

Products of Palm Midrib Torrefaction as Activated Charcoal Raw Material

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ABSTRACT

The activated charcoal is a porous solid containing 85% - 95% of charcoal having undergone a reaction with gas or by addition of a chemical (KOH, NaOH, ZnCl₂) before, during or after carbonization to enhance its absorbency. Activated carbon has an important property that is absorption/adsorption. Materials containing charcoal elements can produce activated charcoal by heating it at high temperatures. Activated charcoal can be utilized as absorbent agent, electrode, catalyst, liquid waste or gas/waste treatment, as storage gas/gas adsorptive storage and water purification process both in drinking water production process and in waste handling. The purpose of this research is the utilization of palm midrib torrefaction product as raw material of activated charcoal through pyrolysis process and analyze the effect of pyrolysis temperature and pyrolysis time on the active charcoal raw material produced. For each torrefaction trial, nitrogen was flowed through the reactor at a flow rate of 150 mL / min for 15 min with a temperature of 275 ° C. Sample of palm midrib used 50 gram is put into reactor and heated for 45 minutes. The resulting torrefaction charcoal product is then processed into activated charcoal through a pyrolysis process of 3 grams with a pyrolysis temperature variable of 550 ° C, 600 ° C, and 650 ° C and a pyrolysis time of 5, 10 and 15 minutes.

KEY WORDS: *Charcoal, Palm Midrib, Torrefaction, Activated Carbon.*

1.0 INTRODUCTION

In large and small industries, activated charcoal is necessary because it absorbs odors, colors, gases, and metals. Increasing industrial growth in our society, the demand for active charcoal increases also. For industries in Indonesia, the use of activated charcoal is still relatively high. Unfortunately, the fulfillment of the need for activated charcoal is still done by locking. The abundant natural resources in Indonesia can disperse the need for use with domestic production. Palm oil agro-industry is growing rapidly in Southeast Asia, especially Indonesia and Malaysia, which is a world oil contributor (Hansen, 2015). Activities in this sector will produce biomass waste with a large volume of 5.5-7% palm kernel shell, empty bunches 22-23%, palm midrib 13.5-15% (Kong, 2014). Biomass waste is generally used as a boiler fuel in the palm oil industry (Kong, 2014).

To produce activated carbon bioadsorbent then made the usual process of making the process of carbonization. Palm stem waste is generally only left to rot away without any further treatment treatment by the people of Riau Province. During this time the palm stem is only used as animal feed, compost, and left in the plantation area (Hidayanto, 2013). To increase the selling value of palm midrib, the palm midrib should be processed into a product that has high selling value. Palm midrib can be used as active charcoal raw material which can be used for household and industrial purposes. One of the processes for obtaining charcoal is that it can be used as a process to replace carbonization and activation processes that have been widely used because the energy required is low and produces relatively little ash.

1.1 Palm Midrib

Palm midrib is one of the waste biomass that is quite a lot produced from oil palm plantations. Generally palm midrib waste is left to rot away without any further treatment treatment. The amount of cut palm oil can reach 40-50 midrib / tree / year with

midrib weight of 4.5 kg dry weight per midrib. In one hectare of palm is estimated to produce 6400-7500 midribs per year with calorific value of palm oil biomass ranging from 17200 kJ / kg (Simanihuruk, et al., 2008).

1.2 Potential of Palm Oil in Riau Province.

A very easy source of biomass today is the solid waste of oil palm plantations that have not been well utilized. Solid waste is in the form of midrib, empty bunches, stems and shells. The development of agricultural sector to date is quite rapid in Indonesia, especially the plantation subsector developed in Sumatra and Kalimantan. Particularly in Riau Province, palm oil is a prima donna commodity cultivated by many public and business entities. Based on data released by the Directorate General of Plantations of the Ministry of Agriculture (2014), the area of oil palm plantations in Indonesia is the highest of other commodities which is 10.95 million ha.

1.3 Torrefaction

Torrefaction is a process of biomass processing in the temperature range 200-300°C at atmospheric pressure without the presence of oxygen. At this temperature occurs the release of hemicellulose and volatile substances, thereby reducing the levels of O / C and H / C. Reduced levels of O / C and H / C will increase the yield mass and yield energy. The purpose of the torrefaction is to increase the calorific value and maximize the mass yield and energy yield (Basu, 2013). Biomass fermentation has successfully improved biomass characteristics as fuel, characterized by increased calorific value, high energy density, low water content, and hydrophobia (Solomon and Anas, 2012).

