International Journal of Smart Grid and Clean Energy

Acceleration in biodiesel production from palm oil process by high voltage electric field

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Abstract

This article aims to introduce an innovative method of acceleration in biodiesel production process. The biodiesel was produced from fatty acids, using palm oil that is widely used in food industry as a raw material. Methyl alcohol is a solvent with a molar ratio of 1:6 and using potassium hydroxide (KOH) as catalyst at 1 wt. %. The reaction of biodiesel production was prepared by 100 ml substrate and conducted in the reactor chamber. The chamber was custom built with coaxial cylindrical electrode consisted of inner rod electrode and outer tube electrode. Supply high voltage levels were at 1, 2.5 and 5 kV and exposure time was selected for 5, 10, 15 and 20 minutes to compare with the controlled sample without electric field. It is found that; electric field can rapidly accelerate the rate of reaction on biodiesel production. Glycerine settling resulting from electric field stress is significantly much faster than conventional sedimentation by gravity method. If electric field stresses is increased, the rate of reaction is also faster. It was also notice that, the higher glycerine content was achieved when applying voltage is increased in the same direction. The electric field stresses that produce the highest glycerine yield is at 5 kV. It can also be noticed that, at 5 kV the rate of glycerol settling content were retarded at 15-20 minutes, which is found to be the saturation point of reaction.

Keywords: Biodiesel, electric field, high voltage, transesterification

1. Introduction

Biodiesel, one of the renewable energy widely produced and developed, is derived from vegetable oil or animal fats through the chemical process and the proper procedure. The product of the process is fuel consist of Mono-alkyl esters of fatty acids (biodiesel)

At present, biodiesel production uses a chemical reaction process called transesterification. Vegetable oil or animal fat reacts with alcohol and catalysts to help with normal reactions. Alcohol that commonly used as a substitute for biodiesel is methanol because it is low cost and can react with fats easily. It is also a good solvent for base catalysts such as sodium hydroxide or potassium hydroxide, etc. The transesterification process can be accelerated by the heating. Reheating of reaction is generally heated by boiling. The reaction time is 2 hours. Then the oil is then transferred to the glycerine separation process in the following order.

In the past of glycerine separation process is sedimentation by gravity that takes more than 2 hours [1, 2] or the centrifuge process that use sediment separator [3,4] which uses expensive tools and uses a lot of energy. The chemical are used to reduce the duration in biodiesel such as deep eutectic solvent (DES) [5] or activated charcoal [6] but there is chemical contamination in water after washing process.

In order to shorten the production time of biodiesel and environment condition, there are many researches about the technology to assist in the process of production [7, 8, 9]. It has been found that the

* Manuscript received December 25, 2017; revised January 15, 2018.
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doi: 10.12720/sgce.7.3.225-230

use of high voltage field helps the reaction of biodiesel production from used vegetable oil [10] by using 100 liter of vegetable oil substrate to supply the voltage by ring and cylinder electrode at 10 kV. It was reported that the process under electrical field for 2 minutes, there is 99.8% yield of biodiesel. The glycerine and ester layer is clearly separated.

A 2-pole square electrode [11] was used with 1 liter of soy oil at a voltage of 14 kV. It was found that the spacing of the 5 cm electrode could cause sedimentation of glycerine. This is the fastest time achieved of 53 seconds, but when electrodes were spaced, it will take more time to precipitate.

The study of transesterification by electrostatic field electrodes have been studied recently [12]. Each electrode consists of a double rod, point-to- Double-plate and wiring of 100 milliliters of oil, using 13 kV, it was found that the double-electrode spacing of 5 cm spaced at the lowest possible separation time about 20 seconds.

Biodiesel can also be produced by high-voltage electric fields process from various vegetable oils and electrode [2, 13, 14]. However, it is necessary to study and extend the results from laboratory experiments to commercial scale production. Soy oil and Palm oil will be used as the substrate and the characteristics of the electrode will be investigated. The author is interested in palm oil, used oil from the food industry, used as a substrate for biodiesel production by using a high voltage field to help in the reaction.

2. Transesterification and electric field

Improvement of biodiesel production process for faster production requires a catalytic reaction between natural oils and alcohols. The process can be done by providing input energy to the substrate during the reaction. In the biodiesel production process, the feedstock is typically heated by heating or boiling with conventional heating method.

Oil is nonpolar molecule that contains balance positive and negative charges. Under electric field, oil molecule will be emitted by moving electron and can be separated into free charges. The positive charges will move in the same path of e-field to collide with negative charges that move in opposite direction, which directly affects the convection coefficient. [6, 15]

Likewise, alcohol was used as a solvent in the reaction, is also polar molecules. Under the electric field, molecules of alcohol move and arrange in the direction of the electric field. If electric fields were exposed, these charges will try to move in the direction of the polarity in electric field. The dipole rotation causes the molecules to rotate as shown in Fig. 1.

