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UTILIZATION OF COFFEE GROUNDS ACTIVATED CARBON BIOADSORBENT FOR RODHAMIN B REMOVAL

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Abstract

Coffee grounds are coffee's starch essence that can be used as activated carbon. Because activated carbon has a high adsorption power and a huge surface area, its utilization is highly maximized. The purpose of this study is to give findings on the utilization of coffee grounds, which may be converted into activated carbon, as a bioadsorbent for the dye Rhodamine B. The study's findings indicate that the larger the surface area of the activated carbon, the greater the adsorption capacity. The production of activated carbon involves two processes: the carbonation process at a high temperature between 400 and 850°C to produce ideal carbon, and the physical activation process at a high temperature between 650 and 900°C. The percentage of Rhodamine B adsorbed by chemically and physically activated coffee grounds activated carbon was 89.1125% and 60.7923%, respectively, indicating that chemically activated carbon is more effective than physical activated carbon in adsorbing Rhodamine B dye waste.

Keywords: Coffee Grounds, Activated Carbon, Bioadsorbent, Rhodamin B.

1 INTRODUCTION

Coffee plays a very important role in the world economy, namely in the agricultural sector as a source of livelihood. Coffee (Coffe sp.) is a tree-shaped plant and belongs to the Rubiacea family and the Coffee genus. The characteristics of this coffee plant are that it is branched, has thick leaves, grows upright, and has round fruit that produces green when young and red when old, indicating that the coffee is ready to be harvested. Coffee plants can be processed into drinks that are useful, including fighting drowsiness, increasing energy and many other benefits [1]. Based on these benefits, it is not surprising why coffee is the most popular drink among consumers throughout the world. Reporting from a sentence reported by the International Coffee Organization (ICO) in 2020 provides information that Indonesia is one of the agricultural countries with the largest coffee commodity in the world, in fourth place after Brazil, Vietnam and Colombia [2]. So, the name coffee in Indonesia is commonly heard among the public. Based on information provided by Statistics Indonesia in 2023, data obtained from the Central Statistics Agency (BPS) shows that coffee production in Indonesia will reach 794.8,000 tons in 2022, this result shows an increase of around 1.1% compared to last year. Aceh is one of the largest coffee producers in Indonesia, ranking fourth after South Sumatra, Lampung and North Sumatra. Where Aceh produces 75,3,000 tons of coffee a year. Coffee grounds are the starch essence from coffee which has benefits as an organic fertilizer that is good for plants because it contains various good and environmentally friendly substances. However, in this case, public knowledge and awareness is still lacking regarding the use of coffee grounds [3].

Aceh is known as the land of 1,001 coffee shops, this title does not seem to be without basis considering the large number of coffee shops in every region in Aceh. It could be said that coffee is like breath for Acehnese people, which is difficult to separate from everyday life. The tradition of drinking coffee in Aceh has developed from generation to generation to become one of the world-class coffee producing areas. One of the familiar ones is Gayo coffee, which is a type of Arabica coffee which is in the premium class of coffee on the world market. This type of coffee is the one that makes Aceh proud as one of the best coffee producers in the country which dominates 40% of the domestic market. With the large number of coffee shops, it will certainly be very easy to obtain coffee grounds, but unfortunately the coffee grounds waste is wasted because it cannot be utilized properly by the community so it is left as waste. This can have a bad impact on the environment where coffee waste contains alkaloids, tannins and polypenolics which can be toxic and difficult to degrade from the environment, thus causing problems such as being a source of disease spread [4]. One waste from agricultural products that can be used as a bioadsorbent is coffee grounds. Coffee grounds come from coffee that has been brewed, resulting in a brownish black powder remaining. Each cup of coffee contains coffee grounds that are removed, weighing an average of 20 grams [5]. Coffee grounds waste can pollute the environment and has no value if it cannot be utilized. In fact, coffee grounds waste has several benefits, including being able to be used as activated charcoal, this is due to the high adsorption capacity and large surface area of activated carbon, so its utilization is highly optimized. In addition, coffee grounds waste can be used as fertilizer because it contains organic components such as carbon, nitrogen and minerals which are good for plants.

