwave heat	200	0.20	10	86.1	0.090	4.293
4	microwave heat	200	0.25	5	93.6	0.157	4.502
5	microwave heat	200	0.25	7	90.1	0.112	4.404
6	microwave heat	200	0.25	10	84.9	0.090	4.293
7	conventional heat	-	0.20	30	95.8	0.056	4.397
8	conventional heat	-	0.20	45	95.8	0.079	4.443
9	conventional heat	-	0.20	60	87.1	0.135	4.293
10	conventional heat	-	0.25	30	97.2	0.045	4.404
11	conventional heat	-	0.25	45	96.0	0.056	4.188
12	conventional heat	-	0.25	60	95.4	0.056	4.083

From the above results, it can be said that transesterification of fat can be operated by using a microwave system. This process was easily operated and less reaction time. In addition, the best results obtained from each system are shown in Table 4.

Table 4 Comparison the best product properties obtained from two operated system.

Mode	Process variables			Yield	Properties		SEC
	Power (W)	Methanol/Fat	Reaction time (min.)	(%)	Acid value (mg KOH/g)	Viscosity (cSt.)	(J/g)
microwave heat	200	0.28	3	98.12	0.135	4.404	2018
conventional heat	-	0.25	30	97.20	0.045	4.404	27778

It shows that product obtained from microwave radiation is comparable with products obtained from conventional heat as shown in Table 4. However, the specific energy consumption of conventional heating system shows 27,778 J/g, which is 13.8 times higher than that of microwave system.

4. Conclusions

Transesterification of lard can be operated by using a microwave irradiation. Properties of products agree with the specification of biodiesel, which are %FAME, viscosity, acid value and heating value. The products are comparable with that obtained from conventional heating system, but less energy consumption.

5. Acknowledgement

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6. References

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