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Activated Carbon from Mayan Bamboo (*Gigantochloa robusta* Kurz) for Liquid Detergent Waste Degradation

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Abstract

Activated carbon was successfully synthesized by using *Gigantochloa robusta* Kurz. The aim of this research is preparation of activated carbon from mayan bamboo for detergent liquid waste degradation. The manufacturing process of activated carbon is carried out using the physics method. Powder of activated carbon was used for of detergent waste degradation is 0.5; 1; and 1.5 mg at 30 min. The activated carbon powders characteristics was determined by proximate analysis like water content, volatile matter, ash, bound carbon content, and iodine value test. From the proximate test, the activated carbon has a water content value of 6.7% at 150 °C. The volatile matter and ash content analysis showed 11.3 and 6.50%, respectively. Furthermore, the activated carbon showed a bound carbon content value was 82.2% with an iodine adsorption value of 795,97 mg/g. The Energy dispersive X-ray (EDX) shows the elemental composition of carbon is 92%. Activated carbon from *Gigantochloa robusta* Kurz has potentially as detergent liquid waste degradation with a degradation value of 65,12%. From these results, can be concluded that activated carbon from *Gigantochloa robusta* Kurz has been successfully synthesized physically and can be applied as a liquid waste purifier in the future.

INTRODUCTION

Activated carbon is a black amorphous solid material that can be produced from organic materials containing carbon atoms (C) (Rizka *et al*. 2020). Physically, activated carbon has forms such as powder, granular, and pellet. Powdered activated carbon has a large surface area with high porosity (Yuan *et al*. 2022). The superior properties of activated carbon materials such as good thermal stability, high performance in electrical conductivity, and pore reactivity on the surface, so many researchers use this material as an adsorbent material in industrial wastewater purification (Ayinla *et al*. 2021). In addition, the porosity on the surface of activated carbon consists of three structural forms, namely microporous, mesoporous, and macroporous. These three pore structures have an important role in the adsorbent properties of

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activated carbon. On the other hand, activated carbon is in great demand for wastewater treatment (Wenxuan *et al*. 2022).

Previous research reported the use of activated carbon material as a supercapacitor in electrodes (Pelin *et al*. 2022), adsorption of 2,4-dichlorophenol (Soremo *et al*. 2022), removing sulfachloropyridazine (Iwan *et al*. 2021), heterogeneous catalyst (Alireza *et al*. 2022), biodiesel production (Samah *et al*. 2022), carbon dioxide absorption (Zohreh *et al*. 2022), adsorbing low concentration toluene (Mingyang *et al*. 2022), cyclohexane and benzene separation (Aniyohana *et al*. 2022), enhance dye and heavy metals adsorption (Marzia *et al*. 2022), and wastewater treatment application (Iwan *et al*. 2018). In this study, we used activated carbon from Gigantochloa robusta Kurz as a degradation of liquid waste resulting from detergent waste. Mayan bamboo plays a very important role in people's lives in Indonesia. Mayan bamboo is known to have good properties to be utilized in the form of strong stems and easily shaped bark. Mayan bamboo is commonly found around residential areas in rural areas, so bamboo is a versatile plant for rural communities (Riki. 2017). The process of activation carbon can be done using two methods, namely chemically and physically. Chemical activation involves chemicals such as alkali metal hydroxide compounds, carbonate salts, sulfates, $ZnCl_2$, and inorganic acids such as H_2SO_4 and H_3PO_4 for the process of breaking the carbon chain from organic compounds (Katia *et al*. 2022). The use of chemical activation is hazardous and not environmentally friendly if the substances run off into the waters. Therefore, physical activation in manufacturing activated carbon is more efficient and suitable for freshwater ecosystems. Physical activation, such as charcoal is only heated in the furnace at a temperature of 800–900°C with air oxidation at low temperatures. In addition, heating with steam or CO_2 at high temperatures can also be used in the manufacture of activated carbon because of the ease of controlling the reactions that take place (Jayachandran *et al*. 2021). In this study, we used physical methods to manufacture activated carbon from mayan bamboo (*Gigantochloa robusta* Kurz).

