

Synthesis And Characterization Of Acid-Activated Sago Dregs Biochar And Testing Its Ability As An Adsorbent For Rhodamine B Dyes

Sintesis Dan Karakterisasi *Biochar* Ampas Sagu Teraktivasi Asam Serta Uji Kemampuannya Sebagai Adsorben Zat Warna *Rhodamine B*

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ABSTRACT

Synthesis & characterization of acid-activated sago pulp biochar as an adsorbent of rhodamine B dye has been carried out. This study aims to synthesize & characterize sago pulp biochar activated with HCl 1 M & H₃PO₄ 0,214 M solutions & to assess its ability as an adsorbent of rhodamine B dye. This biochar is produced through a pyrolysis method with a combustion temperature of 700 °C for 2 hours. The results of the pyrolysis biochar were then activated with HCl 1 M & H₃PO₄ 0,214 M acid solvents & then analyzed the effect of contact time, pH, & initial concentration on its ability to adsorb rhodamine B dye. Characterization using Fourier Infrared (FTIR) showed the presence of alkene groups & aromatic groups (C=C) & bonds (C–O) & (C–C) which play an important role in the adsorption process. The results of the water content of BAS, BAS/HCl & BAS/H₃PO₄ produced were 2.57%, 4.47% & 5.06% which met the requirements of SNI 06-3730-1995. The results of the surface area test showed BAS/H₃PO₄ with the largest surface area of 0,520 m²/g & BAS of 0,452 m²/g while the smallest surface area was BAS/HCl of 0,445 m²/g. The study of the effect of pH & contact time on the adsorption capacity of rhodamine B showed that the optimum adsorption capacity of pure sago pulp biochar (BAS) at neutral pH with a contact time of 15 minutes, BAS/HCl at acidic pH with a contact time of 180 minutes, & BAS/H₃PO₄ at alkaline pH with a contact time of 60 minutes. Based on the analysis results, the adsorption process of rhodamine B on biochar follows the Langmuir & Freundlich isotherms with maximum adsorption capacities for BAS, BAS/HCl, & BAS/H₃PO₄ of 4.285 mg/g, 4.834 mg/g, & 3.934 mg/g, respectively.

Keywords: biochar, sago pulp, adsorption, rhodamine B

ABSTRAK

Sintesis dan karakterisasi biochar ampas sagu teraktivasi asam serta uji kemampuannya sebagai adsorben zat warna rhodamine B telah dilakukan. Penelitian ini bertujuan untuk mensintesis dan mengkarakterisasi biochar ampas sagu yang diaktivasi dengan larutan HCl 1 M dan H₃PO₄ 0,214 M serta mengkaji kemampuannya sebagai adsorben zat warna rhodamine B. Biochar dihasilkan melalui metode pirolisis dengan suhu pembakaran 700 °C selama 2 jam. Hasil biochar pirolisis kemudian diaktivasi dengan pelarut asam HCl 1 M

dan H_3PO_4 0,214 M kemudian di analisis pengaruh waktu kontak, pH, dan konsentrasi awal terhadap kemampuannya dalam mengadsorpsi zat warna rhodamine B. Karakterisasi menggunakan Fourier Infrared (FTIR) menunjukkan adanya gugus alkena dan gugus aromatik ($C=C$), ikatan ($C-O$) dan ($C-C$) yang berperan penting dalam proses adsorpsi. Hasil analisis kadar air BAS, BAS/HCl dan BAS/ H_3PO_4 berturut-turut sebesar 2,57%, 4,47% dan 5,06% (telah memenuhi syarat SNI 06-3730-1995). Hasil uji adsorpsi dengan menggunakan metilen biru menunjukkan bahwa BAS/ H_3PO_4 memiliki luas permukaan paling besar yaitu 0,520 m^2/g dan BAS sebesar 0,452 m^2/g sedangkan luas permukaan paling kecil yaitu BAS/HCl sebesar 0,445 m^2/g . Kajian pengaruh pH dan waktu kontak terhadap kemampuan adsorpsi rhodamine B menunjukkan bahwa kemampuan adsorpsi optimum biochar ampas sago murni (BAS) pada pH netral dengan waktu kontak 15 menit, BAS/HCl pada pH asam dengan waktu kontak 180 menit, dan BAS/ H_3PO_4 pada pH basa dengan waktu kontak 60 menit. Berdasarkan hasil analisis, proses adsorpsi rhodamine B pada biochar mengikuti isoterm Langmuir dan Freundlich dengan kapasitas adsorpsi maksimum untuk BAS, BAS/HCl, dan BAS/ H_3PO_4 berturut-turut sebesar 4,285 mg/g, 4,834 mg/g, dan 3,934 mg/g.

Kata kunci: biochar, ampas sago, adsorpsi, rhodamine B.

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1. INTRODUCTION

Water pollution is a major problem with serious implications for human life and ecosystems. Water pollution caused by dyes, especially Rhodamine B, is one of the most urgent environmental problems to be addressed. Rhodamine B is a synthetic dye that is widely used in the textile industry and has carcinogenic and toxic properties, so it can have a serious impact on human health and aquatic ecosystems (Mahardiani et al., 2024). Waste containing Rhodamine B are often discharged into the environment without adequate treatment, resulting in the accumulation of this hazardous substance in the environment. Therefore, an effective and environmentally friendly method to remove the dye is needed.

