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Synthesis and Characterization of Activated Carbon from Pattikala Fruit Waste (*Etlingera elatior*)

Hilda Rahmawati[1*], Nurmalasari Ismail[1], Nur Asriyani[2], and Risma Jufri[1]

1. Cokroaminoto Palopo University, Palopo, Indonesia, 91911
2. Indonesia Defense University, Bogor, Indonesia, 16810

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Abstract

Activated carbon (AC) is an amorphous material with a suitable size pores distribution, high specific surface area, and high surface reactivity. Activated carbon can be produced from biomaterials and can be used as a water filter material, an absorbent for hazardous substances, and as electrodes in supercapacitors. Etlingera elatior or Pattikala fruit waste has lignocellulose content that can potentially be activated carbon material. This study aimed to synthesize Etlingera elatior or Pattikala fruit waste by chemical activation method into activated carbon. Based on the study's results, activated carbon from Pattikala fruit waste has a high purity level of 87.80%, and SEM results show that pores have begun to form in the activated carbon samples produced. This study demonstrates that activated carbon can be produced from Etlingera elatior fruit waste.

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Abstrak

Karbon aktif (AC) merupakan material amorf yang memiliki pori dengan distribusi ukuran yang tepat, luas permukaan spesifik yang tinggi dan reaktivitas permukaan yang tinggi. Karbon aktif dapat diproduksi dari biomaterial dan dapat digunakan sebagai material penyaring air, penyerap zat berbahaya dan elektroda superkapasitor. Limbah buah Etlingera elatior atau Pattikala memiliki kandungan lignoselulosa memiliki potensi sebagai material karbon aktif. Tujuan penelitian ini adalah mensintesis limbah buah Etlingera elatior atau Pattikala dengan menggunakan metode aktivasi kimia menjadi karbon aktif. Berdasarkan hasil penelitian karbon aktif dari limbah buah pattikala memiliki tingkat kemurnian yang tinggi yaitu 87.80% dan hasil SEM menunjukkan pori sudah mulai terbentuk pada sampel karbon aktif yang dihasilkan. Penelitian ini menunjukkan karbon aktif dapat dihasilkan dari limbah buah Etlingera elatior.

1. Introduction

Etlingera elatior, or Pattikala, is a tropical plant belonging to the Zingiberaceae family (Ernilasari et al., 2021). It has flowers, fruits, stems, and leaves. So far, Pattikala fruit has been used by the people of South Sulawesi as a food flavoring, after which it produces organic waste that is not utilized (Al-Mansoub et al., 2021). Chemically, in Etlingera elatior or Pattikala, there is a fibrous part that contains lignocellulose, so it has the potential to be used as an activated carbon material (Al-Mansoub et al., 2021; Ernilasari et al., 2021; Nor et al., 2020).

Activated carbon (AC) is an amorphous material with a suitable size pores distribution, high specific surface area, and high surface reactivity (Heidarinejad et al., 2020). It has many uses, such as a liquid waste absorber, gas purification, and supercapacitor/battery electrode (Mariana et al., 2021; Wong et al., 2018). Activated carbon can be produced from biomaterials or natural materials such as coconut shells (Lutfi et al., 2021), lemongrass (Ni et al., 2024), sawdust (Oladimeji et al., 2021), and many more, as long as the biomaterial contains carbon elements.

Synthesis of activated carbon consists of two basic procedures: carbonization and activation (Naji & Tye, 2022). Carbonization aims to reduce the volatile content of the material through the pyrolysis of carbon precursors and to create a high primary porous structure (Suyoga Wiguna et al., 2024). Activation seeks to increase activated carbon's specific surface area or pore volume by opening and increasing existing pores (Lutfi et al., 2021). In addition, activation can change or adjust the chemical structure of the activated carbon surface with specific unique properties

