PYROLYSIS OF SUGARCANE BAGASSE FOR BIO-OIL PRODUCTION

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**ABSTRACT**

One potential technique for alleviating environmental concerns from the release of green house gas (GHG) emission from fossil fuel burning is through conversion of biomass residue to other energy products such as bio-oil. This study focused on pyrolysis of sugarcane bagasse for bio-oil production. The pyrolysis of Sugarcane bagasse (SB) as waste from raw sugarcane was carried out in a 35.3 litres capacity fixed bed reactor. The fixed bed reactor has overall dimensions of (238 mm diameter., 794 mm height) with handling capacity of 3 kg of feedstock per batch. The raw sugarcane collected from a local farm in Idanre metropolis was crushed, squeezed to extract the juice and sundried to lessen the moisture content. The dried sample of size < 1 mm was fed into the reactor at room temperature of 25°C and heated to a temperature of 500°C. The product of bio-oil was collected and assayed for their compositions, contents and characteristics. The chemical properties of the produced bio-oil were compared with literature values of bio-oil derived from other biomass wastes. The pyrolytic oils from the SB wastes are characterized by heating value (HV) of 17.33 MJ/kg, negligible amount of Sulphur and Nitrogen (0.88 and 0.01 % wt respectively) which resulted in lower emission of SO₂ and NO₂ consequently slighter environmental impact. The finding indicates that the pyrolytic oil from SB would be a suitable candidate for alternative energy fuels for combustion in a boiler or a furnace without any further chemical treatment. The study revealed that the bio-oil obtained from sugarcane bagasse is combustible and more environmentally friendly.

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1.0 INTRODUCTION

The environmental impact of the use of fossil fuel as the major source of energy coupled with the increasing energy demand as a result of population increase in both developed and developing countries necessitates the search for alternative sources of eco-friendly energy. Report of experts from the study of Goyal et al. (2008) have also estimated that the fossil fuels like petroleum might be depleted by 2050. Faisal et al. (2011) in their study pointed out that, oil crisis and environmental concern on the release of greenhouse gas (GHG) emission from fossil fuel burning has led to an increase in research on development of renewable energy that will help greatly in future energy supply. Similarly, according to Akinola (2018), renewable energy from biofuel in context of the
threat in terms of global environmental impact is one of the best means to resolve the issue of future energy demand and protection to the environment. Moreso, Titiladunayo (2002) in their study reported that the possibility of the future shortage of the conventional fossil oil reserves has generated an overwhelming interest in exploring an alternative source of energy, one of which biomass is vital. As pointed out in the study of Sricharoenchaikul and Atong, (2009), one of the most viable renewable energy sources is biomass from agricultural residues in the sense that it is cheap, abundant and does not require significant effort to collect. Biomass according to Xiu et al. (2017) is also regarded as one of the usable resources for bio-oil and bio-char production.

Findings from the study of Gayubo et al. (2010) have established biomass as carbon neutral substance as it contains negligible amount of sulphur and its combustion yielded zeroth net release of carbon dioxide (CO₂) into the environment. Conversion of biomass to bio-fuel can be achieved through various processes such as (thermal, biological and physical). Among these biomass energy conversion processes with the aims of producing liquid fuel product, pyrolysis has attracted more interest (Bridgwater et al. 1999). According to Wijaya and Wiharto, (2017), pyrolysis of biomass substance to produce liquid product with solid chars and gases is a process in which the biomass decomposes at temperature of about 500°C in the absence of oxygen. Chen et al. (2016) in their study reported pyrolysis as a thermochemical technology for converting biomass into energy and chemical products such as bio-oil, syngas and biochar. According to Muradov and Veziroglu (2008), to find a viable replacement for non-renewable fossil fuels, a high-value bio-oil is to be produced using this technology. Bio-oil has a high energy density, and can be easily stored, transported and utilized through integration into the existing petroleum refineries or future bio-refineries (Sung et al. 2013).

Moreover, Zheng Ji-Lu (2007) pointed out that Bio-oil does not contribute to a net rise in the level of CO₂ in the atmosphere, and consequently to the green-house effect. Bio-oil according to Abdullah, and. Gerhause (2008) is defined as a high density oxygenated liquid that can be considered as a substitute for liquid fossil fuels in some applications like diesel engines, turbines or boilers. However, it is interesting to highlight that the particle size of biomass feed material is an important parameter in determining the efficacy of pyrolysis. This fact is also emphasized and reported by (Sensoz et al. 2006; Kan et al., 2016; Mishra and Mohabty, 2018). In order to obtain high heating rates output products during pyrolysis process, a very fine feedstock is required by conventional pyrolysis. This observation is adopted in the present study involving thermal degradation of Sugarcane Bagasse with a view to produce bio-oils.

In this study, Sugarcane Bagasse was pyrolyzed in a fixed bed batch-type pyrolysis reactor to produce bio-oils. The pyrolytic bio-oil produced using Sugarcane Bagasse were characterized and the result were compared with other bio-oils produced using other biomass feedstocks carried out in the open literature. The finding indicates that the bio-oil obtained in the study was combustible and can be used as fuel for combustion in boilers or furnaces to replace the existing non-renewable fossil fuels such as petrol and diesel through the application of the advanced pyrolysis technology.

2.0 MATERIALS AND METHODS

2.1 Materials

Raw sugarcane was collected from Balogun Farm situated at Ipoa Balogun village, Idaize in Ondo State, Nigeria.

2.2 Apparatus and Equipment

The apparatus and equipment used for this research include: thermal reactor, condensing unit, bio-oil
collector, cyclone, weighing balance, thermocouple, temperature controllers, and gallenkamp ballistic bomb calorimeter.