An interesting approach to dye wastewater treatment is the use of biochar-based adsorbents in the adsorption process. Biochar is a carbon material obtained from the pyrolysis of biomass at high temperatures under low oxygen conditions, such as wood and fibers (Rusdi et al., 2023). Biochar from sago pulp has the potential to be a sustainable solution in waste management because it can be activated with acid solvents to increase its adsorption capacity. The activation

process of biochar aims to increase the surface area and add active functional groups to its surface. Activation with acids, such as HCl and H_3PO_4 , has been shown to increase the surface area and adsorption capacity of biochar, resulting in a higher adsorption capacity of biochar.

Pemakuan village, located in Sungai Tabuk subdistrict, Banjar Regency, South Kalimantan, is the center of the sago industry, which produces large amounts of sago pulp waste. Only about 48% of the starch can be extracted, while the rest is in the form of pulp that is not optimally utilized (Istikowati et al., 2021). Sago pulp is a by-product of the sago starch production process that has the potential to be processed into biochar, thus contributing to waste management and environmental sustainability (Witno et al., 2024). Based on this, it is necessary to study the synthesis and characterization of biochar from acid-activated sago pulp as a Rhodamine B dye adsorbent. The characterization of biochar was studied based on the analysis of functional groups, water content, and surface area. The efficiency of biochar as a rhodamine B adsorbent was investigated by studying the effect of contact time, pH effect, and initial rhodamine B concentration.

The data of this study were obtained from rhodamine B dye dissolved in water to simulate industrial wastewater and biochar produced by pyrolyzing sago pulp collected from Pemakuan village area located in Sungai Tabuk subdistrict, Banjar Regency, South Kalimantan. Biochar characterization was carried out using Fourier Transform Infrared (FTIR) to analyze functional groups. Moisture content analysis was performed using the gravimetric method based on the Indonesian National Standard (SNI) 06-3730-1995. Measurement of absorbance method of the solution was measured using UV-Vis spectrophotometer. Testing the adsorption contact time was done by mixing biochar with 20 ppm Rhodamine B solution at different time intervals, and the absorbance of the filtrate was measured to determine the effectiveness of adsorption. To test the effect of pH on adsorption, rhodamine B solution was used at acidic, neutral and alkaline pH. Then, the adsorption test was carried out with variations in the initial concentration of Rhodamine B solution to determine the adsorption capacity of biochar.

2. MATERIALS AND METHODS

2.1. Materials

The tools used in this research are digital analytical balance (Ohaus), glassware such as goblet glass, watch glass, porcelain cup, glass spoon, glass stirrer, Erlenmeyer, volumetric flask, dropper, volume pipette, desiccator, funnel, glass bottle, spray bottle, shaker (GKL 3005), pH meter, oven; pyrolysis and analytical equipment such as FTIR Spectrophotometer (Shimadzu 8201PC) and UV-Vis Spectrophotometer (Genesys 10v, Thermo Scientific). The materials used in this research are sago pulp biochar with particle size <100 μm , HCl, H_3PO_4 , NaOH, Rhodamine B, Methylene Blue, aluminum foil, distilled water and Whatman No. 42 filter paper.

2.2. Methods

This research was conducted at the Laboratory of Enzyme Technology and Biomaterials, Faculty of Mathematics and Natural Sciences, Lambung Mangkurat University Banjarbaru. The preparation of biochar samples using pyrolysis tools was carried out at the Banjarbaru Standardization and Industrial Services Center (BSPJI), the measurement of sample solutions using UV-Vis spectrophotometer was carried out at the Instrument Laboratory of the Faculty of Mathematics and Natural Sciences Banjarbaru, and the identification of sample functional groups using FTIR spectrophotometer was carried out at the Physics Laboratory of the Faculty of Mathematics and Natural Sciences, Lambung Mangkurat University Banjarbaru.

2.2.1 Preparation of Sago Dregs Biochar

The first step taken in this research is to make sago pulp biochar. Making biochar requires the main raw material, namely sago pulp that has been washed and dried until it is free from contaminants. Sago pulp was burned using a pyrolysis tool at 700 $^{\circ}\text{C}$ for 2 hours. A total of 20 grams of sago pulp biochar was then activated by soaking in acid solvents, namely HCl 1 M and H_3PO_4 0.214 M with 500 mL each for 48 hours. After soaking the biochar for 48 hours, the biochar is filtered using filter paper and rinsed with distilled water until the pH is neutral. The neutral sample was then oven dried at 105 $^{\circ}\text{C}$ until constant weight. The resulting sago pulp biochar is then referred to as BAS, and biochar activated with 1 M HCl and 0.214 M H_3PO_4 is then referred to as BAS/HCl and BAS/ H_3PO_4 .

2.2.2 Moisture content test

A total of 1 gram of sago pulp biochar is put into a porcelain cup that has known weight. The calculation of water content was carried out based on the Indonesian National Standard (SNI) 06-3730-1995 by weighing the weight of the empty

container and weighing the filter paper before use. The cup containing the sample was heated in an oven at 105 °C until constant weight, then cooled in a desiccator, then weighed. The same thing was done repeatedly until the weight was constant.

