



## Utilization of *Borrassus flabellifer* L. Palm Coir Activated with Potassium Hydroxide (KOH) as an Efficient Adsorbent for Rhodamine B Dye Removal

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### Abstract

This research paper presents the preparation and characterization of activated charcoal derived from palm coir (*Borrassus flabellifer* L.) that was activated using potassium hydroxide (KOH). The objective of this study was to assess the key characteristics of the activated charcoal, including moisture content, ash content, and surface area, and to determine the optimal conditions for the adsorption process of Rhodamine B dyes, such as adsorbent mass, contact time, and adsorbate concentration. Additionally, the surface morphology of coir charcoal before and after activation was investigated. The carbonization process was conducted at 300°C for 30 minutes, followed by activation using 1 M KOH for 24 hours. The resulting activated charcoal was subjected to various characterization techniques, including moisture content and ash content analysis, surface morphology examination using scanning electron microscopy (SEM), surface area determination using the Brenauer-Emmet-Teller (BET) method, and functional group identification through Fourier-Transform Infra Red (FTIR) spectroscopy. The findings revealed that the activated charcoal exhibited a water content of 1.537%, an ash content of 16.653%, and a surface area of 36.084 m<sup>2</sup>/g. The optimal conditions for the adsorption process were determined as follows: 1.0 gram of activated charcoal mass, 30 minutes of contact time, and a rhodamine B concentration of 30 ppm, resulting in adsorption efficiencies of 94.46%, 95.75%, and 94.42%, respectively. Furthermore, the surface morphology analysis demonstrated that non-activated charcoal exhibited irregular particle sizes and small pore sizes, while KOH-activated charcoal displayed an enhanced carbon pore surface and larger pore sizes.

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## INTRODUCTION

Pollution can occur in various environments, both air, soil and water caused by the entry of contaminants in the form of heavy metals and synthetic dyes into the environment (Lano et al., 2020). Synthetic dyes are dyes that are made with certain chemical reactions and their use is more desirable than natural dyes because the properties of synthetic dyes are cheaper, easy to use, strong coloring, stable and environmentally resistant (Rahayu, 2020). One of the dyes that is often used is Rhodamine B dye.

Rhodamin B dye is an important basic dye in the dyeing process of the textile and paper industries (Shofiyani et al., 2020). Rhodamine B is in the form of a crystalline powder, odorless, purple in high concentrations and bright red in low concentrations. Rhodamin B is toxic because it can cause irritation and cancer in humans. At high concentrations, the chronic

effect will be damage to the liver (Musafira et al., 2019). In addition, if it enters the environment it will cause environmental pollution. When the colloidal materials and waste dyes mix, the water will become cloudy and smelly. Therefore, it is necessary to treat Rhodamin B before releasing it into the environment. The method for dealing with aquatic environmental pollution and dyeing waste treatment is the adsorption method (Asnawati et al., 2017).

Adsorption is one of the absorption processes by certain adsorbents due to the attractive force of attraction between the adsorbent and the adsorbate molecules (Batu et al., 2022). Adsorbents are solids that can be adsorbed while adsorbates are solids, liquids or gases that are adsorbed (Lano et al., 2020). The adsorbents used for the adsorption process are solids that have pores such as rice husks, areca husks, and coconut shells, which come from natural materials and easily decompose (Rohmah and Athiek, 2014). This adsorption technique can be used to search for adsorbents with high absorption. Making adsorbents from natural materials such as agricultural waste is the most important choice because the basic ingredients are easily available and abundant in nature (Sembiring and Tuti, 2003). One type of natural material that can be used as an adsorbent is palm coir (*Borrassus flabellifer* L.).

