The Effect of Air Flow Rate on Temperature, Yield and Water Content in the Production of Active Charcoal from Palm Oil Shells Using Partial Oxidation Method

Firman[1,3], Siti Hamidah Mohd-Setapar[2,3], Muh. Irwan[1] and Sitti Sahraeni[1]

[1]*Department of Chemical Engineering, Politeknik Negeri Samarinda, Jalan Dr. Cipto Mangunkusumo, Kampus Gunung Lipan Samarinda, 75131, Kalimantan Timur Province, Indonesia*

[2]*Malaysia-Japan International Institute of Technology (MJIIT), Universiti Teknologi Malaysia, Jalan Sultan Yahya Petra, 54100, UTM Kuala Lumpur, Malaysia*

[3]*Razak Faculty of Technology and Informatics, Universiti Teknologi Malaysia, Jalan Sultan Yahya Petra, 54100, UTM Kuala Lumpur, Malaysia*

Keywords: Air Flow Rate, Active Charcoal, Temperature, Palm Kernel Shell, Partial Oxidation, Yield.

Abstract: Palm kernel shell is one of the palm oil processing waste which is quite large, reaching 6.5% of 1 ton of palm oil. This shell can be used as an ingredient to make activated charcoal. Activated charcoal is widely used as adsorbent, gas purification, water purification and so on. The palm shell is the hardest part of the components found in oil palm. Palm kernel shell contain 26.6% cellulose and 27.7% hemicellulose which are good for making activated charcoal. This study aims to determine the effect of air flow rate on the average temperature, yield and moisture content in the manufacture of activated charcoal from oil Palm kernel shell by partial oxidation method. Carbonization and activation were carried out using pyrolysis with the principle of partial oxidation. The pyrolysis process was carried out with air flow rates of 20, 25, 30, 35 and 40 L/min for 5 hours. The best results are shown at an air flow rate of 30 L/min with a product yield of 24,03%, a moisture content of 5.85% and an average temperature of partial oxidation reaching 517.51^{o}C.

1 INTRODUCTION

Oil palm is one of the plantation commodities that has an important role in economic activity in Indonesia 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 (*BPS, 2020*) 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. This shows that the potential 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 PKS is widely used as boiler fuel for heating fruit as well as electricity-producing boilers (*Nahrul et al., 2020*). 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 PKS to be converted into activated charcoal. The potential of PKS as Activated Charcoal really depends on the composition of the PKS. The composition of oil palm shell itself consists of 27.7% cellulose, 21.6% hemicellulose, the lignin content in this plant is 44%, and the results of 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 (Abnisa *et al.*, 2011). 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 (Huang *et al*., 2018).

Based on data from the Central Statistics Agency processed by the Directorate General of Plantation in 2019, Publication of The 2019 Indonesian Oil Palm Statistics is an annual publication of BPS-Statistics Indonesia. This publication presents data of area and production on palm oil by province and by category of producers, and the export and import of palm oil

Firman, ., Mohd Setapar, S., Irwan, M. and Sahraeni, S.
The Effect of Air Flow Rate on Temperature, Yield and Water Content in the Production of Active Charcoal from Palm Oil Shells Using Partial Oxidation Method.
DOI: 10.5220/0011811600003575
In *Proceedings of the 5th International Conference on Applied Science and Technology on Engineering Science (iCAST-ES 2022)*, pages 423-427
ISBN: 978-989-758-619-4; ISSN: 2975-8246

by country of destination and by country of origin. Indonesia's charcoal exports reached 188,050 tons with an export value of 145.09 million US dollars (BPS, 2020). Due to the increasing demand for Activated Charcoal., there is a strong need to sort out the manufacturing technology for Activated Charcoal preparation which must be cost-effective as well as on par with commercially available Activated Charcoal. Although various feedstocks have been explored for the preparation of Activated Charcoal in previous studies, scientists are still trying to explore new materials depending on their availability and suitability for Activated Charcoal production. However, the utilization of Plantation waste as a raw material for making activated charcoal has increased rapidly in recent years. the use of making activated charcoal by the partial oxidation method is still poorly practiced.

