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Production of Activated Carbon by Activation of Tamarind (*Tamarindus Indica*) Wood Charcoal

Erna Astuti [a,1,*], Zahrul Mufrodi [a,2], Shinta Amelia [a,3], Muhammad Imam Zulfi [a,4], Firdaus Ramadhani [a,5]

[a] Department of Chemical Engineering, Faculty of Industrial Technology, Universitas Ahmad Dahlan, Jl. Jend. Ahmad Yani, Tamanan, Banguntapan, Bantul, Yogyakarta, 55191, Indonesia
[1] erna.astuti@che.uad.ac.id *, [2] zahrul.mufrodi@che.uad.ac.id , [3] shinta.amelia@che.uad.ac.id , [4] firdaus1900020083@webmail.uad.ac.id,
[5] muhammad1900020066@webmail.uad.ac.id
* corresponding author

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ABSTRACT

Tamarind or Tamarindus indica is a plant originating from Asia and Africa. Tamarind wood has high cellulose, which can be activated into activated carbon and modified to become a catalyst from its ingredient nature. This study aims to find optimum conditions for producing activated carbon from tamarind charcoal. Research on the activation of tamarind charcoal begins with reducing the size of charcoal. Then the charcoal was sieved to obtain 40, 60, and 60 mesh charcoal sizes. Furthermore, the charcoal was soaked in HCl (1, 2, 3, 4, and 5 M) for 1 hour, after which it was filtered, and the pH of the charcoal was neutralized by washing using distilled water. The steep final is dried activated carbon in an oven at 105℃. Then the performance of activated carbon is sought by using activated carbon to adsorb dyes in a dye solution. The concentration of the dye solution before and after being adsorbed with activated carbon was measured by UV-Vis spectrophotometry at a wavelength of 560 nm. Adsorption effectiveness is measured. The greatest effectiveness value obtained was 82.31%. Optimum conditions for activating carbon from tamarind charcoal were obtained by activating 60 mesh of carbon using a hydrochloric acid solution of 4 M. Using activated carbon at different concentrations of dye solutions produces the same optimum conditions. The contribution of this study is to prove that activated carbon can be made from tamarind charcoal. Tamarind charcoal can be used as an adsorbent material.

1. Introduction

Biodiesel is an alternative energy made from renewable energy to replace fossil energy. Biodiesel synthesis can be accelerated by using various types of catalysts: homogeneous catalysts, heterogeneous catalysts, or with enzymes. Biodiesel production with solid catalyst (heterogeneous catalyst) is more economical than homogeneous catalyst because catalyst congested could be used many times [1]. The disadvantage of using a homogeneous catalyst is that it causes reactor corrosion, catalyst separation needs more costs, and processes produce waste [2]. Another advantage of using heterogeneous catalysts is that the motivation required is much less than that of homogeneous catalysts [3], [4]. Synthesis with enzyme catalyst could run at a temperature room with high yield [1], but this process requires high costs and a more complicated purification process [5]. Reference [6] stated that there are two types of heterogeneous catalysts, namely base heterogeneous catalysts (such as CaO, $CaTiO_3$, $CaZrO_3$, CaO–CeO_2, $CaMnO_3$, $Ca_2Fe_2O_5$, Al_2O_3/KI, alumina/silica-supported K_2CO_3) and acid heterogeneous catalysts (such as ZnO/I_2, ZrO_2 =SO_2, Sr/ZrO_2, TiO_2 =SO_2, and amberlyst-15).

Activated carbon is one of the carriers in the catalyst for transesterification because of its large surface area and has proven effective in gas or liquid phase reactions. Activated carbon is a porous material with 87-97% carbon content and a small amount of hydrogen and oxygen bound to functional groups. It can influence the adsorption properties on the activated carbon surface. Activated carbon is a carrier that makes the catalyst work more effectively [7].