* Corresponding author.
E-mail address: hildarmwt@gmail.com

(Oladimeji et al., 2021), (Suyoga Wiguna et al., 2024). There are three activation techniques to produce activated carbon: physical activation, chemical activation, and physicochemical. Physical activation is a two-stage process involving a carbonization stage in the presence of an inert gas (N_2 or Ar) followed by an activation stage with the help of an oxidizing gas (O_2, CO_2, H_2O vapor) in the temperature range of 800°C - 1200°C (Heidarinejad et al., 2020; Mariana et al., 2021). Chemical activation is a one-step process in which carbonization and activation coincide with the help of chemicals such as ZnCl, KOH, and $H3PO_4$ (Lutfi et al., 2021). The advantages of chemical activation are low heating temperature, short processing time, high carbon yield, well-controlled porosity, and high specific surface area. Physicochemical activation combines physical and chemical processes involving a physical activation step under an oxidizing gas atmosphere followed by chemical impregnation of the carbon precursor with an activating agent (Heidarinejad et al., 2020; Mariana et al., 2021; Wong et al., 2018).

Based on the description above, activated carbon can be produced from various biomaterials (Lutfi et al., 2021; Naji & Tye, 2022; Oladimeji et al., 2021). However, no one has studied activated carbon sourced from Pattikala fruit. Therefore, this study aims to produce activated carbon from Pattikala fruit waste, which will be synthesized using chemical activation with the help of activator agent KOH (Potassium Hydroxide).

2. Research Methods

Pattikala fruit waste is cut and cleaned from dirt. Dry in the sun for 24 hours. To ensure that the waste for pattikala is dehydrated, oven at 100ºC for 12 hours. The dried pattikala fruit waste is crushed using a blender. After that, sift using a 200 mesh sieve to produce pattikala fruit waste powder. The resulting powder is then carbonized using a furnace at a temperature of 300ºC for 2 hours.

In this study, the activation process was carried out using the chemical activation method. Twenty two grams of carbonized patti kala fruit waste charcoal powder were soaked in a 1.5 M KOH solution for 22 hours. After going through the soaking process, the activated carbon was filtered and washed until the pH was neutral. When the pH was neutral, it was dried using an oven at 100ºC for 2 hours. After that, the activated carbon was formed and ready to be characterized. This process is shown in Figure 1.

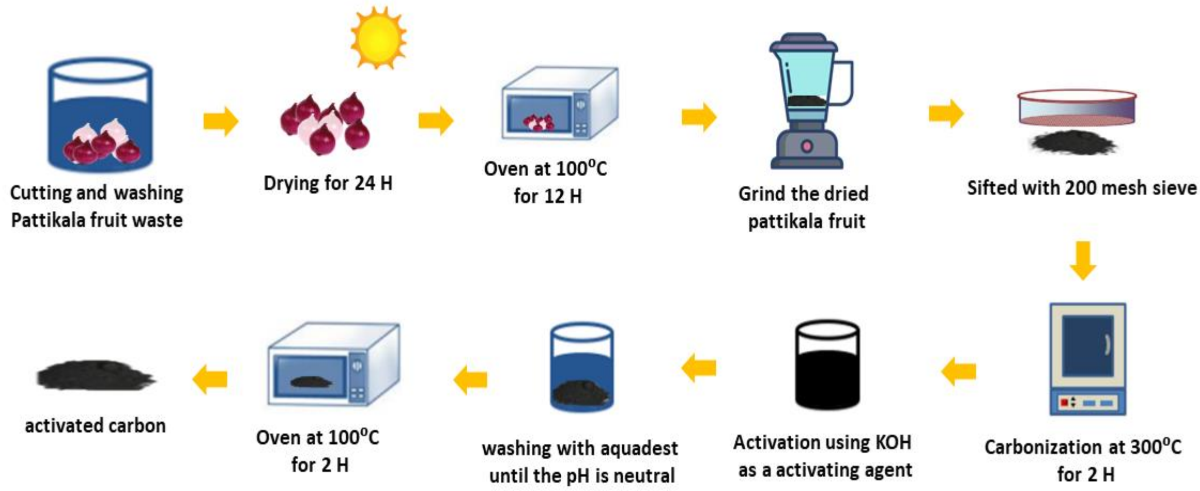

Figure 1. Synthesis of activated carbon from Pattikala fruit waste

The activated carbon produced will be tested proximately consisting of testing water content, volatile matter content, ash content, and purity carbon content based on SNI 06-3730-1995 (BSN, 1995) as a requirement for technical activated carbon quality. In addition, Scanning Electron Microscopy (SEM) will also be characterized to determine the surface structure of the activated carbon produced. Base on SNI 06-3730-1995 (BSN, 1995), the proximate test analysis can be carried out following:

