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REVIEW ARTICLE

PYROLYSIS OF BIOMASS AS A SUITABLE ALTERNATIVE TO FOSSIL FUEL ENERGY IN NIGERIA: AN OVERVIEW

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ABSTRACT

Environmental problems associated with fossil fuel were highlighted to see the need for alternative energy in Nigeria. This review identified the various types of pyrolysis and their major products that make them fit as a suitable alternative energy source. It described pyrolysis as a means of converting waste to wealth and as a good source of energy generation thereby reducing reliance on fossil fuel. It proffers low-cost solutions for energy generation. The study as a whole contributed to the sustainability of the environment and removal of agricultural waste that constitute nuisance to Nigeria physical environment.

KEYWORDS

Pyrolysis, physicochemical properties, biofuel, biomass, biochar, bio-oil.

1. INTRODUCTION

Nigeria is richly blessed with large deposit of fossil fuel. Its exploration involves human activities which spill crude oil into the environment (Cumo et al., 2002). Abandoned and unprotected oil fields, movement and storage of crude oil and its distillation products in the country pose a greater risk of oil spills. Its spillage result into the release of crude oil components; trace metals, sulphur, colour, floating particles, mineral oils, aromatic compound (C_6H_6, $CH_3C_5H_6$, $(CH_3)_2C_6H_4$, polycyclic aromatic hydrocarbons), C_6H_5OH, salt, ammonia, saturated and unsaturated hydrocarbons, etc. into the ecosystem (López-Grimau et al., 2006). If these substances e.g. Heavy metal, aromatic hydrocarbon, suspended particles, chemicals etc. from crude oil find their way into water bodies (groundwater, lakes, rivers, seas, oceans, lagoon), air and land in untreated or partially treated form, they constitute a potential danger to the environment. These oil spills resulted in great deal of damage to the marine ecosystem, coastal and terrestrial habitats which adversely affect the social, environmental and economic activities in the country.

Burning of fossil fuel releases greenhouse gases which are major cause of climatic change that has overtime created worrisome situation due to its negative impact on the environment and its demography and might likely displace millions of people in developing countries and perhaps cause social unrest in a very near future (Debay, 2010). Industrial production supported by burning of fossil fuel is largely done in developed countries hence they are the major contributor to changes in climatic condition but have developed technologies, policies and rich economic status so that they will be least affected (Mcguigan et al., 2002). Assessment of the impact on large number of developing countries showed climate change has an aggregate effect on bio-resources and alters the balanced state of their ecosystem. Nigeria relied on burning of fossil fuel to generate electricity, power automobiles and generator used in homes and industries. This has created a trend of continuous release of greenhouse gases leading to climatic change with negative environmental impacts. In recent times, some sectors supporting the economy growth of Nigeria appear to have been hit by the adverse effects of climate change. These impacts had been recorded in agricultural, mining, health (medicine and pharmaceuticals), species of plant and animal, socio-economic, manufacturing industries and power generation. Food and livestock production have been hampered in Yobe due to sand dunes and desert encroachment that has gulped nearly 30,000 hectares of land (Niasse et al., 2004).

To reduce this drastic effect of fossil fuel there is urgent need to turn to biofuel which can be obtained from biomass wastes. The problems associated with non-renewable source of energy i.e. fossil fuels isn't limited to pollution but also technical knowhow, economical demands, scarce and domestically non-accessible when compared to biomass energy. Nigeria is blessed with some common biomass e.g. herbs and grasses, wood residues, sugarcane residues, animal waste, food companies wastes, palm residues. Energy can be generated from these materials via processes to include; heating in the presence of O_2 (combustion), subjecting to different thermo-chemical conversions, production of hydrogen energy by bio-photolysis and adopting biological conversion methods. It is a common practice amongst farmers or rural dwellers in Nigeria due to poor or inefficient waste disposal system to discard biomass waste as useless materials which constitute another pollution issue to the environment (Arimoro et al., 2007).