Palm coir is one of the plantation wastes which so far has usually been used as animal feed and the rest is disposed of as waste (Fariha et al., 2020). When viewed from its composition, palm coir contains 89.2% cellulose, 5.4% water, 3.1% carbohydrates and 2.3% ash (Sembiring and Tuti., 2003). The cellulose content in palm coir is higher than that of coconut coir and areca coir, which are around 37.9 and 35-65.8% (Ifa et al., 2020). Palm coir has a high cellulose content, so it is necessary to make an effort to utilize palm coir waste as something more useful. One of them is by utilizing waste from palm coir into activated charcoal to absorb heavy metals and dyes, because cellulose is an important component in the adsorption process (Nafi'ah, 2016).

So far, research on the use of palm fruit coir waste as a basic ingredient for making activated charcoal has not been widely carried out, so it is necessary to do research by utilizing palm fruit coir waste for the manufacture of activated charcoal which will later be applied as a natural adsorbent to adsorb dyes such as rhodamine B which can cause environmental pollution. The purpose of this study was to determine the moisture content, ash content and surface area of activated charcoal from palm coir and determine the optimum conditions (adsorbent mass, contact time, and adsorbate concentration) in the adsorption process of Rhodamin B dyes, as well as to determine the surface morphology of palm coir charcoal before and after activation.

## METHOD

### Palm fiber carbonation

The palm coir was taken from Tuabatan Village, Miomaffo Tengah District, NTT, after that it was separated from the fruit, then the palm coir was washed and dried in the sun to dry. The palm coir was then carbonized using a furnace at 300 oC for 30 minutes. Coconut coir charcoal is cooled in a desiccator and crushed with a mortar and pestle, then sieved through a 120 mesh sieve so that the particle sizes are the same (Batu et al., 2022).

### Activation of Palm Coir Carbon

60 grams of palm coir carbon were soaked in 600 mL of 1 M KOH for 24 hours. Then filtered and rinsed using distilled water until the pH is neutral and dried at 110 oC for 3 hours (Lano et al., 2020). After that, put it in a desiccator to cool. The activated charcoal obtained was characterized by its surface morphology using the SEM instrument, the surface area

using the Brenauer-Emmet-Teller (BET) instrument and the analysis of functional groups using an FTIR spectrophotometer.

#### **Determination of Water Content**

Put 1 gram of activated charcoal into a porcelain cup, the weight of which has been recorded. Then dried in the oven at 105 °C for 2 hours. After that, it was cooled in a desiccator and weighed. Repeat drying and weighing until the weight is constant (Nafi'ah, 2016).

#### **Determination of Ash Content**

Put 1 gram of activated charcoal into a porcelain cup that has been dried in the oven and the dry weight is recorded. Then put in the oven and heated slowly at room temperature up to 600 oC for 1 hour. Then cooled in a desiccator and weighed to standard weight (Batu et al., 2022).

#### **Determination of Optimum Adsorbent Mass (Agustina et al., 2022)**

As much as 1 gram of activated carbon into 5 Erlenmeyer flasks and add 50 mL of Rhodamine B solution with different masses, namely 0.5; 1; 1.5; 2; and 2.5 g. Then stirred with a magnetic stirrer at 300 rpm for 90 minutes. Then filter the solution with filter paper. After that, the concentration of Rhodamine B dye in the filtrate was analyzed using a UV-Vis spectrophotometer.

#### **Determination of Optimum Contact Time (Agustina et al., 2022)**

Put 1 gram of activated carbon into 5 different Erlenmeyer flasks and add 50 ml of Rhodamine B solution. Then the solution was stirred with a magnetic stirrer at 300 rpm for different times, namely 30, 60, 90, 120 and 150 minutes. Then filtered with filter paper. After that, the concentration of Rhodamine B dye in the sample was analyzed by UV-Vis spectrophotometer.

#### **Determination of Optimum Adsorbate Concentration (Agustina et al., 2022)**

Put 1 gram of activated carbon into 5 Erlenmeyer flasks and add 50 ml of Rhodamine B solution. Then stir with a magnetic stirrer at 300 rpm for 90 minutes, and adsorption is carried out at different concentrations, namely 10, 20, 30, 40 and 50 ppm . Then filtered with filter paper. In addition, the concentration of Rhodamine B dye in the samples was analyzed using a UV-Vis spectrophotometer.

