Activated Carbon Produced by Carbonization and Chemical Activation of Coconut Frond for Air Batteries

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Abstract. Coconut waste is an abundant biomass that not fully utilized as raw material for producing high added value materials. One of the product that can be made from coconut waste is activated carbon. Activated carbon is an amorphous carbon material with high degree of porosity and an extended surface area. Activated carbon commonly used as adsorbents, catalyst support and energy storage. Activated carbon characteristic with high porosity and good conductivity will produce, activated carbon suitable as air batteries material. This research focused on the process of making activated carbon based on coconut frond by carbonization and chemical activation process. Carbonization process carried out by heating the biomass at temperature 300–650 °C in absence of oxygen. This Process is known as pyrolysis. The activation of the carbon has be taken place by using $ZnCl_2$, NaOH and HCl as chemical activating agent. This research investigated the effect of carbonization temperature and variation of chemical activating agent. In this study activated carbon is used as a working electrode of air batteries.

Keywords: Coconut frond · biomass · activated carbon · air batteries

1 Introduction

Tropical plants such as the coconut plant (*Cocus nucifera.L.*) are abundant in Indonesia and it has a number of applications. However, the use of coconut plants is typically restricted to the fruit's flesh, which is then processed into coconut milk, leaving other plant components such the coconut shell, midrib, stems, and leaves as possible waste and not being used to their full potential. To increase the use value, coconut frond waste must be treated. Activated carbon is one of the items that can be made from coconut fronds. Adsorbent, energy storage, carbon synthesis, catalyst support, and other uses are all common for activated carbon. Because they feature pores with a big surface area, strong conductivity, and stability, as well as being affordable and readily available in the market, porous materials like activated carbon can be used [1].

An air battery is one of the potential energy storage devices. One of the new energy sources with a high energy value that can be utilized for electronic goods, electricity

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transit, and good energy storage is the air metal battery [2]. Aluminum air batteries provide a number of benefits, including low cost, a high theoretical specific capacity value that ranks second only to lithium and is significantly higher than that of magnesium and zinc. In addition, aluminum is a cheap, plentiful, and highly recyclable metal that is also good for the environment. Theoretically, an air aluminum battery has a high voltage and a high energy density [3].

Earlier research was carried out by Fuadi [4]. They studied the effects of carbonation and chemical activation on midrib activated carbon. The outcomes demonstrated that the optimal and most productive conditions were at a carbonization temperature of 500 °C, using 0.3 M HCl activator, with a carbon size of -60 + 115 mesh and an activation time of 24 h, and the activated carbon they produced met the quality requirements of activated carbon according to SII No. 0258–88. And Larasati et al. [5] have made activated carbon using biomass by adding pre-treatment deashing raw material, the effect of pre-treatment is associated with the mass reduction in the original biomass feedstock.

2 Methods

2.1 Research Location

This research was conducted at the Chemical Engineering Study Program Laboratory, Faculty of Engineering, Mulawarman University, Samarinda, East Kalimantan.7513.

2.2 Research Procedures

See Fig. 1.

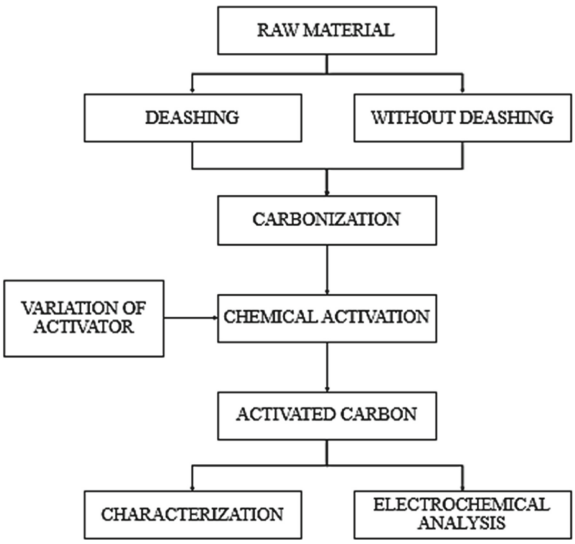

Fig. 1. Process diagram of activated carbon produce

2.3 Data Analysis

a. Removing Ash Content

Raw materials that have successfully completed the preparation step are next put through a deashing process, which removes the ash content from the raw material. To see how the carbonization process would be affected, the ash content was removed. The removal of the ash content aids in the creation of carbon pores by increasing the surface area of the pores. Deashing is a process that involves stirring a 1 M HF (hydrogen fluoride) solution with 50 g of raw material for 60 min in a beaker with a stirrer [6]. The mixture of coconut fronds and HF solution was separated using a filter after 60 min, and the coconut fronds were subsequently dried at 100 °C in oven. The head fronds that have undergone deashing are then used as feed for the following procedure.

