Utilization of $Ca/Si/Fe_3O_4$ magnetic composite as a solid catalyst in transesterification of waste cooking oil

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Abstract

In this research, transesterification of waste cooking oil to methyl ester is being studied with the aid of $Ca/Si/Fe_3O_4$ as a solid magnetic composite catalyst. This catalyst was produced by using waste source to reduce the cost. By using heterogeneous catalyst, some environmental problem can be avoided since the catalyst can be reuse and the final product is easy to separate. As we may know, biodiesel is non-toxic, environmental friendly, high lubricity, biodegrable and renewable. In this study, waste cooking oil is used as a feedstock in producing the promising fuel, which is biodiesel. It thus could encounter many environmental issues since waste feedstock is being used. Preparation of methyl ester using waste feedstock and with the aid of $Ca/Si/Fe_3O_4$ should be properly studied since it is worth to be investigated.

The objective of this study is to synthesize and characterize the catalyst and to utilize $Ca/Si/Fe_3O_4$ as a catalyst. It was tested at different parameters such as catalyst loading, methanol to oil molar ratio and reaction duration. $Ca/Si/Fe_3O_4$ was prepared by impregnation method and calcined at 900 °C for 2 hours and the catalyst was tested by Hammett indicator for its basicity. The catalyst was characterized by FTIR, BET, TGA, XRD and XRF.

Gas chromatography apparatus (Perkin-Elmer, Clarus 500) fitted with a flame ionization detector (FID) was used to analyze standard materials and samples. European regulation procedure EN 14103 is to determine FAME content with a polar capillary column (Supelco Wax, 30 m x 0.25 mm i.d x 0.25 µm) methyl heptadecanoate as internal standard. Methyl esters peaks were identified easily by comparing with standards and the following formula is used to quantify the conversion.

$$\text{Conversion (\%)} = \frac{(A_{total} - A_{ISTD})}{A_{ISTD}} \times \frac{(C_{ISTD} \times V_{ISTD})}{M_{sample}} \times 100\% \quad (1)$$

Where

A_{total} = Total area of methyl ester peak from $C_{14:0}$ to $C_{18:3}$
A_{ISTD} = Area of internal standard
C_{ISTD} = Concentration of internal standard in mg/ml
V_{ISTD} = Volume of internal standard in ml
M_{sample} = Mass of sample in mg

Previous studies have shown that biodiesel can be produced from many types of vegetable oil such as sunflower oil, soybean oil and palm oil (Zhang et al., 2003). Tyson (2005) indicates that SBC give some advantages per biodiesel producing which is abundant availability in Malaysia. For an interesting source of biodiesel which is used for vegetable oil Chhetri (2008) observed that plant species of mole plant or known as caper spurge (Euphorbia lathyris L., Euphorbiaceae) is such a promising source. A research by Al-Widyan et al. (2008) found out that beef fat contains higher saturated fatty acid when compared with dairy cow fat. In addition, beef fat yield higher methyl ester which is 98.4% while dairy cow fat produces 94.1% of methyl ester. Antczak et al. (2009) point out that conversion of grease to biodiesel via one-pot esterification and transesterification with methanol by using biocatalysts is a greener alternative. Goering, Schwab, Daugherty, Pryde and Heakin (1982) illustrate that the WCO can reduce the quantity of farmland that is needed for biodiesel producing crops.

There are various routes to produce biodiesel. Among these routes (pyrolysis, direct use and blending, transesterification and micro-emulsion), transesterification seems to be the most superior on reducing viscosity and minimizing engine complication (Pryde, 1984). The result of a study by Enweremadu and Mbarawa (2009) mentions the transesterification is the key and foremost important step to produce the cleaner and environmental safe fuel from vegetable oil.

For the variation of methanol to oil molar ratio, 9:1 gives the highest ME conversion which is based on Figure 1.