a. Water content

3 grams (initial mass (m_1)) of the sample put into a porcelain cup and oven at 100ºC for 3 hours. After that, put it in a desiccator and weigh the mass (final mass (m_2)),

$$Water\ content\ (\%) = \frac{m_1 - m_2}{m_1} \times 100\% \tag{1}$$

b. Volatile matter content

3 grams (initial mass (m_1)) of the sample put into a porcelain cup and furnace at 900ºC for 10 minutes. After that, put it in a desiccator for 1 hour and weigh the mass (m_2). To obtain Volatile matter content, subtract between m_1 and m_2 to get the lost sample mass (m_3), then:

$$Volatile\ matter\ content\ (\%) = \frac{m_3}{m_1} \times 100\% \tag{2}$$

c. Ash content

3 grams (initial mass (m_1)) of the sample put into a porcelain cup and furnace at 700ºC for 5 hours. After that, put it in a desiccator for 1 hour and weigh the mass (m_2),

$$Ash\ content\ (\%) = \frac{m_2}{m_1} \times 100\% \tag{3}$$

d. Purity carbon content

The purity carbon content is determined based on

$$Purity\ carbon\ content\ (\%) = 100\% - (ash\ content + Volatile\ matter\ content\ ) \tag{4}$$

3. Results and Discussions

Activated carbon produced from Pattikala fruit waste (Etlingera Elatior) is tested proximately to determine the characteristics and quality of activated carbon adjusted to SNI 06-3730-1995 as a requirement for technical activated carbon quality (BSN, 1995). The results of the proximate test of activated carbon from Pattikala fruit waste (Etlingera Elatior) are shown in Table 1.

Table 1. Proximate test results of activated carbon from Pattikala fruit waste

No	Parameters (%)	**SNI 06-3730-1995 (%)** (BSN, 1995)	Pattikala fruit waste (%)
1	Water content	Maximum 15	8.50
2	Ash content	Maximum 10	4.15
3	Volatile content	Maximum 25	8.05
4	Purity carbon content	Minimum 65	87.80

Based on Table 1, the activated carbon produced from pattikala fruit waste meets the quality requirements for activated carbon by SNI 06-3730-1995 (BSN, 1995). The purpose of testing the water content of activated carbon is to determine hygroscopicity (the ability to absorb water), so it is necessary to pay attention to the maximum threshold of the water content of activated carbon (Genli et al., 2021). The water content of activated carbon produced from pattikala fruit waste is 8.50%, so it meets the quality requirements of commercial activated carbon (BSN, 1995). The low water content indicates that only a little water is left behind and covers the pores of the activated carbon (Suyoga Wiguna et al., 2024). Furthermore, testing the ash content, the ash content produced is 4.15%, meeting the tolerance requirements for the quality of the ash content of activated carbon, which is a maximum of 10% (BSN, 1995). Testing the ash content shows the remaining minerals left behind because activated carbon is made from biomaterials containing carbon and other minerals; some are lost during the carbonization and activation process, and some parts are still left on the activated carbon (Maulina & Iriansyah, 2018). Thus, the lower the ash content, the higher the purity of the activated carbon, the higher the absorption capacity, and the larger the surface area (Wang et al., 2021).

The volatile matter content produced by activated carbon from pattikala fruit waste is 8.05% with a maximum threshold of 25% (BSN, 1995); this shows that the activated carbon produced meets the quality requirements of commercial activated carbon. The volatile matter content shows the percentage of minerals lost when the sample is heated at a specific temperature (Budianto et al., 2019; Pui et al., 2019). Furthermore, testing the purity of activated carbon, the purity produced from pattikala fruit waste is relatively high, namely 87.80%, while the minimum limit is 65% (BSN, 1995). Testing the purity of activated carbon is determined by the ash and volatile matter content. The smaller the ash and volatile matter content, the greater the purity of the activated carbon (Budianto et al., 2019).

