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QUALITY OF IODINE NUMBER, VOLATILE MATTER AND YIELD IN MAKING ACTIVATED CHARCOAL FROM PALM SHELLS USING PARTIAL OXIDATION METHOD AT VARIOUS AIR FLOW RATE VARIATIONS

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Abstract

The palm oil industry significantly contributes to household welfare resulting from palm oil businesses. The palm oil industry also has great potential to cause environmental impacts. Some products of high economic value that can be produced from palm oil shells are activated charcoal, liquid smoke, phenol, charcoal briquettes, and shell flour. This research will focus on the quality of iodine number, volatile matter, and yield in making activated charcoal from palm shells using the partial oxidation method at various variations in air flow rate, where carbonization and activation are carried out using pyrolysis with the principle of partial oxidation. by injecting air with limited airflow rates of 20, 25, 30, 35, and 40 L/minute for 5 hours. Based on these variations, the results obtained are the air flow rate on the quality of activated charcoal as referred to the Indonesian National Standard (SNI) 06-3730-1995, especially in the parameters (yield, volatile matter, and iodine number). The best results were shown at an airflow rate of 35 L/minute with a product yield of 20%, a volatile material content of 8.73%, and an iodine number of 750.1403 mg/g. These results have met SNI 06-3703-1995 standards.

Keywords: Activated charcoal, Air flow rate, Iodine number, Palm kernel shell, Partial oxidation.

1. Introduction

The palm oil industry significantly contributes to household welfare resulting from palm oil businesses. The palm oil industry also has great potential to cause environmental problems [1]. Palm oil shells are a by-product or solid waste obtained from the decomposition of palm kernels in the palm oil processing process [2]. Palm shell waste is greyish-black, irregular in shape, and quite high in hardness. Palm oil shells have calories of 3500 kcal/kg-4100 kcal/kg and contain lignin (29.4%), cellulose (26.6%), and hemicellulose (27.7%) [3]. The cellulose and lignin compounds contained in palm oil shells can be converted into carbon. The decomposition process in pyrolysis produces products in the form of solid fuel, namely carbon, liquid tar, carbon dioxide gas, methane, and other gases.

The main results are three types of products, namely solid charcoal, gas, and liquid. The pyrolysis process occurs at temperatures above 300°C; however, the combustion temperature conditions, and length of process time are greatly influenced by the raw materials and manufacturing methods [4]. Palm oil shells are a lignocellulosic material with a high carbon content and a density greater than wood, namely 1.4 g/ml. Where the greater the density of the raw material, the greater the absorption capacity of the activated charcoal produced, making it good for making active carbon. Utilization of palm shells can reduce the impact on the environment because palm shells have the potential to affect the biodiversity of the surrounding environment and can also disrupt the balance of the surrounding ecosystem [5].

Palm oil shells have the potential to be developed into useful products and provide added value from an economic and environmentally friendly aspect. Several products of high economic value that can be produced from palm oil shells are activated charcoal, liquid smoke, phenol, charcoal briquettes, and shell flour [6].

As is known, charcoal is a porous solid containing 85-95% carbon, which is produced from a high-temperature heating process for materials containing high carbon elements. One of these materials comes from biomass, namely palm oil shells, which generally produce charcoal when burned, so the charcoal can also be used as an adsorbent [7]. Activated charcoal that produces adsorbent can be activated. This activation aims to open the pores that are still closed by some materials in the form of metal and other materials. These materials are in the form of hydrocarbons and other components such as ash, water, nitrogen, and sulphur. This can cause the absorption capacity of inactivated charcoal to be low.

In the pyrolysis combustion process, incomplete combustion occurs. The incomplete combustion of raw materials causes complex carbon compounds not to be oxidized into carbon dioxide. Heat energy causes oxidation so that complex carbon molecules break down so that most of the raw materials become carbon or charcoal. Another term for pyrolysis is dry distillation or destructive distillation, which is the process of decomposing organic materials irregularly caused by heating without air [8].

Open or coke pyrolysis is a heating process at a certain temperature of organic materials in a very limited amount of oxygen. This pyrolysis process has a partial oxidation principle because it does not require external heat. The charcoal formed has a porous surface, so it is suitable for use in making activated charcoal. The principle of partial oxidation is that the feed is burned first with direct fire or embers. Then the air is blown consistently until it reaches a constant state, and heat can be used to carry out the pyrolysis process.

