

# Exploratory of Palm Oil Based Catalyst to Produce Fatty Acid Methyl Ester

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**Abstract**—Alternative fuel has attracted considerable attraction in recent years due to limitation of traditional fossil resources as well as concern for environmental protection and conservation of non-renewable natural resources. Fatty acid methyl esters (FAME) which can be produced by transesterification method were shown as promising renewable sources of fuel nowadays. The presence of catalyst in transesterification process is significantly important in order to increase the FAME yield. Base catalysts were preferred compared to acid catalyzed transesterification because of the higher reaction rate and lower process temperature required. The study focus on FAME yield by using active palm oil based catalyst, NaOH/OPKS using one factor a time method. The batch reaction was studied at four different conditions; molar ratio oil to methanol (1:6-1:12), reaction time (3-6 h), ratio catalyst to oil (1-3 wt %) and reaction temperature (30-60 °C). The result showed that oil palm based catalyst can be used as an active catalyst in order to produce FAME.

**Keywords**— Catalyst, Fatty Acid Methyl Ester, Oil Palm Kernel Shell, Transesterification.

## I. INTRODUCTION

**B**IODIESEL is a form of diesel fuel manufactured from renewable sources. The main constituents in the biodiesel is fatty acid methyl ester (FAME) produced by catalysed transesterification reaction of vegetable oil with methanol. FAME is a most attracted to researcher, government, and industries because of renewable, its low emissions and non-toxic, biodegradable and carbon neutral [1].

The transesterification reaction can be completed either using homogeneous catalyst or heterogeneous catalyst. The advantages of heterogeneous catalyst has been found as easy separation of catalyst, higher selectivity, minimal environmental impact and efficient recycling [2].

In contrast, the researchers found that using homogeneous catalyst will involved big production cost due to the process involved in number of washing and purification steps to have a good quality of FAME. The separation of glycerin is also posed the technical challenges [3;4]. Hence, the development of catalyst is important in order to produce FAME in transesterification process.

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Catalytic technologies are an important area of study which criticizes the present and future energy, chemical process, and environmental industries. A large numbers of heterogeneous catalysts such as alkali metal oxides and derivatives, alkaline earth metal oxides and derivatives, transition metal oxides and derivatives, mixed metal oxides and derivatives [5,6,7] and waste material based heterogeneous catalysts are found in literatures in the recent years and their uses in laboratory scale transesterification process. Developing solid catalyst have been intensively studied due to the advantages of the catalysts are not consumed or dissolved in the reaction. Hence, the catalyst is easily separated from the products [8]. Besides, using wastes as raw materials for catalyst synthesis could eliminate the wastes and simultaneously produced the catalysts with high cost effectiveness. The waste materials used as heterogeneous catalysts studied so far include waste snail shell [9], cocoa pod husk [10], mollusk and eggshell [11]. Therefore, this has inspired a growing interest in the utilization of solid wastes as an alternative material as catalyst supports for heterogeneous catalyst development.

Malaysia currently contributes for 39 % of world palm oil production and 44 % of world exports. Besides that, Malaysia also contributes for 12 % and 27 % of the world's total production and exports of oils and fats, respectively [12;13]. Since, being the largest producer of palm oil in the world, Malaysia has to face with the consequences of the huge accumulation of 70 % of fresh fruit bunches are turned into undesired solid waste in the form of palm fiber, shells, and empty fruit bunches [14]. Therefore, Malaysia has an important role in finding the effective way to overcome the agricultural waste problem by expanding and utilizing the oil palm waste in numerous field of application. Thus, a widespread and great progress in this area can be expected in the future. Besides, the sufficiently active and stable solid catalyst for this application is yet to be discovered in order to develop an effective catalyst with high activity and durability specifically in the transesterification reaction. Thus, this study focuses on the production of FAME by using NaOH/OPKS catalyst at different oil catalyst loading and reaction temperature. The successful incorporation of alkali metal (NaOH) on waste material (OPKS) has been studied by the percent of FAME produced.

## II. CATALYST PREPARATION

### A. Preparation of catalyst support

Oil Palm Kernel Shell (OPKS) has been taken from Kilang Kelapa Sawit. First, OPKS has been washed to remove impurities by water. Then, it was dried in the oven for 3 hours at 120 °C to remove moisture. After that, it was placed on the furnace to carbonize for 3 hours at 600 °C. Finally, activated carbon was grinded and sieved to the 1-2 mm of size.

