Available online at www.derpharmachemica.com

ISSN 0975-413X
CODEN (USA): PCHHAX

Der Pharma Chemica, 2016, 8(15):227-232
(http://derpharmachemica.com/archive.html)

Electrical Properties of Supercapacitor Electrode-Based on Activated Carbon from Waste Palm Kernel Shells

Hermansyah Aziz[1*], Olly Norita Tetra[1], Admin Alif[1], Syukri[2] and Wahyu Ramadhan[1]

[1]*Laboratory of Photo/Electrochemistry, Department of Chemistry, Faculty of Mathematics and Natural Sciences, Andalas University, Indonesia*
[2]*Laboratory of Material Chemistry, Department of Chemistry, Faculty of Mathematics and Natural Sciences, Andalas University, Indonesia*

ABSTRACT

Activated carbon prepared from waste palm kernel shells using physical activation at a combustion temperature respectively of 300 and 400°C has been developed as a new supercapacitor electrode material. Activated carbon was characterized by XRD, SEM-EDX and FTIR methods and the electrical properties of supercapacitor have been measured by LCR meter. It was found that the activated carbon which was prepared by the carbonization process at a temperature of 300°C, the particle size of 90 µm, 0.3 N H_3PO_4 as the electrolyte and the surface area of the carbon paper of 3 x 11 cm^2 with a roll method provides the highest capacitance of 41.21 µF and conductivity of 0.143×10^{-6} S / cm with a charging time of 60 minutes.

Keywords : supercapasitor, capacitance, electric properties, palm kernel shells and activated carbon

---

INTRODUCTION

Indonesia is a world's largest producer and exporter of palm oil of which 85-90% of total world palm oil production. According to the statistical data available, one of the most abundant solid waste of palm oil processing is palm kernel shells which reached 60% of the production of palm oil and actually the utilization of waste palm kernel shells is still very small. Palm kernel shells has a chemical composition that is almost similar to wood as the most reasonable sources of lignin, cellulose and hemicellulose with different compositions. Cellulose content of this palm shells by 45% and 26% hemicellulose either to be used as a source of biomass[1].

The development of oil palm kernel shell biomass as a source of bioenergy and reducing the environmental impact must be accompanied by another development of energy storage technology. Regarding next utilization of waste palm kernel shells biomass to produce activated carbon to pursuing a licensing strategy in the future [2-4]. Utilization of various biomass materials as a renewable energy source going into a hot topic of discussion, for example, coconut shell [5], ginkgo shells [6], coffee grounds [7], walnut shell [8] and banana fiber [9] have been used as the precursor to produce activated carbon and has been developed as an electrode material, catalyst and adsorbent. In the recent years, the study of electrical double-layer capacitors (EDLCs) as an energy storage devices in places of chemical batteries. EDLCs often referred to as supercapacitors are energy storage devices with high performance power density characteristics that are up to 1.000 times greater than what is typically found in conventional capacitor technology [10-11]. Supercapacitor consists of electrodes, electrolyte and the separator which prevents facing electrodes from contacting each other. Activated carbon powder is applied to the electricity collector of the electrodes. Capacitance is proportional to the surface area of the supercapacitor. Therefore, using activated carbon, which has an incredibly large surface area electrodes, enables to fabricated a high capacitance supercapacitor [12-13].

In this paper, a supercapacitor based on waste palm kernel shells carbon electrode with phosphate acid electrolyte has been developed. Carbonization of oil palm kernel shell into various particle size of activated carbon was effected and then characterized using SEM - EDX, XRD and FTIR methods. While the electrical properties measurement were made by using LCR meter.

MATERIALS AND METHODS

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

Materials are from waste palm kernel shells obtained from Agam regency, West Sumatra, carbon rods of waste batteries, H_3PO_4 (Merck), paper (padi brand) 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 300° C and 400° C for 60 minutes with a certain particle size of 63, 90 and 125 µm.

