Production Of Activated Carbon From Chicken Feather As An Alternative Hydrogen Storage

A A Alhamidi, T Partuti and D Rachmawati

Department of Metallurgy, Faculty of Engineering, University of Sultan Ageng Tirtayasa, Cilegon, Banten, Indonesia

Abstract. Hydrogen is a reactive gas that requires special storage. Porous material from activated carbon can be used as an alternative storage. Activated carbon is derived from materials containing carbon. Chicken feather is one of the materials that can be used for activated carbon. There are two forms of samples, powder and briquette. The activation process is done physically with variation temperature 200, 300, 400 and 600 °C, activation time 60 minutes and flow rate of nitrogen 0.2 L/min. Activated carbon is analysed by Fourier Transform InfraRed (FTIR), Brunauer-Emmett-Teller (BET) and Scanning Electron Microscope (SEM). Percent of carbon produced is 62.90 wt.%. The FTIR results show that bond of C-H appears at 641-1362 cm$^{-1}$, C-C at 1442 cm$^{-1}$, C=C at 1600-1657 cm$^{-1}$, C≡C at 2130-2220 cm$^{-1}$. The result of BET for powder samples is 137.147 m$^2$/g (200 °C), 0.133 m$^2$/g (300 °C) and 0.000 m$^2$/g (400 °C). While for briquette samples are 77.387 m$^2$/g (200 °C), 0.369 m$^2$/g (300 °C) and 2.629 m$^2$/g (400 °C). The SEM results show that pores appear on the briquette sample are much more and more visible than the powdered samples due to the agglomeration, obtained 16.01% (200 °C); 0.88% (300 °C) and 5.69% (400 °C).

1. Introduction

Energy is the most important component for human life survival. Human still heavily rely on fossil fuels energy. But now the energy source from fossil fuels is limited, so that many researchers are developing renewable energy, such as hydrogen [1]. Hydrogen can be converted into electrical energy with the help of fuel cell system, known as fuel cell [2]. Hydrogen is predicted as fuel in the future because hydrogen has several advantages, such as easy to obtain, available in large quantities in nature, environmentally friendly, and hydrogen combustion is also much more effective because the heat generated is almost 3 times the heat of gasoline’s and diesel’s combustion [3].

Hydrogen is highly reactive at temperature 566 °C and easily explode if triggered by fire or other heat sources. Therefore, handling of hydrogen must be very careful and difficult to store in any place. There are several hydrogen storage technologies, namely high-pressure tanks, liquid (cryogenic), chemical and adsorption tanks [4]. Hydrogen storage by adsorption method has several advantages compared to others, such as easy in making process, easy to obtain raw materials and having low price.
The choice of material as an adsorbent must meet several criteria, i.e. having a large surface per mass unit so that the adsorption capacity will also be greater, naturally can interact with the adsorb pair, materials easy to obtain, cheap and no significant changes of volume during the adsorption process [5].

Activated carbon is one of the materials that meet these criteria. The activated carbon from chicken feathers has a surface area of 430 m$^2$/g, so that chicken feathers can be used as an adsorbent. Chicken feathers is an organic waste that can pollute the environment if not processed properly [6].

Activated carbon can be obtained through two processes: carbonization and activation. The activation process can be done chemically, physics, or chemical-physics. The selection of proper temperature is the most important in physics activation. The carbonization of chicken feathers was conducted chemically with KOH [7], while the activated process has been done physically [8]. This research still met some deficiencies, including the simplicity of carbon-making process was not vacuum well, so the result for surface area was 2.71 m$^2$/g [7] and 3.257 m$^2$/g respectively [8].

The purpose of this research is making activated carbon from chicken feathers as an adsorbent physically with temperature 200, 300, and 400 °C, while flow rate of nitrogen is 0.2 l/min and activation time 60 minutes.

