Utilization of porous carbon from waste palm kernel shells on carbon paper as a supercapacitors electrode material

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Abstract. A porous carbon prepared from waste palm kernel shells has been applied as a new supercapacitor electrode material. Activated carbon was synthesized through a carbonization process at a temperature of 400 °C which has a particle size of 90 μm and provide a surface area of 301.482 m² g⁻¹. Carbon from waste palm kernel shells was distributed on a sheet of carbon paper surface with a variation of carbon paper and palm kernel shells carbon mass ratio. From the results reported that the capacitance value was increased to 1331.8 μF in rolling method with addition of carbon palm shells mass have higher capacitance values than which was obtained in plate or sandwich method.

1. Introduction

Supercapacitors have been attracted much attention as an electrochemical energy storage device due to their high power density and long durability compared to batteries. Activated carbon material has been widely used as electrode materials of supercapacitors because of high surface area, chemical inertness, good thermal and mechanical stability. Generally highly developed surface area, which is characteristic for microporous carbons is necessary for formation of electrical double layer but the presence of mesopores are crucial if a high propagation of charge is demanded specially for transportation system still in acceleration where is the power peak required as well as during braking for energy recovery [1]. Various types of activated carbon materials, for example coffee grounds [2], ginkgo shells [3] waste tea-leaves [4] and palm kernel shell [5] were used in a fabrication of supercapacitor.

The development of oil palm kernel shell biomass as a source of bioenergy and also in reducing the environmental impact must be accompanied by another development of a new electrode material as an important aspect in supporting the energy storage technology development. Regarding for next utilization of waste palm kernel shells biomass to produce an activated carbon to pursuing a licensing strategy of the future supercapacitor electrode [6,7].

The common methods used in the present study is in order to increase the capacitance of a new carbon electrode material is actually our main research objective especially in the electrode surface modification or fabrication of a new carbon fiber paper-based supercapacitors [8], a fabrication of
Polyaniline (PANI) nanofibers supported by carbon paper [9]. In this paper, we choose palm kernel shell carbon which was coated on the commercial carbon paper surface as a template in a new supercapacitor electrodes in order to increase supercapacitor capacitance.

2. Materials and Methods

2.1. Equipments and materials
Equipments which were used are LCR-Meter (Tonghui Electronic TH2820-LCR), Multimeter (Heles UX-838TR), petridish, and other laboratory glasses equipment’s.

Waste palm kernel shells materials were obtained from Agam regency, West Sumatra, carbon rods of waste batteries, \( \text{H}_2\text{PO}_4 \) (Merck), carbon paper (Munix Kangaro) and distilled water.

2.2. Preparation of carbon palm kernel shell
Palm kernel shells are dried and reduced into smaller size. The formation of carbon through carbonization process at a temperature of 400 °C for 60 min with a certain particle size of 90 µm [5].

2.3. Preparation of carbon paper as electrode materials
Supercapacitors were made with such a roll and sandwich form (Fig 1). Carbon rod originally from waste batteries with a length of 5 cm and a diameter of 0.3 cm. Carbon paper electrode plate of palm kernel shells are rolled up circling the carbon rods from the battery. On the first roll is the front of the paper carbon that acts as a positive electrode (sheet 1) and then continue rolling the rear carbon paper acting as a negative electrode (sheet 2). The same treatment is done for variations in particle size and surface area variations of carbon paper [5].

In the sandwich plate method, carbon paper was cut with a variety of sizes. Each carbon paper arranged in layers as Figure 2 and as a current collector is a copper plate that is placed flanking the two electrodes.

![Figure 1](image)

**Figure 1.** Schematic illustration of the supercapacitor preparation (Rolling Method (A) and Sandwich Method (B))

2.4. Preparation of palm kernel shell carbon on the carbon paper
The sheets paper spread up with glue and sprinkle the carbon of palm kernel shells on its surface. Plate electrode of carbon which had been formed then dried at room temperature and the carbon paper weighed before and after being coated with palm kernel shell carbon.
3. Results and Discussions
Characterization of the carbon palm kernel shell obtained at the combustion temperature of 400 °C has been reported previously. From the results of EDX, the percentage of atomic weight of carbon at the combustion temperature of 400°C is 72.70%, and 26.62% are oxygen atoms [5] and is based on the measurement results obtained at the BET 90μm particle size provides the largest surface area is 301 482 m² / g. Therefore for further research of carbon used is from carbon palm shells with the size of 90 μm.