Bamboo is a grassy plant with cavities and joints in the stems. In Indonesia, there are several types of bamboo plants, such as wulung, tutul, apus, andong, betung, ampel, ater, thorn, friends and mayan bamboo. Mayan bamboo (*Gigantoclhoa robusta* Kurz) has chemical components such as 3.24% solubility in alcohol and gasoline, hot water 9.63%, cold water 6.68%, and NaOH (1%) 23.95%. In addition, mayan bamboo has cellulose 57.55%, holocellulose 63.32%, lignin 31.66%, pentoson 18.60%, starch 9.42%, water 9.68%, ash 2.67%, and silica 1.48% content (Iwan *et al*. 2020). The presence of chemical compounds in mayan bamboo can be used as a basic ingredient for making activated carbon. In this paper, the manufacture of activated carbon from mayan bamboo is carried out by a physical approach. In this study, the preparation of activated carbon from mayan bamboo using physical methods and detergent liquid waste degradation is 0.5; 1; and 1.5 mg at 30 min. The carbon powder obtained was then subjected to a proximate test to determine the moisture content, ash content, volatile matter content, bound carbon, and iodine absorption. Optimum activated carbon powder is used for the degradation of detergent liquid waste resulting from washing clothes in the laundry. This study aimed to make a preparation of activated carbon from mayan bamboo for detergent liquid waste degradation.

MATERIALS AND METHODS

Materials

The material used mayan bamboo (Gigantochloa robusta Kurz) obtained from Seputih Banyak, Lampung Tengah area. Liquid waste uses detergent samples from washing clothes taken from UKM (Small and Medium Enterprise/SME) laundry around Institut Teknologi Sumatera (ITERA), Lampung, Indonesia. The chemicals used, namely Na_2S2O_3 (99.99%), I_2 (99.8%) were obtained from PT. Merck Tbk. Indonesia. The starch indicator was obtained from PT. Indochemistry Lampung. The equipment used including evaporating cup (pyrex), beaker equipment (pyrex), burette (pyrex), desiccator, furnace (Vulcan A-550), sieve (BBS), oven (Memmert), activated carbon reactor (Carbolite), analytical balance (Fujitsu), and digital hotplate stirrer (IKA C-MAG HS). The instruments used were UV-Vis Spectrophotometer (Shimadzu) and Energy dispersive X-ray (EDX-Shimadzu).

Experimental Method

Preparation of Charcoal from Mayan Bamboo

The mayan bamboo pieces are dried for a week to reduce the moisture content of the bamboo. Bamboo is carried out by the writing process. The reactor was filled with chopped and dried bamboo slats. Carbonization is carried out at 400 °C for 4–5 hours and cooled for 24 hours. The carbon material formed was tested for proximate and iodine absorption according to SNI-06-3730-1995 standards.

Preparation of Activated Carbon

The carbonized charcoal was then activated using an electric retort with a capacity of 1000 g using steam at 750 °C for 60 min (Anggiyan et al. 2015). The resulting activated carbon was then crushed and characterized using Energy dispersive X-ray (EDX) and tested for proximate and iodine absorption according to SNI-06-3730-1995 standard.

Determination of Water Content

As much as 1 g of the sample was weighed in an evaporating cup of known weight, then dried in an oven at 105, 120, and 150 °C for 24 hours (Nurmalasari et al. 2020). Then the sample was cooled in a desiccator and weighed. Measurement of water content was carried out in triplo. To find out the value of the water content in activated carbon can be done using the following equation:

$$\boldsymbol{Water\ Content}\ (\%) = \frac{\boldsymbol{M2-M3}}{\boldsymbol{M2-M1}}\ \boldsymbol{x}\ \mathbf{100}\% \ \text{.........}\ (1)$$

where, M1 is the mass of the empty cup (g), M2 is the mass of the empty cup + sample weight before heating (g), M3 is the mass of the empty cup + sample weight after heating (g).