The activator agent and activation time greatly influence the success of activated carbon synthesis, wherein this study used KOH (Potassium hydroxide) for 22 hours. Activation time that is too fast is not good, and if it is too long, it will also reduce the quality of the activated carbon produced; several previous studies have shown that the most appropriate time is 22 hours for KOH (Fischer et al., 2024; Jawad et al., 2021; Liu et al., 2020). Based on the description above and the data in Table 1, activated carbon from pattikala fruit waste meets the commercial activated carbon quality requirements by SNI 06-3730-1995.

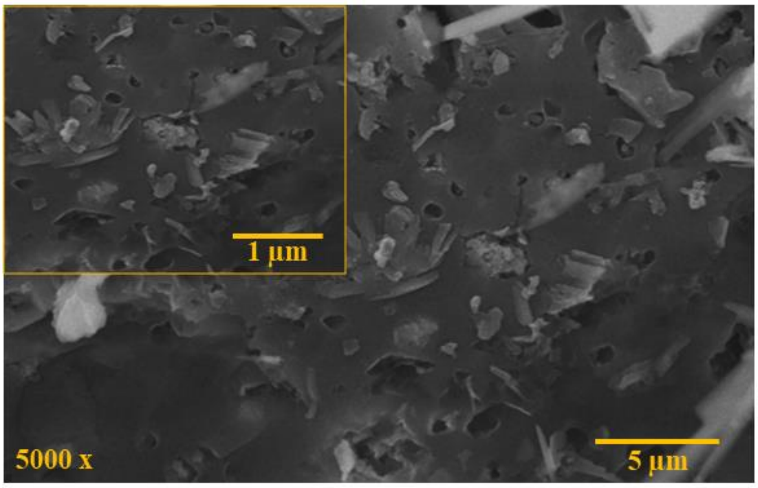

Figure 2. Results of SEM characterization of activated carbon from Pattikala fruit waste.

Scanning Electron Microscopy (SEM) testing was carried out to determine activated carbon's surface structure and morphology. Figure 2 shows the results of the SEM characterization of activated carbon from Pattikala fruit waste. Based on Figure 2, the sample's morphology tends to be rough and irregular but already shows the presence of pores formed. Activated carbon from several biomaterials, such as lemongrass waste (Ni et al., 2024) and candlenut shells (Hasil et al., 2017), has not formed pores. This result shows that the potential for activated carbon production from Pattikala fruit waste is superior used as a candidate for supercapacitor electrode material. Based on SEM results, the pore size of activated carbon from Etlingera elatior fruit waste is 2.87 µm. This is in accordance with previous studies that showed activated carbon pores with a diameter of 2 µm - 5 µm (Waluyo et al., 2017). KOH influences the pores formed in activated carbon from Pattikala fruit waste as an activator agent, where KOH separates the fibers to minimize agglomeration; if agglomeration decreases, it will trigger the formation of pores (Fischer et al., 2024) (Markus Diantoro et al., 2024; I. Luthfiyah et al., 2020). Pores in activated carbon are vital structures that determine the performance of activated carbon, such as filtration, purification, absorption, and catalyst. The pores formed in Figure 2 have a size and shape distribution that is not diverse; this is influenced by the carbonization and activation process of activated carbon (M. Diantoro et al., 2022; Ishmah Luthfiyah et al., 2023).

4. Conclusions

In this study, activated carbon made from pattikala fruit waste was activated using potassium hydroxide (KOH). Based on the results of the proximate test, which included water content, ash content, volatile matter, pure activated carbon, and SEM characterization, it can be concluded that this study was successful. Based on literature studies, comparisons with previous studies, and test results, activated carbon made from pattikala fruit waste produces activated carbon with pore diameter 2.87 µm and 87.80% purity.

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6. Bibliography

Al-Mansoub, M. A., Asif, M., Revadigar, V., Hammad, M. A., Chear, N. J. Y., Hamdan, M. R., Majid, A. M. S. A., Asmawi, M. Z., & Murugaiyah, V. (2021). Chemical composition, antiproliferative and antioxidant attributes of ethanolic extract of resinous sediment from etlingera elatior (Jack.) inflorescence. *Brazilian Journal of Pharmaceutical Sciences*, *57*, e18954. https://doi.org/10.1590/s2175-97902020000418954

BSN. (1995). Arang Aktif Teknis. In *Sni 06-3730-95*.

