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Effect of Air Flow Rate and Temperature on Ash Content, Volatile Ingredients, and Calories Through Partial Oxidation Method in Converting Palm Kernel Shells into Adsorbent

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ABSTRACT

One of the biggest commodities in Indonesia is palm oil. Palm oil production in Indonesia continues to increase from year to year, this of course has an impact on increasing Palm Shell (PKSh) production. It should be noted that PKSh is a by-product of palm oil processing in the form of shells which is quite large in quantity, that is, every ton of palm oil produces 65 kg of PKSh. Palm oil shells contain 26.6% cellulose and 27.7% hemicellulose which is good for making activated charcoal. Basically, PKSh has economic value in the palm oil mill itself because it is used as fuel in boilers, but in large quantities and has the potential to be used as active carbon. Activated charcoal is very useful for gas and liquid-based purification technology, where the activated charcoal will function as an adsorbent medium and can also be used in waste processing. Therefore, this research will focus on the activation method, in this case, the activation method is carried out using the partial oxidation technique, namely a pyrolysis process carried out at air flow speeds of 20, 25, 30, 35, and 40 L/minute for 5 hours. This research aims to determine the effect of airflow rate and activated charcoal yield on the values of Ash Content, Volatile Materials, and Fixed Carbon by referring to SNI standard No. 06-3730-1995. The best results were shown at an airflow rate of 35 L/minute with a product yield of 20%, ash content of 7.51%, volatile matter content of 8.73%, and fixed carbon of 77.94%. These results have met SNI 06-3703-1995 standards.

1. Introduction

One of the commodities that makes a big contribution to moving the Indonesian economy is palm oil where the area of oil palm plantations increased by 1.88 percent from 2018 to 14.60 million hectares with an increase in Crude Palm Oil (CPO) production by 12, 92 percent to 48.42 million tons [1]. Conversion of Fresh Fruit Bunch (FFB) into CPO is around 25 to 28 percent and conversion of Palm Kernel Shell (PKS) production from FFB reaches 6.8 to 7.4 percent [2]. This shows that the potential

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of PKS in Indonesia reaches 11.8 million tons per year. several CPO-producing countries such as Indonesia, Malaysia, Colombia, and Brazil, the use of PKSh is widely used as boiler fuel for heating fruit as well as electricity-producing boilers. The use of PKS to make activated charcoal which has more selling value is still lacking in Indonesia, one of which is the potential for PKSh to be converted into activated charcoal. The potential of PKS as Activated Charcoal really depends on the composition of the PKSh. The composition of the oil palm shell itself consists of 27.7% cellulose, 21.6% hemicellulose, the lignin content in this plant is 44%, and the results of the proximate analysis are 11% Moisture, 2.1% Ash, 19.7 Fixed Carbon and 67.2% Volatile Matter. The ultimate PKS analysis contains 49.7% Carbon, 5.32% Hydrogen, 0.08% Nitrogen, 44, 86% oxygen and 0.16% sulfur [3]. Activated Charcoal Technology has been carried out by many researchers from various countries. The technique used in the manufacture of activated charcoal generally uses a three-stage process principle, namely carbonization, chemical activation, and physical activation [4]. For that, a method is needed by combining carbonization and activation with a method of limiting oxygen from the air by regulating the speed of the air flow rate in the carbonization process, and utilizing excess nitrogen in the air as an activating component. This process is known as partial oxidation.