Determination of volatile matter content

A total of 1 g of sample was weighed in an evaporating cup whose dry weight was known. The sample is then heated in an electric furnace at 920, 935, and 950 °C for 30 minutes (Sarifah et al. 2021). The cup is closed as tightly as possible. The sample is then cooled in a desiccator and weighed. The calculation of the volatile matter content was carried out in triplicate. Determination of volatile matter content in activated carbon can be calculated using the equation:

$$\textbf{Flying Substance Levels}\ (\mathbf{VM}) = \%\mathbf{Loss} - \%\mathbf{M} \ \text{..........}\ (2)$$

$$\%\ \mathbf{Loss} = \frac{\mathbf{M2-M3}}{\mathbf{M2-M1}}\ \mathbf{x}\ \mathbf{100}\% \ \text{..........}\ (3)$$

where, M1 is the mass of the empty cup (g), M2 is the mass of the empty cup + sample weight before heating (g), M3 is the mass of the empty cup + sample weight after heating (g), %M is the water content in activated carbon, VM is the volatile matter content.

Determination of Ash Content

A total of 1 g of sample was weighed in an evaporator cup whose weight was known. The cup was then heated in an electric furnace at 400, 600, and 750 °C for 6 hours (Anugrah et al. 2014). After that, the sample was cooled in a desiccator and weighed. Calculation of ash content was carried out in triplo. The determination of ash content in activated carbon from mayan bamboo can be calculated through the following equation:

$$\boldsymbol{Ash\ content}\ (\%) = \frac{\boldsymbol{M3-M4}}{\boldsymbol{M2-M1}}\ \boldsymbol{x}\ \mathbf{100}\% \ \text{............}\ (4)$$

where, M1 is the mass of the empty cup before heating, M2 is the mass of the cup + sample before heating, M3 is the mass of the cup + sample after heating, and M4 is the mass of the empty cup after heating.

Determination of Bonded Carbon Content

Determination of bound carbon content is carried out by calculating 100% minus the total ash content + elevating substance content (Doly. 2018). Determination of bonded carbon content can be calculated through the equation:

$$\textbf{Bonded carbon content}\ (\%) = \mathbf{100}\% - \textbf{ash content} + \textbf{Volatile content} \ \text{....}\ (5)$$

Determination of Iod Absorption

A total of 0.25 g activated carbon was placed in the Erlenmeyer and was added 25 mL of 0.1 N iodine solution. Then, the Erlenmeyer was tightly closed and shaken for 15 minutes. The suspension was then filtered and as much as 10 mL of the filtrate was titrated with 0.1 N Na-thiosulfate solution until the color of the solution became light yellow. After that, a few drops of the starch indicator were added to the solution and titrated until the color of the solution became clear (Noor et al. 2017). The calculation of the iodine number was carried out in duplicate.

Degradation of Detergent Waste

A total of 0.5, 1, and 1.5 mg of activated carbon was added to 30 mL of detergent waste and stirred at 200 rpm 30 min at room temperature (Shinta et al. 2017). Waste solution and sodium lauryl sulfate (SLS) standard solution. measured using UV-Vis.

RESULTS AND DISCUSSION

Cutting mayan bamboo (*Gigantochloa robusta* Kurz) produces small pieces to facilitate the carbonization process. The carbonization process on the mayan bamboo sample functions so that the bamboo has many pore sizes, and the resulting carbon is black. In addition, the carbonation process also breaks down hydrocarbon compounds such as lignin, cellulose, and hemicellulose to form pure carbon material, which will produce powders with high adsorption power (Maulana et al. 2018). Physical activation functions so that the bamboo charcoal has a wide pore size. Granular activated carbon was crushed to obtain a particle size of 60 mesh powder.

