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Effect of Activation by Alkaline Solution on Properties of Activated Carbon from Rubber Wood

Phawika CHUENKLANG, Samran THUNGTONG and Tharapong VITIDSANT*

Department of Chemical Technology, Faculty of Science, Chulalongkorn University

Abstract

This research is a study of the effect of activation by alkaline solution on the properties of activated carbon from rubber wood. The experiment included both carbonization and activation. The variables studied were a temperature range of 350-500°C and carbonized time (45, 60, 90, and 120 minutes) in the carbonization step. A suitable carbonization condition was at a temperature 400°C for 45 minutes with 27.51 % yield, 70.46 % fixed carbon, 25.90 % volatile matters and 2.32 % ash. Rubber wood char was activated by alkaline solution: KOH and NaOH. The variables were temperature, activation time and size of rubber wood char including the weight ratio of char per alkaline in the activation step. The experimental results were found to be that the suitable conditions for alkaline activation using both KOH and NaOH as activating agent was 700°C for 3 hours with rubber wood char size, 0.60-1.18 mm. Activated carbon prepared from KOH with a 1:1 ratio of char per alkaline gave higher quality than NaOH because stronger alkaline of NaOH developed larger pore sizes. The activated carbon obtained by KOH as an activating agent was 48% yield, 0.114 g/cm^3 bulk density, 5.24% ash, iodine number 1069 mg/g, methylene blue number 202 mg/g and BET surface are 943 m^2/g whereas NaOH gave lowers values of these properties.

Keywords : *Activated Carbon / Rubber Wood / KOH / NaOH /Activation*

**To whom correspondence should be addressed*
E-mail addressed : Tharapong.v@chula.ac.th

Introduction

Activated carbon is manufactured from a wide variety of materials but those most frequently used on a commercial scale are peat, coal, lignite, wood (sawdust), which should exhibit a high adsorption capacity and a large volume of the smallest pores (micropores), coconut shells are usually used. The principal properties of manufactured activated carbons depend on the type and properties of raw material used. Any cheap substance with a high carbon and low ash content as rubber wood can be used as a raw material for the production of activated carbon. The value of the rubber tree untill recently has been mainly for its latex. But this is slowly changing. The utilization of the rubber tree in a holistic sense is now being focused : on for instance, the tree is being looked at from an environmental angle: plant nutrients and other useful chemicals are being soured from effluents and waste from rubber processing and above all, rubber timber is now a valuable resources. Over the last decade the demand for rubber timber had been increasing rapidly. The term "Rubber wood" is usually given to the timber of the species *Hevea brasiliensis* (Boonkri, 2000). The most desirable method of producing activated carbon is by adjusting processing conduction to control precisely the properties of the end product. This is more cost-effective than changing the precursor to suit changing requirements, but necessitates a consistent material. Variations occur in precursors in terms of structure and mineral matter content, associated with locality of growth, climate and cropping. Mineral matter is often responsible for preferential gasification during the activation process resulting in meso-and macropore channeling and pitting, and not the preferred microporosity.

Arriagada, *et al.* (1994) studied the partial gascification of *Eucalyptus globulus* charcoal, using carbon dioxide and steam as activating agents. The influence of some production variables such as temperature and reaction time on texture were given. *Eucalyptus globulus* chips (5-10 cm in diameter, 30-40 cm in length) were carbonized in a metallic kiln. The carbonization time was 2-3 hr and the yield of charcoal was 23%. The charcoal sieved between 10 and 20 mesh was activated in a vertical fixed bed reactor. The reaction temperature between 800-900°C for 10-360 min with flow of the activating agent was 200 cm^3/min (STP) of carbon dioxide or 140 cm^3/min (STP) of steam (100%). The result showed that both activating agents produced microporous activated carbon with a large increase in meso- and macroporosities when steam and high burn-off were used.

