The Effect of Palm-Oil Biodiesel Reaction Time under Microwave Radiation

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Abstract

Biodiesel obtained from vegetable oil is one of the promising fuels for fossil-fuel replacement. Transesterification is often catalyzed by the addition of an acid or base catalyst. Conventional heating process is widely used for biodiesel production, which takes up to several hours. However, as microwave radiation was applied during the reaction, the reaction time can be dramatically decreased. In this study, the effect of 300-watt microwave radiation on palm-oil biodiesel yields was examined. The catalyst utilized was potassium hydroxide at 0.58% by weight. It was found that the optimal reaction time was 2 minutes. The highest yield of biodiesel produced was over 93%.

1.Introduction

Primary energy source can be divided into two categories viz. conventional and renewable sources. Fossil fuels, especially petroleum, coal and natural gas, are the most crucial kinds of conventional sources. Approximately four-fifth of the world's energy supply was from fossil fuels. Nevertheless, this kind of fuels is not renewable and it has become a finite energy source. The price of fossil fuels, therefore, has dramatically increased during the last decade. With regard to environmental impacts, fossil fuel combustion is accounted for about 98% carbon emissions [1].

Renewable energy utilization seems to be one of the promising solutions for these issues. The major sources of renewable energy are hydro, solar, wind, geothermal including biomass. The last kind of renewable energy sources seems to be considerably attractive for developing countries since they are indigenous and environmentally friendly energy resource. Biomass fuels are considered as a renewable energy source and do not affect the overall balance of carbon dioxide in the atmosphere. In nature, carbon dioxide is used in the photosynthesis process. Therefore, zero net carbon dioxide emission can be achieved when biomass plant is incorporated in a sustainable manner.

Biodiesel may be defined as the mono-alkyl ester of long chain fatty acids derived from vegetable oils or animal fats. It is widely accepted as a blending component or a direct replacement for diesel fuel. Biodiesel has similar physical and chemical features to diesel fuel. Besides, it does not contain sulfur, which is the principle cause of acid rain. Biodiesel has a higher cetane number, a higher flash point temperature and no aromatic as compared to diesel fuel. However, the main disadvantages of biodiesel are its higher viscosity, higher cloud point and higher pour point.

Biodiesel can be produced by transesterifying vegetable oils or animal fats to achieve a viscosity similar to that of diesel fuel. Tranesterification may be defined as a process of exchanging the organic groups between an ester and an alcohol to form an ester of the alcohol. The reactions are often catalyzed by the addition of an acid or base catalyst. The final product from this process is comprised of biodiesel and glycerol. With regard to transesterification, the process is affected by the reaction condition, alcohol-to-oil molar ratio, the catalyst including reaction time. Several kind of vegetable oils have been studied as the high potential raw materials for biodiesel production. The examples of vegetable oils examined by many researchers were palm oil [2-5], soybean oil [6-9], rapeseed oil [9-11], rice bran oil [12-14].

Several methods of transesterification process such as supercritical methanol method, high shear method, ultrasonic-mixer method including microwave method can be applied to produce biodiesel. Regarding the last method, the reaction rate of transesterification is efficiently increased when the reaction is carried out under microwave heating. Therefore, less energy consumed and shorter reaction time can be achieved by using this method.

In this study, the effect of microwave reaction time on the yield of palm-oil biodiesel obtained by tranesterification was studied. The prices of raw material during 2008-2010 were also studied.

2. Crude Palm Oil Price

Palm oil is one of the most important agricultural crops of Thailand. Besides, this kind of oil plant is the most prospective raw material for biodiesel production. Palm oil needs low fertilization and low pesticide but it has high yield production. However, according to the price of palm oil in Thailand, it has dramatically fluctuated. The average costs of palm oil in the year 2008-2010 were 25.34, 20.26 and 24.56 baht per kilogram, respectively. Moreover, the average price of crude palm oil during the first

quarter of 2011 was considerably increased to 33.94 baht per kilogram because of the palm-oil crisis in Thailand [15]. The monthly prices of palm oil in Thailand during 2008-2010 are shown in Fig. 1. This is one of the major drawbacks of biodiesel encouragement and it also impacts the production cost at biodiesel plants.

