

Utilization of water hyacinth-based biomass as a potential heterogeneous catalyst for biodiesel production

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Abstract. With the aim to reduce the negative impacts caused by the widespread of water hyacinth to the environment, this paper reports the utilization of water hyacinth as a source of biomass to fabricate a heterogeneous catalyst. The catalyst was prepared by calcinating the grounded hyacinth biomass at 600°C, and K₂CO₃ was then introduced as a co-catalyst through impregnation method. The properties of biodiesel were also evaluated in terms of yield and density. To better understand the impregnation effects, surface topography, particle size, and atom composition of water hyacinth catalyst with K₂CO₃ impregnation were analysed. The performance of the synthesized catalyst was studied for the transesterification reaction of palm oil into biodiesel. The reaction was carried out in a batch mode for 3 hours with stirring at 65°C. The molar ratio of methanol to the oil of 12:1, and the catalyst loading was 15 wt. %. The highest yield (97.57%) was obtained from the process using 15% of the hyacinth-based catalyst which impregnated with 10% of K₂CO₃. The biodiesel produced was in the range of the SNI standard. The water hyacinth can be a promising heterogeneous catalyst for biodiesel production at an industrial scale.

1. Introduction

The transition of human needs from fossil fuel source into more sustainable fuel sources is now very important and increasingly developed [1,2]. Besides the depletion of resources, this transition is also related to environmental problems caused by fossil fuels [3], which encourages researchers to find greener energy sources. Biodiesel is one of the green fuels which has been rampantly produced due to its low emissions impact and zero interference with the performance of injection in diesel engines [4-6]. Biodiesel production commonly uses homogeneous catalysts such as NaOH and KOH [7], however, homogeneous catalysts cannot be reused, produce residual waste and difficult in separation process [8]. This problem does not occur if the reaction is carried out using heterogeneous catalysts which can also increase efficiency in the process [9]. The use of this catalyst is influenced by several parameters such as catalyst loading, reaction time and stirring [10].

Heterogeneous catalysts can be synthesized from various materials, one of those is biomass-sourced material which has been reported to fabricate catalyst with better characteristics than those of conventional catalysts [11]. Water hyacinth (*Eichornia crassipes*) is a water plant that grows abundantly and uncontrollably on the surface of water bodies like rivers, canals, and lakes, it also can grow in tropical and subtropics climates. At certain temperatures, its growth can be more rapid than aquatic



microorganisms [12,13]. Water hyacinth biomass has been used in several applications such as biogas, briquettes and bioethanol fabrication [14]. Water hyacinth contains several organic substances such as lignin, cellulose, and hemicellulose. Through the process of open-air combustion, these compounds turn into chemical components such as potassium, calcium, chlorine, phosphorus and so on in ash form. According to Lara-Serrano et al, the potassium content in water hyacinth ash can reach up to 42.11-47.29% atoms and about 16.11-23.98% of calcium atoms [15]. It is shown that the potassium component is dominant compared to other chemical components. Potassium can increase the efficiency and selectivity of catalysts [16,17].

Along with the development of science, in this study, water hyacinth ash is converted into heterogeneous catalysts with the addition of K_2CO_3 through an impregnation process. The characteristics of prepared catalysts are analysed using X-Ray Diffractometer (XRD) and Scanning Electron Microscopy (SEM) instruments. The Kalium-impregnated water hyacinth heterogeneous catalyst is applied for transesterification of triglycerides into biodiesel. Palm oil is used as the triglyceride source. The potassium involves in the transesterification reaction by changing the ester, take glycerol and replace it with radical alkyl alcohol [18]. This process will produce biodiesel and by-products in glycerol form.

2. Materials and methods

2.1. Materials

Water hyacinth is obtained from drainage in the vicinity of Syiah Kuala University, Banda Aceh, Indonesia. K_2CO_3 (99.9 %) and methanol were provided by Merck (Germany), and palm oil was purchased from the market.

