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Indonesia Natural Zeolite as Heterogeneous Catalyst for Biodiesel Production

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Abstract. The problem associated with biodiesel production is economic feasibility. The biodiesel cost will reduce when the low cost feedstock was used. Kapok seed oil (KSO) is a promising candidate as raw material for biodiesel synthesis. In this research, the investigation of biodiesel synthesis from KSO was studied using Indonesia Natural Zeolite as heterogeneous catalysts. The catalyst was tested to synthesize biodiesel from KSO. The reaction temperatures, KSO to methanol mole ratio, and catalyst amount were varied to examine their effects on biodiesel synthesis. The highest biodiesel yield of 84% were obtained at 65°C of reaction temperature, 1:16 of KSO to methanol mole ratio, and 10% of catalyst amount.

Introduction

The production of biodiesel as the renewable energy to replace crude oil diesel fuel has paid more attention in recent years due to declining fossil fuel supplies and environmental concerns. Biodiesel has many advantages including environmentally friendly, biodegradable, and less toxic. Biodiesel production is conventionally synthesized using raw materials from refined edible oils in the presence of homogeneous catalysts during reaction. However, the use of homogeneous catalyst has many drawbacks, such as requiring advance process for product purification, further catalyst separation, and not reusable. the heterogeneous catalyst have been started to be developed in biodiesel production to eliminate limitations related to the homogeneous catalyst. The heterogeneous catalysts provide several benefits: less chemical waste and waste water, no need to separate processes, and environmentally benign. Many researches have been investigated the heterogeneous catalyst for biodiesel production, such as zeolite synthetic [1], natural clay [2, 3], Amberlyst 15 [4], mesoporous sulfated zirconia solid acid catalyst [5], alumina (Al_2O_3) [6], hydroxyapatite [7], Tungsten supported titania-silica composite [8], SBA-15 [11], niobic [10], Tin oxide [9], sugarcane bagasse [13], rice husk ash [14], and coconut-shell activated carbon biomass waste [15]. Biodiesel produced from Kapok seed (Ceiba Pentandra) oil and is the promising alternative as feed stocks for biodiesel production. Ceiba pentandra locally known as Kapok is grown in Indonesia, India, Malaysia, and other regions in Asia. In average, each kapok pod contains about 25 - 28 wt% of seed with a potential oil yield of 1.500 kg/ha annually. The kapok seed yield oil about 20-25 wt. % of dry mass. The biodiesel production using kapok seed oil as raw material is highly potential to develop in Indonesia. In this research, the transesterifications of kapok seed oil using Indonesia natural zeolite as catalyst was studied. Varying on molar ratios of methanol to oil, reaction temperatures and catalyst to oil mass ratio was employed to evaluate the performances of catalyst.

Methodology

Preparation of Catalyst. Initially, natural zeolite was grinded to get fine particles and then to sieve for obtaining uniform size. The activation was carried out by mixing natural zeolite with 0.5 N sulfuric acid solutions while the temperature heated up to 100°C and kept constant for 4 hours. The mixture was vigorously stirred during activation process. Then, the mixture was separated by filtrated to obtain activated natural zeolite. The activated natural zeolite was rinsed using distilled water until no sulfate ions contains was on the remaining wash water. Finally, the activated natural zeolite was then calcined in a muffle furnace at 400°C for 4 hours.

Transterification of Kapok Seed Oil. Transesterification reactions were conducted out by mixing the kapok seed oil, methanol and natural zeolite catalyst in a batch reactor. In this experiment, a boiling flask was employed as a batch reactor. The batch reactor was placed on the hot plate magnetic stirrer and connected to a condenser. A thermometer was used to monitor the reaction temperature. After the transesterification reactions were finished, the catalyst was separated from the mixture by filtration. The liquid was placed to the funnel to dissociate the biodiesel and glycerol by decantation. The remaining methanol in the biodiesel was evaporated in the oven for 4 h. Many variables such as KSO to methanol mole ratio, reaction temperature, and catalyst amount were investigated to study their effect on biodiesel yield.