2.3 Preparation of electrode plate
The sheets paper (size 3 cm x 5 cm) spread with glue on its surface and sprinkle carbon of palm kernel shells. Plate electrode of carbon formed then dried at room temperature and the carbon paper is weighed before and after being coated with palm kernel shell carbon.

2.4 Preparation of supercapacitors
Supercapacitors are made with such a roll (Fig. 1). Carbon rod of waste batteries was prepared 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 battery carbon rods. The first roll is the front of the paper carbon that acts as a positive electrode (sheet 1) and then continuous rolling the rear carbon paper which act as a negative electrode (sheet 2). The same treatment is done for variations in particle size and surface area variations of carbon paper.

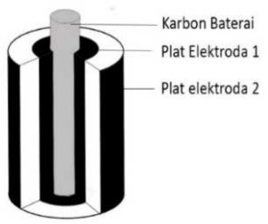

Fig. 1. Schematic illustration of the supercapacitor fabrication

2.5 Characterization techniques
X-ray diffractograms of the samples were recorded using a GE XRD 3003TT X-ray diffractometer with monochromatic nickel filtered CuKα (λ = 1.5416 Å) radiation in the 2θ range of 20° to 80°. The morphology and elemental composition of the carbon were determined from scanning electron microscope (SEM) that has the attachment of an energy dispersive X-ray analyzer (EDX). The FT-IR spectra were recorded with a Perkin Elmer Spectrum Two in the waveband of 400-4000cm^{-1}.

RESULTS AND DISCUSSION

3.1 Synthesis process and structure characterization
The crystallinity and phase characteristics of the samples were analyzed from powder XRD study. Fig 2. shows the XRD patterns of the carbon. All XRD patterns show a broaden diffraction peak centered at 43°, corresponding to the diffractions of graphitic carbon with the amorphous character.

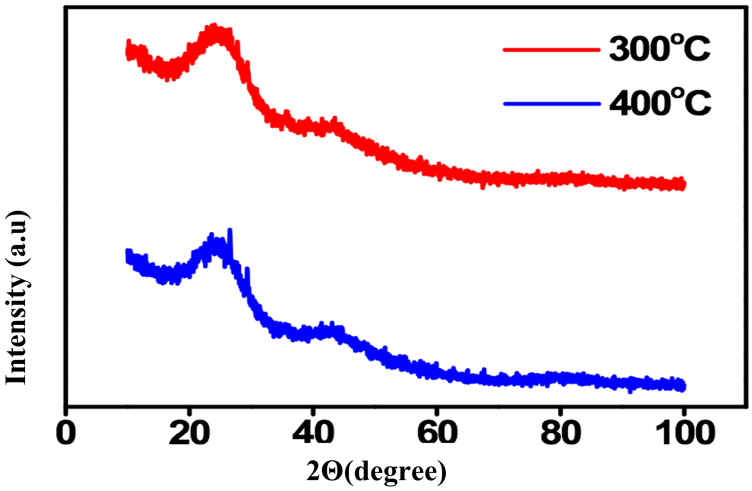

Fig. 2. XRD pattern of oil palm kernel shell carbon with a combustion temperature at 300°C and 400°C

Figure 3 shows that the surface morphology of oil palm kernel shell carbon by carbonization temperature of 300° C and 400° C is granulated. Activated carbon exhibits mesoporous surface.