Activated carbon can be made from biomass waste. Carbon-based catalysts have good thermal and mechanical stability and are ideal for various reactions [2]. The raw materials used to make activated carbon are organic and inorganic materials that contain carbon elements and many pores. These materials include plantation waste such as fresh oil palm bunches, empty oil palm bunches, oil palm shells, coconut shells, peat, agricultural waste, and wood and wood waste [8].

Tamarindus indica is a plant from the *Fabaceae* family and the *Caesalpinaceae* subfamily, which often grows in the continents of Asia and Africa. The tamarind tree is famous for its properties in health, medicine, and seasoning or flavoring. This tree is often found on various soil types in semi-arid and humid climates. Tamarind is also a tropical plant that can live at an ambient temperature of 47°C and with a rainfall of 350-4000 mm [9].

Table 1. Chemical Content of Various Parts of *Tamarindus Indica*

Part	Chemical Content
Stem *	Saturated fatty acid methyl ester of 67.54%; unsaturated fatty acid methyl ester of 30.15%; B-sitosterol of 1.2%; and cycloartanol 1.1%.
Leaf	The pulp contains invert sugar, citric acid, pipecolic acid, nicotinic acid, 1-malic acid, essential oils (geraniol, limonene), pipecolic acid, lupane, lupeol, orientin, isoorientin, vitamin B3, vitamin C, vitexin, isovitexin, benzyl benzoate, cinnemates, serine, pectin, beta alanine, proline, phenylalanine, leucine, potassium, 1-malic acid, tannins, glycosides.
Fruit	Furan and carboxylic acid derivatives, phlorotannins, apple acid, grape acid, succinic acid, citric acid, tartaric acid, pectin, invert sugar.
Seed	Campesterol, β-amyrin, β-sitosterol, palmitic acid, oleic acid, linoleic acid, and eicosanoic acid. Mulsilago, arabinose, xylose, galactose pectin, glucose, and uronic acid. New bufadienolide and cardnolide, cellulose, albuminoid, amyloid, phytohemagglutinin, chitinase.
Bark	Tannins, saponins, glycosides, peroxidases and lipids.
Root bark	n-hexacosane, eicosanoic acid, β -sinosterol, pinitol, octacosanyl ferulate, 21-oxobehenic acid.

Source : [10] and [11]

Some parts of the tamarind tree have various benefits, at least some nutritional or therapeutic value [12]. The most valuable and frequently used part is the fruit [13]. Tamarind fruit is widely processed into sweets with a sour and sweet taste. Tamarind fruit can also be used in pharmacological industries and folk medicine [14]. Tamarind fruit shell has the potential to become an adsorbent to remove fluoride from groundwater [15]. Tamarind flowers and leaves can be consumed as vegetables. Tamarind seeds can be processed into activated carbon [16], [17]. The mucilage of tamarind seeds has potential applications as stabilizers, thickeners, emulsifiers, dietary fibers, etc [18]. Tree trunks are used as raw material for furniture. Tamarind wood can be used as adsorptive media [19]. This study proposes one of the uses of agricultural waste from tamarind wood. The wood waste is turned into charcoal, then processed into activated carbon.

Activated charcoal is an amorphous carbon compound made from materials containing carbon or using charcoal with special treatment so that the surface area of activated charcoal becomes more comprehensive with a range of 300-3500 m^2/gram [20]. Charcoal activation generally has 3 types of process stages: chemical, physical, and physicochemical. Chemical activation is carried out with the help of chemical compounds to react or break the hydrocarbon bonds in charcoal. Meanwhile, the physical activation of charcoal is characterized by burning charcoal, both in a furnace or in an oven, at a temperature of 850ºC. And in physico-chemistry, these two processes are applied to maximize the results of the activated carbon obtained [21].

