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Characterization of Activated Carbon from Mangosteen Peel (Garcinia mangostana L.) Activated with Phosphoric Acid (H_3PO_4)

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Abstract

Mangosteen peel (Garcinia Mangostana L.) represents a waste that has yet to find widespread application. One effort to increase the economic value of mangosteen rind is by processing mangosteen rind into active carbon, which can be used in various industrial processes. This research will examine the manufacture of activated carbon using mangosteen peel as raw material, which is washed clean, cut, and dried, then carbonized using a furnace at a temperature of 250 0C for 1 hour. Activating activated carbon from mangosteen peel is carried out by immersion in a 5 M concentration of phosphoric acid (H_3PO_4). Next, the characteristics of activated carbon from mangosteen peel are examined, including water content, ash content, volatile matter content, and pure carbon content. The study shows that activated carbon meets the SNI-06-3730-1995 standards for its water content (2.76%), ash content (7.24%), volatile matter content (6.02%), and pure carbon content (83.98%).

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INTRODUCTION

Indonesia, recognized as an agrarian nation, possesses abundant biomass energy resources. Among Indonesia's potential biomass energy sources are agricultural waste products, including rice husks, straws, sugarcane bagasse, corn stalks, and cobs, as well as various other agricultural and plantation residues. Using natural materials as adsorbents represents a growing trend in their application for industrial wastewater treatment, with activated carbon derived from mangosteen peel being a notable example. Currently, activated carbon is widely employed across industries for various purification processes, including refining sugar, oils, and fats, as well as in chemistry, pharmaceuticals, and water purification. Its primary function is to absorb undesirable odors, colors, gases, and metals (Smith et al., 1996).

Activated carbon is a product of the carbon activation process, distinguished by its superior adsorption capacity and a broader range of applications than regular carbon. Activated charcoal can be made from plants, coffee bean skin, coconut shells, animal bones, rice husks, coal, and others (Meilianti, 2020; Muhali et al., 2023). Mangosteen peel is a natural ingredient that can transform into activated charcoal and serve as an adsorbent. So far, the skin of the mangosteen fruit has not been used enough and is thrown away. Mangosteen peel (Garcinia Mangostana L.) has a relatively high carbon content, so it can be used as an alternative raw material for making activated charcoal.

Many studies have proven that mangosteen peel can be made into activated charcoal and has various uses. Research by (Haura et al., 2017) shows that mangosteen peels, without physical activation and physically activated, both have good performance in the adsorption process of Pb(II) and Cr(VI) metal ions. Research by (Hanami & Lestari, 2021; Muhali et al., 2023) shows that activated carbon with physical activation using CO_2 gas effectively eliminates ammonia gas. Research by (Nurhasanah et al., 2024) reported that mangosteen peel activated with potassium hydroxide (KOH) effectively reduced COD and BOD levels in liquid waste from the tofu industry. Besides that, research by (Khajonrit et al., 2022) states that mangosteen peels activated with KOH are a suitable electrode material for supercapacitors. In both studies, KOH was used as an activator because KOH is a strong hygroscopic base that can remove impurities in carbon, thereby increasing the number of carbon pores. Apart from bases, the activator in making activated charcoal can also use acids, one of which is phosphoric acid.

Mangosteen peel is a lignocellulosic material rich in cellulose, hemicellulose, and lignin, which makes it a suitable precursor for activated carbon production. Its high carbon content, along with the presence of phenolic compounds, enhances its adsorption properties. However, the efficiency of its transformation into activated carbon depends on the activation method and type of chemical activator used. Research by Haura et al. (2017) demonstrated that both raw and physically activated mangosteen peel exhibited good adsorption capacity for Pb(II) and Cr(VI). However, a critical gap in this study is the comparison of adsorption capacity with other conventional activated carbons (e.g., those derived from coconut shells or coal-based materials). Moreover, the study does not specify the pore structure analysis, which is crucial for understanding adsorption efficiency. Future studies should provide BET surface area analysis and kinetic modeling to establish a deeper understanding of the adsorption mechanism (Muhali et al., 2023; Nurhasanah et al., 2024).