1.4 Pyrolysis

Pyrolysis is the chemical decomposition of organic matter through the heating process with no or little oxygen or other reagents, in which raw materials will break the chemical structure into gas phase. Pyrolysis aims to increase the calorific value of a material. Calorific value increases due to the release of water content and also the formation of tar that can serve as a film coating that prevents the re-absorption of water content by the material. The end result of the pyrolysis process is charcoal (solid carbon), tar (oil liquid in solid black) and gases such as methane and hydrogen. When viewed from the rate of reaction speed, then the pyrolysis is divided into two, namely slow pyrolysis and fast pyrolysis. The slow pyrolysis will occur in the temperature range of 150-300°C. In rapid pyrolysis (above 300°C), the overall reaction produces water vapor, charcoal, gas, and 50% -70% of the pyrolysis oil vapor which composes hundreds of monomer compounds, oligomers, cellulosic and lignin monomers (Zhang, et al., 2016).

1.5 Activated Charcoal

The activated charcoal is a porous solid containing 85% - 95% of charcoal having undergone a reaction with gas or by addition of a chemical (KOH, NaOH, ZnCl₂) before, during or after carbonization to enhance its absorbency. Activated carbon has an important property that is absorption / adsorption. The active

charcoal can be produced from biomass such as bamboo, tobacco, sago, cherry seeds, and almonds. Materials containing charcoal elements can produce activated charcoal by heating it at high temperatures. Activated charcoal can be used as absorbent agent, electrode, catalyst, liquid waste or gas / waste treatment, as storage gas / gas adsorptive storage and water purification process both in drinking water production process and in waste handling (Wu, 2004).

2.0 METHODOLOGY

2.1 Research Stage

This research will be conducted at Oleochemical Technology Laboratory, Chemical Engineering Department, University of Riau. The biomass feedstock from palm fronds used in this study was collected from Pekanbaru City and Kampar regency, Riau. The initial conditions of raw materials may affect the quality of the torrefaction products. Thus, an analysis of the raw materials consisting of testing the calorific value and proximate analysis. Calorific value analysis follows ASTM D-5865-13 procedure. Proximate analyzes (moisture content, volatile content, ash content, and fixed carbon content) follow ASTM D-3172-2013 to ASTM D-3175-2013.

2.2 Research Variables

The variables used in this study consist of fixed and variable variables.

a. Fixed Variables

1. Size of particles of midrib : ± 1 cm
2. Pressure : inert atmosphere
3. Temperature of torrefaction : 275 ° C
4. Torrefaction time : 45 minutes
5. Nitrogen flow rate : 150 mL / min.

b. Changed Variables

1. Pyrolysis temperature : 550 ° C, 600 ° C, and 650 ° C
2. Pyrolysis time : 5, 10, and 15 minutes

2.3 Torrefaction and Pyrolysis

Torrefaction and pyrolysis are performed in a horizontal fix bed reactor system. The horizontal fix horizontal reactor used in this study dimension is 60 cm long and 6 cm in diameter. The reactor is fitted with a 70 cm long condenser and a condensate trap of erlenmeyer vacuum. For each torrefaction trial, nitrogen was flowed through the reactor at a flow rate of 150 mL / min for 15 min before the start of the experiment to maintain an inert atmosphere. After that, the sample of palm stem was heated with a temperature of 275 ° C for 45 minutes. After completion of the torrefaction, the reactor was removed from the furnace to cool the resulting torrefaction. Each process of torrefaction is repeated three times under the same temperature and time conditions.

The resulting torrefaction charcoal product is then processed into activated charcoal through pyrolysis process. In each experiment, 3 grams of sample of charcoal with a variation of pyrolysis temperature of 550 ° C, 600 ° C and 650 ° C were

processed for 5, 10 and 15 minutes in the reactor. Solid, liquid and gas products are collected for further analysis. The solid and liquid results are calculated from the direct weight of each fraction after the reaction is complete, while the gas yield is calculated by differences based on the mass content. All experiments were performed three times. The series of experimental equipment can be seen in Figure 1.