2.2.3 Surface area measurement

Surface area measurement was conducted using UV-Vis spectrophotometer. Samples of BAS, BAS/HCl and BAS/H₃PO₄ biochar were weighed as much as 0.1 g and then each was added to 20 mL of 100 ppm methylene blue solution. The mixture was shaken for 40 minutes. The solution was filtered and then the filtrate was measured for absorbance using a UV-Vis spectrophotometer. Methylene blue standard solutions with concentrations of 2, 3, 4, 5, and 6 ppm were prepared first to obtain the maximum wavelength and standard curve.

2.2.4 Determination of the optimum wavelength (λ) of Rhodamine B using UV-Vis Spectrophotometer

Rhodamine B solution with a concentration of 3 ppm was prepared, then the optimum wavelength was determined by measuring the absorbance of the solution at a wavelength (λ) of 400-700 nm. The wavelength (λ) that gives the maximum absorbance is recorded as the λ_{max} . Measurements were carried out using a UV-Vis spectrophotometer.

2.2.5 Preparation of Rhodamine B standard curve

Make and prepare rhodamine B solution with concentrations of 1.5; 2; 2.5; 3 and 3.5 ppm. Each solution was measured for absorbance using UV-Vis Spectrophotometer with a maximum wavelength (λ) of 552 nm.

2.2.6 Effect of Rhodamine B adsorption contact time on biochar

Weigh each sago pulp biochar (BAS, BAS/HCl and BAS/H₃PO₄) as much as 0.5 g, then put into Erlenmeyer. A total of 50 mL of 20 ppm rhodamine B solution was put into an Erlenmeyer

that already contained sago pulp biochar. The sample was then shaken using a shaker at 120 rpm for 5, 15, 30, 60, 120 and 180 minutes. The sample was then separated by filtering the filtrate using Whatman filter paper no.42 and measured the absorbance using a UV-Vis spectrophotometer.

2.2.7 Effect of pH on the ability of biochar to adsorb Rhodamine B dye

Making a 20 ppm rhodamine B solution with acidic, neutral and alkaline pH variations. Making a pH solution is done by adding HCl to lower the pH and NaOH solution to raise the pH of the solution. Weigh each sago pulp biochar (BAS, BAS/HCl, and BAS/H₃PO₄) as much as 0.5 g, then put into an Erlenmeyer. A total of 50 mL of 20 ppm rhodamine B solution was put into the Erlenmeyer which already contained sago pulp biochar. The sample was then shaken using a shaker at 120 rpm for different times, namely 15 minutes (BAS) 60 minutes (BAS/H₃PO₄) and 180 minutes (BAS/HCl), this was adjusted to the optimum adsorption time in the contact time analysis. The sample was then separated by filtering the filtrate using Whatman no.42 filter paper and measured the absorbance using a UV-Vis Spectrophotometer.

2.2.8 Effect of rhodamine B adsorption capacity on biochar

Rhodamine B solution with concentration variations of 10, 20, 30, 40, 50 and 60 ppm were prepared by diluting the 1000 ppm rhodamine B mother solution. The pH value of each solution is set at the optimum pH analysis. A total of 0.1 grams of BAS, BAS/HCl, and BAS/H₃PO₄ samples were weighed using an analytical balance and put into each Erlenmeyer. Each Erlenmeyer containing the sample was put 50 mL of rhodamine B solution into each Erlenmeyer. The mixture in the Erlenmeyer was shaken using a shaker at a speed of 120 rpm at various times, namely 15 minutes (BAS), 60 minutes (BAS/H₃PO₄) and 180 minutes (BAS/HCl). The sample was then filtered, and the filtrate was

separated using Whatman No. 42 filter paper, then the absorbance was measured using a UV-Vis spectrophotometer.

2.2.8 Moisture content

Determination of biochar moisture content is done by measuring mass changes before and after drying using analytical scales. The data obtained in the form of mass before and after drying, which is then processed using Microsoft Excel to calculate the percent (%) of water content in biochar. The calculation of moisture content uses the following equation:

$$\text{Moisture content \%} = \frac{\text{Initial-Final}}{\text{Initial}} \times 100\%$$

Description:

Initial: weight before heating (g)

Final: weight after heating (g)

2.2.9 Biochar surface area

The surface area of biochar was determined from the amount of methylene blue adsorbed, using the equation:

$$S = \frac{\frac{Ca}{m} \times N \times a}{M}$$

Where,

S = adsorbent surface area (m²/g)

Ca = amount of adsorbed dye (mg)

m = weight of adsorbent (g)

N = avogadro number (6.02 x 10²³ particles/mol)

a = size of 1 molecule of methylene blue adsorbate (197 x 10⁻²⁰)

M = molecular weight of methylene blue (320.5 g/mol)

2.2.10 Adsorption of dyes

The process of dye adsorption by biochar was analyzed using a UV-Vis Spectrophotometer at a wavelength of 552 nm. The measurement results

are in the form of absorbance values which will be converted using Microsoft Excel into concentration values and to determine the percent (%) concentration of dyes absorbed by the archite composite. The following calculations were carried out in this study:

$$Ca = Co - Ce$$

Where,

Ca = Concentration of absorbed substances (ppm)

Co = Initial concentration of solution (ppm)

Ce = Residual concentration of dye (ppm)

Determination of the percentage value of dye adsorption on the adsorbent:

$$(\%) \text{ adsorption} = \frac{Ca}{Co} \times 100\%$$

Data obtained based on parameters such as contact time and optimum pH were made in the form of graphs of the relationship between the percentage of dye adsorption with contact time and the percentage of dye adsorption with optimum pH.