In Nigeria, Agriculture has proven to be the means of livelihood of many

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rural dwellers which had contributed 41% of the GDP (Kankara, 2013). The focus of farming in any country is to produce sufficient food for her citizen and export if possible, but the solid wastes generated can be channeled for energy use as in the case of Nigeria where biomass wastes that could be converted for power generation are quite enormous. Sambo estimated the amount of sawdust generated per annum in Nigeria to be about 1.8 MT, while a group researcher reported a figure for wood residues to be about 5.2 MT/ yr (Sambo, 2009; Francescato et al., 2008). A study Aurela revealed about 43.4 billion kg/yr of fuelwood is consumed in Nigeria while 1.8 million tons/yr wood dust is generated (Aurela, 2013). A value of 1.924×10^{18} J was an estimated energy from agro-residues as reported in (Ojolo et al., 2012) as at 2005. The yearly energy need by Nigeria has enjoyed support of fuelwood by a value greater 60% between 1990 - 2005 (Dayo, 2005). If we assumed this trend to be continuous, then reliance on fuelwood and other agro-residue to meet future Nigeria energy demands is quite acceptable. Although indiscriminate felling of wood is being discourage by Government to prevent deforestation which has a negative effect on the environment, residues is preferable used and another option that could be tapped is to cultivate energy crops in large available and unused land spaces. Their cultivation will reduce Nigeria's energy need through bio-energy.

1.1 Aims and Objectives

Energy from renewable resources e.g. agro-residues hasn't been totally utilized due to the thermochemical conversion method adopted over years in Nigeria. The common practice to derive energy in homes and industries using biomass waste in Nigeria is combustion with inherent huge environmental consequences and with low percentage of utilization of 5 and 15% (Ojolo et al., 2012). Therefore, there is urgent need to explore new or existing methods of thermochemical conversion method which has been proven to perform better than direct combustion. Since Nigeria is largely blessed with agricultural and forest produce, biomass wastes from these materials can be explored as fuel i.e. biofuel. Thermochemical processing or conversion of these waste produces biofuel and pyrolysis has proven to be the best method of extracting energy from biomass waste. Also, efficient use of biomass wastes as solid, liquid and gas can be achieved using pyrolysis. The study aims to look at pyrolysis, its type and benefits in the context of Nigeria fossil fuel for energy production.

1.2 Methodology

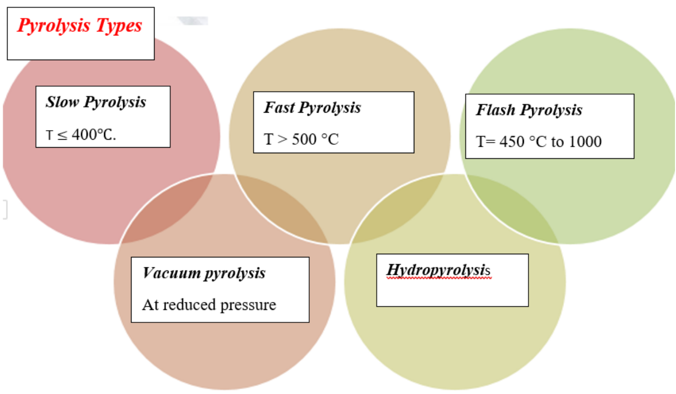

Figure 1: Schematic representation of types pyrolysis

1.3 Pyrolysis

Pyrolysis is the most capable thermochemical conversion process applicable in extracting largest energy from biomass into biofuels (Frederik et al., 2013). Pyrolysis takes place in an oxygen deprived environment making the biomass material not to undergo combustion but decompose into volatile components (liquid and gas) and char.

1.3.1 Types of Pyrolysis

1.3.1.1 Slow pyrolysis

Is a process that takes place at lower temperatures usually less than or equal to 400℃. It has bio-char being the dominant of the three pyrolytic products. Heating process is usually slow and at low-rate releasing gases which is a fraction of bio-oil that makes the process continuous and self-sufficient because the combustion of the pyrolytic gas and a fraction of bio-oil or bio-char can supply all the needed energy for the reaction to proceed. Slow pyrolysis has good potential in biochar production (Frederik et al., 2013). However, slow pyrolysis isn't the best process suitable for producing good quality bio-oil due to certain process constraint. Data from forest and wood processing in Nigeria as at 2010 revealed a total volume of 65,753,628 m^3 as biomass wastes from solid and dust from logging, sawmilling, plywood and particle board (FAOSTAT, 2012). If this was channeled to charcoal production through slow pyrolysis, it would have been a source of clean energy for rural dweller and industrial boilers.