The factor that affects the quality of charcoal when burned using partial oxidation pyrolysis is the speed of the airflow. In partial oxidation pyrolysis, if the combustion temperature is not constant, this is caused by the air entering at a certain speed, so the greater the air speed, the higher the combustion temperature. Then with increasing airspeed, the pressure and amount of oxygen will increase, so that the combustion rate will increase along with increasing temperature [9].

One of the important parameters that affect the drying process is the iodine number and volatile components. The determination of carbon adsorption capacity is identified by iodine absorption capacity. By knowing the iodine absorption capacity, the ability of carbon to adsorb a substrate can be predicted. The method used is the iodometry titration method. The adsorption power shown shows how much adsorbent can adsorb iodine. If data is obtained, the higher the iodine number, the greater the adsorption power. Adsorption of iodine solution is indicated by a decrease in the concentration of iodine solution [9].

Meanwhile, the Volatile Matter Test aims to determine the percentage of substances or compounds that do not vaporize during the carbonization and physical activation processes. High levels of volatile substances can affect the absorption capacity of activated carbon. The higher the level of volatile substances in activated carbon, the lower the absorption capacity [10]. One method used in the principle of partial oxidation is to limit the air entering the pyrolysis reactor. The air that enters mostly contains oxygen and nitrogen gases. The oxygen that enters functions to oxidize the material contained in organic materials [11], but oxygen is limited by regulating the air flow rate in the pyrolysis reactor so that the material as a whole does not become ash. When oxygen is needed in the carbonization process, nitrogen from the air can be used as an activating agent for the resulting charcoal [12].

This research will provide a better solution for making activated charcoal from palm shell waste using the partial oxidation method. In addition, the technique of making activated charcoal with this method can shorten the process from several stages to one stage. The significance of this research depends on three main areas. Until now, there has been little research on the effect of airflow rate on the process of making activated charcoal using palm shells. The purpose of this research is to focus more on how to make activated charcoal, in this case evaluating the effect of airflow rate on the quality of activated charcoal based on Indonesian National Standard (SNI) 06-3730-1995 (Yield, Volatile Matter, and Iodine).

2. Materials and Methods

2.1. Materials

Palm Kernel Shell comes from the PT plant. REA KALTIM PLANTATIONS Kembang Janggut District, Kutai Kartanegara (Kukar) Regency, East Kalimantan Province.

2.2. Methods

Palm oil shells from Rea Kaltim Plantations still have impurities in the form of fibres and palm seeds. Before carrying out the main process, it is necessary to clean the shell by separating the impurities. After it is considered clean, the drying stage is carried out using sunlight. After that, five kilograms of each process are weighed and then stored and ready for use. Material preparation is done by cleaning the shell from fibres and palm seeds. This is done to improve the performance of the equipment during the manufacture of activated charcoal. After ensuring that it is dry, the dry and clean shells are put into the partial oxidation equipment at 5 kg per batch. Research procedures and equipment for partial oxidation can be seen in Figs. 1 and 2.

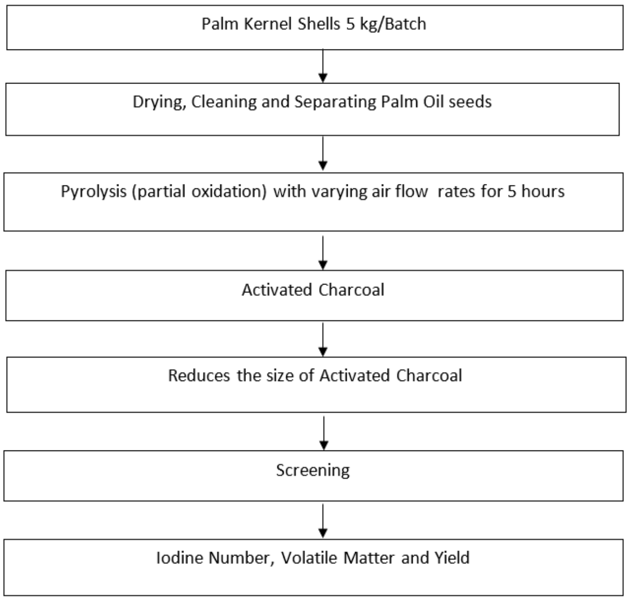
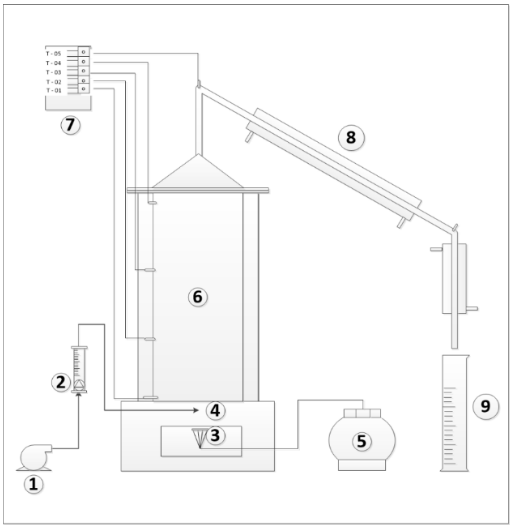


