Preparation and Characterization Activated Carbon Based on Mesocarp of Bintaro Fruit as Electrode Materials Supercapacitor Cell Application

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Abstract. Supercapacitor is an energy storage device that has high energy and power density. One of the main component in supercapacitor cells is electrode. A production of activated carbon made from mesocarp of Bintaro fruit as a supercapacitor cell electrode has been successfully. Activated carbon electrodes were prepared through a pre-carbonization process, chemical with KOH 0.5 M activator, carbonization process using N2 gas and physical activation using CO2 gas. In this study, the physical activation process was carried out with temperature variations of 650°C, 750°C, 850°C and 950°C which of KAMBB-650, KAMBB-750, KAMBB-850 and KAMBB-950 respectively. Microstructure analysis shows amorphous structure for the carbon electrodes which is by the presence of peaks at an angel of 2θ around 24° and 44°. The increasing physical activation cause smaller Lc, high specific capacitance. In this study, the optimum temperature obtained in 850°C of KAMBB-850 sample. High specific capacitance as high as 267.6 F/g was found on KAMBB-850. The lowest capacitance obtained at carbonization temperature 950°C of KAMBB-650 sample with specific capacitance as high as 71.4 F/g.

1. Introduction
The times have made the human population to increase, as the increase makes the need for energy also increases. Energy diversification at this time needs to be done by developing other energy sources as alternative energy in the provision of domestic energy consumption to present a solution to the national energy crisis. Energy storage devices are a solution in facing the energy crisis. some energy storage devices include batteries, fuel cells and capacitors. Batteries and fuel cells are devices for storing electrical energy that have the ability to store high energy, but the problem is that batteries and fuel cells have a fairly small power density and require a long time in the charging process [1]. Therefore we need a technology that has a large energy density and power density as well as a short charging time. Capacitors provide a new breakthrough, namely supercapacitor, which is a device that has a large capacitance value and high energy density and power [1, 2]. The magnitude of the power density value of the supercapacitor is caused by the large surface area of the electrode material. The use of biomass as a material for making supercapacitor electrodes is very good because the price is relatively affordable, easy to obtain and comes from renewable natural resources. Activated carbon from biomass can be made from materials containing carbon such as sawdust[3], wood fiber[4], and in this study the biomass used was the mesocarp of bintaro fruit. The bintaro tree, also known as the pongpong tree or Indian suicide tree, is a non-food plant because it contains toxins in almost all parts such as the trunk, flowers and fruit of bintaro. Bintaro fruit is one of the biomass wastes that is interesting to study because of its relatively large population and its not optimal utilization addition to
the relatively large amount and not optimal utilization, bintaro fruit content is mostly composed of lignocellulose, namely: lignin (58.5%) and cellulose (41.8%). The high cellulose and lignin content in biomass shows the amount of carbon contained.

2. Methods

2.1. Electrodes preparation
Ripe bintaro fruit which is marked with red outer skin taken from the university of riau Indonesia. Chemical activation used potassium hydroxide (KOH) agents purchased from MerckKGa, Germany. The production of activated carbon from mesocarp of bintaro fruit uses a combination of chemical and physical activation. Mesocarp of bintaro fruit were pre-carbonized at a low temperature of 200°C for 2 hours, followed by a grinding and sieving process, resulting in carbon powder with particle size 100 mesh. The next step, chemical activation, was performed using KOH at 0.5 M concentrations. All samples were formed by compression pressure, and thus all carbon pellets samples were integrated carbonization and activation methods. The sample were carbonized at a temperature of 600°C using furnace tube in a nitrogen gas environment with a constant flow rate of 1.5 L/min, followed by physical activation using CO₂ gas at various temperature, i.e., 650°C, 750°C, 850°C, and 950°C.. the carbonization and physical activation processes convert sample into activated carbon (AC), so that each sample is labeled AC-650, AC-750, AC-850, and AC-950.

2.2. Physical characteristics
The mass, diameter, thickness, and crystallinity of the activated carbon samples were measured. The mass, diameter and thickness were recorded to calculate density of all AC samples. The crystallinity of the AC samples was studied X-ray Diffraction (XRD) using a Philip X-pert Pro PW 3060/10 instrument with Cu k-α light source and wavelength of 1.5418 Å. The diffractogram data was examined in the diffraction angle range 10-100°. Interlayer spacing (d_{hkl}) was calculated using the Bragg’s equation, and the microcrystallite dimensions such as the peak height (Lc) and peak width (La) were calculated using Debye-Scherer’s equation.