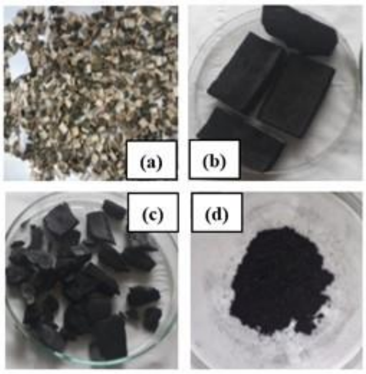

Figure 1. (a) Mayan bamboo pieces, (b) carbon before activation, (c) activated carbon, and (d) activated carbon powder.

The resulting activated carbon powder is subjected to a proximate test to determine the moisture content, ash content, volatile matter content, bound carbon content, iodine absorption, and the application of detergent liquid waste degradation (Fig. 1). The determination of the water content is related to the hygroscopic nature of the activated carbon pores. If the water content in the activated carbon material is high, the pore effectiveness will decrease and if the water content is small, it indicates that the activated carbon has good pore effectiveness (Riki. 2017). Table 1 shows the results of the calculation of activated carbon from mayan bamboo.

Table 1. Water Content of Mayan Bamboo

Sample	Water content (%)
Before Activated Carbon	9,2
Activated Carbon (105 ˚C)	7,6
Activated Carbon (120 ˚C)	7,2
Activated Carbon (150 ˚C)	6,7

The activated carbon sample before activation has a water content value of 9.2%. Meanwhile, for activated carbon samples after activation at heating variations of 105, 120, and 150 °C the water content was 7.6, 7.2, and 6.7% respectively. The molecules contained in mayan bamboo fiber such as hemicellulose and cellulose will decrease with the addition of heating. In the carbonization process, this molecule will break down to form simpler molecules (Elfiyanti et al. 2020). From the water content data calculation it can be indicated that the higher the activation temperature used, the water content in activated carbon will decrease. This is indicated, the pores on the activated carbon have been formed with water content decreases. After calculation, the results of the water content of activated carbon from mayan bamboo are following the Indonesian National Standard, which is a maximum of 15% (SNI No: 06-3730-1995).

Determination of the volatile matter content of activated carbon shows the amount of substance that evaporates during the heating process. Table 2 shows the levels of volatile matter in activated carbon from mayan bamboo.

Table 2. Active carbon volatilization content of mayan bamboo

Sample	Volatile content (%)
Before activated carbon	45,5
Activated carbon (920 °C)	24,3
Activated carbon (935 °C)	20,2
Activated carbon (950 °C)	11.3

It was found that the volatile matter content of activated carbon before activation was 45%. Meanwhile, the volatile matter content of activated carbon from mayan bamboo after the activation process at 920, 935, and 950 °C was 24.3, 20.2, and 11.3%. Based on the results, we found that the higher the heating temperature, the lower the evaporation rate. The heating process above 900 °C can vaporize organo-sulfur and nitrogen compounds. In addition, the high levels of volatile matter in activated carbon result in reduced purity of activated carbon due to the presence of compounds such as CO, CH4, H2, and CO2 which can cover the surface porosity of activated carbon. The results of calculating the volatile matter content of activated carbon from mayan bamboo at activation temperatures of 920, 935, and 950 °C are following SNI No: 06-3730-1995, namely the volatile matter content of activated carbon is a maximum of 25%.

The determination of ash content serves to determine the success rate of activated carbon formed from the results of synthesis. The ash that is formed is due to the large number of minerals contained in activated carbon. The mineral content can cover the pores of activated carbon, so the ash content in activated carbon must be determined. The oxidation of volatile substances and carbon in the form of oxide gas is greatly influenced by the duration and high heating temperature (Sari et al. 2021). Meanwhile, the ash material is not oxidized because it is not a volatile substance. Determination of ash content in activated carbon from mayan bamboo was carried out by varying the heating temperature. Table 3 shows the ash content of activated carbon.