The manufacture of activated carbon from various natural materials has been carried out. Reference [22] made activated carbon from oil palm shells using the Physics-Chemical method. According to the research results as in [21], activated charcoal from palm shells activated by a physicochemical process has better adsorption power than using only one way. The adsorption results of 34.4% of acetic acid solution of 0.5 N at 4 hours and 30ºC. Ironwood as a catalyst begins with size reduction and 100 mesh size sifting, mixing the HCl solution using a reflux system with a temperature of 60ºC for 4 hours, then neutralizing it with water and drying it in an oven [23]. As in [24], corn stem can be made into activated charcoal with optimum operating conditions of activation of corn stem charcoal with a sulfuric acid solution followed by a carbonization process at 300ºC for 1 hour and precursor conditions of 1.25 in optimum adsorption of copper metal ions at pH 5, contact time of 3 hours, and maximum adsorption capacity of 25.1 mg/g. Treatment of Kemiri Sunan shell waste as activated charcoal begins with soaking in 10% H_2PO_4 solution for 24 hours, then washing and draining. After that, it was put into the retort, heated to 850ºC, and steamed hot for 90 minutes. Through testing, the adsorption capacity of the iodine solution obtained was 138.46-768.31 mg/g, benzene was 2.99-21.37%, and methylene blue ranged from 18.239-260.237 mg/g [25]. This research contributes to making activated carbon which will later be used as a catalyst and applied to biodiesel production. The performance of the activated carbon produced was tested by measuring its color adsorption using UV-Vis spectrophotometry.

2. Research Methodology

2.1. Materials

The materials used are shown in Fig. 1. Tamarind charcoal is obtained from a joss coffee charcoal supplier. The charcoal was made from tamarind stem. HCl was obtained from Merck with a concentration of 37%, which is colorless, in liquid form, has a sharp odor, and pH < 1 at 20°C.

charcoal pounded charcoal charcoal powder

Fig. 1. Tamarind charcoal

2.2. Research Procedures

It was pounding and sifting charcoal from Tamarind Wood. Soak 5 g of charcoal that has been homogenized in HCl solution, which concentration was varied in the range of 1 to 5 M for 60 minutes. Neutralize the charcoal by washing the charcoal using distilled water up to a pH of 7. Dry the activated carbon with a neutral pH in an oven for 1 hour at 105ºC to remove impurities.

Prepare standard solutions with various concentrations. Insert the standard solution sample into the cuvette and distilled water as a blank. Measure the adsorption rate with a wavelength of 560 nm and record the measurement results as a standard solution curve. Mixing 0.2 g of certain-sized charcoal with a specific concentration of dye solution, stirring until homogeneous, and allow to stand for 30 minutes. Separating activated carbon from dye solution. Perform adsorption measurements using UV-Vis spectrophotometry.

3. Results and Discussion

Activated carbon is one of the carriers in the catalyst in the reaction because of its large surface area and has proven effective in gas and liquid reactions. As in [18], the activation of charcoal both chemically and physically aims to make the pores of the charcoal wider by breaking the hydrocarbon bonds. In this activation process, the charcoal will experience a mass change from rearranging and reforming the charcoal, which causes the pores in the charcoal to expand and inversely proportional to the weight of the charcoal, which will be lighter because some of the hydrocarbon bonds have been broken. It is characterized by the physical properties of the charcoal, which has a shiny texture and is more brittle than the charcoal before activation, as well as the pores in the charcoal, which are broader and more numerous in facilitating the adsorption or adsorption process. The source of activated carbon in this study used tamarind wood which is easy to obtain and plant in a rural area.

Activation of carbon is carried out in several stages, namely soaking, neutralizing, and drying. Activating activated carbon is assisted by soaking the carbon in HCl solution with 1, 2, 3, 4, and 5 M concentrations for 1 hour. Then the activated carbon is neutralized using distilled water until it reaches a pH of 7 with regular pH measurements using a universal indicator. After being neutral, the activated carbon was dried in an oven at 105°C for 1 hour. Then activated charcoal is classified as a particle size of charcoal with a size of 40, 60, and 80 mesh to test the absorption ability of activated carbon with food coloring. The method used is a UV-Vis spectrophotometer.