Fig. 1. Research procedure diagram.



Caption: 1. Compressor, 2. Air Flow Meter, 3. Burner, 4. Air Distribution, 5. Gas Cylinders, 6. Partial Oxidation Reactor, 7. Temperature Indicator, 8. Double Pipe Heat Exchanger, 9. Bio Oil Collected.

Fig. 2. Pyrolysis equipment.

The method used for the volatile matter test of the ASTM D3174 standard is given by Eq. (1).

$$\text{Volatile Matter (\%)} = \frac{m2-m3}{m2-m1} \times 100\% \quad (1)$$

For Iodine number analysis uses the SNI 06-3730-1995 standard is given by Eq. (2).

$$\text{Iodine Number } (I_2) = \frac{\left(10-\frac{Vtio \times Ntio}{Niod}\right) \times 126{,}9 \times fp \times Niod}{W} \quad (2)$$

3. Results and Discussion

The results of the research on Quality of Iodine Number, Volatile Matter and Yield in Making Activated Charcoal from Palm Shells Using Partial Oxidation Method at Various Air Flow Rate Variations can be seen in Table 1.

Table 1. Research result.

Air Flow Rate (L/min)	Temperature Average (°C)	Yield (%)	Volatile Matter (%)	Iodine Number (mg/g)
20	432.69	29.8	17.61	517.0282
25	474.12	29.01	14.82	620.186
30	517.51	24.03	14.56	671.198
35	565.34	20.2	8.73	750.140
40	585.98	19.01	9.17	732.522
SNI06-3730-1995			Max 25	Min 750

In Fig. 3 it can be seen that the higher the air flow rate in the pyrolysis process, the higher the average temperature and iodine absorption capacity.

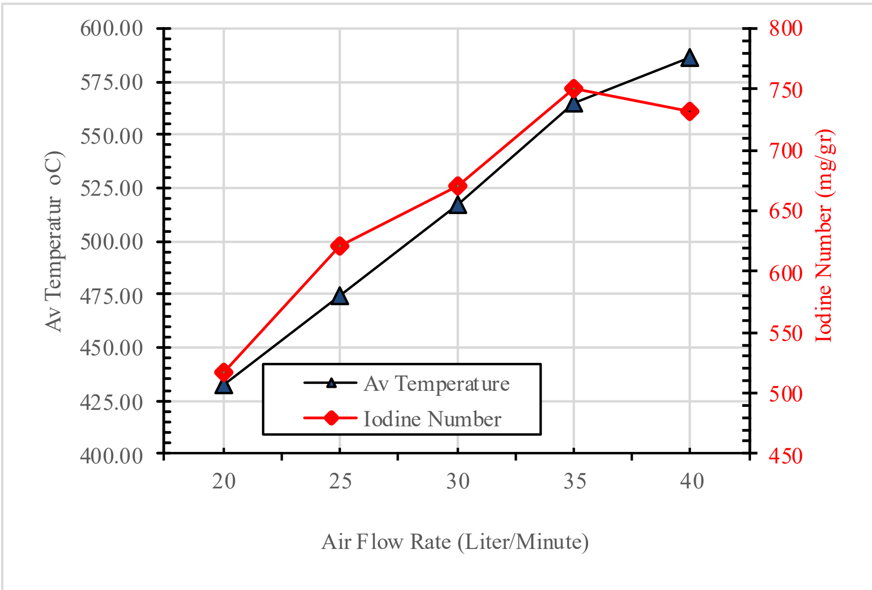


Fig. 3. Iodine number quality and average temperature of activated charcoal on pyrolysis air flow rate.