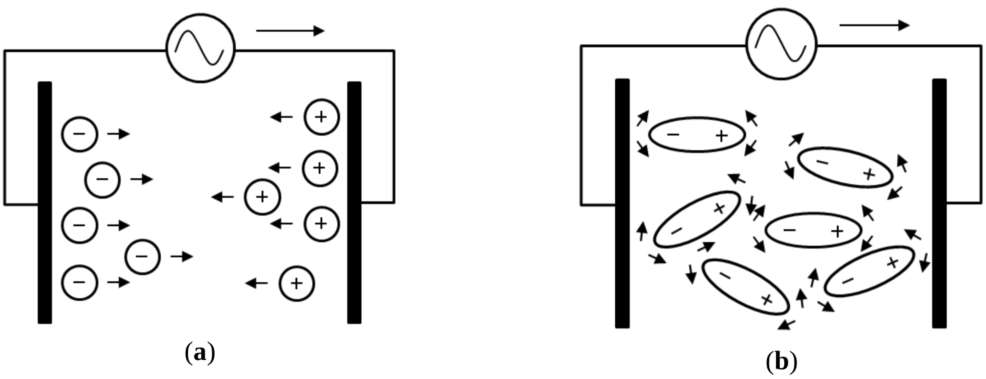


Fig. 1. Effect of electric field to molecule movement: (a) Positive and negative charges and (b) Polar molecules.

The rate of the reaction depends on the frequency and direction of the collision in the reaction. So there is more collisions, the more likely it is to accelerate the reaction. Based on the theory of the electric field, the electric field causes particles to move, it will increases the chance of collisions. So, the electric field can pass on energy to the molecular level. These effects can fasten the biodiesel reaction.

3. Reactor Chamber

The configuration of electrodes for supplying high voltage and creating electric field for biodiesel production is based on a coaxial electrode, which is an electrode that has the ability to widely distribute an electric field as shown in Fig. 2 [16]. The chamber consists of a cylindrical internal electrode, which is exposed to the substrate. The insulation is a container for the substrate. There is also an outside electrode surrounded serving as a return electrode. The design and modification of internal electrodes will be optimized and investigated for biodiesel production.

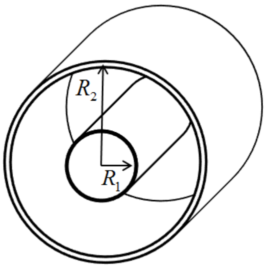


Fig. 2. Coaxial cylinder electrode.

The maximum electric field stresses between the cylindrical electrodes and internal electrode can be calculated by the following equation:

$$E_{max} = \frac{V}{R_1 \ln \frac{R_2}{R_1}} \tag{1}$$

E_{max}	=	maximum electric field stress (V/m)
V	=	supply voltage (V)
R_1	=	radius of inner electrode (m)
R_2	=	radius of outer electrode (m)

4. Materials and Methods

The main raw materials for biodiesel production were palm oil. Methyl alcohol is used as a solvent with a molar ratio of 1:6 also, using potassium hydroxide (KOH) as the catalyst at 1 wt. % [17]. For substrate preparation palm oil 100 mL were warmed up for 2 min with temperature 60 ℃. At the same time the methanol was mixed with KOH to achieve a homogeneous liquid phase in the glass bottle. When the oil was warmed, it was mixed by methanol with catalyst. Stirred for 1 min and filled in reactor chamber as shown in Fig. 3. After that, supply the voltage with different levels and duration to an inner electrode.

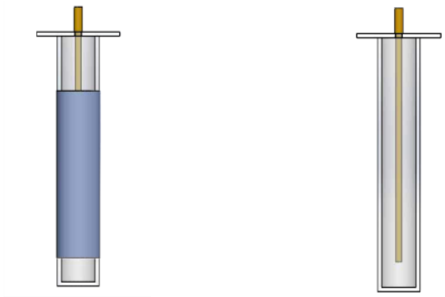


Fig. 3. Reactor chamber

High voltage supply includes voltage variable controller (variac) controls the voltage supplied to the transformer. The voltage from the transformer, supply to the test chamber reactor, is then measured by a voltage divider that is connected to the voltmeter and temperature monitored to prevent the temperature rise in the test kit from exceeding the flash point of the fuel. The supplied voltage to chamber was 1, 2.5 and 5 kV for 5, 10, 15 and 20 min. Also, the control set of biodiesel oil (without supplied voltage) was prepared to compare the result. The devices configuration has shown in Fig. 4.