b. Carbonization

Following preparation, the dry raw materials are placed in a furnace for 15 min, with the combustion temperature set at 400 °C. At a porcelain exchange rate, the resulting biochar is ground.

c. Activation

In the chemical activation stage, $ZnCl_2$, HCl, and NaOH are combined with the biochar that results from the carbonization process. Biochar is made with a 2:1 ratio of raw materials, which are then soaked for 18 h. With distilled water, the activated biochar is washed until the pH of the utilized washing water is neutral. After being cleaned, the activated carbon is dried in a 150 °C oven for two hours.

d. Characteristics of Activated Carbon

Analysis of the gravimetric method for ash removal. To determine the morphological structure of active carbon, SEM examination is employed. The surface area of activated carbon was calculated using a nitrogen adsorption-desorption analysis and BET calculations.

e. Electrochemical Analysis Electrochemical

The electrochemistry of the activated carbon material developed during the investigation was examined using analysis. The application uses air batteries to operate. The purpose of the electrochemical analysis was to gauge the air battery's voltage (in Volts).

3 Result and Discussion

Ash concentration in coconut sheaths, the impact of carbonation and activation variations on the recovery of activated carbon, the physical properties of carbon, and electrochemical testing of activated carbon are all covered in this section.

a. Elimination of Ash Content

The composition of the chemicals present in the biomass is revealed by ultimate and proximate analyses. Each biomass differs from the others in the composition of these chemicals. Based on the proximate analysis's findings, coconut fronds can be used as a raw material to create activated carbon because there is adequate fixed carbon and volatile matter [7] (Table 1).

Table 1. Proximate and Ultimate Analysis

Waste	Proximate analysis (%)					Ultimate Analysis (%)			
	C	H	N	O	S	M	VM	FC	A
Coconut Frond	34,01	7,71	0,46	51,92	0,94	7,08	78,03	17,01	4,96

Using a powerful acid catalyst, the ash content in coconut fronds is removed. Following the completion of deashing, the ash content is estimated using the findings of a gravimetric study of 10 g of coconut frond samples, and the samples are then burned for an hour at a temperature of 600 °C in a furnace [6]. The ash-like remains of combustion that are found inside coconut fronds. Table 2 displays the findings of the calculation of the ash content of coconut fronds both before and after deashing.

b. Effect of Carbonization Treatments and Variations Activator on Activated Carbon
Table 3 displays the activated carbon recovery results that have an impact on the activating agent variation and activating agent ratio (Table 4).

Table 2. Calculating the amount of ash content

Sample	Ash Content (%)
Coconut Frond	3,89
Coconut Frond With Deashing	2,08

Table 3. Mass yield of activated carbon

Activator	Ratio Activator: Biochar	Result of Activated Carbon
$ZnCl_2$	2:1	3,0543 g
NaOH	2:1	2,4704 g
HCl	2:1	3,4496 g

Table 4. Mass yield of activated carbon (raw material deashing)

Activator	Ratio Activator: Biochar	Result of Activated Carbon
$ZnCl_2$	2:1	3,0876 g
NaOH	2:1	2,9840 g
HCl	2:1	2,0878 g

The amount of activated carbon recovered from the raw material increased to 3.0876 g with the inclusion of the deashing pre-treatment. This means that adjustments to process factors like carbonation temperature, activating agent ratio, and deashing addition have a significant impact on the amount of recovered activated carbon [3].

c. BET Surface Area and Scanning Electron Microscopy (SEM)

Table 5 shows the surface area of activated carbon which is produced at different activator.

The surface area of activated carbon with treated raw material is higher than activated carbon without treated. This may happen because some pores which are formed by the decomposition of organic components in material increase [5]. The treatment with hydrogen fluoride is more effective to remove compounds such as carbonates, oxides and silica [5, 6].

The morphology of activated carbon after carbonization and chemical activation process shown in Fig. 2.

More pores are opened on activated carbon structure creating holes along the activated carbon surface, so that enhanced the porosity and the surface area of activated carbon [8].

d. Electrochemical Analysis Electrochemical

Analysis was done to evaluate the activated carbon material created in the study's electrochemical performance when it was used in a supercapacitor cell. A basic supercapacitor made by cutting a 5 cm × 5 cm zinc plate and an aluminum plate with activated carbon was used for the electrochemical analysis. After being cut, the zinc and aluminum plates were coated with tissue to act as a separator, and in the center of the tissue, activated carbon was added.