2.3. Cell fabrication and electrochemical characteristics
The electrochemical property measurements were performed using fabricated supercapacitor cells, i.e., a sandwich type that consist of body cells, current collectors, electrodes, a separator and electrolytes. In this study, AC samples were used as supercapacitor electrodes, a 1M H₂SO₄solution was selected as the electrolyte, and a eggshell membrane was selected as the separator. The body cells and currents collectors were made from made from acrylic and 316 stainless steel tape. Electrochemical measurements were perform using a Physics CV UR Rad-Er 5841 instrument calibrated with a 1280 Solatron® device. Electrochemical measurement was conducted at a scan rate of 1mV/s and a potential window of 0 to 1000 mV controlled using CVV6 cyclic voltammetry software. Electrochemical characteristics of an AC samples based supercapacitor cell were examined via the specific capacitance calculated using the standard equation.

3. Results and Discussion
The mass (m), diameter (d), thickness (t) and density (ρ) are reported for the various temperature in Table 1. AC-650, AC-750, AC-850 and AC-950 showed density before carbonization and physical activation process.
Table 1. Mass, diameter, thickness, and density.

| Samples | Mass Before carbonization (g) | Diameter Before carbonization (cm) | Thickness Before carbonization (cm) | Density Before carbonization (g/cm³) | Mass After carbonization (g) | Diameter After carbonization (cm) | Thickness After carbonization (cm) | Density After carbonization (g/cm³) |
|---------|-------------------------------|-----------------------------------|-----------------------------------|------------------------------------|-----------------------------|---------------------------------|----------------------------------|----------------------------------|
| AC-650  | 0.6765                        | 1.951683                          | 0.203775                         | 1.118564                           | 0.55381                     | 1.745127                       | 0.87181                         | 1.067528                         |
| AC-750  | 0.7205                        | 1.9067                            | 0.200183                         | 1.262138                           | 0.475                       | 1.6685                         | 0.207333                       | 1.047809                         |
| AC-850  | 0.688                         | 1.907767                          | 0.184267                         | 1.306492                           | 0.324286                    | 1.555714                       | 0.169714                       | 0.999752                         |
| AC-950  | 0.695                         | 1.90908                           | 0.20133                          | 1.2063                             | 0.191                       | 1.38458                        | 0.21097                         | 0.57718                          |

XRD data in Figure 1 show the major and minor peaks at 22.642° and 43.690° (AC-650), 23.895° and 44.685° (AC-750), 22.330° and 43.690° (AC-850), 23.338° and 43.102° due to diffraction from (002) and (100) planes, respectively. The calculated values of interlayer spacing ($d_{002}$ and $d_{100}$) and crystallite dimension (stack height $L_c$ (002) and stack width $L_a$ (100)) from diffraction peaks (002) and (100) were shown in Table 2. The relation between $d$, $L$, and specific capacitance for carbon from mesocarp of bintaro fruit reported in ref. [5].

Table 2. Interlayer spacing and crystallite dimension for ACs.

| Samples | $d_{002}$ (Å) | $d_{100}$ (Å) | $L_c$ (Å) | $L_a$ (Å) |
|---------|---------------|---------------|-----------|-----------|
| AC-650  | 3.9239849     | 2.0659775     | 6.1934183 | 31.853408 |
| AC-750  | 3.9494672     | 2.063513      | 3.8504674 | 22.539976 |
| AC-850  | 3.9871014     | 2.0701594     | 2.8095316 | 37.100466 |
| AC-950  | 3.3811176     | 2.0517711     | 7.0872581 | 28.029983 |

The increase in area of rectangular shape of CV curves for the ACs cells, for the potential values from 0 V to 1.0 V at a scan rate of 1 mVs⁻¹ (Figure 2). The specific capacitance was calculated (Table 3) from the CV data using equation $C_{sp} = 2I/(s \cdot m)$, where $I$ is the current, $s$ is the scan rate and $m$ is the mass of electrode. The values of $C_{sp}$ calculated from the CV methods (Table 3).
4. Conclusion
Activated carbon electrode from a mesocarp of bintaro fruit exhibits an excellent combination of physical and electrochemical properties. The use of a low concentration of KOH activation agent 0.5 M, followed by physical activation at variation temperature 650°C, 750°C, 850°C, and 950°C using CO₂ gas, has succeeded in producing an activated carbon electrode. The physical properties of the carbon electrode are strongly related to the specific capacitance of the supercapacitor cell. The lowest density is 0.57718 g/cm³, this electrode has the highest specific capacitance of 267.6 F/g, obtained at a physical activation temperature of 850°C. It can be concluded that the physical activation at 850°C is the best temperature for high capacitance.

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