Charcoal is a light carbon black residue produced by heating wood (or other animal and plant materials) with minimal oxygen to remove all water and other volatile materials. In most cases, this pyrolysis process, called charcoal burning, often results in the formation of a charcoal furnace, where heat is supplied by burning part of the starting material itself, with a limited supply of oxygen. Materials can also be heated in a closed medium. Activated charcoal has the same initial process of making activated carbon. Activated carbon (AC) is a non-graphite, non-graphitizable carbon that has a very irregular microstructure. It is famous for its high adsorption capacity due to its high surface area and porosity. Generally activated carbon can be made from various raw materials including agricultural and forestry residues. Generally most of the precursors used for the manufacture of activated carbon are rich in carbon (Prahas *et al.*, 2008). AC production is achieved usually through two methods, physical activation method and chemical activation method (Bansal *et al.*, 1988)

Physical activation methods involve carbonization of the feedstock followed by activation at high temperatures (between 800 and 1100 ºC) in the presence of an oxidizing gas such as carbon dioxide or steam, while the chemical activation method is mixing chemicals with precursors and then followed by pyrolysis at moderate temperatures in the absence of air High activated carbon uptake is closely related to pore characteristics such as surface area, pore volume, and pore size distribution. All activated carbon has a porous structure, containing up to 15% mineral matter in the form of ash content (Bansal *et al.*, 1988). The AC structure is formed during the carbonization process and is continued during activation, when the space between the forming crystals is cleared of tar and other carbonated materials. The structure of the hole and the size of the hole are very dependent on the nature of the raw material and the activation process. The activating process removes the disorganized carbon by exposing the crystallites to the action of the activating agent leading to the construction of the diamond structure. Activated carbon pore systems are of various types and the individual pores may differ greatly in size and shape. The drying, pyrolysis, and reduction processes are heat-absorbing (endothermic), while the oxidation process is heat-releasing (exothermic). On drying, the moisture content of the solid fuel is evaporated by heat absorbed from the oxidation process. In pyrolysis, the separation of volatile matters (water vapor, organic liquids, and non-condensed gases) from charcoal or fuel carbon solids also uses heat absorbed from the oxidation process. Combustion oxidizes the carbon and hydrogen content of the fuel by an exothermic reaction, whereas gasification reduces the combustion product to gas by an endothermic reaction. Further explanation regarding these processes is given in the following description. One of the important aspects of bioenergy to generate heat, power and biofuels and products in the form of activated charcoal for useful applications is biomass gasification. As technology and materials advanced, the development of gasification technology has increased significantly for applications compared to conventional power sources. This article presents an overview of technical advances, developments in biomass gasification technology and obstacles faced by various stakeholders in the widespread dissemination of technology for the needs of individual communities and the business world to support downstream to upstream activities (Shuit *et al.*, 2009).

2 METHODOLOGY

Palm oil shells from PT. Kebun Mandiri Sejahahtera there are still impurities in the form of fibers 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. The method used in this research is to measure the results of the analysis of activated charcoal based on SNI 06-3730-1995 standards with the main parameters of Moisture content (%). The quality of activated charcoal greatly affects the water content. The equation used to calculate the water content is

$$\text{Moisture content (\%)} = (((M2-M3))/((M2-M1)))x100\% \quad (1)$$

Information:

M1 = Weight of empty petri dish (grams)

M2 = Weight of petri dish containing activated carbon before oven (grams)

M3 = Weight of petri dish containing activated carbon after oven (grams)

3 RESULT AND DISCUSSION

The purpose of this study was to determine the effect of air flow rate on activated charcoal using oil palm shells with a pyrolysis process using the principle of partial oxidation on a pilot plant scale with a raw material capacity of 5 kg/batch, and to determine the quality of charcoal produced by pyrolysis of oil palm shells. The pyrolysis process stage is burned for 5 hours. The results of the study obtained the following data:

Table 1: Research result.

Air Flow Rate (L/min)	***Temperature Average (°C)***	***Yield* (%)**	**Moisture Content (%)**
20	432.69	29.8	6.94
25	474.12	29.01	6.40
30	517.51	24.03	5.85
35	565.34	20.2	5.82
40	585.98	19.01	5.80
SNI06-3730-1995			Max 15

The results of the study in the table1 Shows that the greater the air flow rate, the higher the average temperature in the reactor produced. This is due to the pyrolysis process using limited air, an oxidation process that is exothermic (releasing heat). In this oxidation zone, the large amount of air causes the amount of oxygen present in the air to oxidize the carbon contained in the material so that the heat generated is also greater and causes an increase in temperature. The increase in temperature generally shifts with increasing air flow rate. The greater the air flow rate, the maximum temperature (hot spot) will occur the faster it will occur and then there will be a decrease in temperature due to reduced carbon contained in the raw material (Ramos, L.P., 20035).

