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Experimental Investigation of the Effect of Reactor Temperature on African Oak (*Oldfieldia africana)* Sawdust Pyrolysis

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Abstract

The need to convert waste to wealth for sustainable development cannot be overemphasized. In this work, effect of reactor temperature on product yields from pyrolysis of African Oak (Oldfieldia africana) sawdust in a fixed bed reactor was investigated. Sawdust sample was obtained from Paki-Otan sawmill,Ogbomoso, Oyo state, Nigeria. The sample was sundried for three days and then oven dried at 104 °C for 2 hours in order to reduce its moisture content. Samples of 50 g each were pyrolysed at different temperatures (300, 400, 500 and 600 °C) for 15 minutes at atmospheric pressure. Results showed that char yield decreased while gas yield increased as reactor temperature increased. Tar (bio-oil) yield increased with temperature up to 500 °C and then decreased with further increase in temperature. Secondary pyrolysis became significant above 500 °C. The ranges of char, bio-oil and gas yields were 22.70 – 47.50%, 32.30 – 41.80% and 20.20 – 38.20%, respectively. Sawdust from wood processing industry has the potential to be a source of biofuels for environmentally friendly utilization.

Keywords *Pyrolysis, biomass, sawdust, biofuel, fixed bed reactor, waste to wealth*

1. Introduction

Global concerns about the need to preserve the environment have increased continually. Pollution from indiscriminate dumping of plastic wastes, improper disposal of forest and wood processing residues, poor handling of medical wastes and emissions from fossil fuel combustion has consistently threatened the environment. Although all these cannot be stopped so soon, they can be managed to reduce the severity of their effects on the environment.

The wood processing industry in Nigeria, as in other developing countries, keeps growing with at least two to three sawmills in every municipality. This development implies more wood processing residues (mainly sawdust) will be generated from day to day. Poor management of the resulting huge volume of sawdust will not only adversely affect farmable land but will also endanger the healthy living of the inhabitants.

Over the years, open-air dumping and burning of sawdust has been adopted by sawmill operators (Ogunbode et al., 2013), the practice which has led to all forms of hazards, not only to humans but also to the ecosystem at large. Others have made use of sawdust in making particle board in furniture works, soaking up spills, stoves and as a boiler fuel. In recent times, many researchers have studied the use of sawdust in concrete (Osei and Jackson, 2016; Ganiron Jr., 2014; Oyedepo et al., 2014; Kumar et al., 2014). While all these are steps in the right direction, sawdust pile-up still remains a serious challenge in many developing countries like Nigeria. Therefore, there is need to devise other ways of handling it.

Pyrolysis, a thermochemical conversion process, promises not only to drastically reduce sawdust pile-up but to also convert it into higher calorific value bio-fuels. Many works have been done on pyrolysis of lignocellulosic materials (Abnisa et al., 2013; Mullen et al., 2010; Mohan et al., 2006; Goyal et al., 2008; Kan et al., 2016). The main advantages of using biofuels are their renewability, biodegradability and no contribution to the net rise in the level of CO_2 in the atmosphere (Demirbas, 2008). Moreover, previous research efforts have reported that bio-oil from wood residue pyrolysis have the potential of being used as a blend with petroleum diesel for transportation and also as a raw material for chemical and pharmaceutical industries (Oyebanji and Ololade, 2017; Oyebanji et al., 2018). Although some researchers have studied sawdust pyrolysis (Xu et al., 2013, Wang et al., 2007), data on pyrolysis of wood sawdust of African origin are very scarce. Therefore, in this work, the effect of temperature on the pyrolysis of African Oak (*Oldfieldia africana*) was studied.

2. Sample Procurement and Processing

African Oak (*Oldfieldia africana*) sawdust was procured from Paki-Otan sawmill, Ogbomoso, Oyo State, Nigeria. In order to reduce the moisture content, the sample was sundried for three days, and then dried at 104 ^oC in a microwave oven for 2 hours in Chemical Engineering Laboratory, Ladoke Akintola University of Technology, Ogbomoso, Nigeria.

3. Experimental set up and Procedure

Figure 1 shows the exploded view of the fixed bed reactor used for the pyrolysis experiment. The reactor comprises of a cylindrical retort with a bottle neck to enhance a firm closure of the lid, products collector pipe, tar collectors and a pyrogas receiver. Carrier gas (Nitrogen) was used to purge the reactor and sweep the volatiles from the reactor. The pipe channeled the volatiles stream into the tar collectors which were immersed in an ice- bath (tar trapper) for condensation of condensable gases and non-condensable gases passed on to the gas collector. All components were checked so as to ensure that they were in good condition before they were assembled for the process. 50 g of the dried sawdust was weighed and charged into the retort for each run. The retort cover, together with gasket, was well tightened in order to prevent gas leakage. The reactor was then heated by means of an electric heater to 100 ^oC above the desired pyrolysis temperature in order to compensate for the heat loss that will occur when the retort is being placed into the reactor. The reactor afterwards was set to the actual pyrolysis temperature and then maintained at this temperature till the end of the experiment. Experiments were carried out between 300 and 600 ^oC with an interval of 100 ^oC. Details of the experimental procedure are similar to that reported in Okekunle et al. (2016).