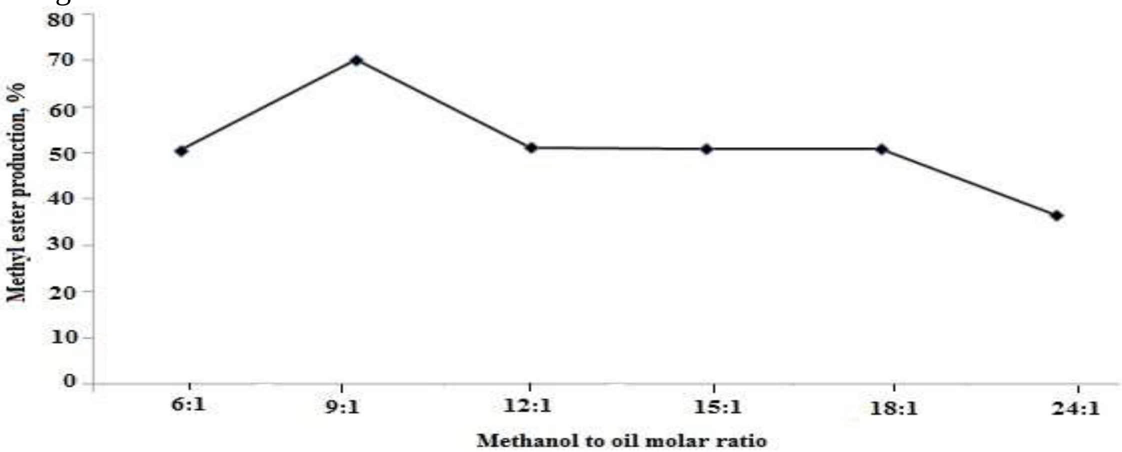

FIGURE 1. Effect of MeOH:oil molar ratio to ME conversion; 2h reaction time, 65±2°C, 5% catalyst loading

Methyl ester is at maximum conversion as depicted in Figure 2 when undergo reaction with 5% catalyst loading which producing 99.5% methyl ester.

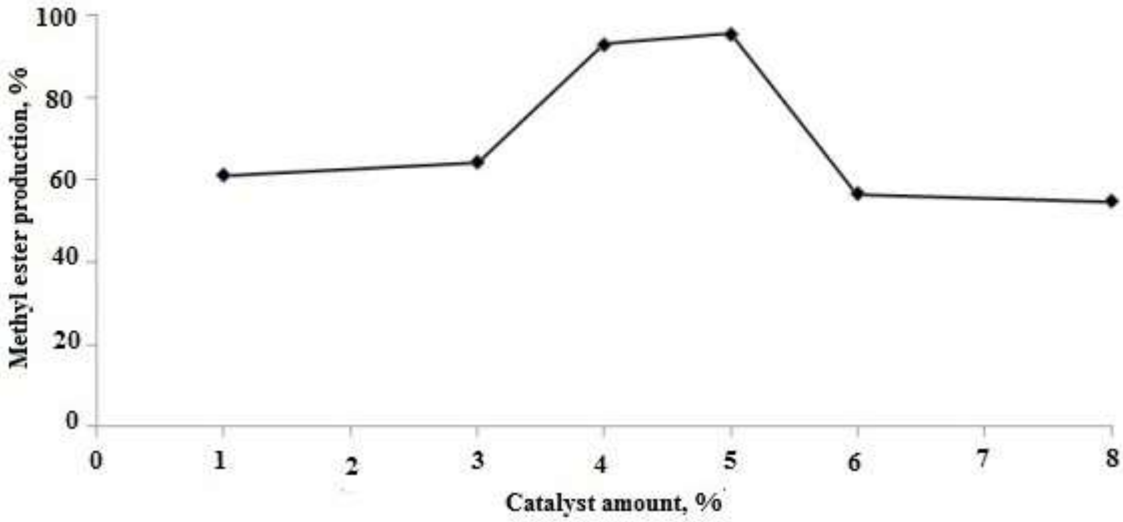

FIGURE 2. Effect of catalyst loading towards ME conversion; 3h reaction time, 65±2°C, 9:1 MeOH:oil molar ratio

While for the effect of reaction time, we could see in Figure 3 that the methyl ester conversion is 99% after the reaction undergo 2h of transesterification.