3.1. Standard Curve Determination

Preparation of a standard solution is done by dissolving 1 g of solid food coloring with 100 ml of distilled water as solution 1, then making solution two by taking 10 ml of solution one and adding 10 ml of distilled water, the concentration of the dye in the solution is obtained as shown in Table 2. Absorbance is measured at a length wave of 560 nm using distilled water as a blank.

Table 2. The concentration of Dye in Solution and its Adsorbance

Solution	Weight of dye (g)	Aquadest (ml)	Dye concentration (g/L)	Adsorbance
1	1	100	0.1	3.201
2	0.1	20	0.05	3.110
3	0.05	20	0.025	2.521
4	0.025	20	0.0125	1.356
5	0.0125	20	0.00675	0.669
6	0.00625	20	0.003125	0.304
7	0.003125	20	0.001563	0.154

The standard curve equation was based on the dye concentration and adsorption data (see Fig. 2.).

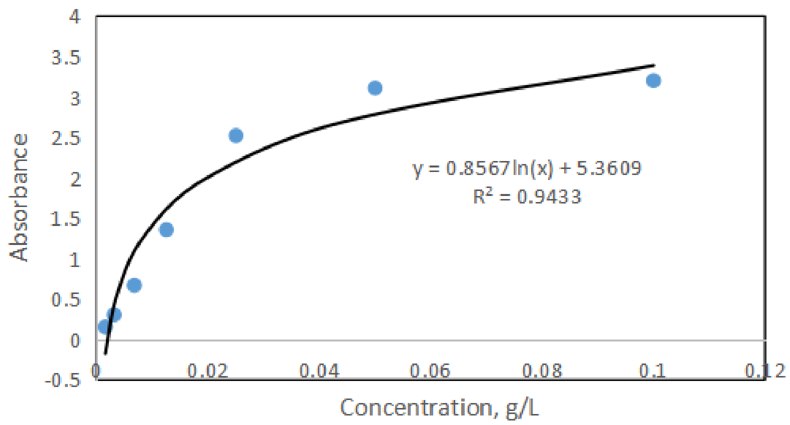

Fig. 2. Curve of standard solution

The higher the dye concentration, the greater the absorbance value, while the less the dye content, the less the absorbance value obtained through the spectrophotometric test. Fig. 2. shows the equation for the relationship between concentration and absorbance is:

$$y = 0.8567 \ln (x) + 5.3609 \text{ and the value of } R^2 = 0.9433 \quad (1)$$

The standard curve decreases the absorbance value proportional to the reduction of the dye concentration in each solution.

3.2. Measurement of the performance of activated carbon at different concentrations of HCl

In this study, activated carbon was activated with HCl solution with varying 1 M to 5 M concentrations. Furthermore, 0.2 g of activated carbon was mixed with solution 3, stirred until homogeneous, and left for 30 minutes. After 30 minutes of immersion, the solution was separated from the activated carbon using filter paper and filtered four times to ensure that no carbon escaped from the filter paper. Furthermore, the solution's adsorption level was measured by UV-Vis spectrophotometer, with the measurement results written in Fig. 3.

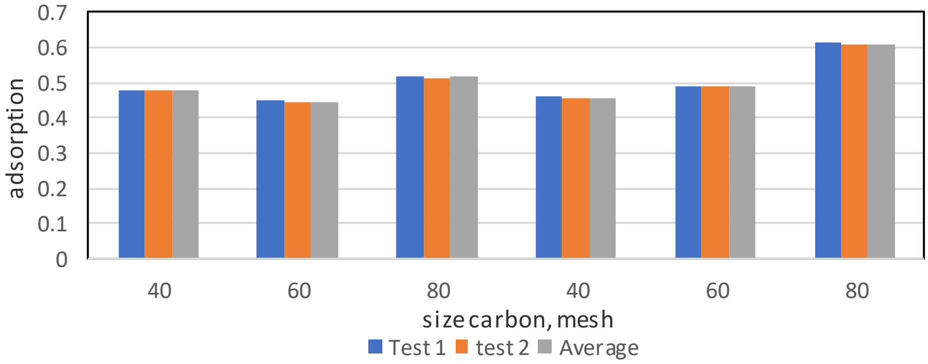

Fig. 3. Adsorption measurement of 0.025 g/L dye solution with 60 mesh carbon size

