Biofuel Production From Pyrolysis of Cocoa Pod Husk

ITABIYI Olukunle Elijah

Department of Mechanical Engineering, Ladoke Akintola University of Technology, P.M.B 4000, Ogbomoso Nigeria

ABSTRACT

This research focused on the pyrolysis of cocoa pod husk (CPH) for biofuel production. 220 g of the dried sample of CPH with a moisture content of 10.06% was introduced into the retort and coupled. The retort was then introduced into the preheated furnace and the sample was pyrolyzed at a temperature of 300°C for 20 minutes. The condensate receiver was placed inside an ice bath containing the mixture of ice and water for quick recovery of liquid product. The process was repeated for pyrolyzing temperatures of 350, 400, 450 and 500°C. The pyrolysis products obtained were char, tar (pyro oil and pyroligneous acid) and gas. The highest conversion yields expressed as percentage weight of oven-dried CPH at their respective pyrolyzing temperatures were 58.29 wt% char at 300°C, 10.10 wt% tar at 450°C, and 68.54 wt% at 500°C

Keywords: Pyrolysis, Cocoa Pod Husk, Biofuels, Fixed bed reactor, Agricultural waste

Corresponding Author's e-mail: oeitabiyi@lautech.edu.ng

INTRODUCTION

Continuous deposition of agricultural wastes without transformation to other usable products has resulted in silting, blockage of water drainage systems, flooding of rivers, and water pollution. This problem could be reduced if these wastes are processed into other products such as biofuels, which is a pressing need for many countries. The problems that are associated with the use of fossil fuels require transition to renewable sources of energy (Kumar, 2020). The methods of extracting crude oil have also led to serious cases of oil spills which tend to destroy the immediate or remote environment where such resources are found. The impact of the high price of fossil fuels on the economic growth of many developing countries has been severe and the growing demand for energy associated with economic growth has emphasized the need to develop alternative sources of energy (Oyedepo, 2012).

Biomass is a naturally occurring carbonaceous resource. It refers to material that is of biological origin and is a complex renewable material with enormous chemical variability (Jekayinfa *et al*., 2020). Due to the wide availability of biomass worldwide, biomass represents a growing renewable energy source with high growth potential. It can be obtained as a byproduct of many agricultural products, such as coconut, cassava, corn and cocoa.

Cocoa is an industrially important crop since cocoa bean and its processed products are the main ingredients of chocolate, one of the world's most popular foods. However, in the production of the beans, waste in the form of cocoa pod husks is also generated (Martinez *et al.,* 2015). CPH constitute about 81% of the cocoa fruit, they are essentially waste products that are left on plantation sites to decompose and this leads to several environmental issues, such as pests and diseases (Maleka, 2016). The residues generated during cocoa pods processing are dumped at the extreme parts of the town which usually causes environmental hazards to the well-being of the people. This can be converted into useful products such as biofuels, via thermochemical conversion processes (Adzimah and Asiam, 2010; Agyeman and Oldham, 1986). The three major thermochemical processes used to produce energy from biomass include combustion, gasification, and pyrolysis (Maleka, 2016; Syamsiro *et al.,* 2012; Martinez *et al.,* 2015).

Pyrolysis is a thermochemical decomposition of organic material at elevated temperatures in the absence of oxygen, it involves the simultaneous change of chemical composition and physical phase and is irreversible (Kumar, 2013). Pyrolysis is the viable process for biomass upgrading by cracking the polymeric structure of lignocellulosic materials and converting them into fractions consisting of a solid carbon-rich residue in form of charcoal and a range of volatile products, which include condensable and non-condensable gases (Itabiyi, *et al*. 2019). Distribution of pyrolysis products depends on such operating conditions such as the type of feedstock, reaction time, pyrolysis temperature and sweep gas flow, particle size, and heating rate. This research work focused on production of biofuel from pyrolysis of cocoa pod husk.