Budianto, A., Kusdarini, E., Effendi, S. S. W., & Aziz, M. (2019). The Production of Activated Carbon from Indonesian Mangrove Charcoal. *IOP Conference Series: Materials Science and Engineering*, *462*(1), 12006. https://doi.org/10.1088/1757-899X/462/1/012006

Diantoro, M., Luthfiyah, I., Istiqomah, Wisodo, H., Utomo, J., & Meevasana, W. (2022). Electrochemical Performance of Symmetric Supercapacitor Based on Activated Carbon Biomass TiO2Nanocomposites. *Journal of Physics: Conference Series*, *2243*(1). https://doi.org/10.1088/1742-6596/2243/1/012077

Diantoro, Markus, Arya, N. D., Luthfiyah, I., Pujiarti, H., & Maensiri, S. (2024). Investigating the CoS2 Mass Fraction Enhancing Performance Supercapacitor for Medium Low Consumption. *E3S Web of Conferences*, *473*, 1–11. https://doi.org/10.1051/e3sconf/202447303003

Ernilasari, Walil, K., Fitmawati, Roslim, D. I., Zumaidar, Saudah, & Rayhannisa. (2021). Antibacterial activity of leaves, flowers, and fruits extract of etlingera elatior from nagan raya district, indonesia against escherichia coli and staphylococcus aureus. *Biodiversitas*, *22*(10), 4457–4464. https://doi.org/10.13057/biodiv/d221039

Fischer, T., Kretzschmar, A., Selmert, V., Jovanovic, S., Kungl, H., Tempel, H., & Eichel, R. A. (2024). Post-treatment strategies for pyrophoric KOH-activated carbon nanofibres. *RSC Advances*, *14*(6), 3845–3856. https://doi.org/10.1039/d3ra07096d

Genli, N., Şahin, Baytar, O., & Horoz, S. (2021). Synthesis of activated carbon in the presence of hydrochar from chickpea stalk and its characterization. *Journal of Ovonic Research*, *17*(2), 117–124. https://doi.org/10.15251/jor.2021.172.117

Hasil, J., Fisika, P. B., Sulaiman, N. H., Malau, L. A., Lubis, H., Harahap, N. B., Manalu, R., Kembaren2, A., Kimia, J., Matematika, F., Ilmu, D., & Alam, P. (2017). Jurnal Einstein Pengolahan Tempurung Kemiri Sebagai Karbon Aktif Dengan Variasi Aktivator Asam Fosfat. *Diterima April*. http://jurnal.unimed.ac.id/2012/index.php/inpafie-issn:2407-747x,p-issn2338-1981

Heidarinejad, Z., Dehghani, M. H., Heidari, M., Javedan, G., Ali, I., & Sillanpää, M. (2020). Methods for preparation and activation of activated carbon: a review. *Environmental Chemistry Letters*, *18*(2), 393–415. https://doi.org/10.1007/s10311-019-00955-0

Jawad, A. H., Saud Abdulhameed, A., Wilson, L. D., Syed-Hassan, S. S. A., ALOthman, Z. A., & Rizwan Khan, M. (2021). High surface area and mesoporous activated carbon from KOH-activated dragon fruit peels for methylene blue dye adsorption: Optimization and mechanism study. *Chinese Journal of Chemical Engineering*, *32*, 281–290. https://doi.org/10.1016/j.cjche.2020.09.070

Liu, Z., Sun, Y., Xu, X., Meng, X., Qu, J., Wang, Z., Liu, C., & Qu, B. (2020). Preparation, characterization and application of activated carbon from corn cob by KOH activation for removal of Hg(II) from aqueous solution. *Bioresource Technology*, *306*, 123154. https://doi.org/10.1016/j.biortech.2020.123154

Lutfi, M., Hanafi, Susilo, B., Prasetyo, J., Sandra, & Prajogo, U. (2021). Characteristics of activated carbon from coconut shell (Cocos nucifera) through chemical activation process. *IOP Conference Series: Earth and Environmental Science*, *733*(1), 12134. https://doi.org/10.1088/1755-1315/733/1/012134