1.3.1.2 Fast pyrolysis

Fast pyrolysis is usually performed around 500 °C and extremely high rate of heating (i.e. 1000 °C/s). The pyrolyzer heat the biological materials to a high temperature in O_2 deprived chamber (Bridgwater, 2007). It takes place at high heating rate and lead to high heat transfer which releases vapour of short residence time that cools rapidly with significantly high bio-oil yield as the common feature (Demibas and Arin, 2002). This technique brings about syngas production in the pyrolyzer which are continuously burned to sustain the system temperature. In fast pyrolysis, 60-70 wt % pyrolytic liquid can be achieved, with as low as 15wt % char and as high as 25 wt% of bio-char, 10-15 wt% pyrolytic gases but largely depends on feedstock (Rolando et al., 2002). Fast pyrolysis technology has extensively been used in producing pyrolytic liquid used as fuels, specific and commercial chemicals. The major product of this process which is bio-oil can also be extracted from agricultural residues largely available in Nigeria and upgraded to biofuel. A study reported that Nigeria corn cobs has great potential to produce bio-oil that could be channeled for energy generation (Bamgboye and Oniya, 2003).

1.3.1.3 Flash pyrolysis

Is a technique for the production of the three pyrolytic products from biomass but can specifically attain 75% of bio-oil yield (Demirbas, 2000). This technique is characterized by rapid devolatilisation of the biomass in an O_2 deprived chamber with gas residence duration less than a second, of sufficient high heating rate and pyrolyzer temperatures between 450 °C to 1000 °C (Aguado et al., 2002; Jahirul and Rasul, 2012). In spite of its high bio-oil yield this method has some technological limitations. A study listed disadvantages associated with flash pyrolysis to include; the poor heat stability and iron rustiness of bio-oil obtained, solids in the bio-oil, char induced catalyst decrease lubrication value over time, alkali in bio-oil, production of pyrolytic liquid etc (Cornelissen et al., 2008).

1.3.1.4 Vacuum pyrolysis

This type of pyrolysis takes place at reduced pressure under vacuum. Klason in 1914 was the first person to perform vacuum pyrolysis (de Jongh, 2001). This method of pyrolysis help restricts secondary decomposition reactions removing the primary volatile products from the hot part of the pyrolyzer chamber (Nachenius and Prins, 2013).

1.3.2 Pyrolysis products

1.3.2.1 Bio-oil

Liquid obtained from condensation of vapour during pyrolysis is known as bio-oil. Most bio-oil are dark brown in colour, moderate viscous liquid and has approximately the same elemental composition from the biomass it is being obtained. Depending on biomass type and the pyrolysis type used, the bio-oil can be almost black, dark red-brown or green and being highly affected by the presence of small particles of carbon left in the mixture. To get bio-oil free of char, it can be subjected to hot vapour filtration which gives an additional glowing red-brown look. If the mixture has N_2 in a significant amount, dark green shade is expected in the bio-oil. Bio-oil are organic material highly rich in oxygenated hydrocarbons with a substantial quantity of water from both the biomass inherent moisture and pyrolytic products (Wihersaari, 2005). Bio-oil cannot serve as a transportation fuel directly. It needs upgrading to reduce high oxygen &

water content and increase H/C ratios. Bio-oil can find application in kilns, boilers, furnaces, diesel engines and heat turbines as fuel (Gbeminiyi and Sunday, 2018). Chemicals from bio-oil could find application as food flavours, resins, pesticide, fertilisers, emissions control agents. A study obtained biochar and bio-oil from thermochemical conversion of Nigeria cashew nut shells with heating value of 16.69 MJ/kg and 13.17 MJ/kg respectively (Ogunsina et al., 2009). It showed cashew nut shells is a promising material that can be used in kiln, boilers, furnace etc. to generate heat.

1.3.2.2 Biochar

Biochar is a major product of biomass slow pyrolysis. Char is a term that could be used generally to describe the solid pyrolytic products. Biochar has application in adsorption and could be used to solve pollution problem caused by cement industry investigated in (Abdus-salam and Adeoye, 2019). Local slow pyrolysis of fell timber produces charcoal largely used in rural areas of Nigeria today for cooking but the practice could lead to deforestation in few years to come as recorded in some Northern states of Nigeria. Hence, attention need to be shifted to forest residue to produce charcoal for domestic and industrial uses.