Ninlanon (1994) produced activated carbon from Mangrove wood by 2 steps : carbonization and activation using superheated steam and carbon dioxide. The first step is carbonization; variables were temperature 250-400°C and time 20-60 min. The optimum condition for carbonization was at 300°C for 60 min. The characteristics of char were found to be: %yield 38.07, %fixed carbon 71.44, %volatile matters 23.02 and % ash 5.54. The second step is to activate the char by using superheated steam and carbon dioxide. The variables were temperature 700-850°C, time 30, 60, 90 and 120 min. and sizes of particle < 0.355, 0.355-0.60, 0.60-1.18, 1.18-2.36, 2.36-4.75 mm. It was found that the optimum condition for activation was at 850°C for 60 min. and 0.60-1.18 mm size of particles. The quantities of air and carbon dioxide were 5l/min. at 30°C, 1 atm with excess superheated steam, respectively. The resulting characteristics were 27.47 % yield, BET surface area 639.74 m^2/g, macropores surface area 156.50 m^2/g, micropores surface area 483.24 m^2/g, Iodine adsorption number 675mg/g and methylene blue adsorption number 254mg/g. It was also found that the capabilities of the activated carbon on color adsorption of dichromate ion were 66.23 and 59.52 mg/g at pH 1 to 2 respectively.

This work shows the study of the optimum conditions, which affect the activation by alkaline solutions on properties of activated carbon from Rubber wood. The appropriate parameters such as temperature, time, size of raw material and concentration of alkaline solution were studied.

Experimental

Procedures

Carbonization of Rubber wood

The optimum temperature and time for carbonization of Rubber wood were studied at 350, 400, 450 and 500°C for the duration of 45, 60, 90 and 120 min. The procedure started with a sample of about 70g (by weight) in a crucible. Next, a muffle furnace was heated at the final temperature as 350, 400, 450 and 500°C. The sample was carbonized for 45, 60, 90 and 120 min. Finally, % yield, % ash, bulk density, % volatile matters and % fixed carbon of products were analyzed following ASTM D 3172-3175 (American Standard of Testing Material (ASTM), D3172, 1993; D3173, 1993; D3174, 1993; D3175, 1993)

Activation of Rubber wood char

The fixed bed reactor was a vertical retort heater. The reactor was a stainless tube of 0.02 m inside diameter and 0.4 m in length for sample feed and removal port. The bed could be operated at a maximum temperature of 1200°C. Air flew into the bed which was controlled by using a rotameter. The variables having an effect on the activation such as: temperature, activation time, size of char and concentrations of KOH were studied in order to determine the optimum conditions. The experimental scheme of the production of activated carbon from Rubber wood was shown in **Figure 1**. The products were characterized as the %yield, %ash, bulk density, iodine number, methylene blue number and BET. surface area.

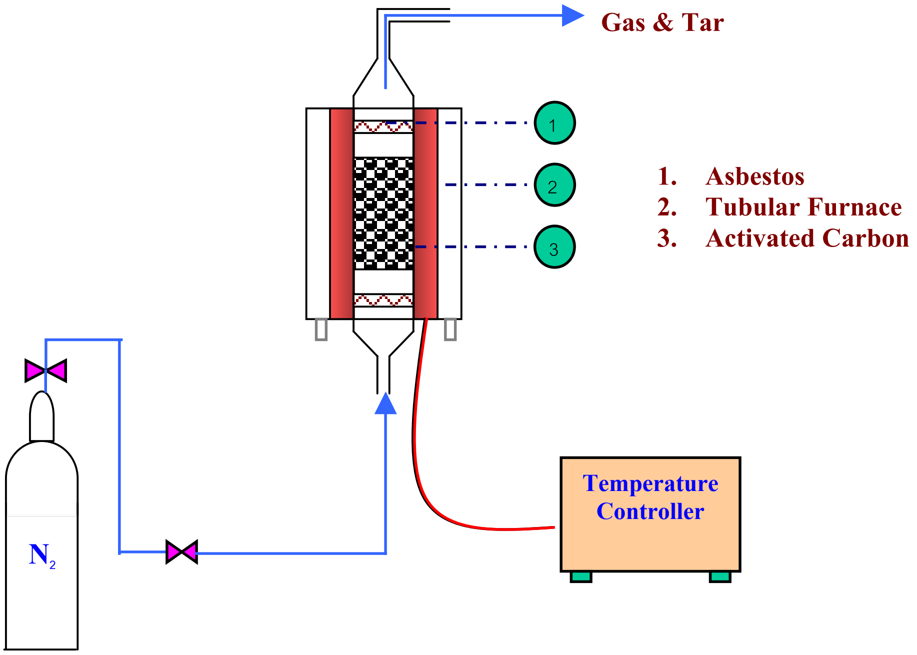

Figure 1 A schematic of the fixed bed activator experimental setup.