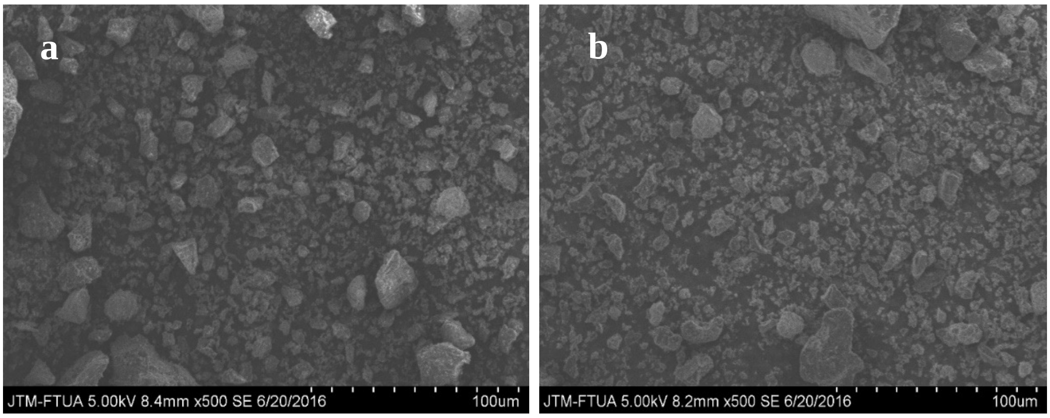

Fig. 3. SEM image of palm kernel shells carbon with a combustion temperature (a.) 300°C (b.) 400°C

The elemental composition obtained from EDX profile indicated the atomic wt% of carbon at a temperature of 300°C containing carbon most widely compared to the amount of carbon from palm kernel shells with a combustion temperature 400°C (Table 1). There is an element of K (potassium) content, although in very small amounts. This is because the basic ingredients of palm kernel shells are natural materials [4]. Therefore carbon from palm kernel shells with a combustion temperature of 300°C is used for electrochemical measurement of supercapacitor.