1.3.2.3 Gases

Synthesis gases called "syngas" e.g H_2, oxides of carbon, light hydrocarbons etc. are common gases obtained during the process of pyrolysis (Jahirul and Rasul, 2012). Study in revealed that processing parameters in a pyrolyzer and type of sample used during pyrolysis determine the gases obtained which could be; hydrogen, oxides of carbon, water vapour, nitrogen, paraffin etc (Wei et al., 2006). The hydrogen gas component of syngas results from thermal cracking of compounds containing hydrogen and carbon only at elevated pyrolyzer system temperature while oxides of carbon gas fractions are biomass carbon conversion products. All biomass are organic substances with some of its compound partially oxygenated and largely rich in carbon, their thermal cracking gives oxides of carbon. Studies reported that the cellulosic percentage of a biomass significantly influence the amount of carbon oxides produced (Couher et al., 2009a; 2009b).

Common light hydrocarbons produced during pyrolysis include; methane, ethane, ethene etc. which might have resulted from reforming and cracking process experienced by hydrocarbons of higher molecular weight and tar (He et al., 2010). Gas conversion to liquid is a technological development with idea gotten from a process developed by Franz Fischer and Hans Tropsch (FT) as far back as 1925 using varying ratio of H_2 and CO to produce liquid hydrocarbons. The process is enhanced with the use of catalyst e.g. Co and optimal ratio of hydrogen to carbon monoxide. And Also, variety of synthetic gas can be used in this process. This technique has found useful application in producing product such as paraffin of large range ($\boldsymbol{C_1 - C_{50}}$), laboratory solvents, lubricants, synthetic gas (H_2) etc (Lam *et al*., 2010).

2. Promising Benefits of Biomass Waste Pyrolysis in Nigeria

There are tremendous benefits Nigeria stand to gain if biomass waste pyrolysis is properly developed. These benefits include:

(i) Reduction in product price: Large number of production companies in Nigeria relied on gas, diesel or petroleum which later amount to the final price of their produce, a drastic reduction in product price by companies using biomass waste for energy will be recorded since it is cheaper as compare to fossil fuel.

(ii) It will serve as large source of chemical additive for industrial use.

(iii) It will lead to poverty reduction amongst rural dweller in the sense that waste generated from their farm produce will become a source of income.

(iv) Reduction in transportation fares as bioenergy might become cheaper than crude oil.

(v) Bioenergy industry would bring about rapid investments and development of both rural and urban infrastructures as proceeds will create socio-economic benefits.

3. Conclusion

The study assessed the volume of available biomass wastes in Nigeria that could be tapped for energy generation to substitute the burning of fossil fuel associated with significant environmental pollution leading to health damages and other problems. The research review discussed biomass wastes as fuels and also as an important renewable source of fixed carbon which does not alter the amount gases in the atmosphere i.e. carbon (iv) oxide. A better method of biomass to energy conversion i.e. pyrolysis was discussed to replace inefficient combustion process as a means of converting Nigeria biomass wastes to wealth and a valuable source of energy generation. This study identified biomass wastes are largely generated in Nigeria but still remain underutilized with major sources from agriculture residue and forestry produce. The study recommends pyrolytic harnessing of biomass waste to create wealth, solve environmental problems and reduce energy issues which will wholly contribute to the sustainability of the environment and removal of agricultural waste that constitute nuisance to Nigeria physical environment.

References

Abdus-salam, N., Adeoye, A.O., 2019. Assessment of the Impact of Industrial Discharges on the Quality of Water Around Lafarge Cement, WAPCO, Ewekoro, Nigeria. Jewel Journal of Scientific Research, 4 (1&2), Pp. 45-44, jjsr.fukashere.edu.ng

Aguado, R., Olazar, M., Gaisan, B., Prieto, R., Bilbao, J., 2002 Kinetic study of polyolefin pyrolysis in a conical spouted bed reactor. Industrial & Engineering Chemistry Research, 41, Pp. 4559-4566.

Arimoro, F.O., Ikomi, R.B., Osalor, E.C., 2007. The impact of sawmills wood wastes on the water quality and fish communities of Benin River, Niger delta area, Nigeria. International Journal of Science and Technology, 2 (1), Pp. 1–12.

Aurela, B., 2013. Nigeria and Renewable Energy, Nigeria and Renewable Energy, Finland.

Bamgboye, A.I., Oniya, O., 2003. Pyrolytic conversion of corn cobs to medium grade fuels and chemical preservatives. Futajeet, 3 (2), Pp. 50-53.

