Determining and Evaluating the Pyrolysis of Candlenut Shell as an Alternative Energy Sources

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Abstract

Candle Nut (*Aleurites moluccana*) is classified as one of Indonesia's substantial available natural resources, is considered a wide prospect marketing commodity either domestic or overseas. The purpose of the study was to find out and evaluate the temperature against the percentage yield and characteristics of pyrolysis products produced for the application of the product as an alternative fuel. The research consists of the initial stage of raw material preparation, pyrolysis process stage and analysis stage of Bio-oil, Gas, Char products. Pyrolysis uses a fixed Batch Reactor equipped with a dual condenser system (SKG) at temperatures varied at 350, 450, 550 °C and pressure 1 (one) atmosphere and sampling time of 30, 60, 90, up to 420 minutes. The use of cooling water temperature in condensers ranges from 25 -35 °C. A Bio-Oil level analysis measured the amount of bio-oil volume produced in the measuring glass during pyrolysis time intervals performed at each temperature used. Product identification carried with GCMS (Gas Chromatography and mass spectrometry). Also, it measures tar products, solid products and gases from pyrolysis processes utilized for alternative fuels. The results showed that at optimum temperatures produced liquid smoke yield products of 8.6%, charcoal 81.6 %, tar 3.7 % and 6.1 %. Identification results using GC Mass Spectrometry (GCMS) at optimum temperature conditions of 450 °C and pyrolysis time of 210 minutes show a smaller number of components that are 7 (seven) components, namely: Cyclopentanone, 2 Cyclopenten1-one, 2 cyclopentene-1-one, Acetic acid, 2 Furancarboxildehide, 2 methoxyphenyl and 2 Methoxy-4-methyl enols.

Keywords
Pyrolysis, Natural Resources, Candlenut shell, Alternative Energy

1. Introduction

Candlenut or Aleurites moluccana is one of Indonesia's prominent natural resources, considered a marketing commodity with broad prospects both domestic and international. Sulhatun et al. 2019. Pyrolysis is a thermochemical technology for converting biomass materials into energy and various other chemical products consisting of liquid organic oil, organic dust, and pyrolysis (Kan, Strezov & Evans, 2016). Bertero, Gorostegui, Orrabalis, Guzmán, Calandri & Sedran, 2014) using the waste of chanar seeds and palm seeds, (Chen & Lin 2016) using palm fibre and (Mabrouki, Abbassi, Guedri, Omri & Jeguirim, 2015) palm oil waste. Bio-Oil produced from the pyrolysis process is used as an alternative fuel. The pyrolysis process influenced by several process variables, including the type of raw material (type of biomass, particle size, initial handling of biomass, reaction conditions (pyrolysis temperature, pressure, heating rate of particles and contact time), reactor configuration used, the process carried out, and various other process variables such as the addition of a catalyst and a steam cooling mechanism as well as the residence time of hot steam (Bridgwater, 2012; Jaszczur, Dudek, Rosen, & Kolenda, 2020). According to Tech (2021) and (Hasibuan, Harahap & Fithra, 2018), pyrolysis using a double condensation system (SKG) will affect the amount of liquid smoke produced by almost 200%.

1.1 Objectives

This study aims to determine and evaluate the temperature on the Yield percentage and the characteristics of the resulting pyrolysis product for product application as an alternative fuel.

2. Materials and Methods

This research was carried out in the North Aceh Indonesia. Research conducted January - December 2021. Preparation of the primary raw material, namely candlenut Shell, is obtained from community plantations atAceh. Pyrolysis using a fixed Batch Reactor, which is equipped with a double condenser system (SKG), is made together with the condensate flow pipe divided into two of the same size. The initial stage of raw material preparation, the Pyrolysis Process Stage, and the Product Analysis Stage of Bio-Oil, Gas, and Char comprise the research design. The research design can show greater detail in Figure 1 below:

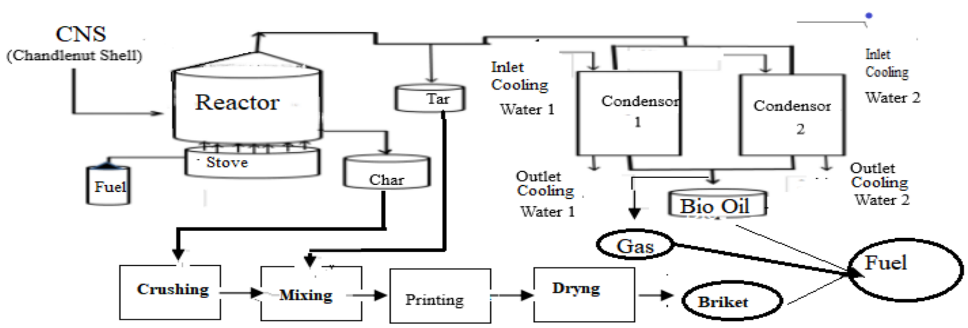

Figure 1. Flow Sheet The Fuel Product of CNS Pyrolysis Process

Preparation of Raw Material , namely drying raw materials until the moisture content reaches 10-13%. Pyrolysis and Condensation Process Stage.The raw candlenut shell material has to dry with a moisture content of 10-12.5%. The pyrolysis process was carried out at temperatures ranging from 350 to 500 degrees Celsius (350, 450, and 550). The condensate comes out of the pyrolysis reactor condensed in a condenser coupled with a pyrolysis device into a series consisting of 2 (two) parallelized condenser system units. The condensation temperature is maintained at 25 to 35ºC. Analysis implemented on Bio-Oil, Gas, Charcoal and Tar products. Product identification by GCMS (Gas Chromatography and mass spectrometry). And GCMS were carried out for the analysis of the components contained in Bio-Oil.