### B. Preparation of Active Catalyst (NaOH/OPKS)

Active catalyst was prepared by impregnation method. The support (OPKS) was impregnated with an aqueous solution of sodium hydroxide (NaOH) compounds. The amount of NaOH used was calculated to obtain the desired amount of transition metal loading in the calcined catalyst. The mixture was impregnated for 24 h to ensure that NaOH diffused and dispersed thoroughly on the surface of support. The solid catalyst obtained was calcined in furnace at 450 °C for 3 h at heating rate 5 °C /min. Then, the active catalyst was ready to be used in the transesterification process.

### C. Transesterification Process

The performance of catalyst was studied in the transesterification process of palm oil with methanol. The reaction was carried out in a 250 ml three-necked glass flask equipped with a water cooled condenser to avoid methanol loss. The reaction procedure was started by a certain amount of catalyst was dispersed in methanol under magnetic stirring. Then, the palm oil was added into the mixture and the temperature was set at desired temperature with continuous stirring. After the desired reaction time, the reaction mixture was taken out and excess methanol was distilled off in a rotary evaporator. Then the sample was taken out from the reaction mixture (glycerol and catalyst) by centrifugation. After the glycerol and catalysts layers were removed, the FAME was collected for chromatographic analysis.

### D. Product Analysis

The samples were analyzed by a gas chromatograph Mass Spectrometer (GCMS, Shimadzu, USA), equipped with a silica capillary column and a flame ionization detector (FID). Helium was used as the carrier gas. The injector temperature was set at 250 °C and the detector temperature maintained at 250 °C. Meanwhile, the column temperature was kept constant at 150 °C. The analysis of FAME for each sample was carried out by dissolving 100 microlitres of FAME into 500 microliters of n-hexane. 1µl of this mixture was then injected into the GCMS.

## III. RESULTS AND DISCUSSION

### A. Effect of Molar Ratio Oil to Methanol

The molar ratio of methanol to soybean oil is one of the important factors that affect the conversion to methyl esters. Stoichiometrically, 3 mol of methanol are required for each mole of triglyceride, but in practice a higher molar ratio is employed in order to drive the reaction towards completion

and produce more methyl esters [15]. The gradual increasing of FAME yield was shown in Figure 1 for the effect of molar ratio of oil to methanol. The ratio was varied from 1:06 to 1:12. The results revealed that the highest yield of FAME, 71 % was obtained at 1:10 molar ratio. However, as the molar ratio increased to the 1:12 molar ratio, the FAME yield decreased to 63%. The decreasing FAME yield at the higher molar ratio was believed that an excess methanol feed was effective to a certain extent and the maximum molar ratio of methanol to oil for NaOH/OPKS catalyst was 1:10.

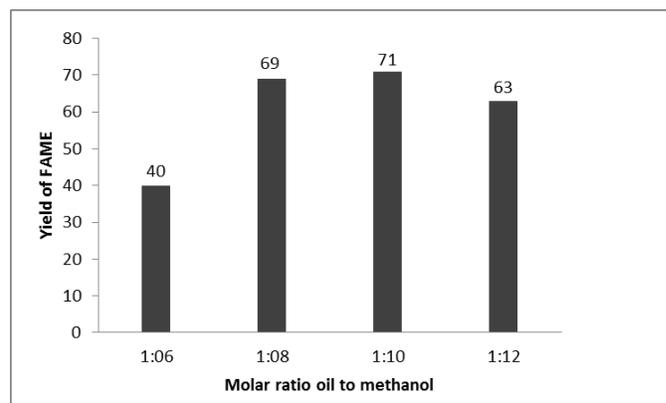


Fig. 1 Effect of Molar Ratio Oil to Methanol

### B. Effect of Reaction Temperature

The influence of reaction temperature on the yield of FAME was investigated by varying the value of temperature from 30 to 60 °C. From the Fig. 2, the FAME yield increased with the increasing reaction temperature from 30 to 50 °C, but decreased at the temperature of 60 °C. When the transesterification reaction was carried out at 50 °C which was lower than the boiling point of methanol (65 °C), the highest yield, 90 % of FAME was obtained. In the presence of heterogeneous catalysts, the reaction mixture constitutes a three-phase system, oil methanol-catalyst, in which the reaction would be slowed down because of the diffusion resistance between different phases. However, the reaction rate can be accelerated at higher reaction temperatures [15].

The decreasing FAME yield at high temperature, 60 °C associated with the unsatisfactory condensation of methanol into the reaction vessel. This led to the lower actual working amount of methanol in the vessel at any time in the reaction to consequently affect the reaction equilibrium. Theoretically, the excess amount of methanol will shift the equilibrium towards the formation of methyl esters.