2. Experimental Method

Initial preparation begins with washing chicken feathers using clean water and then separate between barbs, rachis, and calamus, then dried under the sun until dry completely [9]. Temperature of carbonization process for barbs at 300 °C, while rachis at 400 °C for 60 minutes each. The carbon produced from this process then crushed to powder with size of 100 mesh. Carbon characterization using ultimate and proximate analysis, FTIR, BET and SEM. Briquette sample made from 2 g powder sample added 0.04 g tapioca starch and 2.5 ml water, then printed on a steel cylinder of size 5 mm × 10 mm and pressed at 150 bars for 60 minutes. Activation process for powder and briquette sample is done physically with temperature variation 200, 300, and 400 °C for 60 minutes. Activated carbon produced then analyzed with BET and SEM to determine the difference of surface area and pore between before and after activation.

3. Result and Discussion

The results of the discussion divided into two, namely carbonization and activated carbon. At carbonization result base on proximate, ultimate, and FTIR analysis. While activated carbon result base on BET and SEM analysis.

3.1. Carbonization

Carbonization is a process for converting organic materials into carbon. This process will release combustible substances such as CO, CH$_4$, H$_2$, formaldehyde, methane, formic and acetic acid, also non-combustible substances such as CO$_2$, H$_2$O and liquid tar. The gases released in this process have a high heating value and can be used to meet the heat requirements of the carbonization process [10]. In this process, we can calculate the rudiment of charcoal for 10 grams initial sample in units of percent. This calculation aims to know the percentage efficiency of the amount of charcoal obtained after carbonization process. The rendemen of charcoal from carbonization of barbs is 59.48%, while rachis is 33.20%. The results found that the charcoal rendemen for carbonization of chicken feathers was 35% [11] and 30.06% [7].
The carbonization result by proximate analysis is given in Table 1. This analysis measures moisture content, volatile matter, ash and fixed carbon. Fixed carbon is the solid fuel left in the furnace after the material volatile is distilled off. The main content is carbon. In addition to containing carbon, fixed carbon also contains hydrogen, oxygen, sulfuric and no nitrogen carried by gas. Fixed carbon provides a rough estimate of the value of coal heat. Fixed carbon remains in this research is 47.91%, while percentage of volatile matter is 43.93%. The higher the value of volatile matter then the fixed carbon value will be lower, which means it will increase the number of pores that are formed [12].

Table 1. Proximate analysis result.

| Analysis            | %     |
|---------------------|-------|
| Moisture            | 5.96  |
| Volatile matter     | 43.93 |
| Ash                 | 2.20  |
| Fixed carbon        | 47.91 |

The ultimate analysis result for barbs and rachis is given in Table 2. The ultimate analysis determines the various chemical compounds such as carbon, hydrogen, oxygen, sulfuric, etc. This analysis is useful to determine the amount of air which are required for combustion, volume and composition of the combustion gases, so we can calculate flame temperature. From this analysis we get carbon element obtained is 62.90%, hydrogen 4.20%, nitrogen 15.65% and oxygen 17.25%. The carbon element in oil palm fronds was 50.23% [13], chicken feathers by 60.6% [8] and cashew nut shells by 70.25% [14], so the carbon found in this research was considerable.

Another analysis for carbon resulted from carbonization process is FTIR. This analysis uses infrared radiation to characterize chemical bonds and to identify materials. Pattern absorbance which is absorbed by each compound different from each other, so that the compounds can be distinguished and identified. Chicken feather, as a raw material, are mostly composed of keratin containing natural protein. The chemical structure of chicken feather shown at Figure 1 [11]. When heated, the protein creates crosslinks that strengthen the structure and increase its surface area. The result is a carbonized chicken feather which can absorb as much more hydrogen as possible [6].

![Figure 1. Structure of Keratin.](image)

Table 2. Ultimate analysis result.

| Analysis | %     |
|----------|-------|
| C        | 62.90 |
| H        | 4.20  |
| N        | 15.65 |
| O        | 17.25 |
Figure 2. FTIR analysis result carbonization of chicken feather.