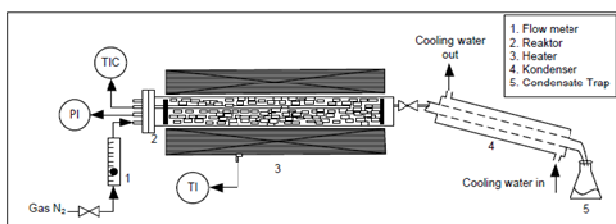


Figure 1: Torrefaction Reactor Scheme

2.4 Analysis Method.

The proximate analysis of the initial palm stem samples, the products of pyrolysis and pyrolysis charcoal were carried out according to GB212-91 standard. The calorific value was analyzed by the SDACM3000 Calorimeter. Specific surface areas were analyzed using Brunauer-Emmett-Teller (BET). Each analysis is repeated three times to ensure the accuracy of the results. The expected output is obtained from the results of research of torrefaction product which will be used as activated charcoal to be compared with theory and data from the literature.

2.5 Data Collection Techniques and Data Analysis.

This data information technique is laboratory research. Data obtained later with some references related to the study. The results obtained are then analyzed ie the proximate analysis of the initial palm stem samples, the products of torrefaction and pyrolysis charcoal carried out according to GB212-91 standard. The calorific value is analyzed by the SDACM3000 Calorimeter and its value is sought by the calorific value formula. The specific surface area was analyzed by using a widely measurable Brunauer-Emmett-Teller (BET) of the obtained torrefaction product

3.0 RESULT

The result of this research is charcoal product. All variables of temperature and pyrolysis research have been conducted, resulting in 9 different types of charcoal products.

3.1 Weight Charcoal Product

The data of Charcoal Product's weigh will be shown in Table 1. As the Yield of Charcoal product.

Table 1: Data Charcoal Product's weight as the Yield.

Variables	Weight (gr)	Yield (%)	Variables	Weight (gr)	Yield (%)
550°C, 5 min	1.13	37.66	600°C, 15 min	1.109	36.96
550°C, 10 min	1.237	41.23	650°C, 5 mn	1.049	34.96
550°C, 15 min	1.331	44.36	650°C, 10 min	1.040	34.66
600°C, 5 min	1.252	41.73	650°C, 15 min	1.037	33.56
600°C, 10 min	1.199	39.96			

In the table above, it can be seen the effect of temperature and time of pyrolysis on yield of char product. In variation of pyrolysis time with fixed variable temperature 550°C, the weight of the biggest charcoal product is at 15 minutes with yield 44.36%, while the smallest weight of charcoal is at 5 minutes temperature with yield of 37.66%. This indicates that with time will affect the pyrolysis process that occurs because at the time of pyrolysis 5 minutes has not happened perfect decomposition. In the pyrolysis variation with fixed variable temperature 600°C, the weight of the largest charcoal product is at 5 minutes temperature with 41.73% yield, while the smallest weight of the charcoal is at 15 minutes with yield 36.96%. This shows that the long process time resulted in less optimum decomposition process because the temperature used is higher than before. This shows the greater the temperature used at less heating time, the more charcoal products are produced.

In the variation of pyrolysis time with fixed variable temperature 650°C, the weight of the biggest charcoal product is at 5 minutes temperature with 34.96% yield, while the smallest weight of the charcoal is at 15 minutes with yield 34.56%. This shows that the long process time resulted in less optimum decomposition process because the temperature used is higher than before. At 650°C, the processing time does not affect significantly because the yield is close. This shows the effect of heating temperature. If the higher the heating temperature, the resulting charcoal product is also less if the time used is also longer. In the current study, Zhang et al. (2016), who conducted a study focusing on the effects of torrefaction on the yield and quality of rice pyrolysis pyrolysis and its application in preparation to activate carbon by chemical activation method using NaOH. The resulting activated car shows the highest yield of 23%. This indicates that the product of torrefaction with raw material of palm stem is better than the use of torrefaction product with raw material of rice husk.