The results of the analysis in procedure 3.5.3 were plotted into the Langmuir (1, 2 and 3) and Freundlich (1, 2 and 3) adsorption isotherm equation graphs to determine the adsorption model on biochar by comparing the greater linearity between the two. The Langmuir isotherm equation graph plots the relationship between Ce/qe and Ce, while the Freundlich equation is the relationship between log qe and log Ce so that a linear equation will be obtained from the two graphs. The optimum adsorption capacity of rhodamine B on biochar (q_{max}) can be obtained from the slope obtained on the plot of Ce/qe against Ce in the Langmuir isotherm equation. Determination of the amount of adsorbate adsorbed:

$$q_c = \frac{Ca(\frac{v}{1000})}{m}$$

Where,

q_e = amount of adsorbed substance (mg/g)

v = volume of solution (mL)

m = mass of adsorbent (g)

3. RESULTS AND DISCUSSION

3.1 Preparation and Manufacture of Sago Dreg Biochar

The main raw material for making biochar in this study is sago pulp. The sago pulp was first washed and dried to be free from contaminants, then burned by pyrolysis method at a temperature of 700 °C for 2 hours. Pyrolysis is the chemical decomposition of organic materials through a heating process, where the raw material will undergo chemical structural breakdown. This process is a decomposition process through

heating with a very limited amount of oxygen (Caturwati et al., 2015). The working principle of pyrolysis involves the decomposition of organic materials through heating at high temperatures in conditions without oxygen or with very limited oxygen. The process starts with drying the material to remove moisture at temperatures below 200 °C. After that, the organic material is further heated to about 200-300 °C, where the decomposition of complex molecules into simpler compounds begins, and light gases are released. Pyrolysis at 300-700 °C causes organic polymer chains to be broken down into gases, liquids, and solids (Herlambang et al., 2020). **Figure 1** is the result of sago pulp biochar before pyrolysis and sago pulp biochar after pyrolysis.

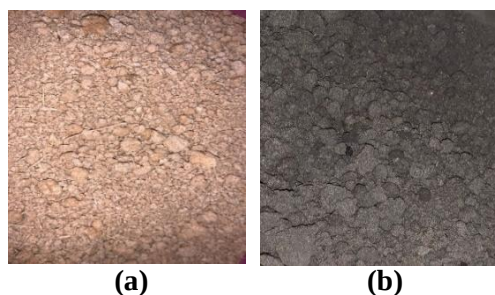


Figure 1. Sago bagasse biochar before pyrolysis (a) and after pyrolysis (b)

In this study, biochar was activated with acid solutions, namely HCl and H₃PO₄. According to research by Arung et al., (2014), hydrochloric acid (HCl) is used as a biochar activator, because hydrochloric acid (HCl) can dissolve impurities so that more pores are formed and the adsorbate absorption process will become more and the selection of H₃PO₄ as an activator because it has thermal stability and can make biochar surface pores more, this is supported by research (Eso, 2021).

3.2 Characterization of sago pulp biochar functional groups using Fourier Transform Infrared (FTIR)

Characterization of biochar functional groups using an FTIR spectrophotometer is carried out to identify functional groups present in biochar. FTIR analysis can accurately identify functional groups present in biochar, such as aromatic rings, alcohols, ethers, carboxylic acids, and esters. This is important because functional groups provide information about the chemical structure and properties of biochar (Hidayat, 2021). The following are the results of the FTIR spectra analysis of BAS, BAS/HCl, and BAS/H₃PO₄ show in **Figure 2** and **Table 1**.

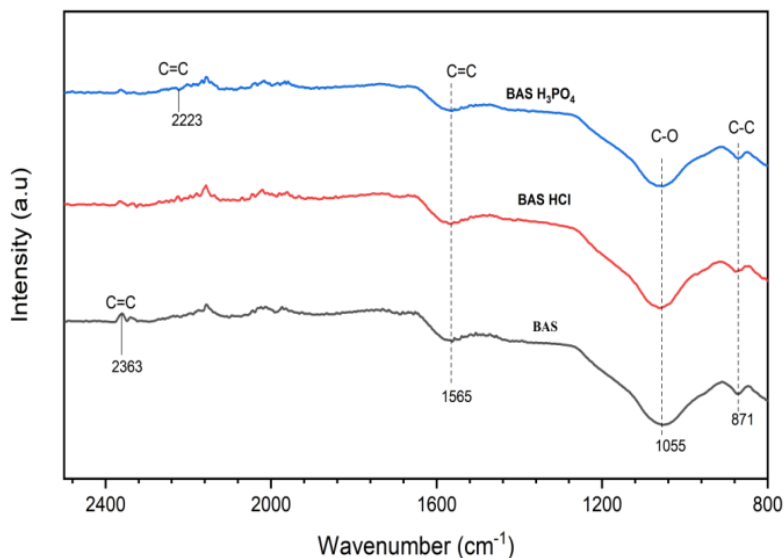


Figure 2. Spectra IR BAS, BAS/HCl, and BAS/H₃PO₄

Tabel 1. Functional groups identification of BAS, BAS/HCl dan BAS/H₃PO₄.