Hanami & Lestari (2021) and Muhali et al. (2023) reported that CO2-activated mangosteen-based carbon effectively removed ammonia gas. The use of CO2 as a physical activation agent is advantageous since it enhances porosity without introducing chemical contaminants. However, these studies lack detailed thermodynamic parameters, such as adsorption isotherms and breakthrough curves, which are essential for evaluating real-world application feasibility. Additionally, a direct comparison with commercial zeolite or activated carbon would validate its effectiveness in industrial settings. Nurhasanah et al. (2024) highlighted the effectiveness of KOH-activated mangosteen carbon in reducing COD and BOD in tofu industry wastewater. This aligns with previous studies on KOH activation, which increases pore volume and surface area. However, the study lacks a long-term assessment of carbon stability and regeneration capacity. In practical wastewater treatment applications, reusability and cost-effectiveness are crucial factors that must be considered.

Khajonrit et al. (2022) identified KOH-activated mangosteen peel carbon as a suitable electrode material for supercapacitors. The advantage of KOH activation lies in its ability to create micropores, enhancing charge storage capacity. However, supercapacitor performance depends on factors such as electrical conductivity, electrochemical stability, and cycling durability. More detailed electrochemical impedance spectroscopy (EIS) and cyclic voltammetry (CV) analyses are required to compare its efficiency with commercial activated carbons and graphene-based materials (Sholikhah et al., 2021).

While KOH is a widely used chemical activator due to its strong base nature and ability to create a well-developed pore structure, phosphoric acid (H3PO4) is also effective. H3PO4 activation is known to produce a different pore structure, favoring mesopores, which can be advantageous in applications like liquid-phase adsorption. Comparative studies between KOH and H_3PO_4 activation on mangosteen peel are limited, and future research should explore the differences in surface functional groups, pore structure, and adsorption performance in diverse applications. This research uses phosphoric acid to activate charcoal of mangosteen peel. The chemical activation enhances the surface area of the activated carbon and alters its compositional structure. Phosphoric acid effectively regulates the pore structure of activated carbon. Its distinct pore distribution compared to other activating agents such as KOH.

Accordingly, the adsorption capacity achieved with acid activators is significantly superior to that obtained with base activators. Furthermore, phosphoric acid (H_3PO_4) is considered more environmentally friendly than other corrosive or hazardous activators (Sholikhah et al., 2021). The objective of this research is to produce activated carbon from mangosteen peel as a means to enhance the economic value of this agricultural byproduct. The synthesis of activated carbon employs H_3PO_4 as an activating agent, with quality assessments of the activated carbon, including measurements of moisture content, ash content, volatile matter, and pure carbon content.

METHOD

Equipment and Materials

The tools utilized include a spatula, porcelain crucible, analytical balance, furnace, oven, and hotplate. The materials used consist of mangosteen peel and phosphoric acid (H_3PO_4).

Carbonization Process

Mangosteen peel is first washed and then cut into small pieces. These pieces are dried under sunlight for four days. Once dried, the mangosteen peel is blended into a fine powder. This powder is placed in a porcelain dish and subjected to a furnace at 300 ^{0}C for one hour. After being removed from the furnace, the charcoal is placed in a desiccator until it reaches room temperature, after which its weight is measured (Nurhasanah et al., 2024).

Activation Process with Phosphoric Acid

Charcoal samples derived from mangosteen rind are sieved using a 50 mesh sieve, followed by weighing 5 grams of the material. Afterward, 50 mL of a 5 M phosphoric acid (H_3PO_4) solution is added, and the mixture is allowed to soak for 24 hours. After this period, the charcoal is filtered and rinsed with distilled water until neutral pH is achieved. Finally, the material is dried in an oven at a temperature of 100 ^{0}C (Sholikhah et al., 2021).

Moisture Content

To determine the moisture content of charcoal, the following steps are taken: First, weigh 1 gram of activated charcoal using a pre-weighed porcelain crucible. The crucible is then placed in an oven at a temperature of 110 ^{0}C for a duration of 2 hours. After this period, the crucible is allowed to cool before weighing it again (Hydhayat et al., 2022).