Adsorbent from activated carbon is the best adsorbent in the adsorption system. This adsorbent can be used from materials that have pores, because adsorption will take place on the pore walls. This is due to the high adsorption power and large surface area of activated carbon so that its utilization is highly optimized. The characteristic of good activated carbon is that it has a large surface so it has a large adsorption capacity. This is what makes adsorbents widely used in experiments because they have advantages compared to other adsorbents. According to previous research [6] stated that the advantages of using adsorbents include relatively cheap prices, easy to obtain, environmentally friendly and the best thing is that using these adsorbents is easy to activate. Biosorbents that are commonly used are biosorbents that come from plantation or agricultural waste such as coffee grounds, sugar cane bagasse, fruit peels, and many more. Adsorbents can absorb various pollutants in the form of organic and inorganic compounds. One application of adsorbents is chitosan and activated charcoal from coffee grounds which were tested by [7] with the aim of reducing the heavy metal arsenic in PXI industrial wastewater which exceeds quality standards. The results of this research state that the higher the dose of activated carbon mixed with chitosan, the greater the efficiency of absorption of arsenic metal in waste water. This is in accordance with the previous statement which stated that the quantity of natural adsorbent is an important factor for the biadsorption process [8].

The adsorption method is one of the most widely used methods because the concept used is economical and simpler. There are two important principles in the adsorption process, namely the moving phase (adsorbate) and absorption (adsorbent). The adsorption mechanism is basically an absorption process that occurs on the surface of a solid [9]. The advantages of this adsorption method when viewed from a cost perspective, adsorption is a method that is cheap, the process is also simple, can absorb metals and what is best does not cause toxic side effects. Various types of natural materials such as agricultural or plantation waste can be used as adsorbents because their potential is quite good, this can be seen in terms of activation, chemical composition and component structure as well as environmental friendliness [10]. However, the adsorption method also has disadvantages, including limited adsorption capacity, it is known that adsorbent materials have limited adsorption capacity. After reaching the saturation point, where all adsorption sites have been filled, the adsorbent material needs to be replaced or generated with a new one. This can increase operational costs and require additional resources. Some adsorbents that are often used for treating waste water are activated carbon, silica gel, alumina, zeolites and other adsorbents that have activation to adsorb chemical substances, for example coffee grounds [11]. The coffee grounds can be used as activated charcoal, this is due to the high adsorption capacity and large surface area of activated carbon so its utilization is highly optimized. In general, adsorbents use carbon, where carbon can be obtained from biomass waste such as agricultural, plantation and trade products and even household waste. One example is coffee grounds produced from agricultural waste.

Besides recently used technology, membrane separation method, to remove dyes like methylene blue from aqueous solution using cellulose-based materials [12], [13], cellulose-based materials from biomass also produced as adsorbent. Recently, a lot of research has been carried out on the use of activated carbon from coffee grounds to be used as an adsorbent, one of which is Rodhamin B adsorbent. Rodhamin B dye is widely used in the textile industry. Nowadays the use of Rodhamin B is also widely used in food, even though the use of Rodhamin B in food is strictly prohibited because it is dangerous for body health. The relatively lower price of rhodhamin compared to permitted food colorings has resulted in many food producers choosing to turn a blind eye to public health. Physically, the dye in Rhodamine B is in the form of green crystals or can be in the form of a reddish purple powder, odorless, easily soluble and at low concentrations in water it will produce a bright red color while at high concentrations it will produce a bluish red color.

Making activated carbon is carried out using two basic processes, namely the carbonation process and the activation process. The carbonization process is the process of increasing carbon content by removing non-carbon species using thermal decomposition. The carbonation process is usually carried out by heating the precursor in an oven at a high temperature to obtain perfect carbon, between 400 – 850 °C to remove all non-carbon components from the precursor such as hydrogen, oxygen and nitrogen in the form of gas and tar. This process will produce charcoal that has a high carbon content but low surface area and porosity. Charcoal porosity can be further developed in the activation process. The activation process is a process that aims to increase the pore volume, enlarge the diameter of the pores and increase the porosity of activated carbon. The activation process can be done using three methods. One method of chemical activation, in chemical activation, activating substances are usually used, such as $ZnCl_2$, KOH, NaOH, and H_3PO4, which aim to activate carbon. The procedure is simple, namely a solution containing chemical activation agents is absorbed onto the surface of the biomass, dried in an oven, and finally activated in a furnace for 1 to 4 hours. Using chemical activation methods results in higher final carbon, a one-step process, generally lower activation temperatures, and easier adjustment of porosity.

