Biodiesel production from palm oil using banana weevil ash as a solid catalyst

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Abstract. The aim of this research was to investigate the performance of a banana weevil ash catalyst for biodiesel production at varied methanol to oil ratio. The method is the ash catalyst prepared through the simple burning of banana weevil in an open room. The powder is crushed by mortar and calcined at 600 °C for 5 hours. The crystallinity and the morphologies of the powder were analyzed by XRD, SEM, and EDX. The biodiesel production was carried out in a batch reactor for 90 minutes using stirrer at 65 °C. The molar ratio of methanol to oil was varied of 6:1, 8:1, 10:1, 12:1, and 14:1 with catalyst loading of 4.0 wt.%. The results showed that the highest yield was reached 96% at methanol to oil ratios of 12:1. The density and viscosity of biodiesel were reported of 0.85 gr/ml and 3.04 cSt, respectively. The properties of biodiesel showed conformity in the range of SNI standard. Based on these results, it can be concluded that, banana weevil ashes can be a promising heterogeneous catalyst for biodiesel production.

1. Introduction
Fossil fuel is much needed for transportation and industry, as a petroleum diesel mixture and industrial process. Nowadays, fuel is converted from a fossil that eventually runs out because of an unapprovable source. The use of fossil fuels also opposes climate change, increase environmental pollution, and change human life because of its emissions effect. Research experts have found an energy artistic to release fossil energy. It will be more clean and renewable, called biodiesel [1-7].

Biodiesel is an alternative diesel which is derived from vegetable oil and animal fat. It has neutral carbons and low emissions [8-10]. There are three classifications of catalyst, homogeneous catalyst, heterogeneous catalyst, and enzyme. Transesterification is a common process for biodiesel production. This process usually using a homogeneous catalyst [11-14]. Homogeneous catalysts cause to participate in biodiesel products, even switch it into a saponification reaction, difficult to separate from a reaction mixture, lack of stability at high temperature [15-17]. In other words, transesterification is potentially disrupted. For environmental purposes, it is important to replace homogeneous catalysts with heterogeneous catalysts. Different phase in reaction mixture shows that heterogeneous catalyst has high thermal stability and easily separated [14,18].

Biomass-based solid catalyst has been developed for transesterification to produce biodiesel—for example, banana (stems and peel), brown peel, coconut stems, and bagasse [19, 20]. Banana is the largest fruit after orange. It produces high waste. It stems and tubers are carbohydrate-protein-fat rich and
normally used as a carbon source for citric acid production [21,22]. Calcined banana husk without any chemical activation has been successfully carried out to convert jatropha oil into biodiesel. It reached a yield of 98.5% using 2.75wt% for 1 h [23]. The selection of banana, namely banana weevil, is high of potassium content and supposed for the transesterification process [20]. Potassium has very high base properties, including alkalinity and strong base, forming metal that commonly used in the process of biodiesel production [24]. The purpose of this study is to develop a solid catalyst from banana weevil for biodiesel production, by examining the effect of the molar ratio of methanol to oil.

2. Materials and methods

2.1. Materials
Banana weevils are gathered from Aceh Utara, Indonesia, methanol (Merck, Germany), and palm oil was purchase from market.

2.2. Catalyst preparation
Banana weevil was cleaned and cut into small pieces to speed up the drying process. Banana weights are washed and dried at a temperature of 100 °C [20]. Dried banana weevil crushed and milled into smooth-banana weevil. Smooth-banana weevil dried burnt into ash with simple combustion and calcined at 600 °C for 5 hours.

2.3. Catalyst characterization
Banana weevil ash was characterized using X-ray Diffractometer (XRD) to find the crystalline phase. The catalyst morphology was analyzed by Scanning Electron Microscopy (SEM).

2.4. Transesterification reaction
The transesterification process was carried out in batch reactor at temperatures of 65°C for 90 minutes, by adding 4wt% of catalyst, 30 grams of palm oil and methanol. The molar ratio of methanol to oil was varied are 6:1, 8:1, 10:1, 12:1, 14:1 and 16:1. After the process, the mixture was put into separating funnel and left for 24 hours. The yield of biodiesel was calculated (using the equation below). Density and viscosity were analyzed.

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\%\text{Yield} = \frac{\text{Biodiesel mass (gram)}}{\text{Palm oil mass (gram)}} \times 100\%
\] (1)

3. Results and discussions

3.1. Characterization of banana weevil catalyst using XRD
Banana weevil ash catalyst was analyzed using X-ray Diffractometer in catalyst. The result of XRD analysis can be seen in Figure 1.