Ash Content

Weigh 1 gram of the sample in a porcelain crucible. Next, place it in a furnace at a temperature 0f 600 ^{0}C for 2 hours. Afterward, allow it to cool and weigh it until a constant weight is achieved (Hydhayat et al., 2022).

Volatile Matter Content

The amount of volatile matter is determined by weighing 1 gram sampel in a crucible. The sample is then heated in a furnace for 15 minutes. After heating, the sample is cooled and weighed until a constant weight is achieved (Hydhayat et al., 2022).

Fixed Carbon Content

The bound carbon content is determined by subtracting the ash content and the volatile matter content (Hydhayat et al., 2022).

RESULTS AND DISCUSSION

Mangosteen peel as an active charcoal ingredient is the right choice for utilizing materials that are no longer used. Activation with an acid, in this case, phosphoric acid, aims to remove or dissolve residual compounds resulting from heating contained in the pores of the charcoal, which causes the adsorption capacity of the charcoal to be small (Manurung et al., 2019). Phosphoric acid (H_3PO_4) is considered more environmentally friendly compared to other more corrosive or hazardous activators (Sholikhah et al., 2021). The results of the testing of activated carbon derived from mangosteen peel using phosphoric acid (H_3PO_4) are presented in Table 2.

Table 2. Results of the testing of activated carbon from mangosteen peel activated with phosphoric acid

Parameter	Experiment Result	Standard	Quality
Yield (%)	51,68	-	
Moisture content (%)	2,76	Maks. 15	SNI 06-3730-1995
Ash content (%)	7,24	Maks. 10	SNI 06-3730-1995
Volatile matter content (%)	6,02	Maks. 25	SNI 06-3730-1995
Carbon content (%)	83,98	Min. 65	SNI 06-3730-1995

Based on the observations from Table 2, it is evident that the activated carbon produced through chemical activation using a 5 M concentration of phosphoric acid (H_3PO_4) achieved a yield of 51,68%. This charcoal yield is 50% of the charcoaled mangosteen peel (Garcinia Mangostana L.). Jaya & Khair's research reveals that the time and temperature of carbonization significantly impact the yield of charcoal (Jaya & Khair, 2020). The higher the heating temperature, the smaller the yield produced, and likewise, the longer the carbonization time, the smaller the yield produced. In addition, Neme et al reported that to obtain good yields and textural characteristics, it is best to use a phosphoric acid activator with a low ratio, which can reduce the cost of producing activated carbon from biomass (Neme et al., 2022).

The moisture content indicated by the activated carbon in this study is 2.76%. This figure still meets SNI 06-3730-1995 standards. The water content shows that water is still trapped in the cavity and covering the active carbon pores. The amount of water content is closely related to the hygroscopic properties of an activator (Efendi et al., 2024). Phosphoric acid is an activated charcoal activator for mangosteen peel and has hygroscopic properties. According to (Ekawati, 2023), the activator's binding of water molecules to activated carbon causes the pores in the carbon to become more prominent. Therefore, activated charcoal may come into direct contact with humid air, which results in the activated charcoal absorbing water vapor (Batu et al., 2022). The water content in activated charcoal must be kept at a low value so that the absorption capacity of activated charcoal runs optimally (Neneng Purnamawati, 2023).

The ash content of activated carbon is assumed to be the residual minerals left behind when heated because natural materials, as the basis for making activated carbon, not only contain carbon compounds but also contain minerals, and some of these minerals have been lost during carbonization and activation, some are thought to remain still. Activated charcoal made from natural ingredients not only contains carbon compounds but also contains several minerals. Ash content indicates the mineral content contained in activated charcoal (Hastuti et al., 2015). The ash content increases as the activator concentration increases, so the active carbon organic compounds decrease, but the inorganic compound content remains relatively constant (Maulina & Iriansyah, 2018).

In this study, an ash content of 7.24% was obtained. The temperature can cause the high ash content in activated charcoal during carbonation and the activation method (Rangabhashiyam, S & Balasubramanian, 2019). Phosphoric acid activators can cause metal corrosion, resulting in the charcoal's metals experiencing corrosion during the activation process. The ash content will cause the quality of the activated charcoal to decrease, which will affect the absorption capacity of adsorption (Alongamo et al., 2021).