Results and Discussions

Carbonization

Rubber wood was carbonized before activation with oxidizing gas and alkaline solution. The carbonization was carried out in a muffle furnace. The studied condition was temperature range of 350 to 500°C. Each temperature was varied carbonization times from 45 to 120 minutes. The proximate analysis of Rubber wood char is presented in **Table 1**.

Table 1 Proximate analysis of Rubber wood char at different temperatures and times.

Temp (°C)	Time (min)	Y(%wt)	M(%wt)	Ash(%wt)	VM(%wt)	FC(%wt)
350	45	31.94	1.50	2.87	34.12	61.51
	60	32.83	1.95	1.22	33.86	62.96
	90	30.36	1.67	3.00	33.20	62.13
	120	28.96	1.99	3.38	31.05	63.57
400	**45**	**27.51**	1.32	2.32	25.90	70.46
	60	26.77	1.54	3.22	23.81	71.43
	90	26.33	1.28	4.15	25.62	68.95
	120	26.14	1.85	3.66	25.72	68.76
450	45	23.92	1.09	4.33	21.99	72.59
	60	24.92	1.53	3.87	21.60	72.99
	90	24.12	1.88	3.94	22.08	72.09
	120	22.92	1.87	2.66	18.81	76.66
500	45	23.53	1.76	4.66	17.42	76.15
	60	22.18	1.85	4.04	14.93	79.18
	90	22.35	2.04	4.20	17.20	76.55
	120	20.83	1.99	4.05	15.90	78.06

After considered volatile matters, VM(%wt), fixed carbon, FC(%wt) and yield,Y% in **Table** 1, the optimum carbonization condition of Rubber wood was 400°C for 45 min because the characteristic of Rubber wood char at this condition contained 20-25 % volatile matters Suravattanasaku, 1998) which was appropriated for activation. The carbonized Rubber woods, were 27.51 % yield, 2.32 % ash and 70.46 % fixed carbon. The Rubber wood char prepared at this condition would be used in the activation steps.

Activation

The effect of concentration of potassium hydroxide

The concentration of potassium hydroxide solution at char: KOH ratio (by weight) 1:1, 3:1, 5:1, :1 and 10:1 were prepared. The char from Rubber wood was soaked by these different solutions for studying the influence of concentration of solution on the characteristics of prepared activated carbon. A mass, 9 g of 1.18-2.36 mm of Rubber wood char were carried out at 500 and 700°C for 1 and 3 hr by passing nitrogen gas though the reactor. The results were shown in **Figures 2-4**.

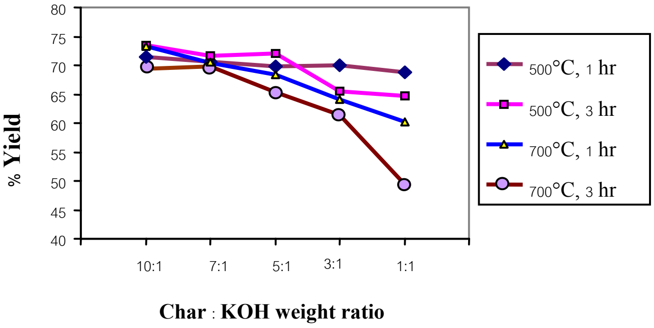

Figure 2 Effect of char : potassium hydroxide weight ratio on % yield at different temperature and time (size 1.18-2.36 mm, 9 g of char, N_2 flow rate 1000 ml/min).

Figures 2, the % yield of activated carbon from Rubber wood decreased when the concentration of potassium hydroxide increased and reached the minimum at char: KOH ratio 1:1. Potassium hydroxide reacted more with char and volatile matters and diffused quickly out of the surface of the particles and the substituted–H group by the –OH group, so the % yield and bulk density had decreased. However, the char : KOH weight ratio 3:1 to 1:1 for 1 and 3 hr at 500°C the % yield and bulk density remained fairly constant. It is probably caused by more potassium hydroxide of higher % concentration of potassium hydroxide inside the particle, which would block volatile matters from gassing out of the surface.