3.2 Result of Proximate Analysis

Table 2: Data Proximate Analysis

Variables	Water Content (%)	Ash Content (%)	Volatile Content (%)	Fixed Carbon Content (%)
Torrefaction Product	3.28	3.95	46.24	46.54
550°C, 5 min	1.8	4.1	12.2	81.9
550°C, 10 min	1.6	5.3	14.6	78.5
550°C, 15 min	1.3	6.5	16.1	76.1
600°C, 5 min	1.1	7.2	17.4	74.3
600°C, 10 min	0.8	7.6	16.9	74.2
600°C, 15 min	0.4	8.1	16.2	75.3
650°C, 5 min	0.3	8	15.7	76
650°C, 10 min	0.25	8.2	15.3	76.25
650°C, 15 min	0.17	8.25	14.7	76.88

In the table above, it can be seen the effect of temperature and time of pyrolysis on charcoal product. The lowest water content is at the temperature of pyrolysis 650°C and the pyrolysis time is 15 minutes, the lowest ash content is at pyrolysis temperature 550°C and the pyrolysis time 5 minutes, the lowest volatile level is at pyrolysis temperature 550°C and pyrolysis time 5 minutes. Good quality charcoal products should have moisture content, ash content and low volatile content so that it has high fixed carbon content. Because, the fixed carbon content is the result of 100% reduction - (moisture content + ash content + volatile levels). The highest fixed carbon content was found at pyrolysis temperature 550°C and pyrolysis time 5 min. This indicates that the temperature is too hot and the longer time resulted in a small fixed carbon content. The higher the carbon content of carbon content, the better the quality of the active charcoal raw material produced.

In the current study, Zhang et al. (2016), who conducted a study focusing on the effects of torrefaction on the yield and quality of rice pyrolysis pyrolysis and its application in preparation to activate carbon by chemical activation method using NaOH. The resulting activated carbon shows the water content for the charcoal product ranging from 3-9%, the ash content for the charcoal product ranges from 39.6 to 42.6%, the volatile content for the charcoal product ranges from 13.8 to 15.7% fixed carbon for charcoal products ranged from 42.4 to 44.7%. This indicates that the product of torrefaction with raw material of palm stem is better than the use of torrefaction product with raw material of rice husk.

3.3 Result of Calorific Value Analysis

Analysis of calorific value of charcoal products aims to determine the calorific value of the resulting charcoal product. The following is the result of the analysis of calorific value of charcoal products obtained are :

Table 3: Results of Charcoal Calorific Value Analysis

Variable	Calorific Value (Cal/gr)	Method	Standard reference
Torrefaction Product	4567,2	Isoperibol	ASTM D 5865
550°C, 5 min	6060,8	Isoperibol	ASTM D 5865
550°C, 10 min	6219,0	Isoperibol	ASTM D 5865
550°C, 15 min	6492,7	Isoperibol	ASTM D 5865
600°C, 5 min	6060,1	Isoperibol	ASTM D 5865
600°C, 10 min	6646,6	Isoperibol	ASTM D 5865
600°C, 15 min	6485,0	Isoperibol	ASTM D 5865
650°C, 5 min	6316,3	Isoperibol	ASTM D 5865
650°C, 10 min	6553,4	Isoperibol	ASTM D 5865
650°C, 15 min	6589,7	Isoperibol	ASTM D 5865

In the table above, we can see the results of calorific value test in caloric / gr. The resulting caloric value has fluctuated data, indicating that the temperature and time of pyrolysis are very influential on the calorific value of the char product. The highest heating value is at 600°C pyrolysis temperature and 10 minutes pyrolysis time. This shows the optimum condition to produce high heating value can be done at 600°C pyrolysis and 10 minutes pyrolysis time. In the current study, Zhang et al. (2016), who conducted a study focusing on the effects of torrefaction on the yield and quality of rice pyrolysis pyrolysis and its application in preparation to activate carbon by chemical activation method using NaOH. The resulting activated car has a calorific value of 4354.16 - 4550.014 Cal / gr. This indicates that the product of torrefaction with raw material of palm stem is better than the use of torrefaction product with raw material of rice husk. The calorific value of torrefaction products and its charcoal products is higher than that of rice husk charcoal.