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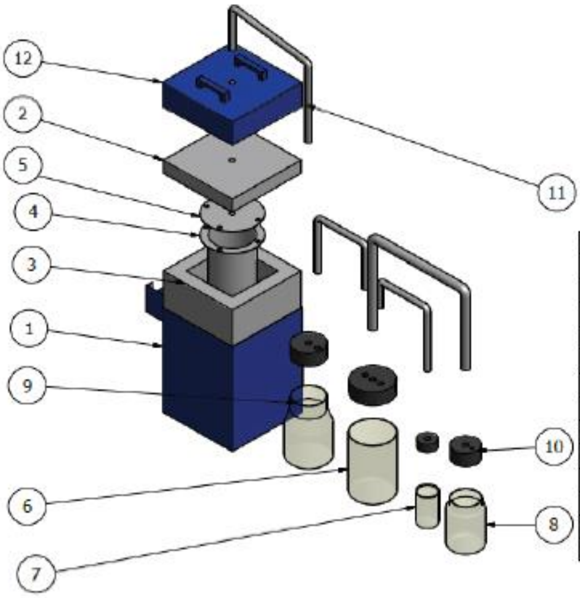

1	1	Metal casing
2	1	Furnace cover
3	1	Furnace
4	1	Crucible
5	1	Crucible cover
6	1	Flask 2
7	1	Overflow flask
8	1	Gas collection flask
9	1	Conical flask
10	4	Glass seal
11	4	Pipe and Hose
12	1	Casing cover
ITEM	QTY	PART NAME
PARTS LIST		

Figure 1. Exploded view of the pyrolysis unit

4 Results and Discussion

4.1 Effect of Temperature on Char Yield

Figure 2 shows the char yields obtained at four different pyrolysis temperatures of 300, 400, 500 and 600 ^{o}C. Char yield was highest at 300 ^{o}C with a percentage of 47.50% and lowest at 600 ^{o}C with a percentage of 22.70%. This result shows that char yield reduces with increasing temperature and this is because further depolymerization of the sample constituents occurs as temperature increases (Levan, 1989). Other researchers have noted that increase in temperature favours the yield of liquid and gas at the expense of char (Di Blasi et al., 1999). From chemical kinetics, increase in temperature doubtless accelerates the rate and extent of biomass conversion into liquid and gaseous products. It has been reported that the solid residue (char) obtained during pyrolysis is mainly from the thermal degradation of lignin (Yang *et al*., 2007 and Jahirul *et al*., 2012).

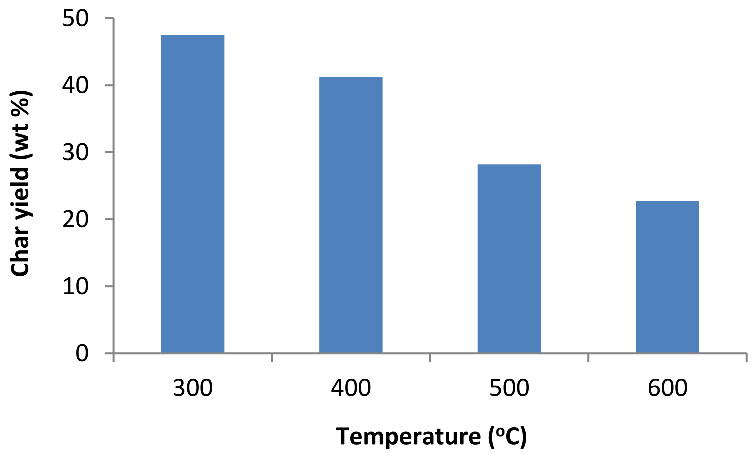

Figure 2. Char yield from pyrolysis of African Oak

4.2 Effect of Temperature on Tar Yield

Figure 3 shows the tar yields obtained at 300, 400, 500 and 600 ^oC. The highest tar yield of 41.80% was obtained at 500 ^oC while the lowest tar yield of 32.30% was obtained at 300 ^oC. From the figure, it is seen that tar yield increased with temperature until 500 ^oC, after which a further increase in temperature caused a reduction in its yield. The sudden change in tar yield pattern after 500 ^oC can be explained from the stand point of secondary pyrolysis (interaction between primary products of pyrolysis). Beyond 500 ^oC, the temperature is high enough to enhance chemical interaction between products of primary pyrolysis (both heterogeneous – between tar and char layer, and homogeneous – between various chemical species in tar) resulting in more gas yield. Other researchers have reported similar findings (Fagbemi et al., 2001). The tar yields obtained were relatively higher and represented a larger percentage of the products from the pyrolysis process.