Luthfiyah, I., Utomo, J., Diantoro, M., Mufti, N., Suprayogi, T., Yudyanto, Y., & Aripriharta, A. (2020). The effect of spincoating speed on ZnONR microstructure and it's potential of ZnONR/Aluminum foil electrodes symmetric supercapacitors. *Journal of Physics: Conference Series*, *1595*(1). https://doi.org/10.1088/1742-6596/1595/1/012001

Luthfiyah, Ishmah, Al Ittikhad, A., Suprayogi, T., Nasikhudin, Diantoro, M., Maensiri, S., & Sujiono, E. H. (2023). The Effect of Concentration PVP on Microstructure Activated Carbon Mesoporous and It's Potential of Activated Carbon Mesoporous-CB Symmetric Supercapacitors. *AIP Conference Proceedings*, *2687*(May 2017). https://doi.org/10.1063/5.0122030

Mariana, M., Abdul, A. K., Mistar, E. M., Yahya, E. B., Alfatah, T., Danish, M., & Amayreh, M. (2021). Recent advances in activated carbon modification techniques for enhanced heavy metal adsorption. *Journal of Water Process Engineering*, *43*, 102221. https://doi.org/10.1016/j.jwpe.2021.102221

Maulina, S., & Iriansyah, M. (2018). Characteristics of activated carbon resulted from pyrolysis of the oil palm fronds powder. *IOP Conference Series: Materials Science and Engineering*, *309*(1), 12072. https://doi.org/10.1088/1757-899X/309/1/012072

Naji, S. Z., & Tye, C. T. (2022). A review of the synthesis of activated carbon for biodiesel production: Precursor, preparation, and modification. *Energy Conversion and Management: X*, *13*, 100152. https://doi.org/10.1016/j.ecmx.2021.100152

Ni, L., Rachmania, S., Mahfud, M., Syauqiah, I., Mirwan, A., & Sir, A. (2024). *Characterization of H3PO4-Activated Carbon from Lemongrass (Cymbopogon S.P) Waste*. *11*(1). https://doi.org/10.33096/jcpe.v9i.686

Nor, N. A. M., Noordin, L., Bakar, N. H. A., & Ahmad, W. A. N. W. (2020). Evaluation of antidiabetic activities of Etlingera elatior flower aqueous extract in vitro and in vivo. *Journal of Applied Pharmaceutical Science*, *10*(8), 43–51. https://doi.org/10.7324/JAPS.2020.10805

Oladimeji, T. E., Odunoye, B. O., Elehinafe, F. B., Obanla, O. R., & Odunlami, O. A. (2021). Production of activated carbon from sawdust and its efficiency in the treatment of sewage water. *Heliyon*, *7*(1). https://doi.org/10.1016/j.heliyon.2021.e05960

Pui, W. K., Yusoff, R., & Aroua, M. K. (2019). A review on activated carbon adsorption for volatile organic compounds (VOCs). *Reviews in Chemical Engineering*, *35*(5), 649–668. https://doi.org/10.1515/revce-2017-0057

Suyoga Wiguna, A. A. G., Mardana, I. B. P., & Artawan, P. (2024). Synthesis and Characterization of Activated Carbon Prepared From Rice Husk By Physics-Chemical Activation. *Indonesian Physical Review*, *7*(2), 281–290. https://doi.org/10.29303/ipr.v7i2.311

Waluyo, H. M., Faryuni, I. D., & Muid, A. (2017). Analisis Pengaruh Ukuran Pori Terhadap Sifat Listrik Karbon Aktif Dari Limbah Tandan Sawit Pada Prototipe Baterai. *Jurnal Fisika FLUX*, *14*(1), 27. https://doi.org/10.20527/flux.v14i1.3777

Wang, H., Xu, J., Liu, X., & Sheng, L. (2021). Preparation of straw activated carbon and its application in wastewater treatment: A review. *Journal of Cleaner Production*, *283*, 124671. https://doi.org/10.1016/j.jclepro.2020.124671

Wong, S., Ngadi, N., Inuwa, I. M., & Hassan, O. (2018). Recent advances in applications of activated carbon from biowaste for wastewater treatment: A short review. *Journal of Cleaner Production*, *175*, 361–375. https://doi.org/10.1016/j.jclepro.2017.12.059.