The operating cost of biodiesel production was about 18% of biomass-oil's price [16]. Therefore, the average production cost of palm oil biodiesel in 2008-2010 should be ranging from 23.9-29.9 baht per kg.

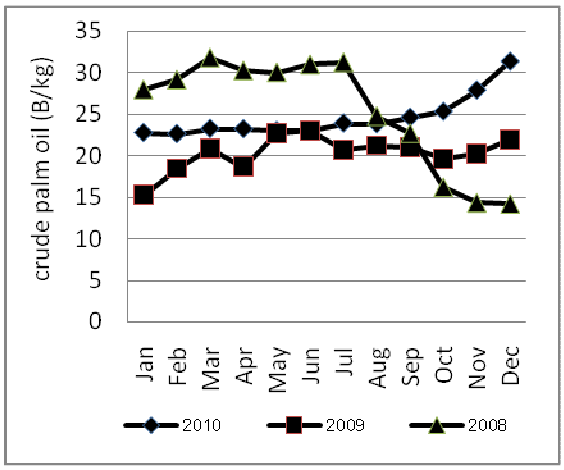

Figure 1. Mixed crude palm oil price during 2008-2010

3.Biodiesel Production

Transesterification reactions were carried out under 300-watt microwave radiation. A household microwave was modified to be used as a reactor. A glass condenser, cooling water line and reactor flask were assembled to the microwave. Twenty percent methanol was set as a constant throughout the experiments. According to the titration, potassium hydroxide at 0.58% by weight was used as the catalyst of the reaction.

First, two hundred gram of palm oil was added into the flask connected to the condenser and mixed with the catalyst and methanol. The reaction was carried out at 4 levels of reaction time viz. 1, 2, 3, and 4 minute. Then, after 4 hours of settling, the glycerol layer was collected at the bottom of the separation funnel. In addition, water was added to the crude biodiesel for washing process. The mixture was allowed to settle for several minutes. This washing process was conducted for 5 times. Air was also introduced into the mixture for accelerating the process. Finally, the aqueous solution was drained after settling.

4. Result and Discussion

Transesterification reactions were performed at four levels of reaction time from 1-4 minutes with an increment of one minute. It was found that the production yields of palm-oil biodiesel varied within the range of 87.93 to 93.52%. As can be seen from Fig. 2, the optimum reaction time for this study was two minutes.

In addition, the effect of microwave radiation power on biodiesel yields was also

investigated. Three levels of microwave power viz. 180, 300 and 450 watts were applied. The reaction time was set to be constant at 2 min. It was found that the yields were ranging from 72.86-93.52%. The maximum yield value was accounted for the case of 300-watts and 2-min reaction condition.

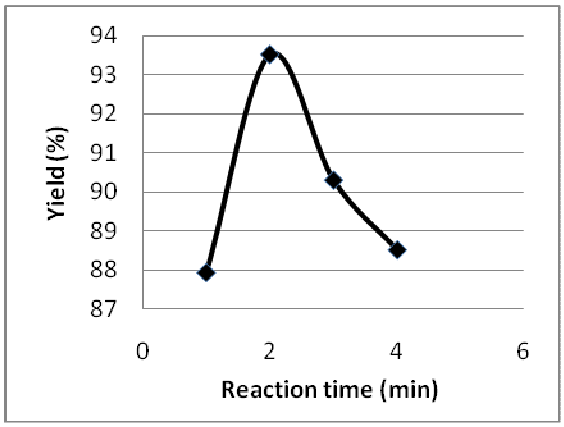

Figure 2. Palm-oil biodiesel yields for the case of 1-4 min reaction times

5. Conclusion

Microwave radiation is one of the promising methods for biodiesel production. The reaction time can be dramatically decreased as compared to the conventional heating method. With regard to palm-oil biodiesel production, the optimal reaction time for the case of 300-watt microwave radiation power was 2 minute.

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