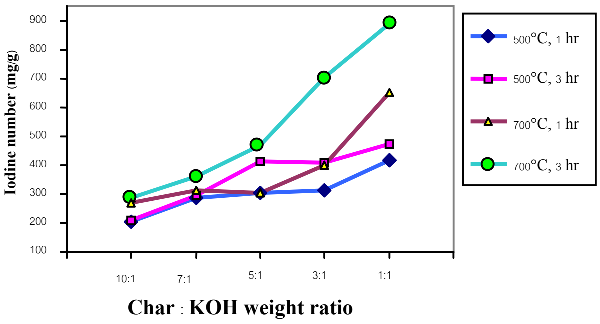

Figure 3 Effect of char : potassium hydroxide weight ratio on iodine number at different temperatures and times (size 1.18-2.36 mm, 9 g. of char, N_2 flow rate1000 ml/min).

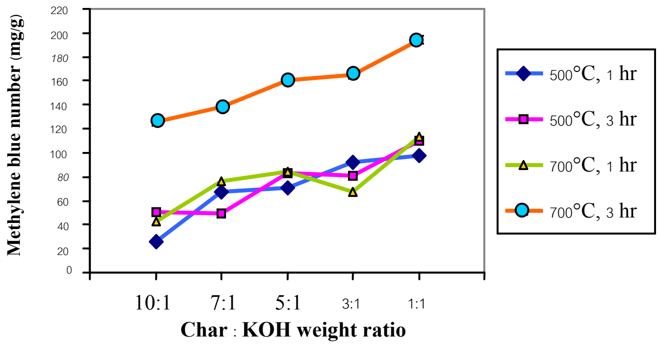

Figure 4 Effect of char: potassium hydroxide weight ratio on methylene blue number at different temperature and time (size 1.18-2.36 mm, 9 g, N_2 flow rate 1000 ml/min).

Figures 3-4, showed that the iodine number, methylene blue number and B.E.T. surface area increased when the concentration of potassium hydroxide solution increased. They reached the maximum at char: KOH weight 1:1. It confirmed that the more reaction took place, the more porosity developed as the result; % yield and bulk density decreased while iodine number, methylene blue number and BET. surface area increased.

The optimum concentration was 1:1 char: KOH ratio at 700°C for 3 hr because at this condition, the highest iodine number of 891 mg/g, methylene blue number of 194 mg/g and B.E.T. surface area 615 m^2/g were obtained.

The effect of temperature for activation

A mass of 9 g 1.18 – 2.36 mm rubber wood char was soaked in 1:1 char: KOH weight ratio and then was dried. These samples were used for each batch. The nitrogen gas was then allowed to flow through the tube reactor. The stainless tube reactor was heated until the temperature in the tube reactor was raised and fixed at the final temperature 500, 600 and 700°C. The nitrogen gas was continued, passing through the tube rector for 3 hr. The results of these experiments are shown in **Figures** 5-7.

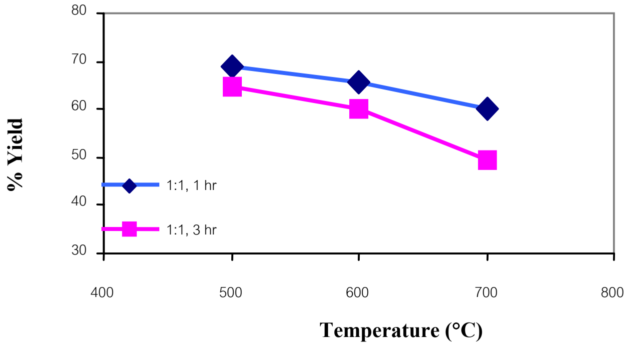

Figure 5 Effect of activation temperature on % yield at different time and char : KOH weight ratio (size 1.18-2.36 mm, 9 g, N_2 flow rate 1000 ml/min).