MATERIALS AND METHODS

Sample Procurement

CPH samples were obtained at low cost from a farm at Igbeti, Oyo, Nigeria. The residues were cleaned, washed to remove the foreign particles such as sand, dead leaves among others, then the samples were sun-dried for about three days and later oven-dried at a temperature of 105°C to reduce the moisture content in the sample. The moisture content of the samples were also determined.**2.2 Experimental Procedure**Two hundred grams of the dried sample of CPH with 10.06% moisture content was introduced into the retort and then coupled. The retort was then introduced into the preheated furnace at a temperature of 300°C for 20 minutes. The condensate receiver was placed inside an ice bath containing the mixture of ice and water. The outlet valve in the condensate receiver which was initially closed was opened and then closed to allow the gas to escape into the gas collection unit whenever the pressure is built. After the outlet valve was closed, the inlet valve of the gas cylinder was opened which allows movement of the gas produced into gas cylinder as shown in Figure 1. The process was repeated for pyrolyzing temperatures of 350, 400, 450 and 500°C.

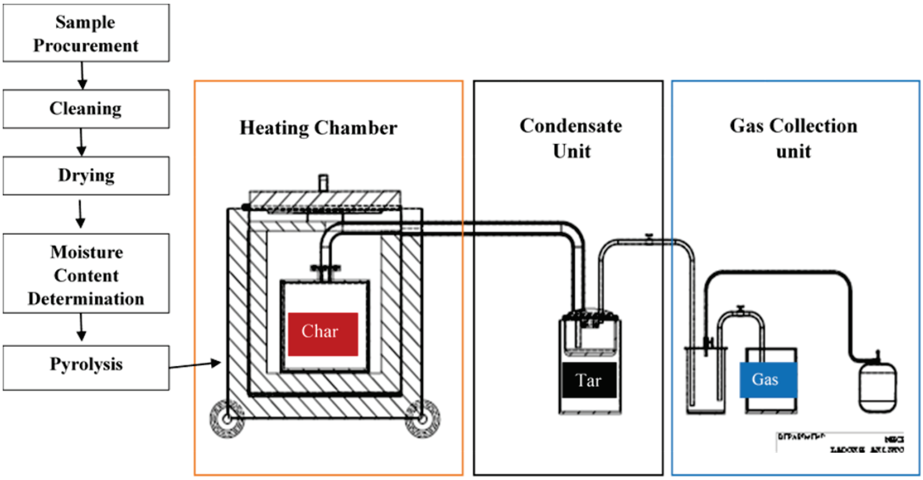

Figure 1: Schematic Diagram of Pyrolysis Unit (Renewable Energy Lab. LAUTECH)

RESULTS AND DISCUSSION

Result of Product Yields from Pyrolysis of Cocoa Pod Husk

Figure 2 showed that at 300°C, the results obtained were 128.94 g char, 9.78 g tar and 81.98 g gas. At a temperature of 350°C the weight of the char reduced to 98.02 g and that of the tar increased to 14.65 g and the weight of the gas increased to 107.33 g. At a temperature of 400°C, the weight of the char reduced to 73.82 g and that of the tar increased to 19.36 g and the weight of the gas increased to 126.82 g. At a temperature of 450°C the weight of the char reduced to 60.06 g and that of the tar increased to 22.21 g and the weight of the gas increased to 137.73 g. At a temperature of 500°C the weight of the char reduced to 48.01 g and that of the tar also reduced to 21.20 g, while the weight of the gas increased to 150.79 g. The maximum char yield was obtained at 300°C while the tar yield reached a maximum at 450°C. The gas yield increases as the temperature increases.