BAS (cm ⁻¹)	BAS HCl (cm ⁻¹)	BAS H ₃ PO ₄ (cm ⁻¹)	Reference Wavelength (cm ⁻¹)	Functional Group (cm ⁻¹)
2363		2223	2380-2260	C=C alkene
1565	1565	1565	1540-1640	C=C aromatik
1055	1055	1055	1000-1350	Stretching C—O
871	871	871	666-909	Stretching C—C

Figure 2 shows the results of the FTIR spectra of BAS, BAS/HCl and BAS/H₃PO₄ informing that there are absorption peaks that appear at several wave numbers. The absorption at wave number 2223 cm⁻¹ in the BAS/H₃PO₄ sample and wave number 2363 cm⁻¹ in the BAS sample, the results of the two samples are in the range of wave numbers 2260-2380 cm⁻¹ which is the absorption of aromatic groups (C=C). Absorption at wave number 1565 cm⁻¹ as absorption of aromatic groups (C=C) in BAS/HCl (Sartika et al., 2014). Absorption at wave number 1055 cm⁻¹ is a stretching vibration (C—O) (Andiani et al., 2022). The absorption at wave number 871 cm⁻¹ is a stretching vibration (C—C) (Deswardani et al., 2020). Based on the spectra results, there are several shifts at wave numbers 2400 to 800 cm⁻¹

which may be due to the delocalization of double bonds or the occurrence of addition reactions by acid solutions during biochar activation. Activation with acid solutions such as HCl or H₃PO₄ can cause addition reactions, where acid molecules interact with biochar this can produce new bonds such as stretching vibrations.

3.2 Determination of Moisture Content

Determination of water content was carried out by gravimetric method. A total of 1 g of sago pulp biochar is put into a porcelain cup that has known weight. The calculation of water content refers to the Indonesian National Standard (SNI) 06-3730-1995) The value of moisture content shows in Figure 3.

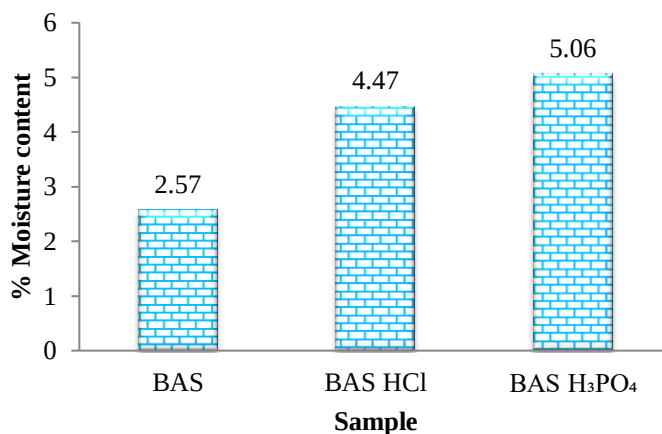


Figure 3. Moisture content value of BAS, BAS/HCl dan BAS/H₃PO₄

Figure 3 shows that activation can increase the water content contained in biochar. Verayana & Iyabu (2018), mentioned that activation with HCl and H₃PO₄ produced biochar with better porosity. Activation with acid solvents can interact with polar functional groups present on the biochar surface. This interaction allows the formation of hydrogen bonds between water molecules. The strong force of attraction between water molecules and atoms that have positive or negative partial charges, thus increasing the ability of biochar to hold moisture and allowing

more water molecules to bond to biochar (Tungadi, 2020). Based on the above data, the moisture content in biochar and activated biochar has met the requirements of SNI 06-3730-1995.

3.3 Surface Area

Determination of biochar surface area using methylene blue adsorption method with a wavelength (λ) of 640 nm. This method is the same as that done by Utomo et al. 2019. The results of the biochar surface area analysis can be seen in **Figure 4**.

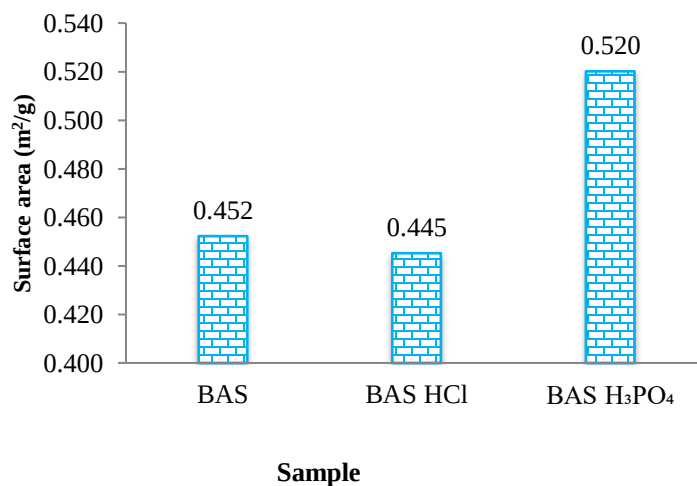


Figure 4. Surface area of biochar

Figure 4 shows that activation with H₃PO₄ can increase the surface area of biochar. There are

three processes that occur during activation with H₃PO₄, namely (1) the opening of previously

closed pores, (2) the opening of new pores, and (3) the expansion of existing pores (Harlianingtyas et al., 2023). Some of these things cause the surface area to increase. This increase in surface area corresponds to the increase in water content in H_3PO_4 -activated biochar. **Figure 4** also shows a decrease in the surface area of biochar activated with HCl. This can occur because HCl is classified as a strong acid that can cause decomposition in biochar organic matter resulting in damage to the biochar structure (Sulistyorini, 2015).