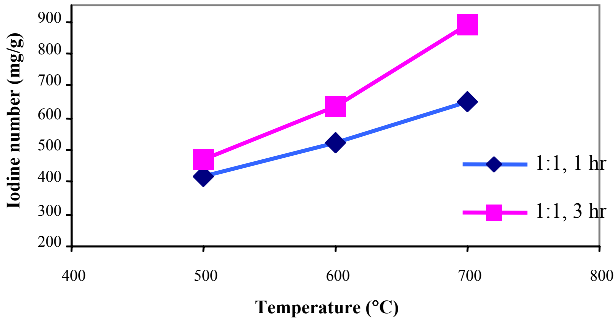

Figure 6 Effect of activation temperature on iodine number and char : KOH weight ratio (size 1.18-2.36 mm, 9 g, N_2 flow rate 1000 ml/min).

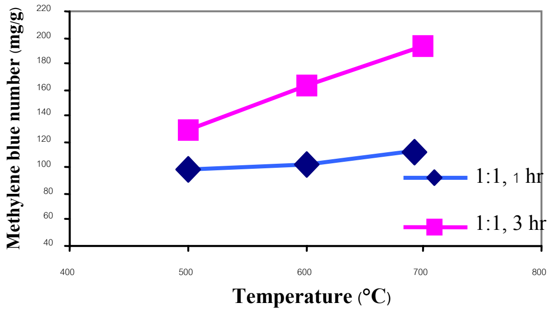

Figure 7 Effect of activation temperature on methylene blue number and char : KOH weight ratio (size 1.18-2.36 mm, 9 g, N_2 flow rate 1000 ml/min)

Figures 5 the % yield decreased conformably as the activation temperature increased. Comparing between range of 500 to 600°C and 600 to 700°C, the range of 500 to 600°C changed more slowly. Owing to the high temperature, loss of volatile matters was greater than that at low temperature. The increase in temperature led to the increased porosity development, as a result, the weight of activated carbon decreased. Moreover, the % yield. The change in the % yield of rubber wood was about 5% from 500 to 600°C, 10.8% from 600 to 700°C, whereas bulk density from rubber wood decreased 17.3 % in total.

Figures 6-7 showed that when the activation temperature increased from 500 to 700°C, the iodine number increased sharply and had a trend to be at the highest at 700°C for Rubber wood. While the methylene blue number increased slightly. The BET. surface area increased with the iodine number, because tar like matter and potassium hydroxide deposited in pores were removed or volatilized well by nitrogen gas from 600 to 700°C, which generated porosity. The higher activation temperature, the more potassium hydroxide was removed therefore, the iodine number and the methylene blue number increased quickly (see slope in **Figures** 6 and 7). The % change of iodine number was from 500 to 700°C about 47.13 % and that of methylene blue number was about 33.5 %.

The optimum temperature was 700°C char: KOH weight ratios of 1:1 for 3 hr because in this condition the highest iodine number of 891 mg/g, methylene blue number of 194 mg/g and B.E.T. surface area 615 m^2/g were obtained.

The effect of time on activation

Rubber wood char 1.18 – 2.36 mm of particle size and mass of 9 g was soaked in potassium hydroxide solution at char: KOH 1:1 and then was dried. Soaked char was used for each batch. Then it was treated at 700°C for 1, 2 and 3 hr as activation time with nitrogen gas by passing through the tube reactor. The results of this experiment were shown in **Table 2**.

Table 2 Effect of activation time (char: KOH 1:1, 700°C, N_2 flow rate 1000 ml/min).

TIME (hr)	Y (%)	BD g/cm^3	Ash (%)	MB (mg/g)	IA (mg/g)	B.E.T. (m^2/g)
1	60.26	0.17	3.27	113	652	546
2	58.42	0.16	3.51	182	670	590
3	49.33	0.15	3.22	194	891	615

Table 2 showed that an increase of activation time could cause an increase of iodine number, methylene blue number and B.E.T. surface area. In the first stage (1-2 hr) iodine number increases slightly but methylene blue number increases sharply, the increasing is caused from volatile matters and moisture in rubber wood char. It is evident that at the first stage, it has more mesopores than micropores and when it is left longer time (2 - 3 hr). It is found that iodine number and methylene blue number tend to increase 24.8 % and 6.18 %, respectively. It is because longer activation time (2-3 hr) could make micropores and mesopores increase.