## **RESULTS AND DISCUSSION**

### **Activated Charcoal Characterization Test from Palm Coir**

The purpose of testing the water content is to determine the ability to bind water molecules (hygroscopicity) of the activated carbon produced. In general, activated carbon has a very high affinity for water (Nafi'ah, 2016). This hygroscopicity affects the use of activated carbon as an adsorbent (Sitanggang et al., 2017). Table 1 shows a lower KOH activated water content compared to activated carbon without activation. This low water content is caused by the ability of the KOH activator (strong base) to bind water to activated carbon so that the water content produced is smaller and the pores in activated carbon are getting bigger (Faisal and Usman, 2021).

The purpose of testing the ash content is to determine the residual minerals and metal oxides that are not dissolved in activated carbon, which are lost in the carbonization and activation processes. The ash content affects the quality of activated carbon, where excess ash can clog the pores of activated carbon and reduce the surface area (Hatimah et al., 2022). Table 1

shows the ash content of KOH activated carbon is lower than that of non-activated carbon. The resulting ash content is lower because it is influenced by the ability of the KOH activator during activation to dissolve impurities in the form of metal oxides and inorganic minerals that cover the pores of the activated carbon. Most of the mineral residues are lost during the activation process so they do not cover the pores of the activated carbon (Sitanggang et al., 2017).

Table 1. Results of Characterization of Activated Charcoal from Palm Coir

| Sample                 | Water content (%) | Ash Content (%) |
|------------------------|-------------------|-----------------|
| Unactivated Charcoal   | 5,697             | 20,816          |
| KOH Activated Charcoal | 1,537             | 14,52           |
| SNI 06-370-95          | ≤10               | ≤15             |

### Determination of Functional Groups of Activated Charcoal from Palm Coir

Functional group analysis using the Fourier Transform Infrared (FTIR) spectrophotometer aims to determine the functional groups on the activated carbon of palm fiber before and after activation with KOH. The IR spectrum of palm coir charcoal without activation and after activation with KOH can be seen in Figure 1.