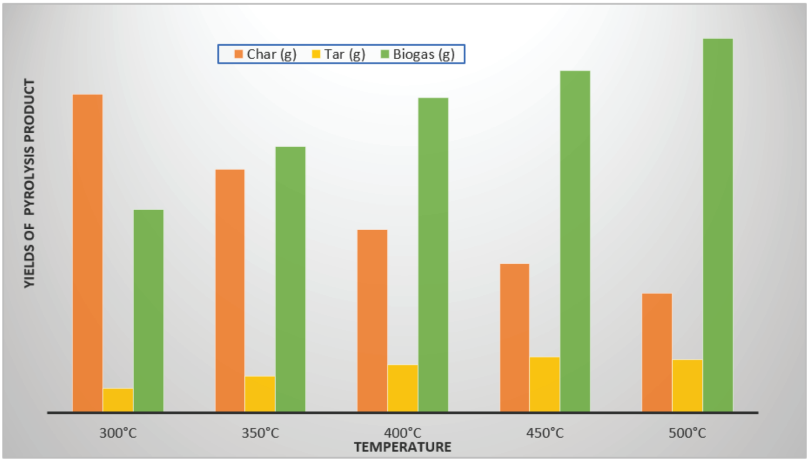

Figure 2: Yields of Pyrolysis Product against Temperature

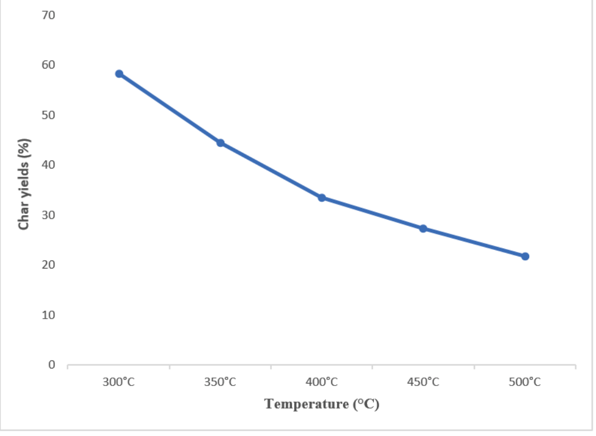

Figure 3: Effect of Pyrolysis Temperature on Char Yields

Effect of Temperature on Char Yield

Figure 3 shows the effect of temperature on char yield. At 300°C the char yield was 58.29%, at 350°C the char yield was 44.55%, and at 400°C the char yield was 33.55%, at 450°C the char yield was 27.30%, finally at 500°C, the char yield was 21.82%. It can be seen that as pyrolysis temperature increases, char yield decreases .This result is in agreement with the result obtained by Kumar (2013) when he carried out an experiment on the pyrolysis of coconut shell.

Effect of Temperature on Tar Yield

Figure 4 shows the effect of temperature on tar yield. At 300°C tar yield was 4.45%. At 350°C tar yield was 6.66%, at 400°C tar yield was 19.36%, at 450°C tar yield was 10.10%, and finally at 500°C the tar yield was 9.64%. It can be seen that as pyrolysis temperature increases tar yield also increases. This result is in agreement with the result obtained by Kumar (2013) when he carried out an experiment on the pyrolysis of coconut shell.

Effect of Temperature on Gas Yield

Figure 5 shows the effect of temperature on gas yield. At 300°C gas yield was 37.26%. At 350°C the gas yield was 48.79%, at 400°C the gas yield was 57.65%, at 450°C the gas yield was 62.60%, and finally at 500°C the gas yield was 68.54%. It can be seen that as pyrolysis temperature increases, gas yield increases. This result is in agreement with the result obtained by Itabiyi *et al.* (2013) when he conducted an experiment on the pyrolysis of palm kernel shell.