From **Table 2** the % yield of Rubber wood char decreases slightly and conformably with increasing the time from 1 to 2 hr (about 3.05 % change), and largely decreased from 2 to 3 hr (15.5 % change). Because the volatile matters outside and inside the particle and char were gasified itself by using potassium hydroxide as a catalyst. The gaseous product, volatile matters and potassium hydroxide in majority diffused out of the particle in the beginning time more slowly (see the slope) than the longer activation time (from 2 to 3 hr) which less remained volatile matters being deeper in the particle diffused out only. The % bulk density of Rubber wood char decreased in the same trend of the % yield. These phenomena showed that porosity developed quickly in 3 hr. **Table 2** showed the change of % yield, bulk density, % ash, iodine number and methylene blue number of activated carbon from rubber wood as a function of activation time range of 1 to 3 hr. The iodine number, methylene blue number and B.E.T. surface area are increased. In the same trend, the high increasing

rate covered in the range of 1 to 3 hr (from 652 to about 891 mg/g for IA, 113 to about 194 mg/g for MB and to 546 to about 615 m^2/g for specific surface area). It is the same reason as % yields that volatile matters and potassium hydroxide diffused out rapidly especially at the external surface, as a result, micropores developed quickly in the form of surface area as well.

The optimum activation time was 3 hr at 1:1 char: KOH ratios 700°C because these conditions give the highest iodine number of 891 mg/g, methylene blue number of 194 mg/g and B.E.T. surface area 615 m^2/g.

The effect of size of rubber wood char for activation

The influence of particle size was determined for different three sizes of Rubber wood char. They were 0.60-1.18, 1.18-2.36 and 2.36-4.75 mm and soaked in 1:1 char: potassium hydroxide ratio solution. The mass of 9 g of each sample of the Rubber wood char was carried out at 700°C while nitrogen gas was passed though the bed for 3 hr. The results of this experiment were shown in **Table 3.**

Table 3 Effect of particle Size (1:1, 3 hr, 700°C, N_2 flow rate 1000 ml/min)

Size (mm)	Yield (%)	BD g/cm^3	Ash (%)	MB (mg/g)	IA (mg/g)	BET. (m^2/g)
0.60 - 1.18	48.00	0.148	4.792	202	1069	943
1.18 - 2.36	49.33	0.150	3.222	194	891	615
2.36 - 4.75	71.51	0.159	2.684	137	446	339

Table 3 **showed the** % **yield and bulk density** (**BD**). **The** % **yields and bulk density had decreased with the increasing of particle size until both were minimum at 0.60-1.18 mm and went upward again at 2.36-4.75 mm, especially % yield (from 48 to 71.51 %) while the bulk density slightly decreased. On the contrary, the iodine number (IA), methylene blue number (MB) and BET surface area decreased with increasing particle size approaching the maximum at 0.60-1.18 mm and going down at 2.36-4.75 mm, these phenomena could be explained by the physical packing of the bed. When the small particles (range of 0.60-1.18m) were packed in the reactor, it seemed that they packed tightly; as a result, the gaps between particles were narrow, so the volatile and potassium hydroxide were difficult to vaporize out of the fixed bed by flowing nitrogen gas. These caused a high % yield and low development of porosity which conformed to a high bulk density, low iodine number, methylene blue number and BET surface area. The particle size of 0.60-1.18 mm seemed appropriate for flowing of nitrogen gas and caused a very good vaporization of potassium hydroxide and diffusion out of volatile matters from the surface of the particle and the bed, so the characteristics of the activated carbon were the best at this size.**

The particle size of 2.36-4.75 mm was bigger about two times than the one of the optimum. They arranged themselves by packing loosely and causing big gaps between particles. The nitrogen gas could flow out rapidly without contact with all of the particles or sometimes a channeling was observed; low development of porosity causing higher % yield, bulk density but lower iodine number, methylene number and B.E.T. surface area.

The experimental results showed that the optimum size of rubber wood char for activation was 0.60-1.18 mm because the characteristic of activated carbon gave the highest iodine number, methylene number and B.E.T. surface area. Its properties were yield of 48.0 %, bulk density of 0.1482 g/cm^3, iodine number of 1069 mg/g, methylene blue number of 202 mg/g, B.E.T. surface area of 943m^2/g.

