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EXPERIMENTAL INVESTIGATION OF PRODUCT DISTRIBUTION FROM PYROLYSIS OF DIFFERENT WOOD SPECIES RESIDUES

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ABSTRACT

The pyrolysis characteristics of different wood species residues [Ayin (Anogneissusleiocarpa), Araba (Ceibapentandra), Dongoyaro (Azadirachtaindica), Iroko (Milicia excels) andGedu (Tectonagrandis)] have been investigated in an electrically heated fixed bed batch reactor at pyrolysis temperature of 500 ^{o}C and 15 minutes residence time. Tar was trapped in an ice bath during the experiment. Product yields (tar, gas and char) were collected, weighed and expressed in percentage of the initial weight of the sample after each run. Results showed that Anogneissusleiocarpagave the highest char yield (33.3%), Azadirachtaindica and Milicia excels, the highest tar yield (42.7%) and Ceibapentandra, the highest gas yield (40.7%). For all the wood species residues, tar yields were relatively high. This was attributed to high percentage of cellulose in the wood species. It was inferred that in situations where pyrolysis oil is most preferred, Azadirachtaindica and Milicia excelsshould be considered as feedstock for pyrolysis and that pyrolysis of woody biomass at 500 ^{o}Cfavoured tar yield.

Keywords: Thermochemical conversion, pyrolysis, product distribution, woody biomass

INTRODUCTION

Biomass is one of the most promising environmentally friendly energy sources. Its renewability, abundance and seeming even distribution across the globe have made it secure the attention of both developing and developed nations. The need to alleviate the problem of greenhouse gases emission resulting from anthropogenic activities has also made this renewable energy source attract various forms of research activities to maximize its energy potentials for sustainable development. Many methods are usually adopted for biomass conversion. These are broadly categorized into biochemical and thermochemical processes. Currently, thermochemical conversion is the best technology for generation of energy from biomass (Li *et al.*, 2009). In thermochemical conversion, pyrolysis is a key process because itis not only an independent process for production of useful fuel but also a precursor of both gasification and combustion (Becidan, Skreiberg and Hustad, 2007). Realising the importance of pyrolysis in thermochemical conversion, numerous works have been done in order to investigate the effect of process parameters, sample type and sample geometry on product distribution during pyrolysis (Cozzani*et al.*, 1996; Koufopanous and Papayannakos, 1991; Scott *et al.*, 1982 and Scott *et al.*, 1984). The pyrolysis characteristics of some agricultural residues have also been investigated (Di Blasi*et al.*, 1999).However, most of these research works made use of biomass materials which are not readily available in Nigeria. To the best of our knowledge, data on product distribution from pyrolysis of agricultural residues, typical of West African countries, especially Nigeria, are scarce. For Nigeria to benefit from thermochemical conversion technology, data as such are necessary for system design and process optimization.

Therefore, in this study, the pyrolysis behaviour of different wood species residues, typical of Nigeria, such as Iroko (*Milicia excels*), Araba (*Ceibapentandra*), Gedu (*Tectonagrandis*), *Dongoyaro* (*Azadirachtaindica*) and Ayin (*Anogneissusleiocarpa*) in a fixed bed reactor was investigated. Sample weight and heating conditions were the same for all wood species residues.

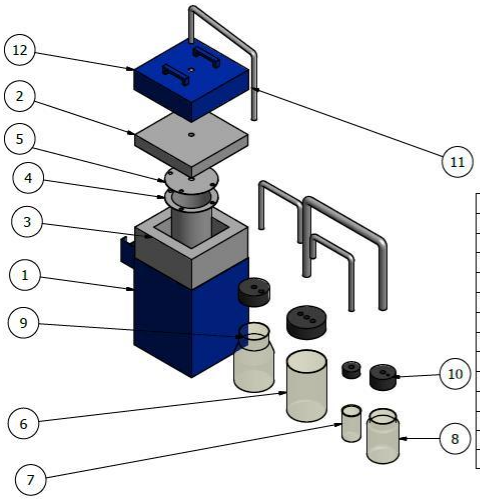
MATERIALS AND METHOD

Materials

Residues of five different wood species (*Anogeissusleiocarpa*, *Ceibapentandra, Azadirachtaindica, Milicia excels and Tectonagrandis*) were obtained from a local wood processing industry (sawmill) in Ogbomoso, Oyo state. The residues were sundried. The samples were then collected and weighed with a digital weighing balance (CAMRY EK 5055 E) with accuracy of $\pm 1g$.

Method

Fig. 1 shows the exploded view of the pyrolysis unit setup for the experiment. It consists mainly of an electrically heated furnace, crucible, heating element, pyrometer, thermostat, pipe channel, tar trap and gas collector. 150 g of each sample was charged into the crucible at the beginning of experiment. The crucible was then covered and secured with bolts and nuts, and then placed inside the furnace. The crucible was made air-tight to avoid volatile leakage into the furnace by using gasket. The furnace was then covered with a lid lined with clay to reduce heat loss. A pipe was connected to the crucible in order to convey volatile release during pyrolysis to the tar trap immersed in an ice bath. Tar trap outlet was connected by means of a hose to a water flask. The water flask was then connected to the gas collector in order to collect samples of the gaseous yield.