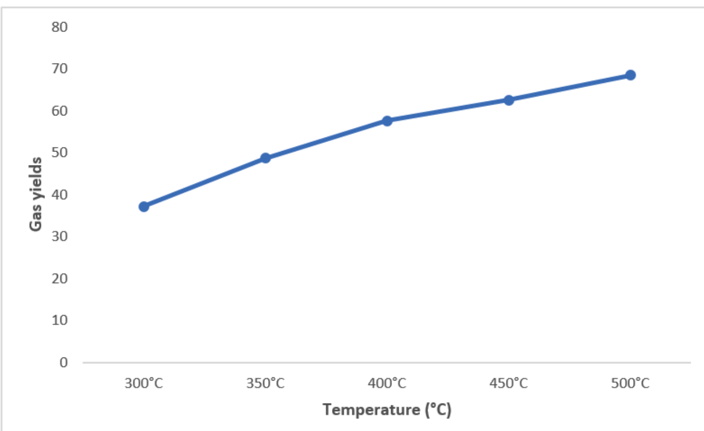

Figure 5: Effect of Pyrolysis Temperature on Gas Yield

CONCLUSION

The results showed that CPH can be converted to useful biofuel. It was observed that the char quantity declined when pyrolyzing temperature increases. It was also observed that tar yield increases as pyrolyzing temperature increases, but at a higher temperature a reduction in the quatity of tar was observed, thus for a higher quantity of tar, it is recommended that pyrolysis temperature of 400-450°C should be used. It was observed that there was a steady increase in the quantity of gas produced as the pyrolyzing temperature increases hence, a pyrolyzing temperature from 500°C and beyond is recommended for a higher yield of gas.

REFERENCES

Adzimah, S.K. and Asiam E.K. (2010). Design of a Cocoa Pod splitting machine. *Research Journal of Applied sciences, Engineering and Technology*. 2 (7): Pp 622-634

Agyeman, K. O. G. and Oldham, J. H. (1986). Utilization of cocoa by-products as an alternative source of energy. *Biomass,* 10 (4): Pp 311–318. doi: 10.1016/0144-4565(86)90004-1.

Itabiyi, O. E. and Lucas E. B. (2013). Development of Pyrolysis Unit for the Conversion of Biomass into Fuels and Chemical Products, *LAUTECH Journal of Engineering and Technology.* 7 (2): Pp 136-142

Itabiyi, O., Okekunle, P., Sangotayo, E., Ogunwobi, D., Ilori, O., Adeleke, K. (2019). Effects of Pyrolysis Variables on the Product Yields During Pyrolysis of Palm Kernel Shells. *International Journal of Engineering Research and Technology*. 8 (8): Pp 407-413. http://dx.doi.org/10.17577/IJERTV8IS080147

Jekayinfa, S., Orisaleye, J., Pecenka, R. (2020). An Assessment of Potential Resources for Biomass Energy in Nigeria. *Resources*. 9 (92): Pp 1-43. 10.3390/resources9080092.

Kumar M. (2020). Social, Economic, and Environmental Impacts of Renewable Energy Resources, Wind Solar Hybrid Renewable Energy System. doi: 10.5772/intechopen.89494.

Kumar. T. (2013). Pyrolysis of coconut shell. M.Tech thesis (Chemical Engineering). Department of Chemical Engineering National Institute of Technology Rourkela. 211CH1036.pdf (nitrkl.ac.in)

Maleka D. (2016). Assessment of the implementation of alternative process technologies for rural heat and power production from cocoa pod husks. KTH Royal Institute of Technology, Stockholm.

Martinez-Angel J. D., Villamizar-Gallardo R. A., Ortiz-Rodriguez O. O. (2015). Characterization and evaluation of cocoa (Theobroma cacao L.) pod husk as a renewable energy source. *Agrociencia* 49: Pp 329–345

Oyedepo, S.O. (2012). Energy and sustainable development in Nigeria: the way forward. *Energy Sustain Society* **2:** 15 https://doi.org/10.1186/2192-0567-2-15.

Syamsiro, M., Saptoadi, H., Tambunan, B.H., Pambudi, N.A. (2012). A preliminary study on the use of cocoa pod husk as a renewable source of energy in Indonesia. *Energy Sustain Dev*.16: Pp 74–77. https://doi.org/10.1016/j.esd.2011.10.005.