Investigations into Pyrolysis of Few Selected Agro-Residues Commonly Found in Nigeria.

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ABSTRACT

In this work, products of pyrolysis of corncob, rice husk, and sawdust were determined with a view to establishing their energy potentials. A pyrolysis system that consists of a brick furnace, condensate receiver, retort, and gas collection unit was used. The moisture content of the residues and the weight of wood used for pyrolysis were determined. Samples of the residues were loaded into the retort and placed inside the furnace chamber for firing one at a time. The process of pyrolysis took 30 minutes. The products collected were each weighed and recorded. The pyrolytic gases collected were taken to laboratory further analysis in order to establish the constituents of the gases.

The yields obtained for corncob was 35.8%, for char, 30.0%, for the mixture of tar oil/pyroligneous acid and 34.2%, for pyrogas. The corresponding values for the rice husk in the order listed above are 30.56%, 45.27%, and 18.17%, respectively, while the values of sawdust were 17.0%, 41%, and 42%, respectively. For the corncob, the pyrogas consists of 52.3% ethane (C_2H_6), 28.6% propane (C_3H_8), and 19.1% methane (CH_4), while for the rice husk; only 100% by volume of ethane (C_2H_6) was produced. In the case of sawdust, the pyrogas consists of 62.5% by volume of ethane (C_2H_6), 33.3% of methane (CH_4), and 4.2% of hydrogen (H_2). The higher heating values obtained for the chars of corncob, rice husk and sawdust are 20.89, 15.3, and 17.1 MJ/kg, respectively.

The results of this work showed that, the three residues examined would make a good biomass fuel and they lent them easily to process of pyrolysis. However, findings show that corncob and sawdust have more positive attributes of biomass fuel than rice husk. Both produced three different pyrogases as against one produced by rice husk. Also, the higher heating values of corncob and sawdust chars are higher than rice husk.

(Keywords: pyrolysis, sawdust, rice husk, corncob, char, pyrogas, tar oil, biomass, energy conversion)

INTRODUCTION

Nigeria's quest to be among the 20 richest nations by 2020 will be a mirage, if the issue of energy availability is not strongly addressed. Indiscriminate and inefficient burning of fuel wood being presently practiced in the country has resulted in environmental pollution and health hazards, thereby making fire wood no solution to our energy needs (Olorunnisola, 2007). Therefore, there is the need to generate alternative forms of energy in order to shift attention from fossil fuels, which are expensive and environmentally unfriendly.

One of the most important energy sources for mankind is biomass, which accounts for approximately 14% of energy consumption in the world (Kaygusaz, 2002). Agricultural residues are often discarded or burned as wastes, occur in large amounts, and have the potential to be an important source of fuel for many people in rural areas. Although it is possible to use agricultural residues directly, many of these residues are loose and low-density materials, which make them difficult to burn in a controlled and effective manner (Musa, 2007).

In Nigeria, large quantities of agricultural residues are produced annually, but it is unfortunate that these residues are badly managed. In most cases, these residues are burned in the field or they are left to rot away (Jekayinfa and Scholz, 2009). Most of these residues contain enormous amounts of energy (Oladeji, et al., 2009). In

Nigeria, large amounts of corncob, rice husk, and sawdust are produced annually and are not utilized for energy purposes. This results in poor waste disposal, which in itself contributes to environmental pollution and constitutes a public nuisance and eye-sore (Oladeji, 2010). However, these residues, if properly harnessed and managed, will go a long way to alleviate some of the energy crisis being experienced in the country. The three residues examined in this work may be converted to products of higher-grade fuels and chemical preservatives through the process known as pyrolysis.

Pyrolysis can be defined as the thermal breakdown of biomass in the absence of oxygen to produce solid fuel, condensable organic liquid and non-condensable gases (Boateng, 2007). Pyrolysis normally occurs under pressure and operating temperature above 450^0C (Bridgewater, 2002). Some researchers of renewable energy have worked on pyrolysis of agro-residues. Examples of such residues studied are oil palm waste (Guo and Lua, 2001), maize cob (Bamigboye and Oniya, 2003; Ogunsola and Oladeji, 2009), and wood residues (Fapetu, 2000) among others. Process of pyrolysis is being made use of in United States of America in handling municipal solid wastes with moisture content of between 30-70% (Bamigboye and Oniya, 2003).

The aim of this work was to investigate the energy potentials of three agricultural residues commonly found in Nigeria and to characterize pyrolytic conversion of these residues with a view to determining which of them give optimal yields.