3.4 Analysis of Brunauer-Emmett-Teller (BET)

The BET analysis which includes three analyzes ie adsorption, desorption and BET (specific surface area) analyzes was conducted to determine the specific surface area of the resulting charcoal product so that it can be compared with the reference. The following is the result of BET analysis of the charcoal

products obtained:

Table 4: Results of BET Analysis of Charcoal Products

Type of Analysis (Charcoal Product 550°C, 5 minutes)	Surface Area (m ² /gr)
Adsorption	58.523
Desorption	50.637
BET	6.950

In the table above, can be seen the results of adsorption analysis, desorption and BET charcoal products in the form of surface area in units of m² / gr. The analysis was performed on only one sample, charcoal product at pyrolysis temperature of 550°C and pyrolysis time of 5 minutes because it has high fixed carbon content. For adsorption of charcoal products has a surface area of 58,523 m² / g, for desorption analysis has a surface area of 50,637 m² / g, and for BET analysis has a surface area of 6,950 m² / g. In the current study, Zhang et al. (2016), who conducted a study focusing on the effects of torrefaction on the yield and quality of rice pyrolysis pyrolysis and its application in preparation to activate carbon by chemical activation method using NaOH. The resulting activated carbon possesses 194.9-217.1 m² / g. This indicates that the product of torrefaction with raw material of palm stem is better than the use of torrefaction product with raw material of rice husk. The specific surface area of the charcoal product is higher than that of rice husk charcoal. In addition, the surface area of palm fruit stove charcoal products for adsorption and desorption applications is also high.

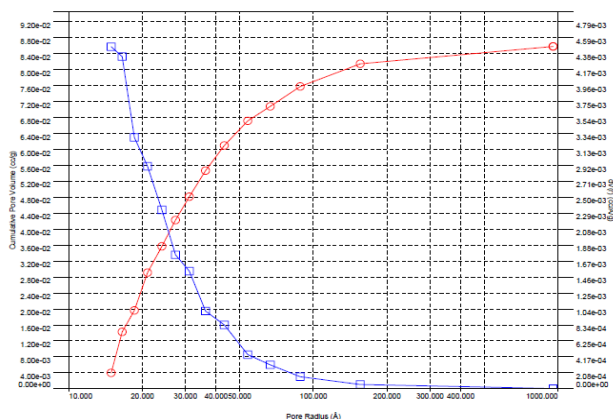


Figure 2: Adsorption isotherms of N2

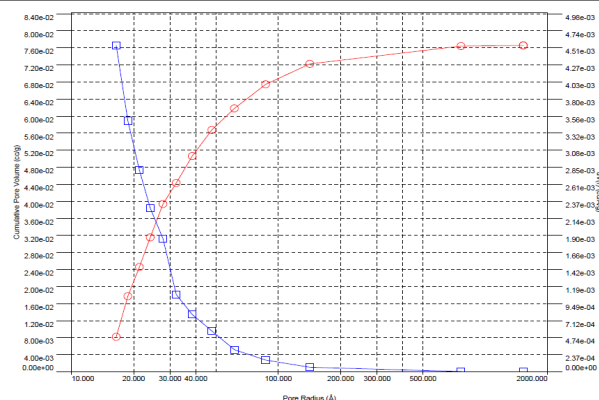


Figure 3: Desorption isotherms of N2

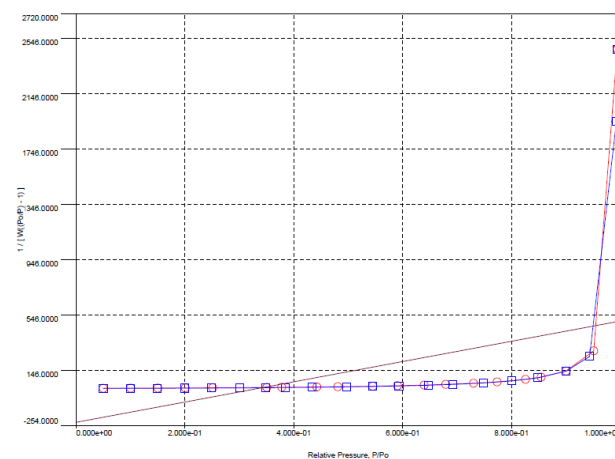


Figure 4: BET Analysis

4.0 CONCLUSION

The results and discussions of Production of Palm Stem Torrefaction as An Activated Raw Material has presented. By using Palm Stem as an raw material, it shows a better quality than rice husk. Mentioned techniques can effectively be implemented for this methods with high accuracy rate.

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