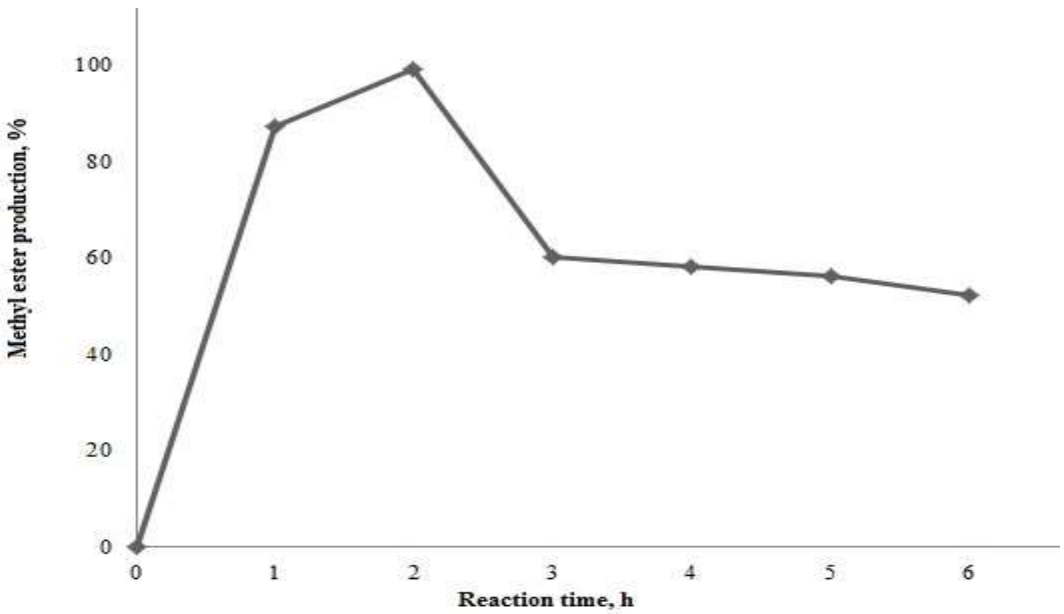

FIGURE 3. Effect of reaction time towards ME conversion; temperature 65±2°C, 5% catalyst loading, 9:1 MeOH:oil molar ratio

$Ca/Si/Fe_3O_4$ show high activity under optimum condition at temperature 65±2°C, 2h of reaction time, 9:1 of methanol to oil molar ratio with 5 wt.% of catalyst. The transesterification yields 99.5% methyl ester. Methyl ester was then analyzed using gas chromatography flame ionization detector (GC-FID). Therefore, this catalyst has the potential to be used in the transesterification of waste cooking oil in producing biodiesel due to its high activity.

Key words: magnetic composite catalyst; biodiesel; transesterification; waste source; heterogeneous base

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REFERENCES

A.B. Chhetri, M.S. Tango, S.M. Budge, K.C. Watts, M.R. Islam. 2008. Non edible plants as a new sources for biodiesel production. Industrial Crops and Products, 9: 169-180.

C.C. Enweremadu, M.M. Mbarawa. 2009. Technical aspects of production and analysis of biodiesel from used cooking oil- A review. Renewable and Sustainable Energy Reviews, 13: 2205-2224.

C.E. Goering, A.W. Schwab, M.J. Daugerty, E.H. Pryde, A.J. Heakin. 1982. Fuel properties of elven vegetable oils. Trans ASAE, 85: 1472-1483.

E.H. Pryde. 1984.. Vegetable oils as fuel alternatives. Symposium overview. 61(10): 1609-1610.

K.S. Tyson. 2005. DOE analysis of fuels and coproducts from lipids. Fuel Processing Technology, 86: 1127-1136.

M.I. Al-Widyan, A.O. Al-Shyoukh. 2002. Experimental evaluation of the transesterification of waste palm oil into biodiesel. Bioresource Technology, 85: 253-256.

M.S. Antczak, A. Kubiak, T. Antczak, S. Bielecki. 2009. Enzymatic biodiesel synthesis- key factors affecting efficiency of the process. Renewable Energy, 34: 1185-1194.