MATERIALS AND METHODS

The yellow corncob from *Zea mays*, rice husks from *Oryza sativa,* and the sawdust from *Chlorophora excelsa* were utilized in this experiment. The three residues were sundried until they have stable moisture content and their weights were determined. The three residues were oven-dried at a temperature of 103 ± 2^0C and their moisture contents were determined one after the other in line with the procedure as highlighted in accordance with ASAES269.4 (2003).

A simple pyrolysis chain was set up and developed to facilitate the process of pyrolytic conversion of these residues into biomass fuels (Figure 1). The pyrolysis chain is made of retort, where the biomass residue was put, brick furnace, where the retort was placed for firing, and condensate receiver, where the liquid products of pyrolysis were collected. Another important unit of the pyrolysis chain is the gas collection unit, where the pyrogases were collected. 1 kg of each sample was put inside the retort and placed in the brick furnace for direct burning using firewood of 1.5 kg closely packed around the retort. A little amount of kerosene was sprinkled over the firewood to initiate combustion. A stop watch was employed to record the duration of the experiment. The retort became gradually red hot and the residue began to pyrolyze. The pyrolyzed products slowly went into the condensate receiver, which was surrounded by ice bath to cool the products entering the receiver. The pyrolytic gases were collected in the cylinder, which was attached to the condensate receiver. The whole process took 30 minutes. The products collected were each weighed and recorded. The pyrolytic gases collected were taken to laboratory for further analysis in order to establish the constituents of the gases.

Figure 1: Pyrolysis Chain Setup.

RESULTS AND DISCUSSION

The results obtained for the pyrolysis trials are presented in Tables 1-4. The pyrolysis of corncob, rice husks, and sawdust yielded the following products: mixture of pyrolytic oil/pyroligneous acid and pyrolytic gas.

For corncob, the average percentages by weight of charcoal, mixture of pyrolytic oil/pyroligneous acid and pyrogas are 35.8, 30, and 34.2%, respectively, while the corresponding values for rice husk are 30.56, 43.27 and 18.17%, respectively.

Table 1: Compositions of Products of Pyrolysis of Corncob, Rice Husk, and Sawdust.

Parameter	Residue/Value		
	Corncob	Rice husk	Sawdust
Weight of oven dried of residue (kg)	1.0	1.0	1.0
Weight of firewood used (kg)	1.50	1.50	1.50
Weight of char obtained (kg)	0.343	0.258	0.144
Weight of mixture of oil and pyrolytic acid (kg)	0.288	0.407	0.369
Weight of gas (kg)	0.328	0.164	0.378
Conversion efficiency %	96.3	82.9	89.1
Higher heating Value (MJ/kg)	20.89	15.3	17.1

Table 2: Products of Pyrolysis Expressed as % of Input Feedstock.

Product	% Composition		
	Corncob	Rice husk	Sawdust
Char yield	35.8	30.56	17
Mixture of tar oil and pyrolytic acid	30.0	45.27	41
Pyrogas	34.2	18.17	42

Table 3: Constituents of Pyrogas.

Product	% Composition		
	Corncob	Rice husk	Sawdust
Carbon	76.54	77.28	74.69
Hydrogen	23.46	22.72	25.31

Table 4: % Composition by Volume of Gases Formed.

Gas	Chemical Formula	% Composition		
		Corncob	Rice husk	Sawdust
Ethane	C_2H_6	52.3	100	62.5
Propane	C_3H_8	28.6	Nil	Nil
Methane	CH_4	19.1	Nil	33.3
Hydrogen	H_2	Nil	Nil	4.2

The values obtained for the sawdust in the order listed above are 17, 41, and 42%. The results showed that for corncob, the solid char had the highest yield, while the mixture of pyrolytic oil/pyroligneous acid had the least yield. However, for rice husk the mixture of pyrolytic oil/pyroligneous acid had the highest yield, while the pyrogas recorded the least yield. In the case of sawdust, pyrogas had the highest yield, while the char yield had the least yield. The char yield of 30.56 % of rice husk appears to be in agreement with the work of Fapetu, (2000), where the char yields from pyrolysis of palm kernel, ekki wood and coconut shell gave values of 28.07%, 25.07% and 29.62%, respectively. The 17 % char yield of sawdust, however, deviates from these values. The results obtained for corncob appear to be in agreement with the works of Bamigboye and Oniya (2003) and Ogunsola and Oladeji (2009), where similar values were got for the pyrolysis of corncob. The implication of this is that the products of pyrolysis and the percentage yields depend on the type of biomass residue used, its chemical constituents, quality, and operating conditions.

The constituents of pyrogas for corncob are 76.54% carbon and 23.46% hydrogen, while for rice husk; it was 78.28% for carbon and 22.72% for hydrogen. The values recorded for sawdust are 74.69% carbon and 25.31% hydrogen.