2.2. Preparation of catalyst

Water hyacinth was dried at an ambient temperature of about 32°C. After drying, water hyacinth was cut and crushed using a mechanical crusher. The water hyacinth was burned to ash in the open air. The ash of water hyacinth was calcined at 600°C for 8 hours. The K_2CO_3 solution of different concentration (10, 20, 30, 40 and 50%) was impregnated into the ash. The ash and K_2CO_3 mixture were stirred for 6 hours then placed into the oven at 80°C for 12 hours.

2.3. Catalyst characterization

The impregnated water hyacinth ash catalyst was characterized using X-Ray Diffraction (XRD) to analyse its crystalline property and Scanning Electron Microscopy (SEM) analysis was also conducted to observe the morphology.

2.4. Transesterification reaction

The transesterification process was carried out by adding 30 ml of palm oil and 17 ml of methanol (molar ratio palm oil to methanol of 1:12) and 15% of water hyacinth ash catalyst into a batch reactor which equipped with a water hose condenser and hot plate. The reaction was conducted was kept constant at a temperature of 65°C for 3 hours. The generated biodiesel was separated from the catalyst residue and glycerol using separating funnel and filter paper. After being separated, the biodiesel was then dry-washed in an oven at 80°C for 12 hours. The yield of biodiesel was determined using Eq. (1):

$$\% \text{yield} = \frac{\text{weight of biodiesel produced}}{\text{weight of oil used}} \times 100\% \quad (1)$$

3. Results and discussions

3.1. Characterization of water hyacinth ash catalyst

The XRD analysis of water hyacinth ash catalyst can be seen in Fig. 1.

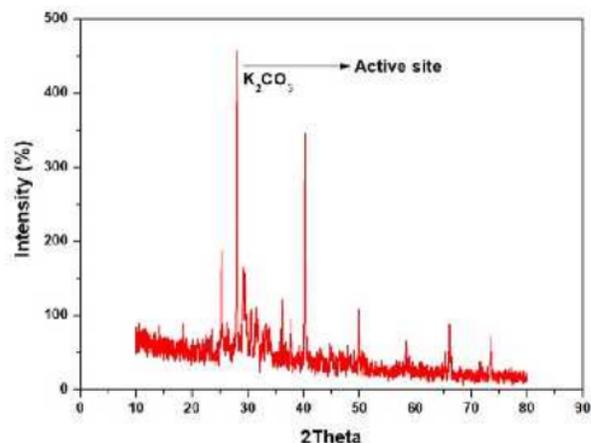


Figure 1. XRD analysis of the Kalium-impregnated water hyacinth ash catalyst.

Figure 1 shows that water hyacinth ash has a high content of potassium carbonate and several other minor components. The highest intensity of K_2CO_3 in the catalyst indicates the optimum deposition of K_2CO_3 to the active group on the surface of the water hyacinth ash [19]. It also means that potassium plays an important role in this reaction. Potassium improves catalyst efficiency by increasing the active phase. Moreover, it increases methoxide anion to break carbon carbonyl bonds from triglycerides to form biodiesel (methyl ester) [16]. Abdullah et al. report that K_2CO_3 contains potash-mineral which has been proven to increase the selectivity of the catalyst in the transesterification reaction [20].