This research will focus more on the method for making activated charcoal, in this case, to evaluate the effect of airflow rate on the quality of activated charcoal based on Indonesian National Standard (SNI) 06-3730-1995 (Ash Content, Volatile Materials, Fixed Carbon). To produce activated charcoal, one of the main processes is thermal activation. With the initial process through thermal activation, this process is more likely to occur because the morphological characteristics and structural properties can change, namely the amount of porosity is greater [5]. The impregnation pretreatment process is carried out to improve the pore structure of the precursor to increase the surface area [6]. Biomass has the potential to be a very promising alternative source of raw material for activated charcoal production because of its abundant availability. Activated charcoal can be produced from biomass gasification products. Energy consumption during the gasification process is a major constraint on the thermal efficiency and design of gasification equipment. Therefore, significant improvements and process optimization are very important in developing sustainable use of renewable natural resources [7]. Activated carbon derived from renewable biomass is a potential source as an adsorbent in various industrial sectors [8]. This is due to several advantages, including the availability of raw materials which is quite abundant, the results of activated carbon sourced from biomass which is very efficient in reducing pollutants in water sources and wastewater, the price of raw materials is very cheap, and the processing process is good. designs that require relatively cheaper costs [9]. Research related to the manufacture of activated charcoal has been carried out [10]. by looking at changes in the chemical composition and pore structure of palm oil shells using pyrolysis with temperature variations. The best characteristics were obtained at a temperature of 750℃ and flowing directly with nitrogen at a rate of 300 mL/minute. The ash content produced was 17.41%, the volatile matter content was 5.31%, and the fixed carbon content was 77.28%. In addition, in research on the effect of pyrolysis on the physical and chemical properties of changes in activated charcoal from palm oil shells by [11,12]. varying the pyrolysis temperature. From the research, the charcoal yield was 32.78%, water content 2.19%, volatile matter 9.14%, ash content 8.14%, and fixed carbon 80.23% at a temperature of 700℃ and direct nitrogen flow at a speed of 3 l/min.

The Objective of this research is produce carbon residues that have a high iodine number, through a partial oxidation technique, namely with minimal oxygen, to maximally help remove volatile compounds that cover the active surface area. Burning charcoal often results in the formation of a charcoal furnace, where heat is supplied by burning part of the starting material itself, but with limited oxygen supply, it is possible for the material to be heated in a closed medium. through this research it is hoped that a very irregular microstructure will be formed which has high porosity characterized by large absorption capacity [12,13,14].

2. Methodology

Palm Shells come from PT. Kebun Mandiri Sejahahtera, North Penajam Pasir Regency, East Kalimantan. The shells are cleaned from other impurities, then dried and then put into a partial oxidation reactor of 5 kg. Partial oxidation equipment can be seen in Figure 1 below

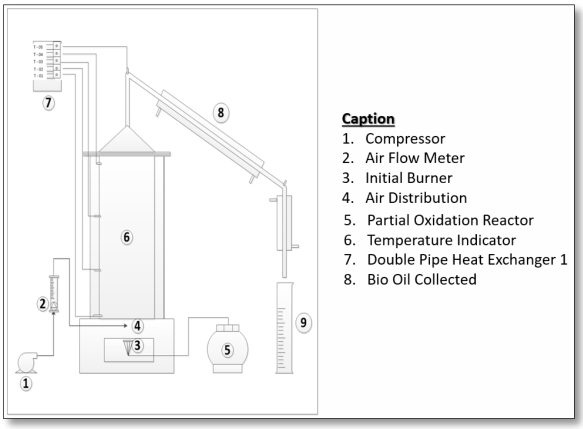

Fig. 1. Partial Oxidation Equipment

Input 5 kg of PKS at the top of the reactor. Turn on the fire at the bottom as an initial combustion for 5 to 10 minutes, then the compressor is turned on, and at the same time, the air flow rate at 20 L/minute at the same time runs the cooling water in the condenser. Data collection is carried out every 20-minute interval, run the process for 5 hours. Collect condensate that occurs during the pyrolysis process. indicate when the time has been reached, then take the activated charcoal product at the bottom of the reactor. Repeat the process from the step above onwards for flow rates of 25, 30, 35, and 40 L/minute. The process is stopped by setting the time for 5 hours by stopping the air flow rate. At the end of each process, the solid product in the form of charcoal at the bottom of the pyrolysis reactor is removed by ensuring that no combustion has occurred. Analysis of activated charcoal that has been obtained through testing for ash content, volatile matter, and heating value using the ASTM method, respectively as follows Ash Content (ASTM D 3174-12), Volatile Material (ASTM D 3175-11), Fixed Carbon (ASTM D 3172- 07a).

3. Results

The results of the analysis of activated charcoal at various flow rates based on the oxidation method provide results that meet Indonesian national standards based on volatile matter content, ash content, and fixed carbon as can be seen in table 1 below.