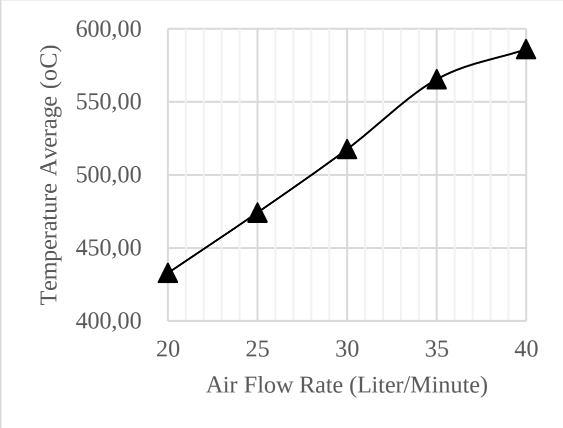

Figure 1: Effect of air flow rate on the average temperature of pyrolysis.

In Figure 1 it can be seen that at a flow rate of 20 L/min the activated charcoal product produced is at the maximum yield, which is 29.8%, while at a flow rate of 40 L/min the minimum yield of activated charcoal product produced is, which is 19%. It can be seen that the yield continues to decrease along with the addition or flow of air into the reactor, namely the more oxygen and nitrogen gas that is circulated, the yield of activated charcoal obtained is also relatively decreased (Hasan et al., 2020). In addition, temperature is also very influential on the pyrolysis process. The higher the temperature, the better the decomposition/decomposition process, but the less amount of charcoal obtained while the more liquid and gas results, due to the large number of decomposed and evaporated substances. The maximum yield was obtained at an average temperature of 182.68 °C at 29.8% and the minimum yield was obtained at a temperature of 448.98 °C at 19%, this is in accordance with the statement of Haji et al., 2010 that due to the high temperature some charcoal turns into ash and volatile gases, so the yield tends to be low. It can be concluded that the oxygen and nitrogen that are flowed into the reactor help the pyrolysis process occur perfectly, the incoming oxygen reacts with the activated charcoal to become CO_2 which causes the amount of solids to decrease. The function of oxygen here is to oxidize the material while nitrogen is a physical activating agent (Gao and Li, 2008).

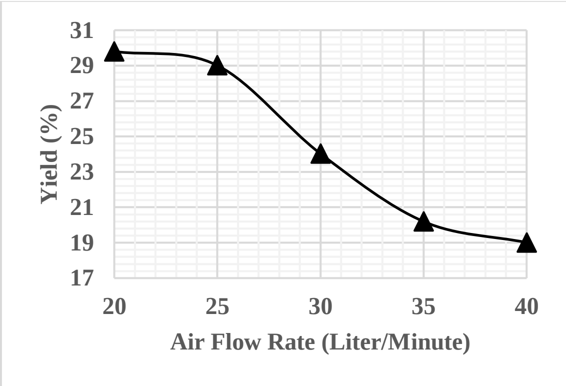

Figure 2: Effect of air flow rate on activated charcoal yield.

Comparison of Figure 1 and Figure 2 From this data, it can be concluded that the yield of activated charcoal produced relatively decreased as air was added or flowed into the reactor during the pyrolysis process. The calculation of the water content of activated charcoal aims to determine the hygroscopic nature (water absorption) of activated charcoal. Activated charcoal is hygroscopic so it is very easy to bind moisture from the air. From this very hygroscopic nature, activated charcoal is used as an adsorbent (Ikawati & Melati, 2010).

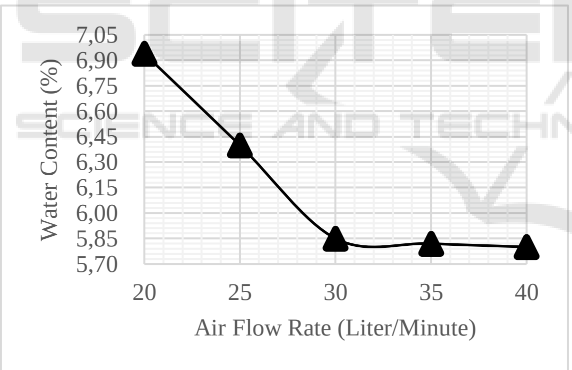

Figure 3: Effect of air flow rate on water content.