Table 3. Active carbon ash content from mayan bamboo

Sample	Ash content (%)
Before Activated carbon	15,23
Activated carbon (400 ˚C)	8,12
Activated carbon (600 ˚C)	9,56
Activated carbon (750 ˚C)	6,50

The activated carbon sample before activation had a volatile matter content of 15.23%. For activated carbon samples at temperatures of 400, 600, and 750 °C each produced an ash content of 8.12, 9.56, and 6.50%. The quality of activated carbon is determined by the low ash content. The amount of ash content can cover the surface porosity of activated carbon, which can lead to reduced adsorption effectiveness. This is due to the difference in heating temperature. The results of calculating the ash content of activated carbon from mayan bamboo with activation temperatures of 400, 600, and 750 °C are following SNI No: 06-3730-1995, which is a maximum of 10%.

Bonded carbon content is a component of the carbon fraction (C) contained in the activated carbon material. The higher the bonded carbon content, the better the purity of the activated carbon. The bonded carbon content is affected by the value of ash content and volatile matter content in activated carbon. The lower the ash and volatile matter content, the higher the bound carbon content.

The ash content and volatile matter content used to calculate the bonded carbon content were at 750 and 950 °C, respectively. After doing the calculations, the bonded carbon content was obtained at 82.2%. This result is following SNI No: 06-3730-1995, namely the minimum limit of 65% bonded carbon.

Determination of iodine absorption serves to see the absorption capacity of activated carbon synthesized from mayan bamboo. The higher value of the absorption capacity of activated carbon for the iodine solution indicates a large number of pores present on the surface of the activated carbon (Muhammad et al. 2016). Determination of iodine absorption using the Iodometric titration method. Mayan bamboo-activated carbon powder reacts with iodide solution. First, Na-thiosulphate reacts with iodide ions to produce sodium iodide and sodium tetrathionate as shown in equation (6):

$$\mathbf{2Na_2S_2O_3 + I_2 \rightarrow 2NaI + Na_2S_4O_6} \quad (6)$$

The reaction between Na-thiosulphate and iodide ions produces a yellow color (Figure 2a) and after the addition of starch indicator and titration with Na-thiosulfate produces a clear color (Figure 2b). Figure 2 shows the color change before and after the titration. The results of the calculation of the determination of the absorption of iodine on activated carbon from mayan bamboo before activation and after activation at 750 °C were 523.67 and 795.97 mg/g, respectively.

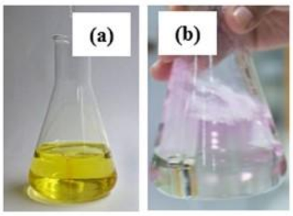

Figure 2. Exchange solution (a) after and (b) before of titration process

The Energy dispersive X-ray (EDX) instrumentation was used to determine the number of carbon atom compositions contained in the activated carbon material synthesized from mayan bamboo. Activated carbon material synthesized using mayan bamboo through physical methods obtained the composition of carbon (C), silica (Si), and oxygen (O) atoms with levels of 92, 6, and 2%, respectively (Table 4).

Table 4. Elemental composition of activated carbon

Elemental	Content (%)
C	92
Si	6
O	2

The degradation activity test of detergent liquid waste was carried out by preparing a standard sodium lauryl sulfate (SLS) solution. This is because, in the manufacture of liquid detergents, many SLS compounds are used as the main ingredient. The process of degradation of liquid detergent waste from activated carbon uses a UV-Vis spectrophotometer. The relationship between the variation of the SLS standard solution and the maximum absorbance value is obtained by a linear equation y = 65380x-0.1254 with a regression value of 0.999 (Fig 3.).