Table 1
Data on flow rate, average temperature, Ash Content, Volatile Matter and Fixed Carbon

Air Flow Rate (L/min)	***Temperature Average (°C)***	**Ash Content (%)**	**Volatile Matter (%)**	***Fixed Carbon (%)***
20	432.69	6.44	17.61	69.01
25	474.12	6.75	14.82	72.03
30	517.51	7.45	14.56	72.14
35	565.34	7.51	8.73	77.94
40	585.98	7.72	9.17	77.31
SNI06-3730-1995		**Max 10**	**Max 25**	**Min 65**

Ash is the metal oxides in charcoal which consist of minerals that cannot evaporate (non-volatile) during the ashing process. The ash content greatly influences the quality of activated carbon. Determination of activated charcoal ash content is carried out to determine the metal oxide content in activated charcoal

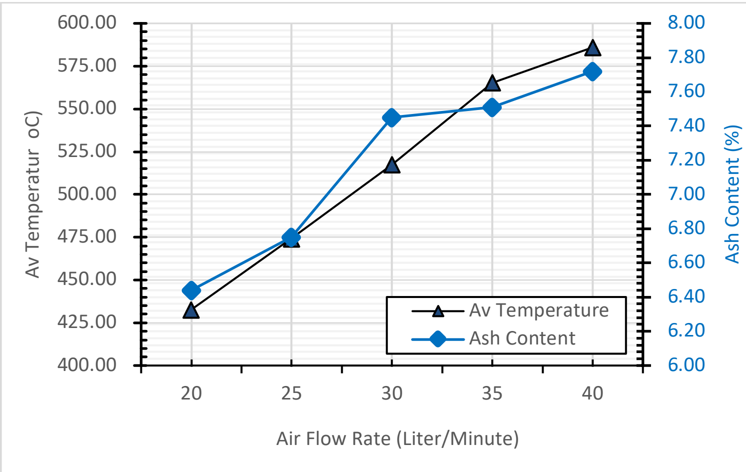

Fig. 2. Relationship between average partial oxidation temperature and ash content on variations in air flow rate

The results of the ash content analysis in Figure 2 show that varying air flow rate treatments have an effect on the ash content produced. The higher the flow rate, the higher the pyrolysis temperature, and the ash content tends to increase. At an airflow rate of 40 L/min, the average temperature obtained was 585.98 °C and the highest ash content was 7.72%, while at an airflow rate of 20 L/min, the average temperature obtained was 432.69 °C. C and the lowest water content was 6.44%. This is because the amount of air entering is greater which causes more raw materials to burn. Ash content is the mineral fraction remaining during the pyrolysis process, so the relative content will tend to decrease or increase as the volatile fraction or volatile matter disappears during the pyrolysis process [15]. Excessive ash content can cause blockage of the activated charcoal pores. This is possible because palm oil shells contain several minerals such as potassium, magnesium, and calcium which are thought to come from the soil or fertilizer applied. The mineral content contained in ash, such as calcium oxide, sodium oxide, magnesium oxide, and potassium oxide will spread within the pores of the charcoal so that it greatly influences its absorption ability in both gas and solution molecules [16]. From this figure, it can be seen that the ash content values of all activated charcoal samples produced have met the activated charcoal quality standards according to SNI 06-3703-1995

Determination or calculation of volatile matter levels (parts that are lost during heating) or volatile matter levels aims to determine the content of volatile compounds contained in activated charcoal [17]. The levels of volatile substances in this study are shown in Figure 3, It can be seen that the higher the flow rate, the higher the pyrolysis temperature and the lower the volatile matter content. At an airflow rate of 35 L/min the average temperature obtained was 565.34 °C and the lowest volatile matter was 8.73%, while at an airflow rate of 20 L/min, the average temperature obtained was 432.69 °C and the highest volatile substances were 17.61%, then at an airflow rate of 40 L/min the volatile substances increased because they had reached optimum conditions.