Table 1. EDX measurement results from palm kernel shells

Atom	% mass	
	300°C	400°C
C	77,82	72,79
O	21,48	26,62
K	0,70	0,59

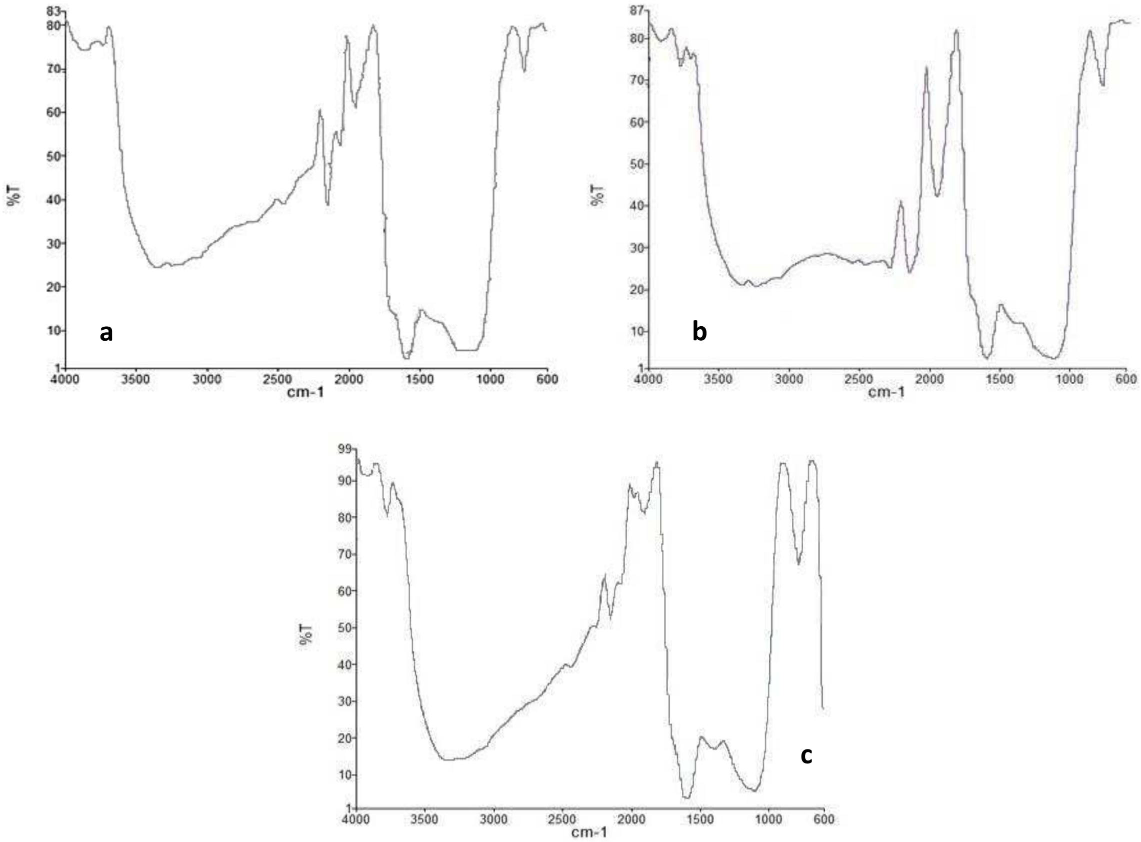

Fig. 4. FT-IR spectra of palm kernel shells carbon (a. 125 µm, b. 90 µm, dan c. 63 µm)

3.2 Determination electric properties

Effect of carbon particle size

The increased surface area of the particles results in the greater ability of the supercapacitor to store an electric charge due to large surface area which allows carbon to be able to store more electric charge [5].

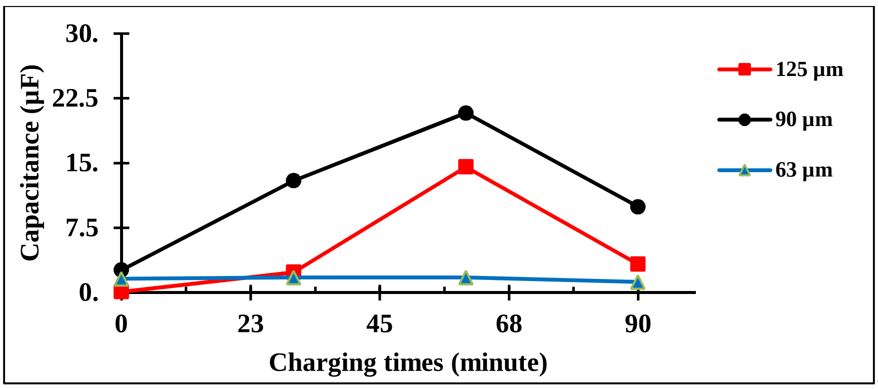

Fig. 5. Effect of carbon particle size of oil palm kernel shell to the capacitance value

The lowest capacitance of the supercapacitor was found for the particle size of 63 µm. This is because during the carbonization process, when the heat of combustion is too high may results a complete combustion and reduce the carbon content [5]. At the time of the paper making process, where is the carbon electrode material of a very small size is not spread evenly across the surface of the carbon paper so that the capacitance value becomes lower.

Effect of carbon paper surface area

The surface area of the carbon paper would affect the value of capacitance. This is because the more larger the surface area of the carbon paper used, the more electrical charge to be stored on the surface of carbon palm kernel shells.

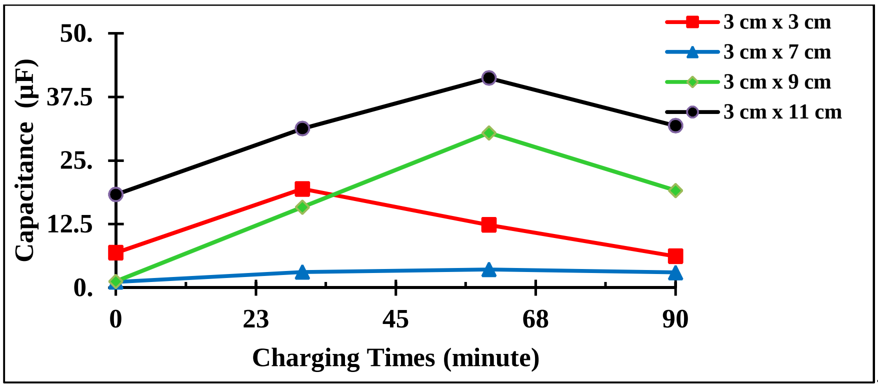

Fig. 6. Effect of carbon paper surface area on the capacitance value

Various surface area which is evaluated in this study are as following 3x3 cm^2, 3x7 cm^2, 3x9 cm^2 and 3x11 cm^2. The highest capacitance value is given by the surface area of the carbon paper of 3x11 cm^2 with a charging time in 60 minutes.