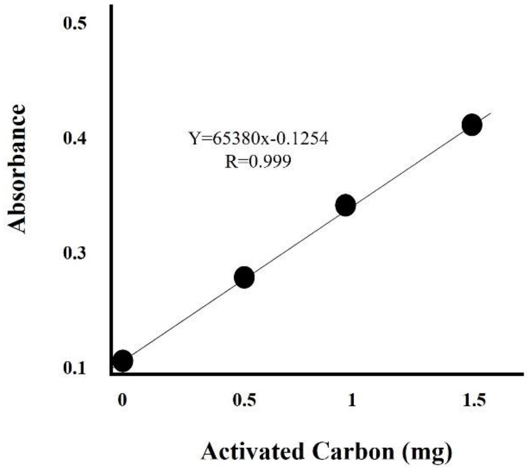

Figure 3. Regression value of detergent liquid waste degradation

Degradation activity using activated carbon was tested on detergent wastewater with a concentration based on the weight of activated carbon (Iwan et al. 2020). The results of the degradation of detergent liquid waste with various weight variations of the activated carbon (Table 5).

Table 5. Percentage of degradation of detergent liquid waste with various weight variations of activated carbon

Weight of activated carbon (mg)	% Detergent waste degradation
0,5	56,72
1	62,34
1,5	65,12

Degradation of detergent wastewater using activated carbon weight of 0.5, 1, and 1.5 mg, respectively, resulted in a degradation of 56.72, 62.34, and 65.12%. From the calculation data, the best results were obtained, namely the use of 1.5 mg of activated carbon which resulted in a degradation of detergent liquid waste of 65.12%.

CONCLUSION

Mayan bamboo (Gigantochloa robusta Kurz) has been successfully used as a base material in the manufacture of activated carbon materials. The preparation of activated carbon was synthesized using physical methods. The temperature in the activation process greatly influences the value of the activated carbon proximate test. Degradation of detergent waste water using activated carbon weight of 0.5, 1, and 1.5 mg, respectively, resulted in a degradation of 56.72, 62.34, and 65.12%. The best results were obtained, namely the use of 1.5 mg of activated carbon which resulted in a degradation of detergent liquid waste of 65.12%. From these data, it can be concluded that activated carbon was successfully prepared from the basic ingredients of mayan bamboo. The resulting activated carbon can be applied and has the potential to degrade liquid waste in the future.

AUTHOR CONTRIBUTION

All authors contributed equally as the main contributor to this study.

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CONFLICT OF INTEREST

The authors declare no known conflict of financial interest or personal relationships that could have appeared to influence the work reported in this paper.

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REFERENCES

Alireza, M., Eskandar, K., Maryam, G., Mohammad, A.Z. 2022. Immobilization of –OSO3H on activated carbon powder and its use as a heterogeneous catalyst in the synthesis of phthalazine and quinoline derivatives. *Diam. Relat. Mater.* 124, 108908. https://doi.org/10.1016/j.diamond.2022.108908.

Anggiyan, R., Usman, M., Zulkarnain. 2015. Pembuatan dan Karakterisasi Karbon Aktif dari Bambu Betung dengan Aktivasi Menggunakan Activating Agent H2O. *JOM. FMIPA.* 2, 102-106.

Aniyohana, V., Roberto, M.V., Silvia, G.C., Cintia, K.R.M., Adrian, B.P, Jorge, G., Ismael, A.A.V. 2022. Cyclohexane and benzene separation by fixed-bed adsorption on activated carbons prepared from coconut shell. *Environ. Technol. Innov.* 25, 102076.https://doi.org/10.1016/j.eti.2021.102076.

Anugrah, R.P., Lia, U.K., Esti, W. 2014. Karakterisasi karbon aktif kulit singkong (manihot utilissima) dengan variasi jenis aktivator. *Jurnal Teknologi Hasil Pertanian*. 7 (2), 70−75. https://doi.org/10.20961/jthp.v0i0.13004.