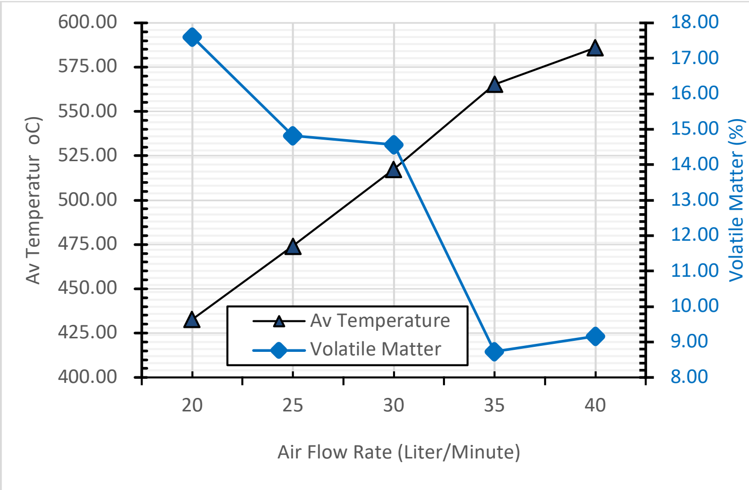

Fig. 3. Relationship between average partial oxidation temperature and volatile matter on variations in air flow rate

Where in conditions above optimum, activated charcoal has reached a saturation point. It can be concluded that the large amount of air flowing into the reactor causes the temperature to rise higher so that most of the evaporated fraction in the raw material is lost [18]. 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, and condensing vapors 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 [19]. From Figure 4.4 it can be seen that the volatile substance values of all the activated charcoal samples produced have met the activated charcoal quality standards according to SNI 06-3703-1995. Determination of carbon content (fixed carbon) aims to determine the carbon content after the carbonization and activation process. Fixed carbon is one of the quality criteria for the activated charcoal produced. The mechanism for increasing the value of fixed carbon in making activated charcoal has been widely used, including physical and chemical methods [20]. In this research, the speed of airflow turns out to have a big influence on the quality of the fixed carbon produced. Varying the air flow rate, causes changes in the process temperature so that the oxidation mechanism will be able to change the structure of the material and dominate the formation of various fixed carbons.

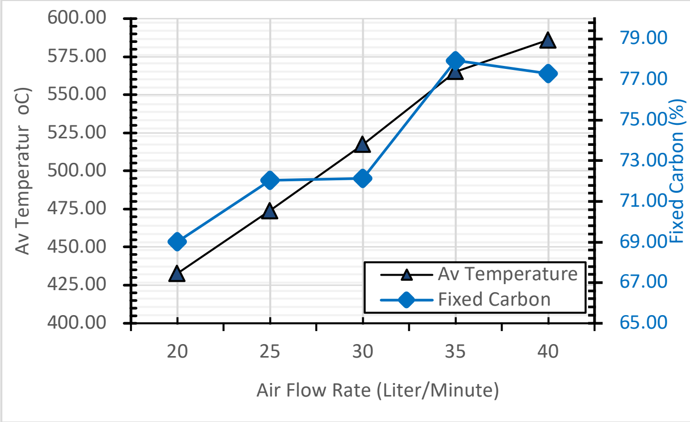

Fig. 4. Relationship between average temperature of partial oxidation and Fixed Carbon with variations in air flow rate

In Figure 4 it can be seen that at a flow rate of 35 L/min the average temperature obtained was 565.34 °C and the highest Fixed Carbon was 77.94%, while at an airflow rate of 20 L/min, the average temperature obtained was 432.69 °C and the lowest Fixed Carbon was 69.01%. The more air that flows into the reactor causes the temperature to rise higher, and the fixed carbon also relatively increases, this is because the combustion or pyrolysis process is complete so that the water component or water fraction, ash, and flying substances will easily evaporate and will increase the fixed carbon value [21]. So the higher the water content and volatile matter analysis obtained, the lower the bound carbon, and vice versa, the bound carbon will be high if the water content and volatile matter content are low. The fixed carbon content in this study ranged from 69 - 77.94%, which meets the SNI 06-3703-1995 standard, namely a minimum of 65% for fixed carbon

4. Conclusions

Based on the results obtained, it can be concluded that the use of air flow rate in the pyrolysis process is quite effective, where it was found that optimum conditions were achieved when the air flow rate was 35 L/minute. if the air flow rate is higher than 35 L/minute then a saturation state is reached, the process temperature is obtained on average 565.34 °C, the ash content is 7.51%, the volatile matter content is 8.73% and the fixed carbon content is 77.94%. These results have met SNI 06-3703-1995 standards

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