Volatile content is the content of volatile compounds other than water in activated charcoal. The level of volatile substances obtained in this study was 6.02%. The level of volatile substances in carbon shows that in the mangosteen rind activated carbon that is made, little volatile substances remain in the activated carbon so that they do not cover the pores of the activated carbon anda the activated carbon can absorb adsorbate maximally (Ramayana, D; Royani, I;, Arsyad, 2017).

The pure carbon content test results from active carbon from mangosteen peel were 83.98%. The aim of determining the pure carbon content is to determine the pure carbon content contained in active carbon. One of the advantages of the H_3PO_4 chemical activator is that H_3PO_4 can prevent biomass loss through evaporation during the heating process, thereby increasing the yield of pure carbon after the carbonization process (Ferreira et al., 2022).

CONCLUSION

Based on the research results, mangosteen peel can be made into activated carbon using an H_3PO_4 activator. The research results showed that the characteristics of activated charcoal activated by H_3PO_4 met SNI 06-3730-1995 standards, namely water content (2,76%), ash content (7,24%), volatile matter content (6,02%), and bound carbon content (83,98%). This characteristic information can be used to apply activated carbon from mangosteen peel for industrial needs.

RECOMMENDATIONS

Further testing is necessary to evaluate the adsorption capacity of the activated carbon derived from mangosteen rind, particularly its application as an adsorbent for liquid waste. Additionally, further research should explore various parameters to enhance the activated carbon's quality per SNI standards, including variations in temperature, carbon size, soaking duration, type of activator, and concentrations of activating compounds, ensuring its practical application in daily life.

BIBLIOGRAPHY

Alongamo, B. A. A., Ajifack, L. D., Ghogomu, J. N., Nsami, N. J., & Ketcha, J. M. (2021). Activated Carbon from the Peelings of Cassava Tubers (Manihot esculenta) for the Removal of Nickel(II) Ions from Aqueous Solution. *Journal of Chemistry*, *2021*. https://doi.org/10.1155/2021/5545110

Batu, M. S., Naes, E., & Kolo, M. M. (2022). Pembuatan Karbon Aktif dari Limbah Sabut Pinang Asal Pulau Timor sebagai Biosorben Logam Ca dan Mg dalam Air Tanah. *Jurnal Integrasi Proses*, *11*(1), 21. https://doi.org/10.36055/jip.v11i1.13181

Efendi, E. A., Djatmiko, F. P., & Kurniati, E. (2024). *Indonesian Journal of Chemical Science Synthesis and Characterization of Activated Carbon from Green Banana Peel*. *13*(3).

Ekawati, C. J. K. (2023). *Alternatif Bahan Baku Arang Aktif*.

Ferreira, L. M., de Melo, R. R., Pimenta, A. S., de Azevedo, T. K. B., & de Souza, C. B. (2022). Adsorption performance of activated charcoal from castor seed cake prepared by chemical activation with phosphoric acid. *Biomass Conversion and Biorefinery*, *12*(4), 1181–1192. https://doi.org/10.1007/s13399-020-00660-x

Hanami, Z. A., & Lestari, P. (2021). Characterization and application of mangosteen peel activated carbon for ammonia gas removal. *Environment and Natural Resources Journal*, *19*(4), 320–329. https://doi.org/10.32526/ennrj/19/2020298

Hastuti, N., Pari, G., Setiawan, D., Daud, & Godang, M. (2015). Tingkat Keasaman Dan Kebasaan Arang Aktif Bambu Mayan (Aabm) Terhadap Uap Jenuh Hcl Dan Naoh Acidity and Alkalinity Level of Mayan Bamboo Activated Charcoal (Mbac) on Saturated Vapor of Acid Chloride and Natrium Hydroxide. *Widyariset, 1*(December), 41–50. https://doi.org/10.14203/widyariset.1.1.2015.

Haura, Ulfa., Razi, Fachrul., & Meilina, H. (2017). Karakterisasi Adsorben dari Kulit Manggis dan Kinerjanya Pada Adsorpsi Logam Pb (II) dan Cr (VI). *Biopropal Industri*, *8*(1), 47–54.