Ayinla, R.T, John, O.D., 2021. Activated carbon from composite of palm bio-waste as electrode material for solid-state electric double layer capacitor. *J. Energy. Storage*. 42, 103087. https://doi.org/10.1016/j.est.2021.103087.

Doly, P.S. 2018. Sintesis karbon aktif dari arang tempurung kelapa limbah mesin boiler sebagai bahan penyerap logam cd, cu dan pb. *Jurnal Dinamika Penelitian Industri*. 29 (2), 119−127.

Elfiyanti, L., Wati, S., Maslahat, M. 2020. Pembuatan dan Analisis Karbon Aktif dari Cangkang Buah Karet dengan Proses Kimia dan Fisika. *Jurnal Ilmu Kehutanan*. 14 (94). https://doi.org/10.22146/jik.57479.

Iwan, S.S., Siti, S., Yoki, Y., Sudirman. 2020. Synthesis and characterization of gold nanoparticles (AuNPs) by utilizing bioactive compound of Imperata cylindrica (L.) Raeusch. *J. Kim. Terap. Indones*. 22 (1), 1-7.

Jayachandran, M., Babu, S.K., Maiyalagan, T., Rajadurai, N., Vijayakumar, T. 2021. Activated carbon derived from bamboo-leaf with effect of various aqueous electrolytes as electrode material for supercapacitor applications. *Mater. Lett*. 301, 130335. https://doi.org/10.1016/j.matlet.2021.130335.

Iwan, S.S., Anjar, H.S., Nur, Adliani., Dwinna, R., Sudirman S., Yogi, N. 2021. Eco-friendly synthesis of gold nanoparticles through Gracilaria sp seaweed extract for foam height stability in liquid hand soap formulations. *The Journal of Pure and Applied Chemistry Research*. 10 (3), 193-202.

Katia, A.K.A, Achour, T., Chafia, A.R.T., Hakim, B., Khaldoun, B., Didier, H., Djillali, M. 2022. Electrochemical performance of new hybrid activated carbon materials from binary and ternary Date-Olive pits for supercapacitor electrodes. *J. Energy. Storage.* 47, 103559. https://doi.org/10.1016/j.est.2021.103559.

Marzia, S., Mahbub, H.R., Meherunnesa, S., Hafezur, R., Nur, A. 2022. A review on experimental chemically modified activated carbon to enhance dye and heavy metals adsorption. *Clean. Eng. Tech*. 6, 100382. https://doi.org/10.1016/j.clet.2021.100382.

Maulana, S., Iriansyah, M. 2018. Characteristics of activated carbon resulted from pyrolysis of the oil palm fronds powder. *IOP Conf. Ser. Mater. Sci. Eng*, 309 (1). 10.1088/1757-899X/309/1/012072.

Mingyang, W., Ying, S. 2022. Molecular simulation to analyze the influence of ultrafine particles on activated carbon adsorbing low concentration toluene. *Build. Environ*. 213, 108875. https://doi.org/10.1016/j.buildenv.2022.108875.

Muhammad, A., Yusnimar., Sri, H. 2016. Penentuan daya jerap aktif dari pelepah sawit terhadap ion Fe (III). *Jom FTEKNIK*. 3 (1), 1-8.

Noor, R., Puji, K. 2017. Sintesis dan Karakterisasi Karbon Teraktivasi Asam dan Basa Berbasis Mahkota Nanas. Prosiding Seminar Nasional Kimia dan Pembelajarannya 2017. 154-161.

Nurmalasari, Afni, M., Risna, Surianti, Diana. 2020. Analisis proksimat karbon aktif limbah serat sagu teraktivasi KOH. *Cokroaminoto Journal of Chemica Science*. 2 (1), 18-20.