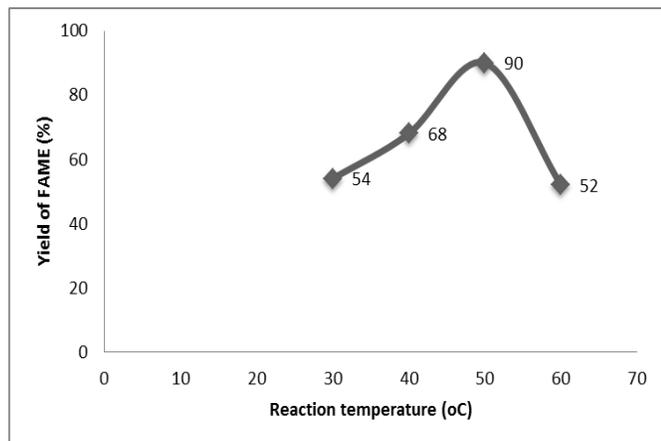


Fig. 2 Effect of Reaction Temperature

### C. Effect of Catalyst Loading

Fig. 3 shows a gradual increase in the FAME yield for the different of catalyst loading from 1 to 3 wt.% with constant condition of 4 hr of reaction time and 50 °C of temperature. The highest FAME yield (78 %) was obtained at a NaOH loading of 3 wt. %. The increasing NaOH loading meant the corresponding increase in the number of active site to contribute to the increasing FAME yield. From the result, it can also be pointed out that 3 wt. % of NaOH was the maximum loading that can be properly distributed on the pores of OPKS support. Reference [16] stated that additional catalysts increased the contact opportunity of the catalyst and the reactant, directly influencing the reaction speed and the conversion. Mass transfer and reactant adsorption on the catalyst are crucial in heterogeneous catalysis.

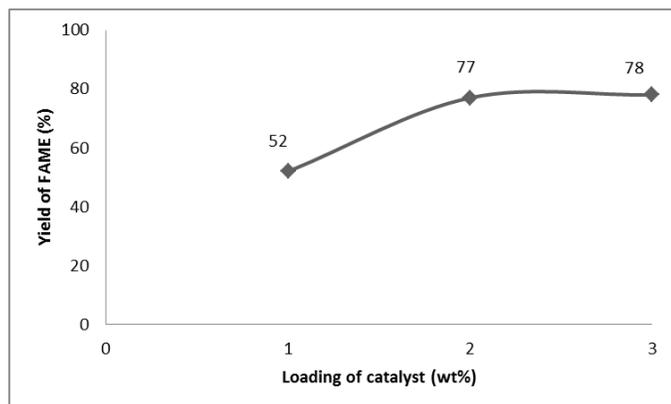


Fig. 3 Effect of Catalyst Loading

### D. Effect of Reaction Time

The results of FAME yield for the effect of reaction time was shown in Fig. 4. The reaction time varied from 3 to 6 h with 3 wt% of catalyst loading and 50 °C of temperature. From the result, the maximum conversion of FAME (86 %) was achieved at 4 hr of reaction. The FAME yield decrease to 65 % at the longer reaction time. The influence of catalyst loading in increasing the FAME yields was attributed to the increase in the amount the active catalytic component that led to improvement of the FAME selectivity and shorter reaction times was required to complete the transesterification process.

References [17] has been compared with the obtained result which reported that the transesterification reaction using activated ash wood catalyst, achieved the maximum conversion at 3 h of reaction time with 3 wt% of catalyst loading. Moreover, excess reaction time led to a bit reduction in the product yield due to the backward reaction transesterification, resulting a loss in FAME yield.

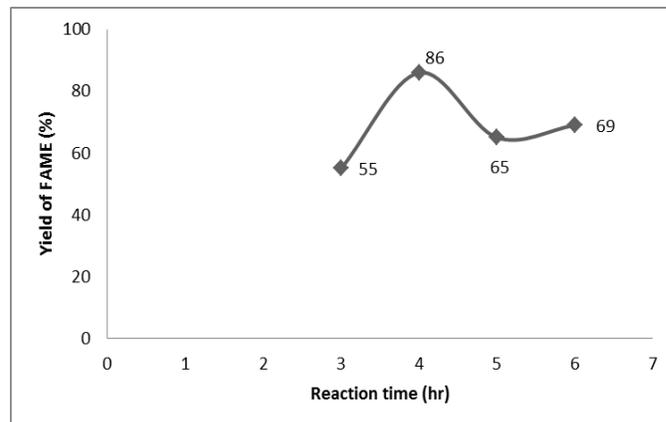


Fig. 4 Effect of Reaction Time

## IV. CONCLUSION

Based on the experimental result obtained, it can be concluded that oil palm ash support could be used as an effective catalyst after modified with active metal (NaOH). However, future research on this catalyst is still needed to investigate wider range of the parameters, and also new possible parameters which can be included in the synthesis process such as the different active metal, ratio of support and active metal loading, impregnation time and calcinations time.

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