3. Results And Discussion

Product of the Candlenut Shell Pyrolysis Process. The pyrolysis process also produces other products, namely: charcoal, tar and a small amount of non-condensable gas as a by-product. The pyrolysis process was carried out at various temperatures of 350 °C, 450 °C and 550 °C with a pyrolysis sampling time every 30 minutes to 420 minutes. The candlenut shell pyrolysis process carried out at an optimum temperature of 450 oC produced a yield of 8.6% Bio-Oil, charcoal 81.6%, tar 3.6% and 6.2%

1. Product Bio Oil

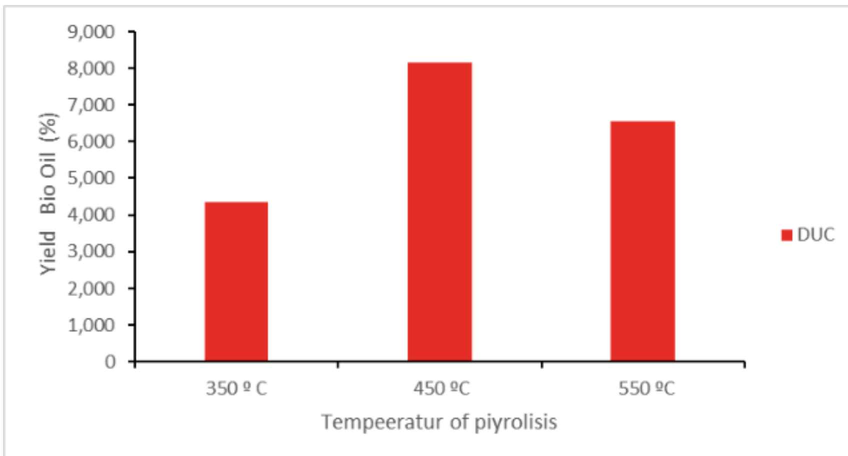

Figure 2. Effect of temperature on the yield of Bio-Oil production on SKG

Figure 2 shows that the increase in temperature causes a significant effect on increasing the yield of Bio-Oil products produced from the pyrolysis process. The higher the temperature, the more complete the biomass material's degradation and the higher the amount of condensate, the higher the condensate produced (see Figure 3). The increase in pyrolysis products occurred in the temperature range of 350 oC to 550 oC.

Figure 3. Bio-Oil from Kemiri Shell

2. Tar Products

Tar is a by-product of the candlenut shell pyrolysis process, produced from the condensate pipe connected to the pyrolysis reactor consisting of solids and dark black liquids. The yield of tar produced in the pyrolysis process at a temperature of 350-550 C reached 2,243 - 4,009% of the total pyrolysis product. The Figure 4 shows the tar product from the pyrolysis of the candlenut shell produced in this study.

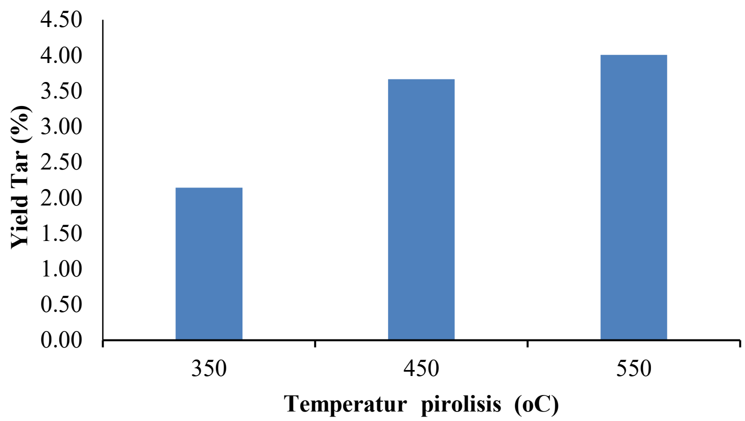

Figure 4: The Effect of Temperature on Pyrolysis Tar Yield Percentage

3. Charcoal Materials

Charcoal is a black carbon residue produced during the pyrolysis process. At a temperature of 350-550 °C, the charcoal produced is approximately 79-81.6 per cent. The percentage of charcoal products produced in the pyrolysis process shown in Figure 5.