Hydhayat, Y. W., Rifai, M. A. S. A., & Sani, S. (2022). Karbon Aktif Dari Limbah Daun Jati Menggunakan Aktivator Larutan Koh. *Jurnal Teknik Kimia*, *16*(2), 87–92. https://doi.org/10.33005/jurnal_tekkim.v16i2.3050

Jaya, D. D., & Khair, M. (2020). Pembuatan Karbon Aktif Melalui Karbonisasi Batang Kelapa Sawit. *Chemistry Journal of State University of Padang*, *9*(1), 7–10.

Khajonrit, J., Sichumsaeng, T., Kalawa, O., Chaisit, S., Chinnakorn, A., Chanlek, N., & Maensiri, S. (2022). Mangosteen peel-derived activated carbon for supercapacitors. *Progress in Natural Science: Materials International*, *32*(5), 570–578. https://doi.org/10.1016/j.pnsc.2022.09.004

Manurung, M., Ratnayani, O., & Prawira, R. A. (2019). Sintesis dan karakterisasi arang dari limbah bambu dengan aktivator ZnCl2. *Cakra Kimia (Indonesian E-Journal of Applied Chemistry)*, *7*(1), 69–77.

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). https://doi.org/10.1088/1757-899X/309/1/012072

Meilianti, M. (2020). Pembuatan Karbon Aktif dari Arang Tongkol Jagung dengan Variasi Konsentrasi Aktivator Natrium Karbonat (Na2CO3). *Jurnal Distilasi*, *5*(1), 14. https://doi.org/10.32502/jd.v5i1.3025

Muhali, M., Hendrawani, H., Mirawati, B., & Hulyadi, H. (2023). Effectiveness of Activated Carbon CaCl2 and NaNO3 Reducing Fatty Acids and Increasing the Quantity of Biodiesel Production. *Jurnal Penelitian Pendidikan IPA*, *9*(1), Article 1. https://doi.org/10.29303/jppipa.v9i1.2624

Neme, I., Gonfa, G., & Masi, C. (2022). Preparation and characterization of activated carbon from castor seed hull by chemical activation with H3PO4. *Results in Materials*, *15*(July). https://doi.org/10.1016/j.rinma.2022.100304

Neneng Purnamawati. (2023). Uji Kualitas Sintesis Karbon Aktif Dari Pelepah Aren Teraktivasi Asam Fosfat. *Journal of Research and Education Chemistry*, *5*(2), 120. https://doi.org/10.25299/jrec.2023.vol5(2).15225

Nurhasanah, A., Supriatna, A. M., & Rizka, F. (2024). Sintesis Karbon Aktif dari Kulit Manggis (Garcina Mangostana) dengan Aktivator Kalium Hidroksida (KOH) sebagai

Adsorben untuk Reduksi Biological Oxygen Demand (BOD) dan Chemical Oxygen Demand (COD) pada Limbah Cair Industri Tahu. *Aplikasi Kimia Material Untuk Kehidupan Masa Kini Dan Masa Depan*, 112–121.

Ramayana, D; Royani, I;, Arsyad, F. S. (2017). Pembuatan Carbon Black Berbasis Nanoserbuk Tempurung Biji Karet Menggunakan High Energy Miling. *Jurnal MIPA*, *40*(1), 20–23.

Rangabhashiyam, S & Balasubramanian, P. (2019). The potential of lignocellulosic biomass precursors for biochar production: Performance, mechanism and wastewater application—A review. *Industrial Crops and Products*, *128*, 405–423. https://doi.org/10.1016/J.INDCROP.2018.11.041

Sholikhah, H. I., Putri, H. R., & Inayati, I. (2021). Pengaruh Konsentrasi Aktivator Asam Fosfat (H3PO4) pada Pembuatan Karbon Aktif dari Sabut Kelapa terhadap Adsorpsi Logam Kromium. *Equilibrium Journal of Chemical Engineering*, *5*(1), 45. https://doi.org/10.20961/equilibrium.v5i1.53572

Smith, D. J., Pettit, P., & Schofield, T. (1996). Activated carbon in water treatment. *Water Supply*, *14*(2), 85–98.