The purpose of the activation process itself is to ensure that adsorption performance is more optimal. Based on the results of a literature study, it is known that the chemical activation process has been proven to improve the performance of adsorbents in processing various pollutants. Overall, the adsorption process is carried out at the same temperature, length of contact time and pH of the solution. Where the experimental results show that the double activation process obtained the highest efficiency value for reducing metal ion concentrations with a percentage of more than 51%, while the adsorbent that received chemical treatment and carbonation alone showed relatively competitive efficiency. Apart from that, a directly proportional relationship was also found between the increase in carbonation temperature and the increase in adsorbent performance in absorbing Cr(III) pollutants. Based on this, either chemical or physical treatment can improve the performance of the adsorbent to a certain level [14].

Based on the explanation above, this research aims to present information regarding the use of coffee grounds which can be made into activated charcoal as an adsorbent for Rhodamine B dye as well as determining the pore surface area, synthesis process, optimum contact time, optimum pH and temperature of coffee grounds as an adsorbent for Rhodamine B dyes. It is hoped that the results of this research will increase the use of coffee grounds so that it can help reduce waste in the environment.

2 METHODOLOGY

This article is a collection of journal reviews based on the most recent original research from journals published during the last three years. We chose the most recent study journal to collect data from numerous previously examined arguments so that later conclusions could be reached using the keywords "Coffee grounds", "Activated charcoal", "Adsorbent", and "Rhodamine B". Variations of data in national and international publications were gathered and evaluated to integrate data from numerous studies that had been investigated into a mix of data from which conclusions could subsequently be derived.

3 RESULTS

The adsorption method is an alternative that is widely used because this method uses a simple and economical concept. Adsorption itself is a process of absorbing certain substances on the surface of a substance, this is because the surface of a solid substance will produce a molecular attraction force without any absorption [15]. An adsorbent is a substance that acts as an absorbent while an adsorbate is a substance that will be absorbed.

Activated carbon is an adsorbent that is often used in various industries to remove various pollutants from water bodies and air. Coffee has a carbon content of between 47.8 % -58.9% and also has lignocellulose with active hydroxyl and carbonyl groups which are able to absorb dangerous metals and dyes [16]. Since activated carbon is synthesized from agricultural products and waste, it has proven to be a great alternative to the non-renewable and expensive resources used traditionally. To make activated carbon, there are two basic processes, namely carbonization and activation.

3.1 Carbonation Process

Carbonation is the phase of carbon formation from raw materials. The carbonation process is usually carried out at high temperatures to obtain perfect carbon, between 400 – 850 °C to remove all volatile components. High temperatures will remove all non-carbon components from precursors such as hydrogen, oxygen and nitrogen in the form of gas and tar. This process produces charcoal that has a high carbon content but low surface area and porosity. Even though it is still relatively low, it can be developed at this stage before experiencing further development in the activation process. The product of the carbonization stage is a solid with a high carbon content, usually in the range of 25–50% calculated by mass, depending on the starting materials and process parameters used. Careful selection of carbonization parameters is important because this process leaves significant effects on the final product [17].

3.2 Activation Process

The second step is the activation process. This activation process is a process of treating carbon to enlarge the pores. The increase in pore size during the activation process can be categorized into three: opening of previously inaccessible pores, development of new pores by selective activation, and widening of existing pores.

Typically, there are two physical and chemical approaches used for activation to obtain the desired surface area and porosity. Physical activation involves activating carbonized char using oxidizing gases such as air, carbon dioxide and steam at high temperatures (between 650 and 900°C). Carbon dioxide is usually preferred because of its purity, easy handling, and controllable activation process around 800°C. High pore uniformity can be obtained with carbon dioxide activation compared to steam. However, for physical activation, steam is much preferable to carbon dioxide because active carbon with a relatively high surface area can be produced.