Pelin, O., Ceren, D., Hakan, D., Ugur, M., Salim, E., Canan, S., Derya, Y., Ilknur, D. 2022. Activated carbons prepared from hazelnut shell waste by phosphoric acid activation for supercapacitor electrode applications and comprehensive electrochemical analysis. *Renew. Energy*. 189, 535-548. https://doi.org/10.1016/j.renene.2022.02.126.

Riki, R. 2017. Kajian etnobotani bambu mayan (*Gigantochloa robusta* Kurz) di kecamatan sobang pandeglang banten. *Scientiae Educatia: Jurnal Pendidikan Sains. 6* (1). 54-

61. http://dx.doi.org/10.24235/sc.educatia.v6i1.1298.

Rizka, A.F.L., Hafni, I.N., Moondra, Z. 2020. Production of Activated Carbon from Natural Sources for Water Purification. *IJCST-UNIMED*. *3*(2). 67-73.

Samah, Z.N, Ching, T.T. 2022. A review of the synthesis of activated carbon for biodiesel production: Precursor, preparation, and modification. *Energy. Convers. Manag*. 13(100152), 1-15. https://doi.org/10.1016/j.ecmx.2021.100152.

Sari, W., Savitri, Firda, M., Muhammad, A., Lindawati. 2021. The application of goat bone waste activated charcoal as manganese heavy metal absorbent in borehole water. *Journal of Islamic Science and Technology*. 7 (2), 328-340. 10.22373/ekw.v7i2.9586.

Sarifah, M., Sahrul, H., Risdana. 2021. Analisis proksimat karbon kulit kemiri (aleurites moluccana) dengan variasi suhu karbonisasi. *Jurnal Ilmu dan Inovasi Fisika*. 5 (2), 157-163. https://doi.org/10.24198/jiif.v5i2.35056.

Shinta, A., Wahyudi, B.S., Imam, P., Teguh, A. 2017. Degradasi limbah zat warna dengan katalis karbon aktif teremban oksida besi. Prosiding SNST ke-8 2017 Fakultas Teknik Universitas Wahid Hasyim Semarang, ISBN: 978-602-99334-7-5, 24-29.

Soremo, L.E., Mridushmita, B., Aola, S., Shisak, S., Dipak, S. 2022. Experimental and theoretical insight into the adsorption of 2,4-dichlorophenol on low-cost bamboo sheath activated carbon. *Sustain. Chem. Pharm*. 26, 100643. https://doi.org/10.1016/j.scp.2022.100643.

Iwan, S.S., Nanda, D.S., Yoki, Y., Yogi, N.P. 2020. Synthesis of CdS nanocrystalline using Parkia speciosa Hassk seeds extract: Optic, Structure, and Morphology. Seminar Nasional Sains (SINASIS), 7 (1).

Standar Nasional Indonesia, Arang Aktif Teknis, Badan Standar Nasional Indonesia (SNI: 06-3730-1995).

Iwan, S.S., Yoki, Y., Sudirman. 2018. Effect of Concentration of Imperata cylindrica Lleaf extract on synthesis process of gold nanoparticles. *Indonesian Journal of Materials Science*. 19 (2), 72-76.

Wenxuan, T., Fang, H., Lihui, C., Hui, W., Xiangxing, Z. 2022. Methylene blue enhanced bamboo activated carbon as high performance supercapacitor electrode materials. *Ind. Crops. Prod*. 180, 114786. https://doi.org/10.1016/j.indcrop.2022.114786.

Yuan, G., Qing, W., Guozhao, J., Aimin, L. 2022. Degradation of antibiotic pollutants by persulfate activated with various carbon materials. *Chem. Eng. J*. 429, 132387. https://doi.org/10.1016/j.cej.2021.132387.

Zohreh, K., Ahad, G. 2022. Presence of activated carbon particles from waste walnut shell as a biosorbent in monoethanolamine (MEA) solution to enhance carbon dioxide absorption. *Heliyon*. 8 (1), 08689. https://doi.org/10.1016/j.heliyon.2021.e08689.