Table 5. Surface Area of activated carbon

Activator	BET Surface Untreated Material (m^2/g)	BET Surface Treated Material (m^2/g)
$ZnCl_2$	740	1141
NaOH	469	637
HCl	323	375

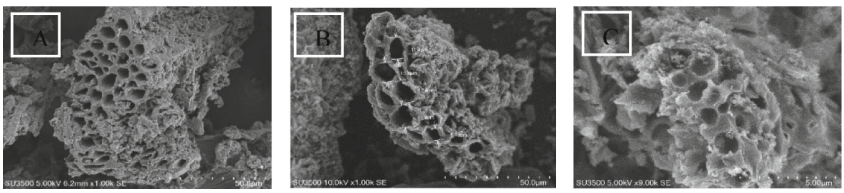

Fig. 2. SEM Result of (A) AC-$ZnCl_2$, (B) AC-NaOH, (C) AC-HCl

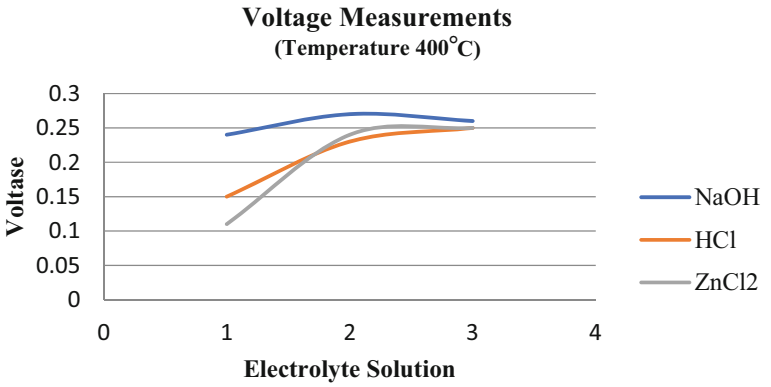

Fig. 3. Shows a comparison of voltage measurements at 400 °C

3.1 Voltage Test of Activated Carbon Without Deashing Treatment

Based on the findings of Fig. 3, it can be seen that the HCl electrolyte solution produced the maximum electric voltage of 0.27 V when activated carbon was used in combination with a NaOH solution activator at 400 °C.

3.2 Voltage Test of Activated Carbon with Deashing Treatment

Based on the findings of Fig. 4, it is evident that the $ZnCl_2$ electrode produced the maximum electric voltage, which was 0.25 V, when activated carbon was used in conjunction with a 2:1 NaOH solution activator at a temperature of 400 °C.

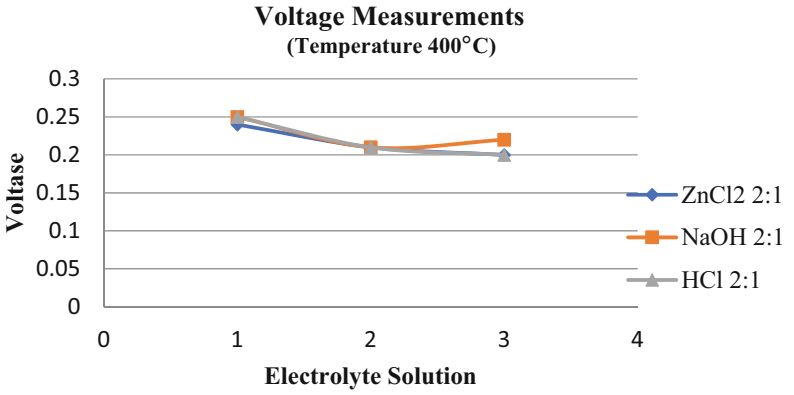

Fig. 4. Voltage Measurements at 400 °C Compared

4 Conclusion

Activated carbon as an electrode material of air batteries can be obtained from coconut frond waste through the carbonization and activated process. Voltage measurement with the deashing process obtained the highest electrical voltage namely with activated carbon using 2: 1 $ZnCl_2$ solution activator at a temperature of 400 °C with a NaOH electrolyte solution of 0,25 V and Voltage measurement without the deashing process obtained the highest electrical voltage namely with activated carbon $ZnCl_2$ solution activator at a temperature of 400 °C with a NaOH electrolyte solution of 0,27 V.

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