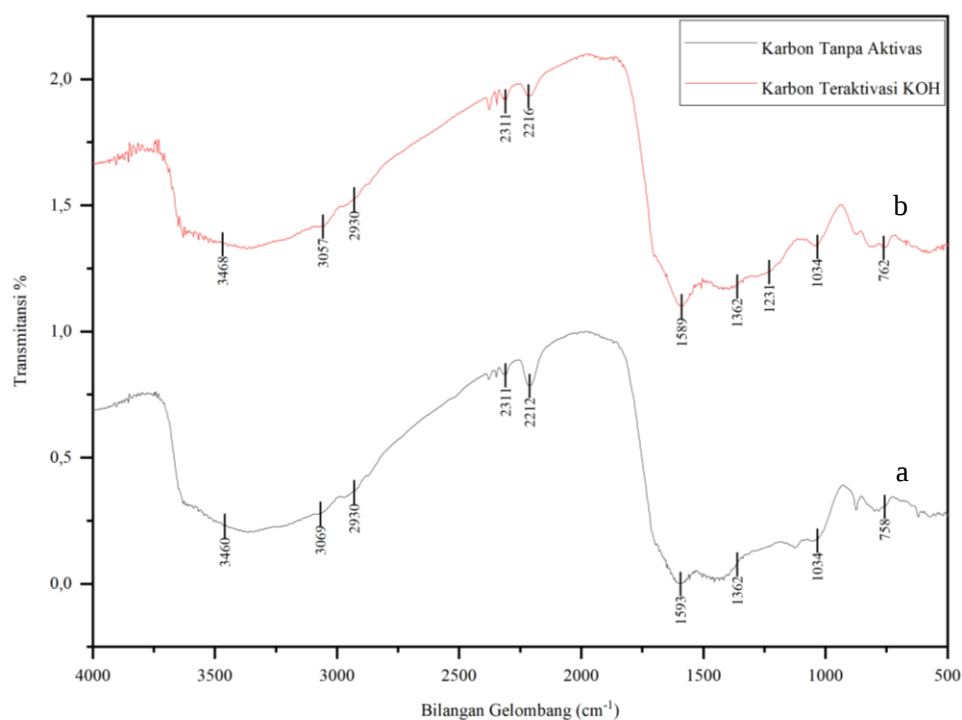


Figure 1. FTIR Spectrum of Palm Coir Charcoal  
(a) Without Activation and (b) KOH activated

Based on the FTIR Spectral Data of charcoal without activation in Figure 1(a), it shows the presence of alcohol and carboxylic acid OH groups which are indicated by the presence of broad peaks at wave numbers 3069–3460  $\text{cm}^{-1}$ . The appearance of an absorption band at wave number 2930  $\text{cm}^{-1}$  indicates the presence of aliphatic C-H functional groups (Fariha et al., 2020). The appearance of absorption bands at wave numbers 2311–2310  $\text{cm}^{-1}$  indicates the  $\text{C}\equiv\text{N}$  functional group and at wave numbers 1593–1589  $\text{cm}^{-1}$  indicates the  $\text{C}=\text{C}$  aromatic alkene functional group. Wave number 1361–1362  $\text{cm}^{-1}$  indicates the aromatic C-C functional group (Amri et al., 2017). The appearance of the wave number 1034–1033  $\text{cm}^{-1}$  indicates the C-C alkane group, while the wave number 758–761  $\text{cm}^{-1}$  is a group resulting from the vibration (rocking) of the aromatic C-H group (Sahara et al., 2018). The appearance

of a new peak of wave number  $1230.58\text{ cm}^{-1}$  from KOH-activated charcoal (Figure 1(b)) indicates the presence of a C-O ester group (Ariyani et al., 2017). Functional groups in unactivated charcoal and KOH-activated charcoal are utilized as interactions with the adsorbate in the adsorption process.

### Surface Morphological Characterization of Activated Charcoal from Palm Coir

The purpose of SEM testing is to determine the surface morphology of the material from changes in temperature and its activator. The results of surface morphology testing can be seen in Figure 2.