Results and Discussions

Mole Ratio Effect. Theoretically, the transesterification reaction is the reversible reaction. To shift the equilibrium to the product side, the mole ratio necessary be provided excessively than the stoichiometric ratio. Stoichiometrically, three mole of triglyceride requires one mole of methanol to complete the reaction. In this research, the Kapok Seed Oil (KSO) to methanol mole ratio is varied (1:8, 1:10, 1:12, and 1: 16), meanwhile the other operation reaction was maintained constant (catalyst amount of 10 wt. % of KSO, reaction temperature of 60 °C, and reaction time of 2 h). Initially, the biodiesel yield was achieved at 67% as the KSO to methanol mole ratio was 1:8. As shown in Fig. 1, when the KSO to methanol mole ratio was increase from 1:10 to 1:12 resulted the the increasing of biodiesel yield from 77% to 81% respectively. At the mole ratio of 1:16, the biodiesel yield achieved 84%. It was summarized that an increasing of KSO to methanol mole ratio would lead to an increasing of biodiesel yield.

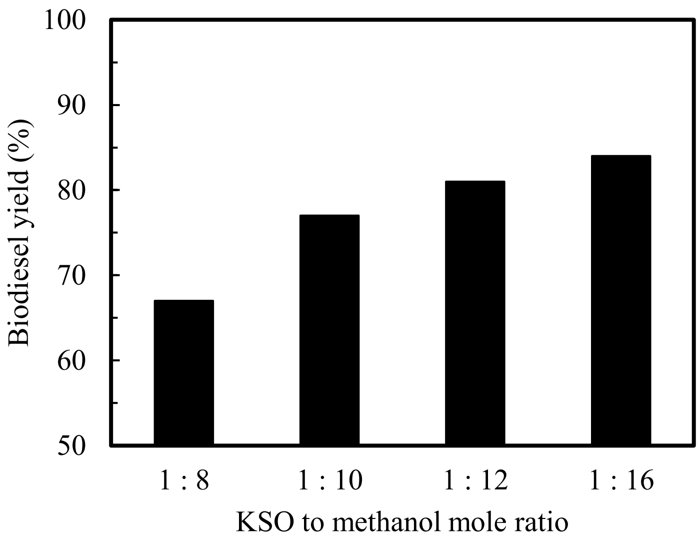

Fig. 1 Mole ratio effect on Biodiesel Yield.

Reaction Temperature Effect. The reaction temperatures were varied in different values (35, 45, 55, and 65°C) to study the effect on the biodiesel yield. During the experiments, the other operation condition was kept stable (catalyst amount of 10 wt. % of KSO, reactant mole ratio 1:16, and reaction time of 2 h). The effect of reaction temperature on biodiesel yield can be show on Fig. 2. As exhibited on Fig. 2, the biodiesel yield was influenced by the reaction temperature the transesterification reaction. The biodiesel yield was 61% when reaction temperature of 35°C. Furthermore, at reaction temperature of 45 and 55°C the biodiesel yield achieved to 69 and 76%, respectively. The highest biodiesel yield was obtained at acquired 84% reaction temperature of 65°C. It was can be concluded that the biodiesel yield would increased when the reaction temperature elevated. The biodiesel yield increase due to accelerating of the reaction rate at high temperature.

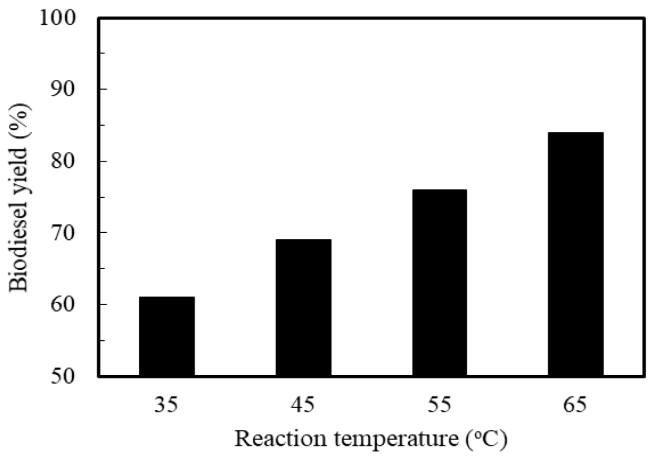

Fig. 2 Reaction temperature effect on Biodiesel Yield.