3.1. Effect of carbon paper size
Figure 2 indicates that the larger the surface area of an electrode, the greater the capacitance value. This is because the larger the surface area of the electrode, the greater the ability of the electrodes to store charge. Large surface area electrodes will provide a place for the storage of electrical charge layer formed on the electrode surface.

Comparison of capacitance values in both methods with the same surface area (30cm²) showed the differences in the ability of supercapacitors charge storing. Supercapacitor with the rolling method has a capacitance value of 63 times higher than it is in the sandwich method.

3.2. Effect of charging time
Figure 3 shows that the capacitance value for both methods of rolling or sandwich increased progressively with increasing charging time to 60 min and then decreases with increasing time charging.
In the method of scrolling obtained capacitance was 105 time higher than it is in the sandwich method at the optimum charging time of 60 min.

3.3. Effect of time charging on the conductivity electrode

Conductivity is calculated based on the measured resistance value of supercapacitor by rolling and sandwich methods of a surface area of the carbon paper as 3 x 20 cm² on the rolling method and carbon paper size of 6 x 5 cm² on the sandwich method.

![Figure 4](image.jpg)

**Figure 4.** Effect of charging time to the conductivity of the electrode (a) the method of scrolling (b) the method of sandwich.

Figure 4 shows the influence of the charging time on the conductivity where is the conductivity increased by the charging time of 60 min, and then decreased after 60 min.

3.4. Effect of H₃PO₄ concentration

H₃PO₄ electrolyte concentration variations performed on carbon paper sizes 3 x 20 cm² on the rolling method and carbon paper size 6 x 5 cm² on the sandwich method with a charging time of 60 min.

![Figure 5](image.jpg)

**Figure 5.** Effect of H₃PO₄ concentration on the capacitance supercapacitor (a) the method of rolling, (b) the method of sandwich.

Figure 5 shows higher concentration of H₃PO₄, lower capacitance of the supercapacitor. Greater concentration of electrolyte, electrolyte ions will be accumulated at electrolyte and separator interface during charging. The great number of ions will disturb the discharge process because of the bulk ions makes the ions or the charge is difficult back to its initial position.
3.5. The effect of addition of carbon palm shells on carbon paper on the value of the supercapacitor capacitance

The addition of carbon in the carbon electrode supercapacitor will improve the ability of charge storage [2]. Therefore, in this study, the addition of palm kernel shells carbon on carbon paper has been considered. Carbon palm shells are added in the variation mass ratio between carbon paper and palm kernel shells carbon.

The optimum addition of carbon of the rolling and the sandwich method is on a carbon paper of 3 x 20 cm² size for the rolling method and carbon paper of 6 x 5 cm² size for the method of plate with 0.1 N H₃PO₄ electrolyte and the charging time of 60 min. The addition of carbon from palm shells was made by variations of mass ratio as 1: 1, 1: 2, 1: 3, 1: 4 and 1: 5.

In the rolling method by addition of oil palm shell carbon on the carbon paper electrodes show the capacitance values as 32 times higher than carbon electrode made of palm kernel shells.

Table 1. Differences in capacitance of the supercapacitor electrode material on a rolling method

| Treatment                                           | Capacitance (µF) |
|-----------------------------------------------------|------------------|
| Without addition of palm kernel shells carbon      | 1.2665           |
| With addition of palm kernel shell carbon in ratio of 1: 2 | 1331.8           |

Table 1 shows that the addition of carbon palm kernel shell can increase the capacitance equal to 1052 times greater than without the addition of the carbon. Carbon has pores that will absorb and store incoming charge. By addition another carbon than carbon paper will increase the amount of carbon occurring in the carbon paper surface so that more charge will be stored by these new electrodes.