Further chemical analysis revealed that the pyrogas of corncob contained three different gases, namely, 52.37% by volume of ethane (C_2H_6), 28.6% by volume of propane (C_3H_8), and 19.1% by volume of methane (CH_4), while for rice husk, the pyrogas is made of only one gas, which is 100% by volume of ethane (C_2H_6). Three gases were also produced by the sawdust and these are 62.5% by volume of ethane (C_2H_6), 33.3% by volume of methane (CH_4) and 4.2% by volume of Hydrogen (H_2). The higher heating values of chars from corncob, rice husk, and sawdust are 20.89, 15.3, and 17.1 MJ/kg, respectively.

The char products obtained could be used for traditional and industrial cottage applications as in domestic cooking and as fuel in open earth furnace for blacksmithing and goldsmithing operations (Fapetu, 2000). The pyrolytic gas could be used as household cooking gas and as fuel for gas lamps (Bamigboye and Oniya, 2003), while the pyrolytic oil can be used as fuel in the internal combustion engines (Bridgewater 2002).

CONCLUSION AND RECOMMENDATIONS

From the study, the following conclusions can be drawn:

(1) The three agricultural residues examined in this study were easily applied to process of pyrolysis

(2) The products of pyrolysis and its percentage yields depend on the type of the biomass feedstock used, its quality, chemical constituents and operating conditions

(3) Of all the three residues examined, corncob and sawdust have more positive attributes of pyrolysis than rice husk judging from the fact that three different types of gases can be obtained from the same quantity of residue as against only one type for rice husk. The higher heating values of the chars produced from these residues are also sufficient for domestic and industrial cottage applications and in this regards corncob appears to be the best. Furthermore, conversion efficiency of corncob and sawdust is higher than that of rice husk.

Finally, the study recommends that, the three biomass feed stocks examined in this study could be subjected to process of briquetting. All these will ensure judicious use of agro wastes and will ensure proper waste management and control.

REFERENCES

1. ASAE. *ASAE 269.4 2003 Cubes, Pellets and Crumble Definitions and Methods for Determining Density, Durability and Moisture Content.* ASAE: St. Joseph, MI.

2. Bamigboye, A.I. and Oniya, O. 2003 "Pyrolytic Conversion of Corncobs to Medium Grade Fuels and Chemical Preservatives". *FUTAJEET*. 3(2): 50-53.

3. Boateng, A.A., Daugaard, D.E., Goldberg, N.M. and Hicks, K.B. 2007 "Bench-Scale Fluidized-Bed Pyrolysis of Switch grass for Bio-Oil Production". *Industrial and Engineering Chemistry Research*. 46(7):1891-1897.

4. Bridgewater, A.V. 2002. *An Introduction to Fast Pyrolysis of Biomass for Fuel and Chemicals in the Fast Pyrolysis of Biomass: A Handbook*. CPL Press: Newbury, U.K.

5. Fapetu, O.P. 2000 "Production of Charcoal from Tropical Biomass for Industrial and Metallurgical Process". *Nigerian Journal of Engineering Management*. 1(2):34-37.

6. Guo, J. and Lua, A.C. 2001 "Kinetic Study on Pyrolytic Process of Oil Palm Solid Waste using Two-Step Constructive Reaction Model". *Biomass and Bioenergy*. 20:223-225.

7. Jekayinfa, S.O. and Scholz, V. 2009 "Potential Availability of Energetically Usable Crop Residues in Nigeria". *Energy Sources, Part A*. 31:687-697.

8. Kaygusaz, K. and Turker, M.F. 2002 "Biomass and Energy Potential in Turkey". *Biomass and Bioenergy.* 26:661-678.

9. Musa, N.A. 2007. "Comparative Fuel Characterization of Rice Husk and Groundnut Shell Briquettes". *NJRED*. 6(4):245-262.

10. Ogunsola, A.D. and Oladeji, J.T. 2009 "The Development of a Pyrolysis Unit for Conversion of Corncobs to Improved Biomass Energy". *IJAAAR*. 5:17-21.

11. Oladeji, J.T., Enweremadu, C.C., and Olafimihan, E.O. 2009. “Conversion of Agricultural Wastes into Biomass Briquettes”. *IJAAAR*. 5(2):116-123.

12. Oladeji, J.T. 2010. “Fuel Characterization of Briquettes Produced from Corncob and Rice Husk Residues”. *Pacific Journal of Science and Technology*. 11(1):101-106.

13. Olorunnisola, A.O. 2007. “Production of Fuel Briquettes from Waste paper and Coconut Husk Admixtures”. *Agricultural Engineering International: The CIGR E-Journal.* Manuscript EE 06 006. 123-128

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