These findings explain that there is a significant influence on the airflow rate provided, where the higher the airflow rate used, the more optimal the oxidation mechanism will be. The shell will oxidize and cause the shell pores to open so that the entanglement mechanism will be more effective. The effectiveness of the adsorption mechanism depends on the oxidation method provided as well as the heat supply, as indicated by the higher temperature of the process that occurs, the oxidation mechanism. This will also be effective in the activation process, which causes the content of volatile substances to decrease, which causes more pores to form in activated charcoal products [13].

From the results of the iodine content analysis, the greater the decrease in the concentration of the iodine solution, the higher the iodine absorption capacity. From Fig. 3, for airflow rates of 20 L/minute, 25 L/minute, and 30 L/minute with average temperatures of 432.69 °C, 474.12 °C, and 517.51 °C, the power analysis results are obtained. The iodine absorption of 517.0282 mg/g, 620.1861 mg/g, and 671.1982 mg/g does not meet the standard; this is because the oxygen and nitrogen entering the pyrolysis process are not optimal, causing the pyrolysis process not to run well. The best results for iodine absorption by activated charcoal in this study were shown at an airflow rate of 35 L/minute of 750.1403 mg/g. These results have met the quality standards for activated charcoal according to SNI 06-3703-1955 standards, namely 750 mg/g.

From these data, it can be concluded that the higher the value of the iodine number, the lower the yield. The higher air flow rate will cause the oxidation temperature to increase, which causes the material oxidation mechanism in the reactor to increase during the pyrolysis process. This is inversely proportional to the value of the iodine number. Based on the results obtained as shown in the data shown in Fig. 4, it shows that if the flow rate is 20 L/minute, the resulting activated charcoal product has a maximum yield of 29.8%, with a minimum iodine number of 517.028 mg/gr, whereas in the higher flow rate of 40 L/minute, the iodine number was 732.522 mg/gr, but the yield obtained was smaller, where under these conditions only a 19% yield was produced. The decrease in yield was caused by an increase in process temperature, which could burn more optimally, using several carbon bonds to be converted into volatile components. Based on Table 1, at a flow rate of 20 L/mL/minute, process temperature shows 432.69 °C, which explains that more air L/minute simultaneously increases the process temperature.

The increase in temperature will then have the effect of causing the volatile content to increase, resulting in a decrease in carbon residue, which is counted as sediment. Oxygen from the air causes the combustion mechanism to approach perfectly, resulting in thermal decomposition. Oxygen functions to oxidize materials, while the percentage of nitrogen in the air can function as a physical activating agent. Due to high temperatures, some charcoal turns into ash and volatile gases, so the resulting yield tends to be small [14]. So that the function of oxygen and nitrogen flowing into the reactor helps the pyrolysis process to occur perfectly, the incoming oxygen will react with the activated charcoal to become CO_2, which causes the number of solids to decrease.

Determining the levels of volatile substances is one way to find out how much the surface of activated charcoal contains substances other than carbon, thereby affecting its adsorption capacity. The lower the level of volatile substances, the greater the absorption capacity of activated charcoal because the bound carbon content will be greater. High levels of volatile matter indicate that there is still non-carbon compounds bound to charcoal. These non-carbon compounds can cover the surface or pores of the charcoal, thereby affecting the absorption capacity of the charcoal [15].

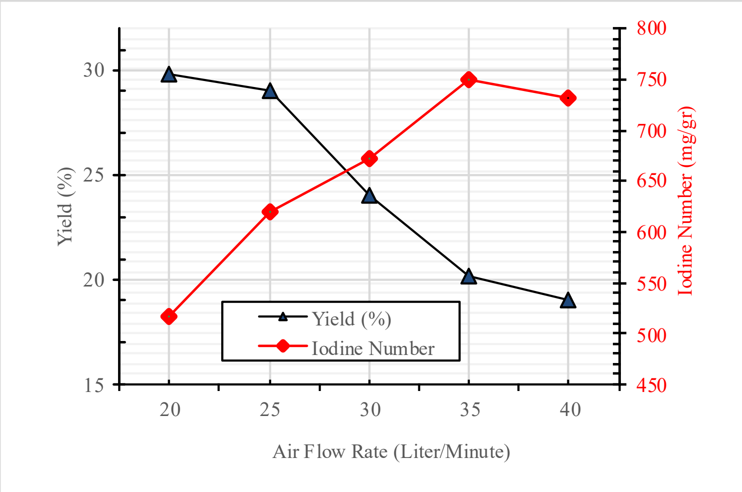


Fig. 4. Iodine number quality and yield of activated charcoal on pyrolysis air flow rate.