3.4 Effect of contact time on adsorption of rhodamine B on BAS

The effect of contact time in the adsorption process of rhodamine B dye on biochar is an important aspect in studying adsorption

efficiency. The contact time test involves the adsorption process between adsorbent and adsorbate. Analysis of the effect of contact time aims to determine the length of time needed to adsorb the solution until it reaches equilibrium. Adsorption equilibrium is reached when the amount of substance adsorbed on the surface of the adsorbent is saturated so that it becomes constant, which means that there is no longer a change in the concentration of solute in solution or on the surface of the adsorbent (Atok et al., 2024). Analysis of the effect of contact time on rhodamine B adsorption on each type of biochar (BAS, BAS/HCl and BAS/ H_3PO_4) was carried out at a variety of contact times, namely 5, 15, 30, 60, 120 and 180 minutes. The results are shown in **Figure 5**.

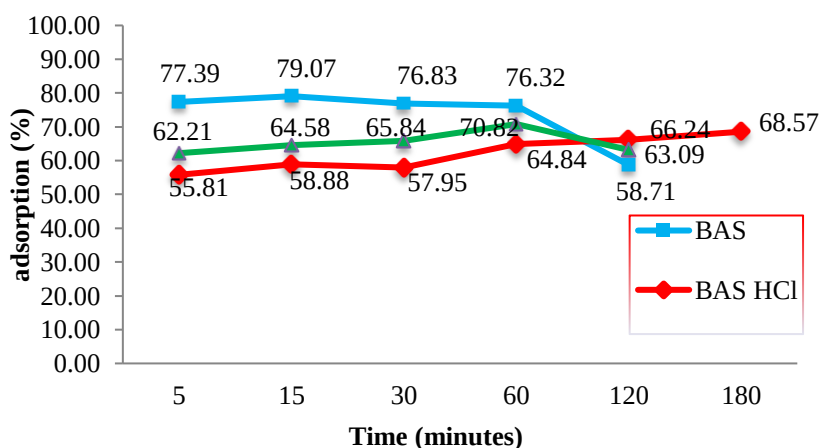


Figure 5. Relationship between contact time and percentage adsorption of rhodamine B dye on biochar

Figure 5 shows that the high percentage of adsorption is influenced by the type of sago pulp biochar and contact time until it reaches equilibrium time. The results showed that the optimum adsorption ability of BAS was 79.07% with a contact time of 15 minutes, BAS/HCl was 68.57% with a contact time of 180 minutes and BAS/ H_3PO_4 was 70.82% with a contact time of 60 minutes. These results indicate that the adsorbent has reached saturation point.

Adsorption equilibrium is a condition in which all active sites on the adsorbent surface have been filled by the adsorbate, so that the adsorption state has reached a maximum or saturation point. After the equilibrium time is reached, there is no more significant increase because the adsorbent surface is saturated with dyes that form a layer so that it covers the adsorbent layer (Kurniawati & Indriyanti, 2021).

Based on the curve in **Figure 5**, too long contact time can cause a decrease in adsorption on BAS and BAS/H₃PO₄, this can occur because the adsorbate can be released back into the solution which indicates the type of interaction between the adsorbent and the adsorbate occurs physically (Aisyahlika et al., 2018). Unlike the case with BAS/HCl, up to 180 minutes there is still an increase in the percentage of adsorption, which indicates that the interaction that occurs between the adsorbent and adsorbate is more stable.

3.5 Effect of pH on the ability of BAS to adsorb rhodamine B dye

The degree of acidity or pH value is a variable that can determine the performance and interaction

between compounds. The pH condition in the adsorption process can affect the charge of the adsorbent (biochar) and the adsorbed compound (rhodamine B) in the solution which affects the type of adsorption interaction that occurs. The following is the alleged structure of rhodamine B under various pH conditions, as follows:

In this experiment, the pH variation of rhodamine B dye solution was carried out in acidic (2.92), neutral (7.00), and alkaline (9.71) conditions. The solution before and after adsorption was measured absorbance with UV-Vis spectrophotometer with a wavelength of 552 nm. The results of the study are shown in **Figure 6**.

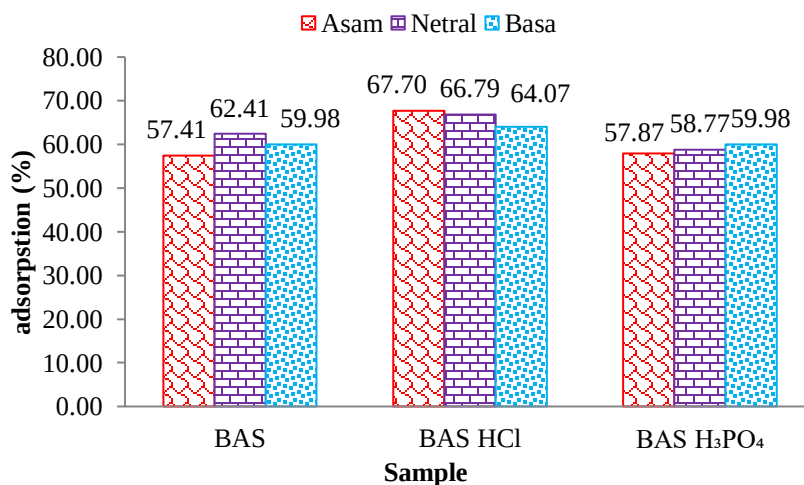


Figure 6. the effect of pH on the adsorption ability of rhodamine B on sago pulp biochar

Based on **Figure 6**, the adsorption percentage of BAS is optimum at neutral pH with adsorption ability of 62.41%, BAS/HCl is optimum at acidic pH with adsorption ability of 67.70% and BAS/H₃PO₄ is optimum at alkaline pH with adsorption ability of 59.98%. However, based on **Figure 6**, the pH of the solution does not have a significant effect on the adsorption ability of biochar.