Fig. 7. showing that the charging time of 60 minutes, supercapacitors with 3x11 cm^2 surface area has an optimum ability to store electrical charges. These characterization curves indicated the supercapacitor capacitance value depend on the electrode surface area [8].

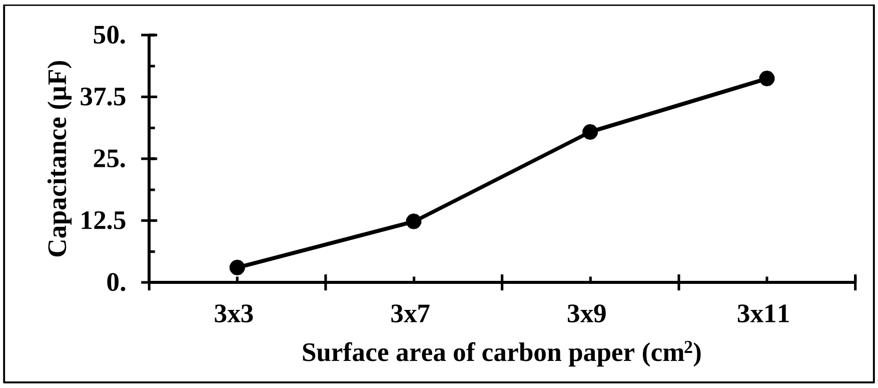

Fig. 7. Effect of surface area of carbon paper on capacitance on the charging time of 60 minutes

Effect of H_3PO_4 electrolyte concentration against capacitance

The increase in the concentration of electrolyte solution causes the capacitance value will also increase until the optimum value of 0.3 N, then the capacitance value decreases with increasing the concentration.

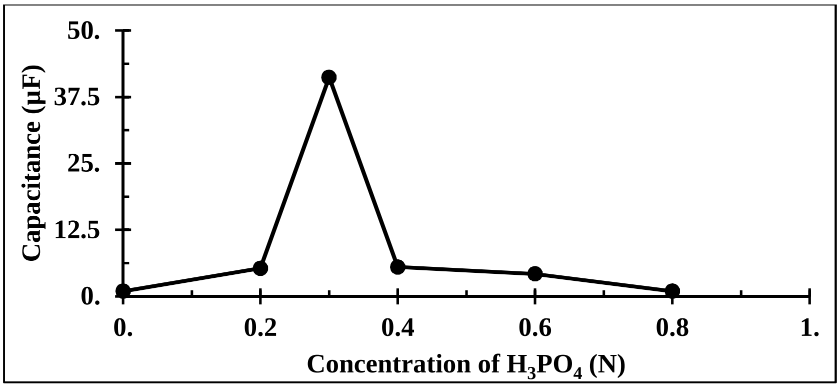

Fig. 8. Effect of H_3PO_4 electrolyte concentration against capacitance with charging time of 60 minutes

Effect of the electrolyte concentration H_3PO_4 against conductivity of the electrode supercapacitor
Conductivity is calculated based on the resistivity value obtained from the value measured on the supercapacitor is the resistant in the variations of the concentration of the electrolyte solution at the optimum charging time of 60 minutes and a surface area of 3 x 11 cm^2.

In Fig. 9, the concentration of electrolyte solution of 0.3 N on the particle size of 90 µm has the highest conductivity values. This is because the ions can move freely in the solution there by increasing the value of conductivity [7]. This value is also supported by the capacitance value, which is inversely proportional to the resistance value.