The effect of type of alkaline

The different reagents such as potassium hydroxide and sodium hydroxide were studied to determine the optimum reagent for activation. A mass of 9 g of rubber wood char (0.06 - 1.18 mm) were soaked in different reagent at char: reagent ratio was 1:1 and then were dried. These samples were used for each batch. The reactor was heated until the temperature in the tube increased and being fixed at the final temperature of 700°C. The nitrogen gas was passing up through the tube reactor for 3 hr. The results of this experiment were shown in **Table 4**.

Table 4 Effect of alkaline (1:1, 3 hr, 700°C, N_2 flow rate 1000 ml/min and size 0.60-1.18 mm)

Alkaline	Y (%)	BD g/cm^3	Ash (%)	MB (mg/g)	IA (mg/g)	B.E.T. (m^2/g)
KOH	48.00	0.114	5.236	202	1069	943
NaOH	55.15	0.148	4.792	146	465	286

Table 4 showed the iodine number, methylene blue number and BET. surface area which KOH, as an activating agent has higher properties than NaOH. It is because NaOH is a stronger alkaline than KOH. NaOH could react with char more violently and cause larger pores than using KOH. It is because NaOH had a high reaction inside the char as a result corresponding to the higher % yield and bulk density developed the large-scale pores (macropores). NaOH caused a violent internal reaction, which then resulted in large-scale pores. Meanwhile, KOH reacted with the char surfaces and then resulted in a large number of small-scale pores. Therefore, it was found out that when using NaOH as an activating agent, it will give a higher % yield and a higher bulk density value as shown in **Table 4**.

The experimental results showed that the optimum reagent for alkaline solution activation was using KOH. Because the characteristics of activated carbon gave the highest iodine number and methylene blue number. Properties were at a yield of 48.00 %, bulk density of 0.114 g/cm^3, 5.24 % ash, iodine number of 1069 mg/g, methylene blue number of 202 mg/g and B.E.T. surface area of 943 m^2/g.

Comparison of this work with other works

This work compared with the results of Thawatchai (2001) in the case of using KOH as an activating agent but a different raw material and last with Lozano-Castallo (2001) : 741; and Lozano-Castallo (2001) : 751 in case of using NaOH as an activating agent but different raw material as well, the characteristics of activated carbon obtained were expressed in **Tables 5.**

Table 5 Comparison of this work with Thawatchai (2001) (different raw material but same activating agent)

Description	This work	Thawatchai's
Raw material	Rubber wood	Thai lignite
Carbonization	400°C 45 min.	450°C 45 min
Activation	700°C 3 hr.	800°C 4 hr
Activating agent	KOH	KOH
Char : KOH ratio	1:1	1: 0.7
Size	0.60 - 1.18 mm	0.50 – 0.85 mm
% yield	48.00 %	50.87 %
Iodine number	1069 mg/g	846 mg/g
Methylene blue number	202 mg/g	229 mg/g
BET. surface area	943 m^2/g	1292 m^2/g

Thawatchai produced the activated carbon form Thai lignite through chemical activation by using KOH as an activating agent .It was found that the optimum condition for activation was at 1: 0.7 of ratio char : reagent temperature at 800°C for 4 hr. and particle size range 0.50-0.85 mm., which the properties of obtained activated carbon was a yield 50.87 %, bulk density 0.318 g/cm^3, 14.61 % ash, 846 mg/g of iodine number, 229 mg/g methylene blue number and 1292 m^2/g B.E.T. surface area. This work produced the activated carbon form Rubber wood which used the same activating agent, (KOH) .It was found that the optimum condition for activation was at 1:1 of ratio char : reagent temperature at 700°C for 3 hr. and particle size range 0.60-1.18 mm., which the properties of obtained activated carbon was a yield 48 %, 1069 mg/g of iodine number, 202 mg/g methylene blue number and 943.35 m^2/g B.E.T. surface area.

Table 5 shows that when comparing to absorption of iodine, it was found that this work gove a higher iodine adsorption than that of Thawatchai. However, it appeared that the methylene blue number and B.E.T. surface area was lower than that of Thawatchai. This is probably because of the different scale of porosity. Thawatchai's porosity could be very small scale (supermicropores) which did not allow iodine to be absorbed. Meanwhile, N_2, which is used for measuring B.E.T. surface area, has a smaller size as shown in **Table 5**. Besides, it was different raw material. Rubber wood used in this work has a structure with existing porosity of xylem & phloem**.** When activated by this work, it enlarged the existing porosity or created a new porosity in some part. Meanwhile, Thawatchai's Thai lignite was activated with KOH. The porosity that occurred would be a new one rather than expansion of the existing ones.