Figure 6. Effect of the mass ratio of carbon paper to palm kernel shells carbon against the capacitance : (a) the scrolling method (b) the sandwich method.

The addition of carbon in the variation of mass show an increase in capacitance at mass ratio of 1: 2, after which the capacitance value decrease at mass ratio of 1: 5 as shown in Figure 6 (A). This is because increasing in mass, the thickness of the electrode can also be increased, and the attachment process of oil palm shell carbon on carbon paper is uneven, so that the rolling process becomes difficult to attain safely.
Figure 6 (B) shows that the capacitance will increases with the addition of palm kernel shells carbon mass. On the sandwich method, palm kernel shell carbon attachment to the carbon paper is more easily prepared because that paper used smaller carbon size.

**Table 2.** The capacitance value of supercapacitors without and with addition of palm kernel shell carbon.

| Treatment                                | Capacitance (nF) |
|------------------------------------------|------------------|
| Without addition of palm kernel shells carbon | 12.043           |
| With addition of palm kernel shell carbon in ratio of 1:4 | 99.05            |

Table 2. shows that the addition of carbon palm shells can increase the capacitance value of 8.22 times higher than without the addition of this carbon. Based on the capacitance value it can be seen that the method of rolling has higher capacitance values than the sandwich method.

**4. Conclusion**

In this present study show that the carbon paper made from palm kernel shells is capable to increase supercapacitor capacitance by using both methods, namely the rolling method and sandwich method. The rolling method has higher capacitance values (1331.8 μF on carbon paper size of 3 x 20 cm²) than the sandwich method (12665 μF on carbon paper size of 6 x 5 cm²), the optimum charging time found to be in 60 min and optimum concentration of electrolyte found as 0.1 N H₃PO₄. The addition of palm kernel shell carbon on the carbon paper can increase the capacitance value where is found respectively as 1052 times in the rolling method and 8.22 times in the sandwich method which were higher than values obtained without the addition of palm kernel shells carbon.

**References**

[1] Frackowiak E 2006 supercapacitors based on carbon materials and ionic liquids J. Braz. Chem. Soc. 17 1074-82
[2] Kamikuri N, Hamasuna Y, Tashima D, Fukuma M, Kumagai S, John D W, and Madden W 2014 Low cost activated carbon materials produced from used coffee grounds for electric double-layer capacitors International journal of engineering science and innovative technology (IJESIT) 3 492-501
[3] Jiang L, Yan J, Hao L, Xue R, Sun G, and Yi B 2013 High rate performance activated carbons prepared from ginkgo for electrochemical supercapacitors Carbon 56 146-54
[4] Peng C, Yan X B, Wang R T, Lang J W, Qu Y J and Xue Q J 2013 Promising activated carbons derived from waste tea-leaves and their application in high performance supercapacitors electrodes Electrochimica Acta 87 401-8
[5] Hermansyah A, Tetra O N, Alif A and Syukri W R 2016 Electrical properties of supercapacitor electrode - based on activated carbon from waste palm kernel shells Der Pharma Chemica 8 227-232
[6] Gultom E M and Lubis M T 2014 Aplikasi karbon aktif dari cangkang kelapa sawit dengan aktivator h₃po₄ untuk penyerapan logam berat Cd dan Pb Jurnal Teknik Kimia 3 5-10
[7] Kurniati E 2008 Pemanfaatan cangkang kelapa sawit sebagai arang aktif J. Penelitian Ilmu Teknik 8 96-103
[8] Danga W, Dong C, Zhang Z, Chen G, Wang Y and Guan H 2016 Self-grown MnO₂ nanosheets on carbon fiber paper as high-performance supercapacitors electrodes Electrochimica Acta 217 16–23
[9] Wang G, Zhang Y, Zhou F, Sun Z, Huang F, Yi Y, Chen L and Mu P 2016. Simple and fast synthesis of polyaniline nanofibers/carbon paper composites as supercapacitor electrodes *Journal of Energy Storage* **7** 99-103