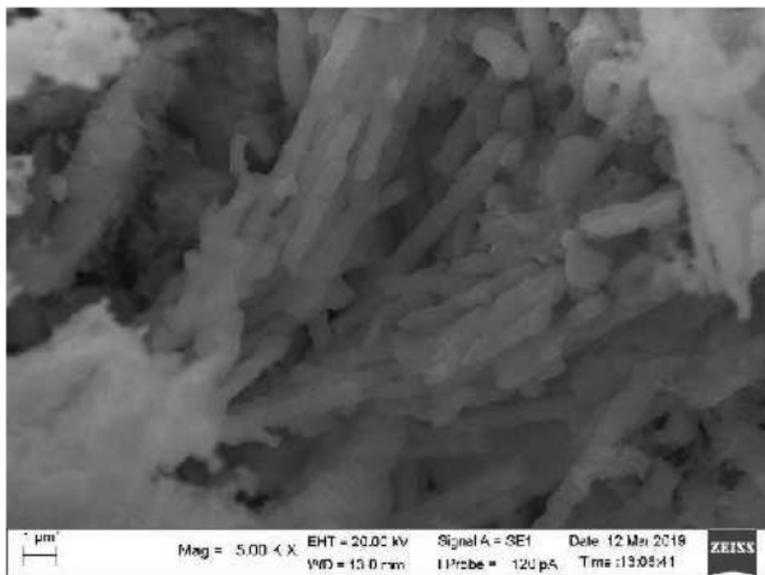


Figure 2. SEM micrographs of the Kalium-impregnated water hyacinth ash catalyst.

The SEM imaging result in Fig. 2 shows the morphological structure of water hyacinth ash catalyst. It is seen that the prepared catalyst is in the form of cylindrical-tube like agglomerated particles with size ranging from 0.6 to 4.8 μm which distributed on the catalyst surface. Agglomeration is the result of interactions among particles during the synthesise of water hyacinth ash catalyst [21]. In addition, the calcination also contributes to the complexity of the crystal structure due to the evaporation of impurity components which cover the pores of the catalyst [22].

3.2. Biodiesel production using water hyacinth catalyst

3.2.1. *Yield.* The catalyst performance can be observed from the amount of generated yield. In this research, the biodiesel yield was studied with a variation of impregnated K_2CO_3 loading. Results are presented in Fig. 3.

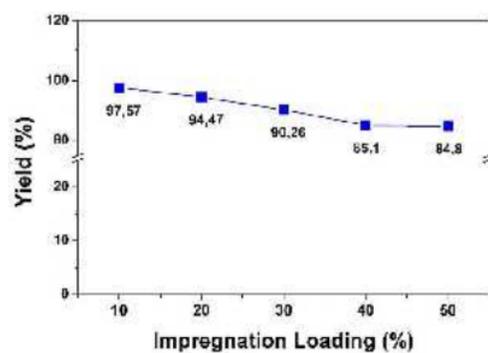


Figure 3. Effect of impregnation loading on biodiesel.

Figure 3 shows that, in certain circumstances, impregnation loading is very influential on the biodiesel yield because it affects the activity of the catalyst. The transesterification process using water hyacinth ash catalyst which impregnated with 10wt% K_2CO_3 produced the highest biodiesel yield of 97.57%. Increasing the K_2CO_3 loading results in a decline in biodiesel yield [23]. This presumably because the exceeding amount of K_2CO_3 will hinder the dispersion of potassium resulting in agglomeration of the carbonate component which increases the mixture viscosity and interferes with the stirring process [16,24]. The stirring process that is not fully achieved certainly affects the yield.

3.2.2. *Density of biodiesel.* Density greatly influences the composition of free fatty acids, purity of biodiesel, as well as its usage for injectors [23]. Measurement of biodiesel density was carried out using pycnometer with a volume of 5 ml. The density results of biodiesel which produced from transesterification reaction using water hyacinth catalyst with varied K_2CO_3 loading are given in Table 1.

Table 1. Biodiesel density.

Impregnation (%)	Density (gram / mL)
10	883,808
20	868,704
30	862,496
40	861,816
50	865,528

From overall results, the produced biodiesel has a density in the range of 865-884 kg/m³ with the highest density of 883 kg/m³ obtained from the transesterification using catalyst impregnated with 10wt% K₂CO₃. All of the obtained density is in accordance with SNI 7182: 2015.

4. Conclusions

A heterogeneous water hyacinth catalyst was successfully synthesized through impregnation method. The major component of heterogeneous catalyst from water hyacinth ash is K₂CO₃. The water hyacinth ash heterogeneous catalyst has a particle size of 0.6 to 5.8 μm. Impregnating 10% of K₂CO₃ into the water hyacinth catalyst brings about the highest biodiesel yield of 97.57%. In conclusion, water hyacinth can be a promising heterogeneous catalyst for biodiesel production at an industrial scale.

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