Catalyst Amount Effect. The catalyst amount that employed during reaction was examined to observe their effect on biodiesel yield. The reactant mole ratio (1:16) as well as the reaction temperature of 60°C were retained constant when the amounts of catalyst were varied. Fig 3 illustrated the effect of catalyst amount on the biodiesel yield. The biodiesel yield increase when more catalyst were added in to the reactant mixture. The highest biodiesel yield was achieved at 84% when using 10 wt. % of KSO catalyst amount during transesterification reaction. The addition of catalysts will lead the more of active sites available in catalyst surface.

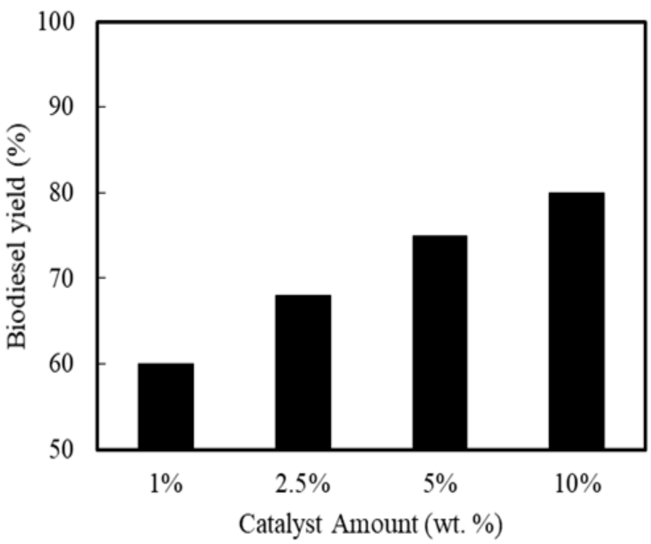

Fig. 3 Reaction temperature effect on Biodiesel Yield.

Reusability of Catalyst. The performance of catalyst need to be test repeatedly for knowing the ability to catalyze the identical reaction. Prior to reuse, the catalysts were washed with hexane and dried in the oven to activate. Then, the catalysts were used for a transesterification reaction under the similar operation conditions as before. The reusability test of catalyst was depicted in Fig. 4. As shown in Fig. 4, the biodiesel yield was reduced in the second and third successive reactions.

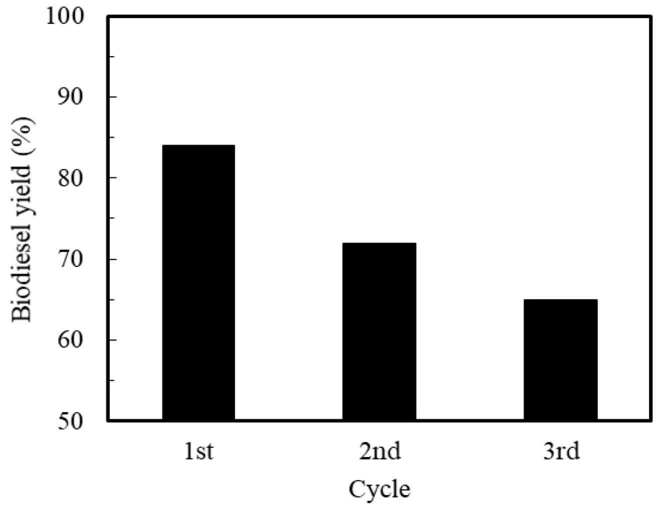

Fig. 4 Reusability of catalyst.

Conclusions

In this research, the investigation of biodiesel synthesis from KSO was studied using Indonesia Natural Zeolite as heterogeneous catalysts. The catalyst was tested to synthesize biodiesel from KSO. The reaction temperatures, KSO to methanol mole ratio, and catalyst amount were varied to examine their effects on biodiesel synthesis. The highest biodiesel yield of 84% were obtained at 65°C of reaction temperature, 1:16 of KSO to methanol mole ratio, and 10% of catalyst amount.

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