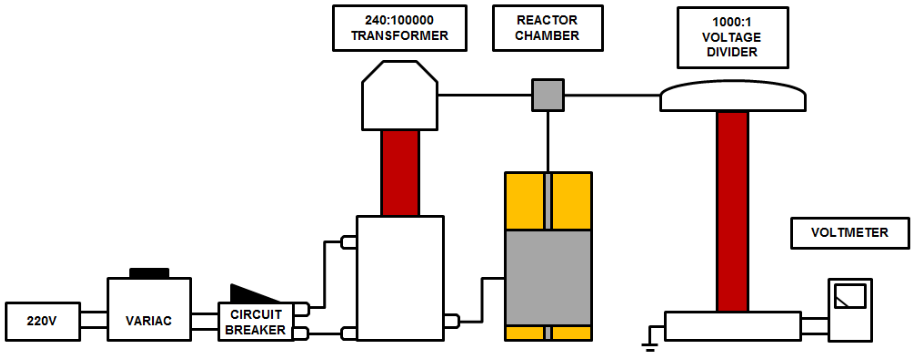


Fig. 4. High voltage supply equipment.

In order to compare the rate of reaction in each period, researchers have measured and compared the volume of glycerine by-products from the reaction. In some cases, the reaction is not completed and the substrate is not formed as biodiesel but the experiment will have to terminate at 20 minutes time.

5. Results

The reactor supplied voltage was measured by voltage divider device to determine the e-field stress by equation (1). The calculated e-field results are shown in Table 1.

Table 1. Maximum e-field stress in reactor chamber in each supply voltage.

Voltage (kV)	Maximum e-field stress (kV/m)
1	163.9
2.5	409.8
5	819.6

The relation between the supply voltage and the electric field stress in the reactor have shown that e-field stress is increased when supplied voltage is increased due to the increment of V in as shown in equation (1).

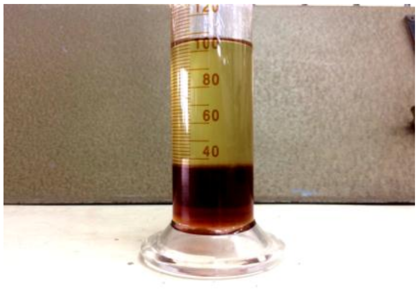
Substrates were exposed with each of applied voltage at 1 – 5 kV for 5 – 20 min. The glycerine volume product is shown in Table 2.

Table 2. The obtained volume of glycerine form each process

Duration (min)	Volume of glycerine product (ml.)			
	0 kV	1 kV	2.5 kV	5 kV
5	-	6.28	10.04	15.07
10	-	10.05	15.10	22.61
15	3.45	12.56	25.12	30.14
20	5.12	18.02	28.05	31.24

Over time, the amount of glycerine is accumulated as shown in Fig. 5. The voltage that produces the highest glycerine yield is at 5 kV. It was observed that at 5 kV the rate of glycerol yield content start to slow down the process at 15-20 minutes which is the saturation point of reaction.

(**a**)



(**b**)

Fig. 5. Biodiesel from palm oil process: (a) Before e-field supply (b) After e-field supply.

6. Conclusions

Electric field can accelerate the reaction rate of palm oil biodiesel production. Glycerine settling by an application of electrical stress via electric field is significant faster than sedimentation by gravity. If electric field stress is higher, the rate of reaction is faster accordingly.

Increasing of supply voltage will result to higher electric field stresses between inner and outer cylinder electrode. The higher electric field stress affects the substrate movement in the level of molecular scale. The palm oil which is nonpolar molecule will be collided and emitted free electrons so that the collisions of positive and negative charge have occurred. These charges move back and forth between electrodes along an electric-field direction. The switching of e-field direction under alternating current supply voltage affects molecule to continuously rotate. This movement of molecules will increase the collision frequency so that it is directly affects higher rate of reaction.

The rate of glycerine settling resulting from electric field process using 1, 2.5 and 5 kV supply voltage calculated from the results from table 2 are 0.83, 1.67 and 2.01 mL/min respectively. While the reaction without using e-field is 0.23 mL/min. The fastest process that can produce biodiesel was using supply voltage of 5 kV with glycerine separation at 31.4 mL within 15 minutes. This is faster than the conventional process (without e-field) by 8.8 times and faster than the process with lower e-field stress at 2.4 and 1.2 times when using lower supply voltage of 1 kV and 2.5 kV respectively.

Acknowledgement

This research project is fully supported by Center for Alternative Energy Research and Development, Khon Kaen University.

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