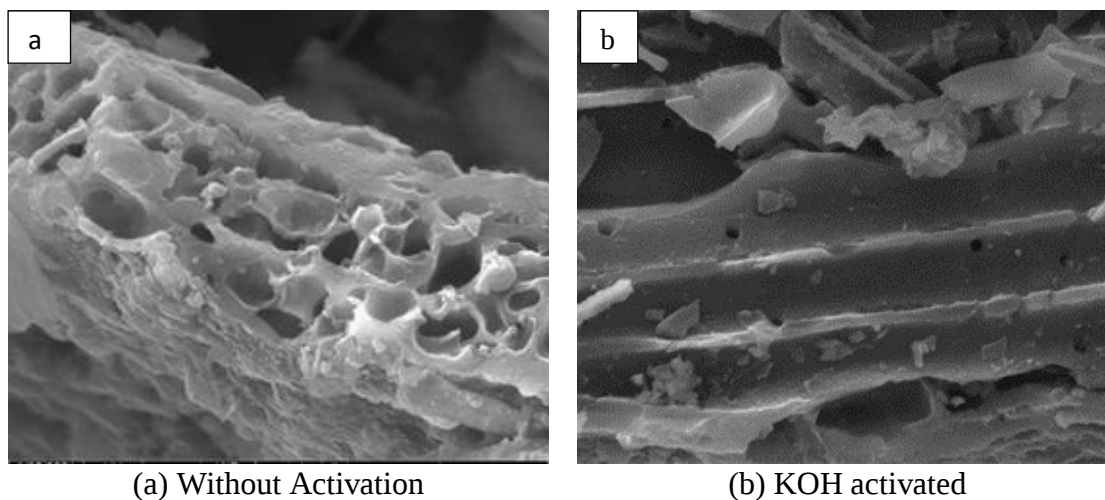


Figure 2. Surface Morphology of Activated Carbon Palm Coir

The surface morphology of inactivated carbon has irregular particle sizes and small pore sizes, whereas the surface morphology of KOH-activated carbon has more open carbon pores with larger pore sizes compared to non-activated carbon (Fariha et al., 2020). This is because KOH-activated charcoal uses an activator which aims to increase the surface area of the charcoal pores and remove impurities in the form of metal oxides produced during the carbonation process. The pore size on the surface of activated charcoal affects the adsorption process. The surface pores of activated charcoal are increasingly open, so the adsorption process is going well and perfectly (Faisal and Usman, 2021).

### Surface Area Characterization Using Instruments *Brenauer-Emmet-Teller* (BET)

BET surface characterization aims to determine the surface area of activated carbon. Determination of surface area was carried out by comparison of unactivated charcoal and KOH activated charcoal. The carbon surface area greatly affects the adsorption capacity of carbon, because the larger the surface area, the greater the carbon adsorption capacity (Ariyani et al., 2020). The results of surface area characterization with the BET instrument are seen in Table 2.

Table 2. Results of characterization of carbon surface area using BET

| Charcoal Type          | Surface area ( $\text{m}^2/\text{g}$ ) |
|------------------------|----------------------------------------|
| Unactivated Charcoal   | 5,865                                  |
| KOH Activated Charcoal | 36,084                                 |

Based on the characterization data in Table 3, it shows that KOH-activated charcoal has an increasing surface area of  $36,084\text{ m}^2/\text{g}$ . when compared with charcoal without activation which is  $5.865\text{ m}^2/\text{g}$ . This is because activated carbon without activation has a decreasing adsorption capacity. While the pores formed are more numerous and controlled, the surface area of KOH-activated charcoal increases (Sudibandriyo and Lydia, 2011).

## Rhodamine B Adsorption Process Using Activated Palm Coir Charcoal

### Determination of Optimum Adsorbent Mass

The purpose of determining the optimum adsorbate mass is to determine the mass of the adsorbent which absorbs a lot of adsorbate in the Rhodamine B adsorption process. The results for determining the optimum adsorbent mass are shown in Table 3.

Table 3. Results of Optimum Adsorbate Mass Determination

| Activated Charcoal (gram) | C <sub>0</sub><br>(ppm) | C <sub>e</sub><br>(ppm) | Q<br>(%) |
|---------------------------|-------------------------|-------------------------|----------|
| 0,5                       | 30                      | 2,922                   | 90,26    |
| 1,0                       | 30                      | 1,661                   | 94,46    |
| 1,5                       | 30                      | 1,676                   | 94,11    |
| 2,0                       | 30                      | 1,940                   | 93,53    |
| 2,5                       | 30                      | 2,456                   | 91,80    |

Based on the data in Table 3, it can be seen that there was an increase in the adsorption efficiency of rhodamine B dyes on masses of 0.5 and 1.0 grams of activated charcoal. The increase in adsorption power was due to the addition of adsorbent mass which caused the active side on the surface of the adsorbent to increase, so that a lot of Rhodamin B dyes were absorbed by the adsorbent (Nurlaili et al, 2017). Meanwhile, at a mass of 1.5 to 2.5 grams, the absorption capacity of activated charcoal as adsorbent decreases. This is because the adsorbent has experienced saturation due to the formation of a layer on the top of the adsorbate which is bound to the surface of the adsorbent so that the rhodamine B dye is not absorbed by the adsorbent (Febriani et al., 2022). From the research results, it was obtained that the optimum adsorbent mass was at a mass of 1.0 gram with an adsorption efficiency of 94.46%.