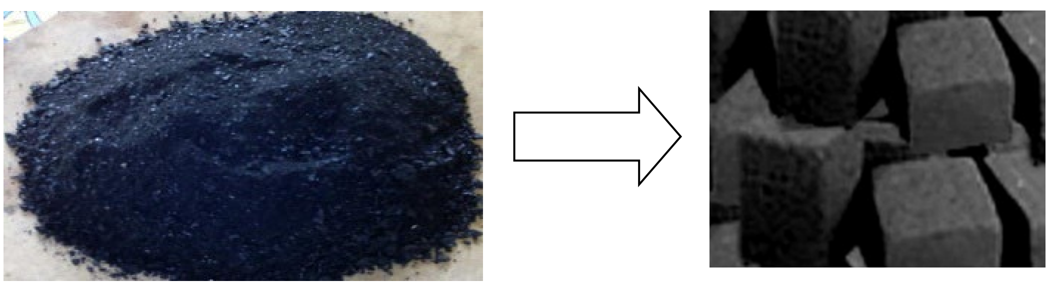

Figure 5. Candlenut shell charcoal products into briquettes

Figure 5 Effect of temperature on % yield of charcoal in the pyrolysis process. Temperature affects the decrease in charcoal products in the pyrolysis process. The higher the temperature, the higher the decomposition and the lower the charcoal product produced. The maximum product yield obtained at the lowest temperature at 350 C.

3. Gas Products

Gas as a by-product resulting from the candlenut shell pyrolysis process can be used as an alternative energy source. Percentage of gas that is not condensed. At a temperature of 350-550 C, the resulting 7.124 - 10.49%.

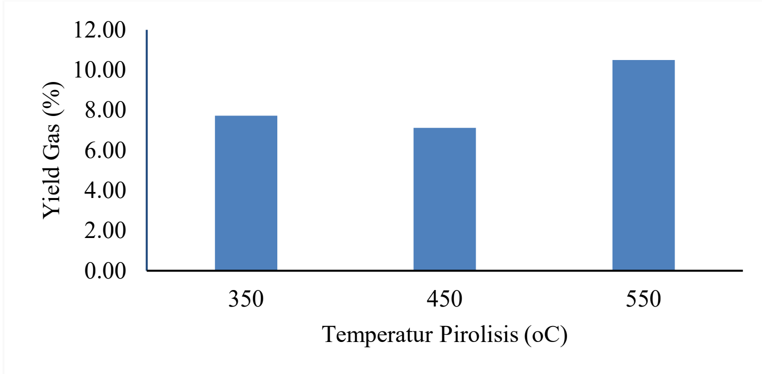

Figure 6. The effect of temperature on the % yield of pyrolysis gas

The resulting gas flow products consist of CO2, CO, H2, CH4, ethane, ethylene, propane, ammonia, NO, SO2. As a by-product, the gas product can be used as cofiring for additional gaseous fuels used in the pyrolysis process (see Figure 7.

Figure 7. The product gas produced from the pyrolysis of candlenut shell

4. Conclusion

In conclusion, this study identified that the products yield % Bio-Oil of candlenut shell 8.65%, charcoal 81.6%, tar 3.67% and gas 6.12% at a temperature of 559 C. Also, the results of identification using GC Mass Spectrometry (GCMS) at the optimum temperature of 450 °C and pyrolysis time of 210 minutes showed that the number of components was less, namely 7 (seven) elements, namely: Cyclopentanone, 2 Cyclopenten1-one, two cyclopentane-1-one, Acetic acid, 2 Furancarboxyldehide, two methoxyphenyl and 2 Methoxy-4-methyl phenol.

References

Bertero, M., Gorostegui, H. A., Orrabalis, C. J., Guzmán, C. A., Calandri, E. L., & Sedran, U. (2014). Characterization of the liquid products in the pyrolysis of residual chañar and palm fruit biomasses. *Fuel*, *116*, 409–414.

Bridgwater, A. V. (2012). Review of fast pyrolysis of biomass and product upgrading. *Biomass and Bioenergy*, *38*, 68–94.

Chen, W. H., & Lin, B. J. (2016). Characteristics of products from the pyrolysis of oil palm fiber and its pellets in nitrogen and carbon dioxide atmospheres. *Energy*, *94*, 569–578.

Hasibuan, R., Harahap, H., & Fithra, H. (2018). Improving Production of Liquid Smoke from Candlenut Shell by Pyrolisis Process. In *Proceedings of MICoMS 2017*. Emerald Publishing Limited.

Jaszczur, M., Dudek, M., Rosen, M. A., & Kolenda, Z. (2020). An analysis of integration of a power plant with a lignite superheated steam drying unit. *Journal of Cleaner Production*, *243*, 118635.

Kan, T., Strezov, V., & Evans, T. J. (2016). Lignocellulosic biomass pyrolysis: A review of product properties and effects of pyrolysis parameters. *Renewable and Sustainable Energy Reviews*, *57*, 1126–1140.

Mabrouki, J., Abbassi, M. A., Guedri, K., Omri, A., & Jeguirim, M. (2015). Simulation of biofuel production via fast pyrolysis of palm oil residues. *Fuel*, *159*, 819–827.

Tech, J. E. T. (2021). Effect of Temperature and Pyrolysis Time in Liquid Smoke Production from Dried Water

Hyacinth. *Journal of Environmental Treatment Techniques*, *9*(1), 164–171.

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