The results of the water content are shown in comparison of Figure 1 and Figure 3 , from the figure it can be seen that the higher the air flow rate, the combustion process is close to complete and the temperature tends to be higher, the less water vapor trapped in the pores than the low air flow rate. At air flow rate of 40 L/min the average temperature obtained is 448.98 °C and the lowest water content is 5.80%, while at air flow rate of 20 L/min the average temperature obtained is 182.68 ° C and the highest water content of 6.94%. This increase in water content is not only caused by an increase in the hygroscopic nature of activated charcoal to water vapor, it is also due to the binding of water vapor molecules (Hasan et al., 2020). The moisture content of charcoal can be affected by the amount of water vapor in the air, the length of the cooling, grinding, and sifting processes. From Figure 4.2 it can be seen that the water content of all samples of activated charcoal produced has met the quality standard of activated charcoal according to SNI 06-3703-1995.

4 CONCLUSIONS

The best results in the process of making activated c From the research that has been carried out on variations in air flow rates of 20 L/min, 25 L/min, 30 L/min, 35 L/min, and 40 L/min, it can be concluded that the air flow rate reaches the optimum condition at a speed of 30 L/min. min. with Optimum results shown at air flow rate of 30 L/min, with a product yield of 24%, water content of 5.85%,

ACKNOWLEDGEMENTS

The author would like to thank the Research and Development Center of the Samarinda State Polytechnic which has funded this research, and also to the Chemical Engineering Laboratory of the Samarinda State Polytechnic as the research site. and special thanks to Razak Faculty of Technology and Informatics, Universiti Teknologi Malaysia, UTM Kuala Lumpur, Malaysia who helped push this article

REFERENCES

Abnisa, F., Daud, W. M. A. W., Husin, W. N. W., & Sahu, J. N. (2011). Utilization possibilities of palm shell as a source of biomass energy in Malaysia by producing bio-oil in pyrolysis process. *Biomass and Bioenergy, 35*(5), 1863-1872. doi:10.1016/j.biombioe.2011.01.033

Bansal, R.C., Donnet, J.B., Stoeckli, H.F. Active carbon. Marcel Dekker, (1988), New York.

BPS. (2020). *Statistik Kelapa Sawit Indonesia 2019*. In N. P. 05130.2002 (Ed.), (Nomor Publikasi: 05130.2002 ed., pp. 137).

Bansal, R.C., Donnet, J.B., Stoeckli, H.F. Active carbon. Marcel Dekker, (1988), New York.

Gao, N., Li, A., (2008), "Modeling and Simulation of combined Pyrolysis and Reduction Zone for a downdraft Biomass Gasifier", Energy Conversion and Management 49, 3483-3490

Huang, Y., Liu, H., Yuan, H., Zhan, H., Zhuang, X., Yuan, S., Wu, C. (2018). Relevance between chemical structure and pyrolysis behavior of palm kernel shell lignin. *Sci Total Environ*, *633*, 785-795. doi:10.1016/j.scitotenv.2018.03.238

Hasan, S., Aladin, A., Syarif, T., & Arman, M. (2020). Pengaruh Penambahan Gas Nitrogen Terhadap Kualitas Charcoal Yang Diproduksi Secara Pirolisis Dari Limbah Biomassa Serbuk Gergaji Kayu Ulin (Euxideroxylon Zwageri). *Journal of Chemical Process Engineering*, *5*(1), 61–68. https://doi.org/10.33536/jcpe.v5i1.472

Ikawati, & Melati. (2010). Pembuatan Karbon Aktif Dari Kulit Singkong UKM Tapioka Kabupaten Pati. *Area*, 1–8.

Mohd Salleh MA, Nsamba HK, Yusuf HM, Idris A, Ghani WAWAK. Effect of equivalence ratio and particle size on EFB char gasification. Energy Sources, Part A Recover Util Environ Eff 2015;37:1647e62. https://doi.org/10.1080

Prahas, D., Kartika, Y., Indraswati, N., Ismadji, S. (2008),Activated carbon from jackfruit peel waste by H3PO4 chemical activation: Pore structure and surface chemistry characterization. Chemical Engineering Journal., 140, 32-42.

Ramos, L.P., (2003). The chemistry involved in the stram treatment of lignocellulosic materials. Quim. Nov. 26, 863–871.

Shuit SH, Tan KT, Le KT, Kamaruddin AH, (2009). Oil palm biomass as a sustainable source: a Malaysian case study. Energy;34:1225–35.

Yuliusman. (2015). Production of activated carbon from oil palm shells with KOH and N_2/CO_2 as activating ingredients. Seminar on Technology and Engineering (SENTRA), 978–979.

Nahrul Hayawin, Z., Astimar, A. A., & Idris, J. (2020). Nor Faizah. *J., Ropandi, M., Astimar, AA, Noorshamsiana, AW, & Abd-Aziz, S.*