3.6 Effect of initial concentration of rhodamine B solution on biochar adsorption capacity

Analysis of the effect of initial concentration aims to determine the amount of rhodamine B dye that can be adsorbed on each gram of sago pulp biochar. This analysis was carried out by contacting biochar of 0.1 g BAS, BAS/HCl, and BAS/H₃PO₄ into a solution of rhodamine B dye with a concentration variation of 10, 20, 30, 40, 50 and 60 ppm. The data in **Table 2** shows the amount of rhodamine B absorbed by each gram.

Table 2. The effect of initial concentration of rhodamine B towards biochar adsorption capacity

Variasi konsentrasi <i>rhodamine B</i> (ppm)	BAS (mg/g)	BAS/HCl (mg/g)	BAS/H ₃ PO ₄ (mg/g)
10	0,370	0,536	0,806
20	0,318	1,327	0,787
30	1,730	2,630	1,493
40	1,588	3,483	2,109
50	4,265	4,834	3,934
60	0,474	0,995	0,00066

Based on **Table 2**, the initial concentration of rhodamine B solution affects the amount of dye adsorbed on biochar. The higher the initial concentration, the higher the amount of dye adsorbed on biochar up to the initial concentration of 50 ppm. The higher initial concentration causes more rhodamine B molecules in the solution thus triggering a higher adsorption rate, because more rhodamine B molecules are encouraged to move to the biochar surface and occupy active sites on the biochar surface until it reaches the adsorption equilibrium point. However, if the initial concentration exceeds 50 ppm (past the adsorption equilibrium point) there is a decrease in adsorption. This can be caused by rhodamine B molecules that are crowded and interact with each other, thus forming larger aggregates. This interaction will inhibit and slow down the rate of dye diffusion into the biochar pore. Sulistyaningsih, (2021) reported that adding more adsorbate (rhodamine B) will not increase the amount adsorbed, which explains that adsorption has reached a saturation point. The surface of the adsorbent that has been completely filled by rhodamine B molecules and the addition of a high concentration amount will cause desorption, where molecules that have been bound to the surface of the adsorbent will again release or return to the solution, this is supported by research (Agustina et al., 2022).

In this study, the adsorption capacity of BAS, BAS/HCl, BAS/H₃PO₄ reached 4.285 mg/g, 4.834 mg/g, and 3.934 mg/g, respectively. This result does not correspond to the surface area of the absorbent. BAS/H₃PO₄ has the highest surface area, but its adsorption capacity is smaller than BAS without activation. This indicates that activation with H₃PO₄ can produce large porosity with very small pores so that dye molecules with larger molecules cannot be absorbed into the pores. BAS/HCl has a lower surface area, but greater adsorption capacity than biochar without activation. This can be caused by activation with HCl to produce larger pores so that dyes with large molecules can be adsorbed to the adsorbent surface.

The results of Langmuir and Freundlich isotherm adsorption plots of rhodamine B dye on BAS, BAS/HCl and BAS/H₃PO₄ can be seen in **Figures 6**, **Figure 7**, and **Figure 8** below.

The isotherm plot results in **Figure 6** show that the adsorption of rhodamine B on BAS more closely follows the Freundlich isotherm. The isotherm plot results in **Figures 7** and **Figure 8** show that the adsorption of rhodamine B on HCl and H₃PO₄ activated biochar more closely follows the Langmuir isotherm. The Langmuir adsorption isotherm model assumes that the dye only forms a single layer (monolayer) on a homogeneous adsorbent surface. In contrast, the Freundlich adsorption isotherm assumes that additional absorption occurs in the dye layer above the adsorbent surface (multilayer). An illustration of the Langmuir and Freundlich isotherms is shown in **Figure 9**.

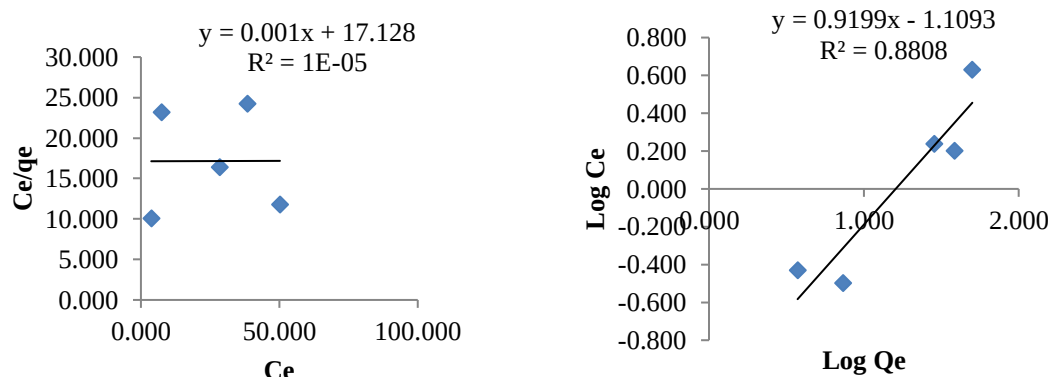


Figure 6. Isotherm plots of (a) Langmuir and (b) Freundlich BAS/against rhodamine B