The levels of volatile substances in this study are shown in Fig. 5. The higher the flow rate, the higher the pyrolysis temperature, and the content of volatile substances tends to be lower. The results shown are that when the airflow is 35 L/minute, the average temperature is 565.34 °C, the iodine number is 750.140 mg/gr, and the volatile components are 8.73% lower, whereas at the air flow rate of 20 L/minute, the average temperature obtained was 432.69 °C, with an iodine number of 517.028 and higher volatile substances of 17.61%, then at a higher air rate of 40 L/minute, volatile substances increased because it has reached optimum conditions, but the iodine number value has decreased slightly to 732.522. This decrease is due to the action of oxygen as an oxidizer, which turns cellulose into ash.

Volatile substance content testing is carried out to determine the volatile substance content contained in activated charcoal, such as H_2, CO, and CH_4, as well as condensing vapours such as CO_2 and H_2O. The lower the level of volatile substances, the greater the absorption capacity of activated charcoal because the bound carbon content will be greater [3, 10]. This shows that as long as the pyrolysis process is carried out well, where there is excess N_2 gas, the pyrolysis process becomes more perfect so that most of the evaporated fractions in the raw material are lost. A good pyrolysis process will produce charcoal with low levels of volatile substances and high levels of bound carbon so that the calorific value of the charcoal is high. The low level of volatile matter indicates that components with high oxygen content, such as hemicellulose and amorphous cellulose, have been thermally decomposed and only produce the main charcoal products from lignin and crystalline cellulose. From Fig. 5, it can be seen that the volatile matter values of all the activated charcoal samples produced have met the activated charcoal quality standards according to SNI 06-3703-1995.

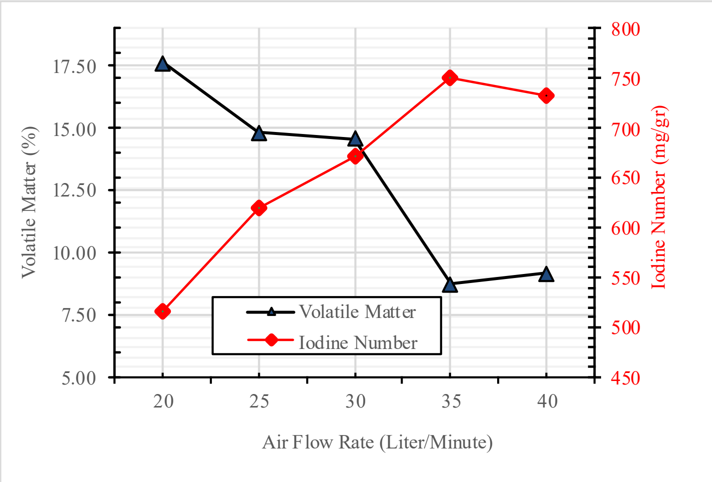


Fig. 5. Iodine number quality and volatile matter of activated charcoal on pyrolysis air flow rate.

4. Conclusions

A series of experiments were conducted to determine the study on the production of activated charcoal from palm shells by partial oxidation at different airflow rates. The trend of increasing flow rates has a significant effect on the yield, iodine number, and volatile matter quality of the charcoal produced. The optimum conditions obtained in this research were achieved at an airflow rate of 35 L/min. The resulting yield shows that a higher flow rate produces a lower yield due to the greater influence of the combustion reaction; the carbon residue calculated as soaking was 20%. For other parameters, such as volatile components, the result was 8.73%, and the absorption capacity determined as the iodine number was 750.1403 mg/g. The quality of the charcoal produced has met the requirements of SNI 06-3703-1995.

Nomenclatures

Fp	Dilution factor
m_1	crucible weight
m_2	The weight of the carbon filled crucible
m_3	The weight of the carbon-filled crucible after being in the oven
Niod	solution Concentration of iodine solution (N)
Ntio	Concentration of Sodium Thiosulfate (N)
Vtio	Volume of Sodium Thiosulfate solution (ml)
W	Carbon mass (gr)
126,9	Iodine atomic weight

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