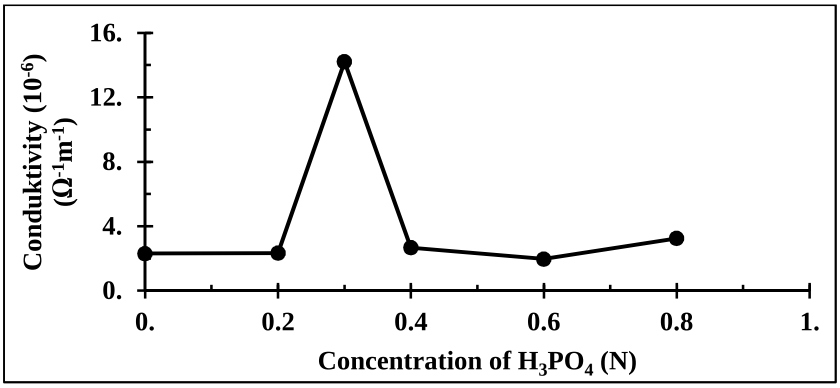

Fig. 9. Effect of H_3PO_4 electrolyte concentration on the conductivity

CONCLUSION

Activated carbon from waste palm kernel shells can be used as an electrode material in supercapacitors fabrication. Synthesis of activated carbon made by carbonization process at a temperature of 300°C and supercapacitor designed using a roll electrode method. The highest capacitance value produced from oil palm kernel shell carbon electrode at a particle size of 90 µm, 0.3 N H_3PO_4 electrolyte concentration, the surface area of the carbon paper 3 x 11 cm^2 by 41.21 µF with a charging time of 60 minutes and a conductivity value of 0.143 $x10^{-6}$ S / cm.

Acknowledgements
We would like to express our gratitude to Hibah Riset Guru Besar, contract number 40/UN.16/HKRGB/LPPM/2016, Research Centre of Andalas University for all the support provided.

REFERENCES

[1] Ketaren, S. Pengantar Teknologi Minyak dan Lemak Pangan, Jakarta : UI-Press, **1986**, 35
[2] A. Jain, S.K. Tripathi. *Mater. Sci. Eng.: B.*, **2014**, 183, 54 – 60
[3] E. Kurniati, *J. Penel. Ilmu Teknik.*, **2008**, 8, 2, 96 – 103
[4] U. Malik, *J. Ilmiah Edu research.*, **2013**, 2, 1 – 8
[5] S. Hartanto, Rantnawati, *J. Sains Materi Indonesia*, **2010**, 12,1, 12 -16
[6] L. Jiang, J. Yan, L. Hao, R. Xue, G. Sun, Baolian Yi. *Carbon*, **2013**, 56, 146 –154
[7] M.H. Park, Y.S. Yun, S. Y. Cho, N.R. Kim, H.J. Jin, *Carbon Lett.*, **2016**, 19, 66 - 71
[8] W.S. Choi, W.G. Shim, D.W Ryu, M.J.Hwang, Hee Mo, *Micropor. Mesopor. Mater.*, **2012**, 155, 274 – 280.
[9] S. Trasatti, P. Kurzweil, *Platinum Metal Rev.*, **1994**,2, 46 - 56
[10] R.Kotz, M.Carlen, *Electrochim. Acta*, **2000**, 45, 2483 - 2498
[11] V. Subramanian, Cheng Luo, A. M. Stephan, K.S. Nahm, S.Thomas, B. Wei, *J.Phys. Chem. C*, **2007**, 111, 20, 7527 – 7531
[12] Tao Chen, Liming Dai, *Mater. Today*, **2013**, 16, 272 – 280.
[13] F.N.I.Sari, Jyh-Ming Ting, *Surf. Coat. Tech.*, **2016**, 303, 176 – 183
[14] R.R.Rajagopal, L.S. Aravinda, R.Rajarao, B.R. Bhat, V. Sahajwalla, *Electrochim. Acta*, **2016**, 211, 488 – 498.