ITEM	QTY	PART NAME
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

PARTS LIST

Figure 1: Exploded view of the pyrolysis unit

The furnace was heated to a temperature of 500^{o}C and held at this temperature for 15 minutes. The furnace temperature was controlled by means of a thermostat and was monitored by means of K-type thermocouple probe. Tar was collected at the tar trap. In this experiment, tar was defined as condensable volatile species collected at the tar trap. After 15 minutes, the experiment was terminated and the char residue in the crucible was carefully removed and weighed to determine its mass. Tar yield was also collected from tar trap and weighed. The mass of gas produced was determined by using mass balance analysis (subtracting tar and char masses from the mass of sample). The same procedure was repeated for other runs making use of the five samples in turn.

RESULTS AND DISCUSSION

The product yield distribution resulting from the pyrolysis of different woody biomass species at 500^{o}C has been presented in Table 1. From the table, it can be seen that the product yields from different wood species under the same pyrolysis condition vary. This is in agreement with the findings of Di Blasi*et al.* (1999).

Table 1: Product distribution from pyrolysis of wood species at 500 ^{o}C

Wood species	Initial weight (g)	Char yield (g)	Tar yield (g)	Gas yield (g)
Ayin (*Anogneissusleiocarpa*)	150	28.0	40.0	320
Araba (*Ceibapentandra)*	150	19.3	40.0	40.7
Dongovaro (*Azadirachtaindica*)	150	23.3	42.7	34.0
Iroko (*Milicia excels*)	150	33.3	42. 7	24.0
Gedu (*Tectonagrandis*)	150	26.0	39.3	34.7

Tar yield

Fig. 2 shows tar yields obtained from the pyrolysis of the wood species considered in percentage of the sample weight. From the figure, Iroko(*Milicia excels*)and Dongoyaro (*Azadirachtaindica*) gave the highest tar yield of 42.7% while Gedu (*Tectonagrandis*) gave the lowest tar yield of 39.3%. Ayin (*Anogneissusleiocarpa*) and Araba (*Ceibapentandra*) yielded 40% tar. The tar yields in all wood species were relatively high and represented a larger percentage of products from the pyrolysis process. This indicated the presence of high percentage of cellulose in all the wood species because the main source of tar yield in pyrolysis process has been attributed to cellulose (Yang *et al.*, 2006). In a situation where tar yield is given priority, these results suggest that either Iroko(*Milicia excels*) or Dongoyaro (*Azadirachtaindica*) will be the best material for pyrolysis.

Figure 2: Tar yield from pyrolysis of different wood species at 500^{o}C

Gas yield

Fig. 3 shows the gas yields obtained from the pyrolysis of the wood species. From the figure, Araba(*Ceibapentandra*) has the highest gas yield (40.7%) while Iroko(*Milicia excels*) has the lowest yield (24.0%). Except for Araba(*Ceibapentandra*), tar yields were higher than gas yield in all cases. It is plausible that both intra-particle and extra-particle secondary reactions of tarry compounds, which could have increased gas yield due to tar cracking, were not significant at this pyrolysis temperature. Fagbemi, Khezami and Capart (2001) have reported reduction in tar yield with accompanying increase in gas yield slightly above 600 ^{o}C during pyrolysis.

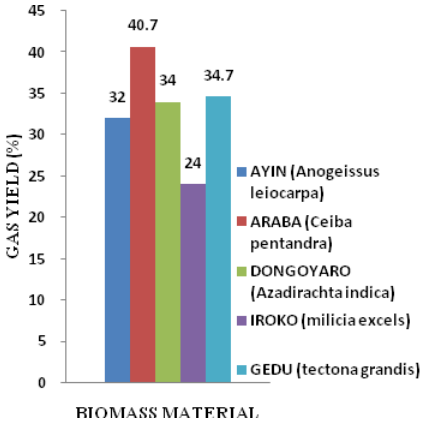


Figure 3: Gas yield from Pyrolysis of different wood species at 500^{o}C

Char yield

Fig. 4 shows the char yields obtained for all the wood species considered. From the figure, it can be seen that Iroko(*Milicia excels*) gave the highest char yield of 33.3% while Araba (*Ceibapentandra*) gave the lowest char yield of 19.3%. The char yields ranged between 19 and 33.3%. These results are in agreement with the range reported (Daweie*t al.*, 2006). It has been reported that char yield during pyrolysis is mainly from thermal degradation of lignin (Yang *et al*., 2006 and Yang *et al*., 2007). It was also reported that feedstock with high lignin content produce the highest char yield when pyrolyzed at moderate temperature of around 500 ^{o}C (Yang *et al*., 2007).

Figure 4: Char yield from pyrolysis of different wood species at 500^{o}C

CONCLUSIONS

The product distribution of five wood species during pyrolysis at 500°C has been experimentally investigated in a fixed bed batch reactor. Results showed that in a situation where pyrolysisoil is given priority, either Iroko (*Milicia excels*) or Dongoyaro (*Azadirachtaindica*) will be the best option. Pyrolysis oil is used as industrial fuel to substitute furnace oil or industrial diesel and also as raw materials for chemical and processing industries. Where pyro gas fuel is most desired, Araba (*Ceibapentandra*) may be considered as feedstock for pyrolysis. In situations where bio char is desired, Iroko (*Milicia excels*) appears to be the best option. Findings also revealed that pyrolysis of woody biomass around average temperature of 500°C favours tar production. This study has given some facts on the product distribution of wood species, typical of Nigeria, during pyrolysis and will serve as a guide to knowing which wood species is most suitable for high yield of pyrolysis gas, oil and char.

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