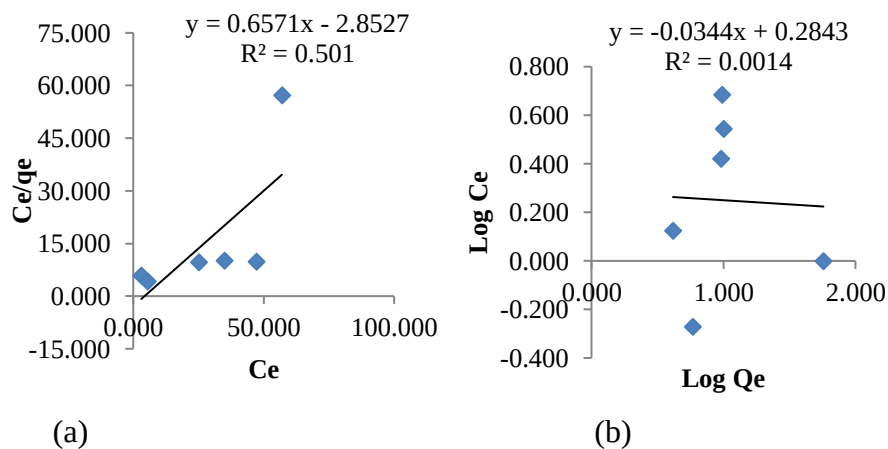


Figure 7. Isotherm plots (a) Langmuir and (b) Freundlich BAS/HCl against rhodamine B

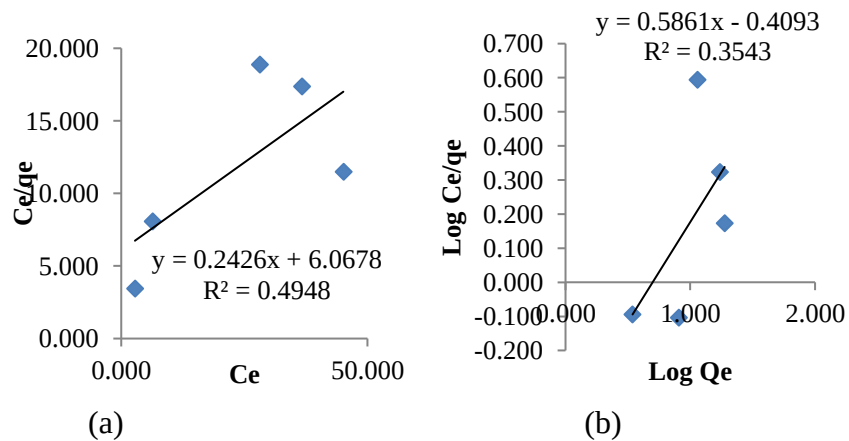


Figure 8. Isotherm plots (a) Langmuir and (b) Freundlich BAS/ H_3PO_4 against rhodamine B

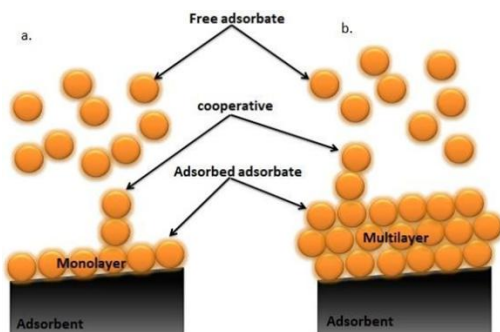


Figure 9. (a) Illustration of the Langmuir adsorption isotherm (b) Illustration of the Freundlich adsorption isotherm (Maryanti et al., 2020).

4. CONCLUSIONS

The conclusion of this research shows that the FTIR spectra of sago dregs biochar shows the presence of functional group absorption peaks from sago dregs as an adsorbent, namely the aromatic ring structure (C=C) and C–O bonds and C–C bonds. The water content of BAS, BAS/HCl, and BAS/H₃PO₄ respectively was 2.57; 4.47; and 5.06% which fulfilled the requirements of SNI 06-3730-1995. The results of surface area analysis show that BAS/H₃PO₄ has the largest surface area, namely 0.520 m²/g and BAS of 0.452 m²/g, while the smallest surface area is BAS/HCl of 0.445 m²/g. The longer the contact time, the greater the adsorption percentage until it reaches equilibrium. BAS reaches optimum at a contact time of 15 minutes with an adsorption percentage of 79.07%, BAS/HCl reaches optimum at a contact time of 180 minutes with an adsorption percentage of 68.57%, and BAS/H₃PO₄ reaches optimum at a contact time of 60 minutes with an adsorption percentage amounting to 70.82%. The optimum adsorption of rhodamine B on BAS occurs at neutral pH with a percentage of 62.41%, BAS/HCl occurs at acidic pH with a percentage of 67.70%, and BAS/H₃PO₄ occurs at alkaline pH with a percentage of 59.98%. The adsorption capacity of biochar without

activation reached 4.285 mg/g. The adsorption capacity increased in HCl-activated biochar with an adsorption capacity reaching 4.834 mg/g, while H₃PO₄-activated biochar experienced a decrease in adsorption capacity with an adsorption capacity of 3.934 mg/g.

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