![Figure 1. XRD Analysis of banana weevil ash catalyst.](image)
Figure 1 shows that the banana weevil ash catalyst has a high main component of $\text{K}_2\text{O}$ and several other components. High potassium content identified maximum decomposition and active site for transesterification. It is potassium has very high alkaline properties [13]. High potassium content also increases catalyst selectivity for transesterification between triglycerides methanol [15].

Besides using XRD, the catalyst was also identified the atomic percentage of the component in banana weevil ash, which can be seen in Figure 2 and Table 1.

![EDX analysis of banana weevil ash catalyst](image1)

**Figure 2.** EDX analysis of banana weevil ash catalyst.

| Element  | Weight (%) | Atom (%) |
|----------|------------|----------|
| Carbon   | 5.18       | 5.78     |
| Oxygen   | 42.36      | 47.34    |
| Chlorine | 2.67       | 2.99     |
| Silicon  | 3.74       | 4.14     |
| Sodium   | 0.07       | 0.08     |
| Calcium  | 2.38       | 2.66     |
| Potassium| 32.05      | 35.91    |

**Table 1.** Catalyst acquisition spectrum.

3.2. **Morphology characteristic of banana weevil ash catalyst**

Figure 3 illustrates particle agglomeration with shaper surface structure. As can be seen from Figure 3, the pores do not distribute on the surface of the ash catalyst. The same condition also report that the banana ash catalyst was shiny, supple, and coagulate [20].

![SEM analysis of banana weevil ash catalyst](image2)

**Figure 3.** SEM analysis of banana weevil ash catalyst.
This condition produces a complex crystal structure called agglomeration \([5,13]\). Agglomeration is a particle that allows to collect in a mass, in which some particles exist that cover the pores of the catalyst \([16]\). The particle size of the ash catalyst is ranging from 1.2 μm - 3.9 μm. The calcination process also affects the crystal structure and pore size \([8,9]\).

### 3.3. Effect of methanol to oil ratio

One of the most important variables that affect biodiesel production is the molar ratio of methanol to oil \([17]\). The yield of biodiesel is shown in Figure 4. As shown in Figure 4, to increase a methanol to oil ratios tend to increase the yield of biodiesel. The highest yield obtained at a molar ratio methanol to the oil of 12:1. Methanol and \(\text{K}_2\text{O}\) are reacted with triglycerides to accelerate a high yield of biodiesel (96.22%) using potassium catalyst loading of 4wt\% \([18]\).

![Figure 4. Effect of molar ratio of methanol to oil.](image)

The transesterification reaction could run well along with the increasing basicity of catalyst \([13]\). Further increase of the methanol to oil ratio of 14:1 and 16:1, the yield of biodiesel slightly decreases. This fact can be explaining, when the concentration of methanol is increased, it will cause an increasing glycerol formation and emulsions. It is also, the catalyst triggered by increased mass transfer resistance and reduces catalyst surface area, thereby reducing catalyst reactivity \([19]\).

### 3.4. Biodiesel characteristic

The physical and chemical properties of biodiesel such as density and viscosity are depicted in Table 2. As demonstrated in Table 2, the density and viscosity of biodiesel are in accordance to SNI 7182:2015. Density value is in range of 850-890 kg/cm3 and viscosity in the range of 2.3-6 cSt. Density shows the ratio of mass to the unit of volume. The characteristic of biodiesel density is related to the heat and power produces by diesel engines per unit volume of fuel. Excessively, it will cause an imperfect reaction of conversion because it will increase engine wear, emissions, and damage \([20]\). Viscosity is the resistance possessed by fluid to flow in a capillary tube to the force of gravity needed at a certain distance. The higher viscosity and resistance will affect the performance of the injector in a diesel engine \([21]\).

| Molar ratio of Methanol to oil | Density (gr/ml) | Viscosity (cSt) |
|-------------------------------|----------------|----------------|
| 1:6                           | 0.85           | 3.95           |
| 1:8                           | 0.85           | 4.84           |
| 1:10                          | 0.86           | 3.80           |
| 1:12                          | 0.86           | 3.58           |
| 1:14                          | 0.86           | 3.15           |
| 1:16                          | 0.85           | 3.09           |
4. Conclusions

Solid catalyst from banana weevil ash was successfully developed by the process of calcined at temperature of 600°C for 5 hours. The main component produced is K₂O of 32 wt% and several other components. The highest yield of biodiesel was obtained of 96.22%) at a molar ratio methanol to oil of 12:1 with catalyst loading of 4 wt%. Biodiesel characteristics are accordance to biodiesel quality standards. Banana weevil ash catalyst is potentially contributing to industrial scale of biodiesel production.

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