The chemical activation process usually involves mixing the precursor with an activating agent such as NaOH, KOH, $ZnCl_2$, H_3PO_4, $FeCl_3$, etc. This activating agent acts as an oxidant as well as a dehydrating agent. In this approach, carbonization and activation are carried out simultaneously at relatively lower temperatures of 300-500°C compared to the physical approach. Consequently, this influences the pyrolytic decomposition and results in better expansion of the porous structure and high carbon yield. The main advantages of chemical activation methods over physical activation are low temperature requirements, high microporosity structure, large surface area, and minimized reaction completion time.

Table 1. *Carbonation and activation process of activated charcoal from previous research*

Precursors	Carbonation Temperature (°C)	Carbonation Time (hrs)	Activation Time (hrs)	Activation Ingredients	References
Shell coconut, sugar cane bagasse, rice husk	600	3	1	Silicon, Sulfur, Calcium,	[18]
Coffee grounds	450	0.75	48	HCl	[19]
Coffee grounds	800	2	1.5	CO_2	[20]
Bagasse	900	4	4	Extract starfruit	[21]
Coffee grounds	600	4	48	HCl	[22]
Coconut shell	260	3	24	$NaHCO_3$	[23]
Coffee grounds	500	1	24	HNO_3, H_3PO_4, and $ZnCl_2$	[24]
Bagasse	500	1	1	Methylene blue solution, HCl/	[25]

				NaOH	
Coffee grounds	450	0.75	48	HCl	[26]
Coffee skin	400	5	24	NaOH solution	[27]
Coffee grounds	500	0.75	24	HCl	[28]
Palm shells	600	4	4	NaOH and HCl	[29]
Coffee grounds	450	0.33	4	H_2SO_4,	[30]
Coffee grounds	110	3	3	HCl	[31]
Coffee grounds	500	0.75	24	H_3PO_4	[32]
Coffee grounds	120	5	1.5	TiO_2, HCl	[33]
Green coffee grounds	600	1	1	H_3PO_4	[34]
Coffee grounds	800	1	48	KOH	[35]
Ketapang leaf powder	120	2	2	H_2SO_4	[36]
Coffee grounds	600	3	5	HCl	[37]
Bangkir ai wood sawdust waste	150	1	0.25	H_3PO_4 solution	[38]
Coffee grounds	120	2	1	H_3PO_4	[39]
Coffee grounds	600	2	1	KOH	[40]
Coffee grounds	400	3.5	2	HCl	[41]
Coconut shell	550	2	1.5	HCl	[42]
Coffee grounds	700	0.33	1	HCl	[43]
Coffee grounds	650		1.5	Nitrogen	[44]
Coffee grounds	400	0.33	48	H_3PO_4	[45]

3.3 Characteristics of Activated Carbon

Adsorption capacity is determined by activated charcoal porosity, porous volume, surface area and other structural characteristics. The characteristics of activated charcoal can be seen from its porous solid form. The greater the surface area of activated charcoal, the higher the adsorption power. The surface properties and functional groups of activated carbon depend on the precursor, activating agent, process and activation conditions [46].

Darus. E, et al have published on the effect of coffee grounds activated charcoal adsorbent (Coffea Sp.) on the quality of siwalan liquid sugar showing that the pore size of coffee grounds activated charcoal is classified as micropores where the surface area of the coffee grounds activated charcoal obtained is 27.70 m^2 /g with the pore volume is 0.023 mL/g and the adsorption pore size is 1.63 nm. This is based on the pore size classification according to the International Union of Pure and Applied Chemistry (IUPAC), namely the micropore size d< 2 nm. The smaller the adsorbent particle size, the greater the surface area. The micropore type shows that in adsorption, the adsorbate particles will stick around the adsorbent walls to form strong bonds [47].