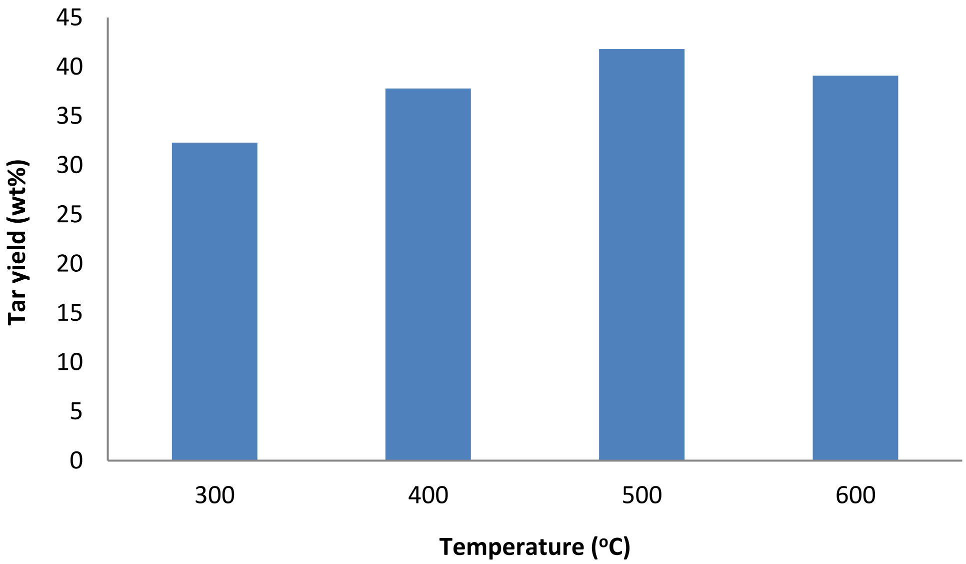

Figure 3. Tar yield from pyrolysis of African Oak

4.3 Effect of Temperature on Gas Yield

Figure 4 shows the gas yields obtained at 300, 400, 500 and 600 ^oC. The highest gas yield of 38.20% was obtained at 600 ^oC while the lowest gas yield of 20.20% was obtained at 300 ^oC. It was observed that gas yield increased with increase in temperature because further break down of wood constituents occurs at higher temperatures and this leads to more gas formation (Levan, 1989). This should be expected because increase in temperature does not only favour the rate and extent of biomass conversion into liquid and gaseous products but also enhances the severity of both homogeneous and heterogeneous secondary reactions. Gas yields at different temperatures in this work falls within the reported range in literature (Di Blasi et al., 1999).

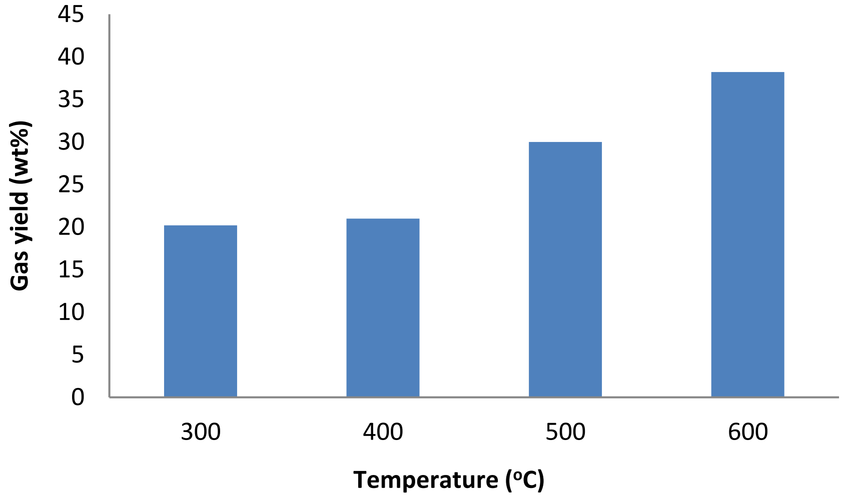

Figure 4. Gas yield from the pyrolysis of African Oak

5. Conclusions

Effect of temperature on the pyrolysis of African Oak (*Oldfieldia africana*) sawdust in a fixed bed reactor has been investigated. Findings revealed that the yields of char and gas with increase in temperature followed a consistent trend. While char yield decreased with increase in temperature, gas yield increased with it. Tar (bio-oil) increased with temperature up to 500 °C and then decreased beyond this temperature. Results also showed that secondary pyrolysis becomes significant beyond 500 °C, changing bio-oil yield pattern. The maximum yields of tar, gas and char were 41.80, 38.20 and 47.50% at 500, 600 and 300 °C, respectively. This work has also shown that sawdust from wood processing industry, which usually is a nuisance to the environment, is a potential source of bio-fuels for sustainable development.

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