Fig. 3. shows that manufacturing activated carbon using higher concentrations of HCl results in less adsorption. Thus, the higher the concentration of HCl used, the better the ability of activated carbon from tamarind wood to absorb dyes. The lowest absorbance value was obtained at 4 M HCl concentration, the absorbance increased at 5 M HCl concentration. This indicates the optimum concentration of HCl for manufacturing activated carbon from tamarind wood of 4 M.

3.3. Measurement of the performance of activated carbon on different carbon sizes

The performance of activated carbon from tamarind wood was also analyzed at different sizes of carbon, at 4 M and 5 M HCl concentrations. Then sieving was carried out with activated charcoal particle sizes of 40, 60, and 80 mesh, and the HCl concentrations used were 4 and 5 M. Adsorption measurements were carried out with 0.025 g/L dye solution for two repetitions, with the results as seen in Fig. 4.

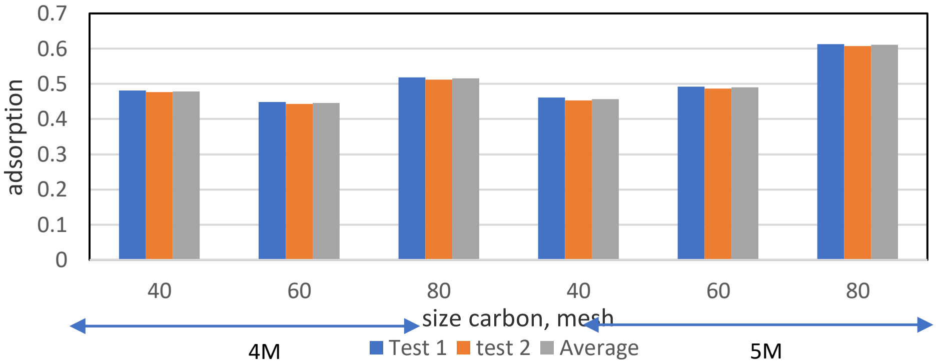

Fig. 4. Measurement of carbon adsorption resulting from activation of 4 M and 5 M HCl concentration in 0.025 g/L dye concentration

The optimum condition obtained in samples with 4 M HCl concentration was 60 mesh charcoal particle size. The effectiveness calculation is carried out to determine the optimum conditions more clearly. The activation process will cause the surface of the activated charcoal to become more expansive due to the organic acids and hydrocarbons that were originally present on the surface of the activated charcoal, which has been removed by the activating agent [26]. The chemicals that can be used as activators are alkali metal hydroxides, salts carbonates, chlorides, sulfates, phosphates, and alkaline earth and steam at high temperatures [27]. In this study, using hydrochloric acid with a greater concentration as an activator will expand the surface area of the activated charcoal from the tamarind stem so that the adsorption effectiveness is more significant. The most excellent entrapment effectiveness was obtained by using 4 M HCl concentration.

3.4. Measurement of the performance of activated carbon on different carbon sizes

The adsorption effectiveness of activated carbon from tamarind wood was calculated from the decrease in sample adsorption after soaking the activated carbon for 30 minutes. The results of the effectiveness calculation are presented in Table 3.