2.3 Description of Experimental Set-up

As shown in Fig. 1, the experimental device mainly consists of a fixed bed batch-type reactor, one cyclone, a condenser, as well as installed K-type thermocouples for the system temperature measurement. The condenser is equipped with some nozzles and a heat exchanger. The condenser can quickly condense the cleaned hot gas into liquid oil. Thermocouples and pressure guage meters are used to monitor pyrolysis system temperature and pressure respectively. The cyclone separator provides a method of removing particulate matter such as charcoal and ash from the gas stream. The cyclone separator consists of an upper cylindrical part called the barrel and the lower conical part referred to as cone. The gas stream enters tangentially at the top of the barrel and travels downward into the cone forming an outer vortex. The increasing gas velocity in the outer vortex results in centrifugal force on the particles separating them from the gas stream. When the gas reaches the bottom of the cone, an inner vortex is created reversing the direction and exiting out the top as a clean gas while particulate (char) fall into the dust collection chamber attached to the bottom of the cyclone. The cyclone was designed using standard dimensions for designing a high efficiency cyclone adopted from Coulson and Richardson, (2005). The typical characteristic of which an efficiency of 85% was attained by the authors in their study. In order to obtained the expected bio-oil from the thermal degradation of biomass wastes, a rapid cooling of the pyrolysis vapour product is needed to promotes high liquid oil yield (bio-oil). In this study an air cooled condenser (radiator) is incorporated in the reactor as a condensing unit. This type of condenser was selected due to the fact that as reported by Balat, et al., (2009) the heat transfer area attained in using air for condensation in their study is typically 15 times larger than that of water.

![Figure 1: Picture of the Experimental Set-up of the Pyrolysis Unit](image-url)
2.3 Experiments

2.3.1 Feedstock Preparation

The raw sugarcane collected from a local farm situated at Ipoja Balogun village, Ijanre was crushed in a wooden mortal, squeezed to extract the juice and sundried for 4 days to reduce the moisture content from 50 w% moisture content in moist sugarcane bagasse state to 7 wt % moisture content dried bagasse state. (Fig. 2a, showing the partially processed bagasse). The dried bagasse was milled and sieved to a smaller size < 1 mm, (Fig. 2b presenting the final processed bagasse) to increase the feedstock surface area in lieu of increasing its pyrolysis rate of reaction.

Figure 2: Feedstock preparation

2.3.2 Experimental Procedures

Sugarcane bagasse was pyrolyzed into bio-oil using a 35.3 litres capacity fixed bed reactor designed and constructed by Akinsade (2018) as shown in Fig. 1. At first, the feedstock sample (Fig. 2b) was weighed using weighing balance and 3.0 kg of the feedstock was fed into the reactor chamber at room temperature of 25 °C for thermal degradation. Presented in Figure 3 is the flowchart showing the experimental procedure while the reactor temperature controller was preset at 500 °C and thermocouple was used to monitor the temperature within the reactor chamber. The volatiles coming from the heating chamber was scoured of removing particulate matter such as charcoal and ash with the aid of the cyclone device and subsequently passed through air cooled condenser to condense the cleaned hot gas into liquid oil (bio-oil). Presented in Fig. 4 is the sample of the obtained bio-oil in this study. At the end of the experimental test, the quantity of bio-oil yield was determined to be 56.5 % wt. Proximate and ultimate analysis of the collected bio-oil was carried out to determine the product fuel properties. Energy content of the collected bio-oil in terms of heating value was also determined with the aid of gallenkamp ballistic bomb calorimeter.

3.0 RESULTS AND DISCUSSION

3.1 Bio-oil characterization

With a view to obtain the fuel properties of the bio-oil produced using sugarcane bagasse, proximate and ultimate analysis of the obtained bio-oil was carried in this study. The compositions of bio-oil was analysed with gas chromatography–mass spectrometry while the heating value of bio-oil was obtained with the use of oxygen bomb calorimeter. The proximate and ultimate analysis properties of the bio-oil are presented in Table I. From this table, it can be found that: (i) The obtained bio-oil using sugarcane bagasse has a high moisture content of 8.52 % wt. improves its flow characteristic consequently beneficial for combustion in terms of pumping and atomization. (ii) The bio-oil has a high volatile matter of 79.45 % wt indicating high
Figure 3: Bio-oil production procedure
4.0 CONCLUSION

The ignition property of the bio-oil. The properties of the bio-oil such as the water content, heating value (HV) and volatile matter obtained in this study, is basically similar to those reported in the previous studies of (Hensley, 2014, Suleiman et al. (2011), Zheng Ji-Lu (2007) and Zheng Ji-Lu et al., 2008) despite using different biomass feedstock in their respective studies compared to the sugarcane
Table 1: Comparison of the bio-oil produced with other bio-mass feedstock

<table>
<thead>
<tr>
<th>Component/Property</th>
<th>Literature values of some pyrolysis oil</th>
<th>Measured value for Sugarcane Bagasse</th>
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<tr>
<td></td>
<td>Empty fruit branches (EFB)</td>
<td>Corn cob</td>
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Ultimate analysis (wt. %)

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<tr>
<th></th>
<th>Carbon</th>
<th>Hydrogen</th>
<th>Nitrogen</th>
<th>Sulphur</th>
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<tr>
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<td>45.21</td>
<td>4.94</td>
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Proximate analysis (wt. %)

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<th>Ash</th>
<th>Fixed carbon</th>
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REFERENCE


Chen, T., Liu, R. and Scott, N.R., (2016): Characterization of energy carriers obtained from the pyrolysis of white ash, switchgrass and


Hensley, M. D. (2014) Bio-oil production from lignocellulosic biomass using fast pyrolysis in a fluidized-bed reactor; PhD Thesis Submitted to The Department of Wood Science And Technology, Kwame Nkrumah University of Science and Technology, Ghana.