### Determination of Optimum Adsorbate Contact Time

The purpose of determining the optimum adsorbate contact time is to determine the minimum time by absorbing the adsorbate until it reaches saturation (Sahara *et al.*, 2018). The results of determining the optimum time for the adsorption process of rhodamine B dyes are shown in Table 4.

Table 4. Results of Optimum Adsorbate Contact Time Determination

| Contact Time (Minute) | C <sub>0</sub><br>(ppm) | C <sub>e</sub><br>(ppm) | Q<br>(%) |
|-----------------------|-------------------------|-------------------------|----------|
| 30                    | 30                      | 1,873                   | 93,75    |
| 60                    | 30                      | 1,794                   | 94,02    |
| 90                    | 30                      | 1,674                   | 94,42    |
| 120                   | 30                      | 1,701                   | 94,33    |
| 150                   | 30                      | 1,847                   | 93,84    |

From Table 4 above, the adsorption capacity of activated charcoal on rhodamine B has increased from a contact time of 30 to 90 minutes. The increase in adsorption power is due to the fact that the active side in the pores of the activated carbon has not yet experienced a saturation point (Indah and Safnowati, 2019). Meanwhile, the contact time of 120 to 150 minutes experienced a decrease in adsorption efficiency caused by the adsorbent experiencing saturation due to the adsorbent pores being fully filled, resulting in desorption, namely the release of the adsorbate back into the solution (Indah et al., 2021). From the research results, it was obtained that the optimum contact time using activated charcoal occurred at a contact time of 90 minutes with a concentration after adsorption of 1.674 ppm and an adsorption efficiency of 94.42%.

### Determination of Optimum Adsorbate Concentration

The purpose of determining the optimum adsorbate concentration is to determine the ability of activated charcoal to adsorb rhodamine B dye. The results of determining the optimum concentration are shown in Table 5.

Table 5. Results of determining the optimum adsorbate concentration

| $C_0$<br>(ppm) | $C_e$<br>(ppm) | Q<br>(%) |
|----------------|----------------|----------|
| 10             | 1,847          | 81,53    |
| 20             | 1,900          | 90,50    |
| 30             | 1,501          | 94,42    |
| 40             | 2,830          | 92,92    |
| 50             | 2,830          | 92,34    |

Based on the data in Table 5, the adsorption efficiency of activated carbon on rhodamine B has increased from a concentration of 10 ppm to 30 ppm. This is due to the unsaturated surface area of the adsorbent, so the higher the concentration, the more rhodamine B molecules are adsorbed (Agustina et al., 2022). Meanwhile, at a concentration of 40 ppm to 50 ppm, there was a decrease in adsorption capacity. This is because the surface of the adsorbent has passed its saturation period, preventing the adsorbent from binding back to the rhodamine B molecule (Pradhana et al., 2021). The results of the study obtained the optimum concentration using KOH-activated activated charcoal at an adsorbate concentration of 30 ppm with a concentration after adsorption of 1.501 ppm and an adsorption capacity of 94.42%.

### CONCLUSION

Based on the research results, the characteristics (moisture and ash content) of 1 M KOH-activated palm coir activated charcoal complied with SNI Number 06-3730-1995 so that it could be used as an adsorbent. In the adsorption process of rhodamine B, optimum conditions were obtained at a mass of 1.0 gram of activated charcoal, a contact time of 30 minutes and an adsorbate concentration of 30 ppm with adsorption efficiencies of 94.46%, 95.75% and 94.42% respectively. The surface morphology of palm coir charcoal without activation has an irregular particle size and has a small pore size, while KOH activated charcoal has an increasingly open carbon pore surface with a larger pore size. Active charcoal from coconut coir can be used as an adsorbent to reduce the dye rhodamine B in textile industry waste which has a negative impact on the community and the surrounding environment.

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