Table 3. Value of Effectiveness Carbon Active 60 Mesh in Solution Dye 0.025 g/L

HCl concentration (M)	Adsorption	Adsorption effectiveness (%)
1	0.600	76.20
2	0.565	77.59
3	0.543	78.46
4	0.446	82.31
5	0.490	80.56

The most excellent adsorption effectiveness of 60 mesh-sized activated carbon was obtained at a concentration of 4 M HCl with a value of 82.31%. Furthermore, the adsorption effectiveness of activated carbon with sizes of 40 mesh, 60 mesh, and 80 mesh was calculated by producing activated carbon using 4 M and 5 M HCl solutions. The calculation results can be seen in Table 4.

Table 4. Effectiveness of Activated Carbon as a Result of Activation of 4 M and 5 M HCl Concentration in 0.025 g/L Dye Concentration

HCl concentration (M)	Size carbon (mesh)	Adsorption	Effectiveness entrapment (%)
4	40	0.479	81.00
	60	0.446	82.31
	80	0.516	79.53
5	40	0.457	81.87
	60	0.49	80.56
	80	0.611	75.76

Calculation results show that work carbon is the best active obtained from carbon active 60 mesh size obtained with activation use HCl with a concentration of 4 M. The effectiveness of activated carbon was also measured using a dye solution with a concentration of 0.1 g/L. The measurement results are in Table 5 and Table 6.

Table 5. Effectiveness of 60 Mesh Sized Activated Carbon in Dye with a Concentration of 0.1 g/L

Adsorbance				Effectiveness (%)
Concentration (M)	Test 1	Test 2	Average	
1	3.341	3.325	3.333	-4.12
2	3.207	3.182	3.195	0.20
3	3.186	3.147	3.167	1.08
4	3.038	3.002	3.020	5.65
5	3.165	3.139	3.152	1.53

Table 5 shows the most excellent entrapment effectiveness obtained from activated carbon activated with 4 M HCl solution. The same results were obtained using dye solutions with different concentrations (0.1 g/L and 0.025 g/L).

Table 6. Effectiveness of Activated Carbon as a Result of Activation of 4 M and 5 M HCl Concentration in 0.1 g/L

Adsorption					**Effectiveness (%)**
Concentration (M)	***Mesh***	***Test 1***	***Test 2***	***Average***	
4	40	3.157	3.121	3.139	1.94
	60	3.038	3.002	3.020	5.65
	80	3.132	3.113	3.123	2.45
5	40	3.193	3.179	3.186	0.47
	60	3.165	3.139	3.152	1.53
	80	3.180	3.178	3.179	0.69

Table 6 reinforces the previous conclusion that the highest adsorption effectiveness was obtained using 60 mesh-sized activated carbon produced by activating carbon using HCl with a concentration of 4 M. These results are by using activated carbon in dye adsorption with the attention of 0.1 g/L. The most excellent entrapment effectiveness, 82.31%, was obtained with 60 mesh-sized activated carbon with 4 M HCl concentration (see Table 6). The benzene adsorption capacity of activated charcoal in kemiri sunan shells ranges from 2.99% [25]. Increasing the concentration of sodium carbonate in manufacturing activated carbon from corn cobs causes an increase in the absorption of phenol in liquid waste [28]. Absorption of free fatty acids by activated carbon from corn cobs reduced free fatty acids by 60.72% [29]. This means using activated carbon from tamarind performs better than activated carbon from kemiri sunan shells and corn cobs.

4. Conclusion

The larger the particle size, the more cavities or pores can adsorb the dye solution. However, if the particle size is too large, it will affect the cavity or pore size and cause the level of absorption effectiveness to decrease. The higher the concentration of HCl used to activate the charcoal, the better it will be in activating it. Optimum conditions were obtained at HCl with a concentration of 4 M. Activated charcoal from activating Asem Jawa wood charcoal using HCl solution and drying in an oven can absorb the dye. This proves that the activated carbon from Asem Jawa wood in this study was successful. The maximum effectiveness of activated carbon was obtained at HCl with a concentration of 4 M with a size of 60 mesh of 82.31%.

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