Widiyarta, et al have published on the effect of the holding time of the activation process on the pore structure of activated carbon from brewed coffee grounds, which shows that the longer the activation, the more the pore surface area and pore volume decrease. Activation time of 30 minutes provides a pore surface area of 121.765 m^2/g. When the activation time was increased to 60 minutes the pore surface area fell to 75.799 m^2/g and fell again to 34.819 m^2/g when the activation time was increased to 90 minutes. A similar condition also occurred in the pore volume, where when the activation time was increased from 30 to 60 minutes the pore volume decreased from 0.058 cc/g to 0.048 cc/g. When the activation time was increased to 90 minutes, the pore volume fell again to 0.018 cc/g. In this case, the higher the pore surface area, the higher the pore volume and the higher the nitrogen that can be absorbed.

The activation time has a fluctuating effect on the average pore diameter of activated carbon. An activation time of 30 minutes resulted in an average pore diameter of 1.915 nm. When the activation time was increased to 60 minutes the average pore diameter increased to 2,513 nm and fell again to 2,014 nm with the activation time increased to 90 minutes. According to IUPAC-1985, pores are classified into micropores (pore size less than 2 nm), mesopores (pore size between 2 to 50 nm) or transitional pores and macropores (pore size greater than 50 nm) based on the width (w) which indicates the gap distance between the pore walls or the radius of the cylindrical pore. Based on this definition, K-A30 has most of its pores in the micropore area, while K-A60 and K-A90 have most of its pores in the mesopore range.

Beautiful. D. R has published on the adsorption of methylene blue using carbon baggase without activation. From the calculation data it can be seen that the optimum pH for methylene blue is pH 5 with the amount of methylene blue dye solution adsorbed at 85.5%. At pH 6 and 7 the adsorption capacity of methylene blue is still high, namely 84.7% and VD 84.3%. At neutral pH the adsorption efficiency is still relatively high, this shows that adsorption will mostly occur through van der Waals forces and will not be affected by electrostatic interactions [48].

3.4 Absorption Studies of Rodhamin B

Previous study have reported in previous research on the use of coffee grounds as activated charcoal for Rhodamine B adsorbents. In testing the absorption capacity of iodine on chemically and physically activated coffee grounds, each obtained a result of 342.9786 mg/g and 180.8471 mg/g. This value does not meet the standards because it is below the minimum SNI value, namely 750mg/g. Testing coffee grounds activated charcoal for iodine absorption is to determine the ability of activated charcoal to absorb adsorbate with a small molecular size of around 1 nm. The high absorption capacity of activated charcoal towards I_2 shows that the more activated charcoal micropores are formed, the better the activated charcoal is at absorbing adsorbate with small molecular sizes [49].

The results obtained showed that the increase in adsorption by chemically and physically activated activated charcoal at concentrations of 14mg/L and 10mg/L respectively, was caused by the surface of the activated charcoal not being saturated so that the activated charcoal could still absorb RhodamineB molecules. However, if the surface of the activated charcoal has reached saturation, the activated charcoal will release the Rhodamine B molecules that it has absorbed so that its adsorption capacity will decrease. The increase in adsorption power is caused by the interaction between activated charcoal and Rhodamine B molecules, which increases if the concentration of Rhodamine B is increased. To determine the maximum adsorption capacity of chemically and physically activated charcoal, data in the form of mg/g is used, namely the number of adsorbed ions. From this data it can be used to determine the appropriate isotherm for the two activated charcoals. Data obtained on the % of Rhodamine B adsorbed by chemically and physically activated coffee grounds activated charcoal were 89.1125% and 60.7923% respectively, this shows that chemically activated activated charcoal is more effective when used to adsorb Rhodamine B dye waste from on physics activated charcoal.

4 CONCLUSION

Activated carbon can be identified by its porous solid shape. The larger the surface area of activated charcoal, the greater its adsorption power. Activated carbon is produced by two processes: carbonation and activation. The carbonation process is carried out at a high temperature ranging from 400 to 850°C to produce ideal carbon capable of removing all volatile components. Meanwhile, the physical activation procedure is carried out at high temperatures ranging from 650 to 900°C. The percentage of Rhodamine B adsorbed by chemically and physically activated coffee grounds activated charcoal was 89.1125% and 60.7923%, respectively, indicating that chemically activated activated charcoal is more effective than physical activated charcoal in adsorbing Rhodamine B dye waste.

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