Table 6 Comparison of this work with Lozano-Castallo (2001) : 741; and Lozano-Castallo (2001) : 751 (different raw material but same activating agent)

Description	**This work**	**D. Lozano-Castallo**
Raw material	Rubber wood	Spanish anthracite
Carbonization	400°C 45 min.	N/A
Activation	700°C 3 hr.	750°C 1 hr
Activating agent	NaOH	NaOH
Char : NaOH ratio	1:1	1: 3
Nitrogen flow rate	1000 ml/min	500 ml/min
Size	0.60 - 1.18 mm	< 0.60 mm
% yield	55.15 %	64.00 %
Iodine number	465 mg/g	N/A
Methylene blue number	146 mg/g	N/A
BET surface area	286m^2/g	1248 m^2/g

Lozano-Castallo (2001) prepared the activated carbon form Spanish anthracite, through chemical activation by using NaOH as an activating agent. It was found that the optimum condition for activation was at 1: 3 of ratio char: reagent temperature at 750°C for 1 hr. and particle size < 0.60 mm., which the properties of obtained activated carbon was a yield 64 % and 1248 m^2/g B.E.T. surface area. This work produced the activated carbon form Rubber wood which used the same activating agent (NaOH). It was found that the optimum condition for activation was at 1:1 of ratio reagent: char temperature at 700°C for 3 hr. and particle size range 0.60-1.18 mm. The properties of obtained activated carbon was a yield, 55.15 %, 465 mg/g of iodine number, 146 mg/g methylene blue number and 286 m^2/g B.E.T. surface area.

Table 6 shows that when compared to the B.E.T. surface area of this work with Lozano-Castallo (2001) it was found out that B.E.T. surface area of Lozano-Castallo (2001) was higher. This is because of different raw materials. Anthracite contains a high quantity of fixed carbon and higher density than Rubber wood. When activated with NaOH, it would create a new porosity, meanwhile using Rubber wood as a raw material. In this research, the porosity of the xylem and phloem already existed. When NaOH was used for activation, it would rather expand the pores than developing new ones.

Besides, it was found that this might be an effect from the ratio of the char : NaOH used for activation. This work used ratio char : NaOH 1:1 while Lozano-Castallo (2001) used a ratio of 1:3. It is clear that more than 3 times the amount NaOH was used in this work. Therefore, it is possible that the higher ratio of NaOH used in activation with anthracite would result in building more porosity.

Conclusions

The experimental results showed the possibility for the production of activated carbon from Rubber wood. In this research, an experiment was undertaken to produce activated carbon from Rubber wood by a production process, which concluded carbonization and activation. The variables studied in the carbonization step were temperature (350-500°C) and carbonized time (45, 60, 90, and 120 minutes). The suitable conditions found for the carbonization were : temperature 400^{o}C for 45 minutes with 27.51 % yield, 70.46% fixed carbon, 25.90 % volatile matters and 2.32 % ash.

The activation step was realized by alkaline solution (potassium hydroxide and sodium hydroxide). The variables in this research were activation temperature, activation time and size of Rubber wood char including the ratio of char: alkaline. From the results of the experiment, it was found that the suitable condition for alkaline solution activation using KOH and NaOH as an activating agent 700°C for 3 hours using char from Rubber wood size 0.60-1.18 mm. Char activated obtained from activation by using KOH with 1:1 ratio of char per alkaline as activating agent has 48.00 % yield, 0.114 g/cm^3 bulk density, 5.24 % ash, iodine number 1069 mg/g, methylene blue number 202 mg/g and a BET surface of 943 m^2/g. Meanwhile activated char from using NaOH as an activating agent would produce a yield of 55.15%. Bulk density 0.148 g/cm^3, ash 4.79 %, iodine number 465 mg/g, methylene blue number 146 mg/g and B.E.T. surface area 286m^2/g. Finally, the properties of activated carbon prepared from KOH activation was used as a high commercial grade.

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