FTIR analysis results for carbonized chicken feather show that bond of C-H appears at 641-1362 cm\(^{-1}\), also appears at 1508 cm\(^{-1}\), 2522-2730 cm\(^{-1}\) and 3121 cm\(^{-1}\). C-C bond appears at 1442 cm\(^{-1}\), 2352 cm\(^{-1}\), 2874 cm\(^{-1}\) and 2960 cm\(^{-1}\), C=C bond appears at 1600-1657 cm\(^{-1}\) and 3076 cm\(^{-1}\). C≡C bond appears at 2130-2220 cm\(^{-1}\). O-H bond appears at 3634-3908 cm\(^{-1}\) (Figure 2). It shows that C-H bond is the dominant.

3.2. Activated carbon

After the carbonization process was complete, the activation process is done physically by using temperature variations at 200, 300, 400, and 600 °C with 60 minutes of time referring to studies before where the optimum temperatures were 450 ℃ with activation for 60 minutes [6]. In the activation process used nitrogen with a flow rate of 0.2 l/min. It’s used to avoid oxidation process that can damage existing pores and getting low surface area. The higher of the temperature used, the oxidation will accelerate so that the resulting carbon is reduced due to the amount of carbon eroded and damaged, this is based on the kinetic energy formula of the gas as shown in equation 1, where \(v\) is average speed of gas or molecule (m/s), \(R\) is molar gas constant (8.314 JK\(^{-1}\)mol\(^{-1}\)), \(T\) is temperature (K) and \(M\) is mass of mole (kg).

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v = \sqrt{\frac{3RT}{M}}
\]

At temperatures of 600 °C, carbon eroded about 90-100%. It’s obviously seen that on the bottom layer is black while the top layer is white bone for powder sample, while for briquettes, the color turn from black into white bone as a whole. So that, the research for temperatures of 600 °C was not continued. The next analysis result is BET. It is used for determining the value of pore’s surface area per unit mass. After activation process, the surface area decreases with increasing activation temperature. This occurs both on powder and briquette samples (Figure 3). The surface area for powder samples is 137.147 m\(^2\)/g (200 °C), 0.133 m\(^2\)/g (300 °C) and 0.000 m\(^2\)/g (400 °C). While for briquette samples are 77.387 m\(^2\)/g (200 °C), 0.369 m\(^2\)/g (300 °C) and 2.629 m\(^2\)/g (400 °C).

Figure 3. Surface area after activation process for powder and briquette samples.
For powder sample, the increasing temperature causes a decrease in the pore surface area due to the oxidation process occurring with the use of a constant nitrogen flow rate (0.2 l/min) so that oxygen is not completely impeded. The higher the activation temperature and gas flow rate used in the activation process, the higher the surface area will be produced [15]. As well as for briquette samples, the phenomenon of surface degradation is also present in briquette samples due to oxidation. The results of this research were inversely proportional to the theory which the higher the temperature of activation used, the surface area will also be higher [16].

BET analysis results also reinforced with SEM analysis. This SEM analysis aims to see whether or not pores are present in materials. Figure 4 shows SEM analysis for powder samples with 4000x magnification. There is only a few pore at activation temperature 200 °C, while for activation temperature 300 and 400 °C is not showing any pores. The pore percentage calculation using ImageJ software was obtained 0.02%.

In briquette sample occurs agglomeration due to the addition of binder in the form of tapioca starch as much as 0.04 g (2% of total carbon weight) with water as an adhesive which resulted in the union of carbon particles due to pressing process of 150 bar during briquette making. Figure 5 shows that pores appear on the briquette samples are much more and more visible than the powdered samples due to the agglomeration with 700x magnification. The pores obtained 16.01% at activation temperature 200 °C, 0.88% at 300 °C and 5.69% at 400 °C.

Figure 4. SEM analysis results for powder sample at activation temperature 200 °C(a), 300 °C (b), and 400 °C (c).

Figure 5. SEM analysis results for briquette sample at activation temperature 200 °C(a), 300 °C (b), and 400 °C (c).

4. Conclusion
The optimum activated temperature is at 200 °C to give surface area 137.14 m²/g for powder and 177.387 m²/g for briquette sample, and the pores appear on the briquette sample obtained 16.01%. This activated carbon from chicken feather can be used as an alternative hydrogen storage.
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