Bridgwater, T., 2007. Pyrolysis of biomass. IEA Bioenergy: Task 34, Bioenergy Research Group, Aston University, Birmingham, UK.

Cornelissen, T., Yperman, Y., Reggers, G., Schreurs, S., Carleer, R., 2008. Flash co-pyrolysis of biomass with polylactic acid. Part 1: influence on bio-oil yield and heating value. Fuel, 87, Pp. 1031–41.

Couher, C., Commandre, J.M., Salvador, S., 2009a. Failure of the component additivity rule to predict gas yields of biomass in flash pyrolysis at 950 °C. Biomass Bioenergy, 33, Pp. 316–26.

Couher, C., Commandre, J.M., Salvador, S., 2009b. Is it possible to predict gas yields of any biomass after rapid pyrolysis at high temperature from its composition in cellulose, hemicelluloses and lignin? Fuel, 88, Pp. 408–17.

Cumo, F., Gugliermetti, F., Guidi, G., 2002. Best available techniques for oil spill containment and clean-up in the Mediterranean Sea. Water Resources Management, 103, Pp. 527-33.

Dayo, F.B., 2005. Nigeria Energy Balances: 1990-2005. Tech. Rep., Triple "E" Systems Inc.

de Jongh, W.A., 2001. Possible applications for vacuum pyrolysis in the processing of waste materials. Stellenbosch; SU. (Thesis-M.Sc.).

Debay, T., 2010. The impact of climate change in Africa. Institute for Security Studies. Paper 220.

Demibas, A., Arin, G., 2002. An overview of biomass pyrolysis. Energy Source Part A., 24, Pp. 471-82.

Demirbas, A., 2000. Recent advances in biomass conversion technologies. Energy Education Science and Technology, 26, Pp. 77–83.

FAOSTAT. 2012. FAO statistics division. http://www. faostats.fao.org. Accessed 31/08/2020

Francescato, V., Antonini, E., Bergomi, L.Z., Metschina, C., Schnedl, C., 2008. Wood Fuels Handbook. AIEL: Italian Agriforestry Energy Association, Legnaro.

Frederik, R., Sven van, H., Dane, D., Wolter, P., 2013. Production and characterization of slow pyroylysis biochar: influence of feedstock type and pyrolysis conditions. Global Change Biology Bioenergy, 4, Pp. 104-115, doi: 10.1111/gcbb.12018

Gbeminiyi, M.S., Sunday, J.O., 2018. Techno-Economic Analysis of Biomass Energy Utilization through Gasification Technology for Sustainable Energy Production and Economic Development in Nigeria. Hindawi Journal of Energy Volume 2018, Article ID 4860252, 16 pages https://doi.org/10.1155/2018/4860252

He, M., Xiao, B., Liu, S., Hu, Z., Guo, X., Luo, S., 2010. Syngas production from pyrolysis of municipal solid waste (MSW) with dolomite as downstream catalysts. Journal of Analytical and Applied Pyrolysis, 87 (2), Pp. 181-87.

Jahirul, M.I., Rasul, M., 2012. Recent Developments in Biomass Pyrolysis for Bio-Fuel Production, Its Potential for Commercial Applications. Recent Researches in Environmental and Geological Sciences, Pp. 256-65.

Kankara, A.I. 2013. Energy-Environment Interactions: Potentials and Problems of Renewable Energy in Nigeria," Advances in Electronic and Electrical Engineering, 3, Pp. 25–30.

Lam, S.S., Russell, A.D., Chase, H.A., 2010. Microwave pyrolysis, a novel process for recycling waste automotive engine oil. Energy, 35, Pp. 2985-91.

López-Grimau, V., Guadayol, J.M., Griera, J.A., Gutiérrez, M.C., 2006. Determination of nonhalogenated solvents in industrial wastewater using solid phase microextraction (SPME) and GC-MS. Latin American Applied Research, 36 (1), Pp. 49-55.

Mcguigan, C., Reynolds, R., Wiedmer, D., 2002. Poverty and Climate Change: Assessing Impacts in Developing Countries and the Initiatives of the International Community. London: School of Economics Consultancy Project for the Overseas Development Institute.

Nachenius R.W., Prins, W., 2013. Advances in Chemical Engineering 2013.

Ogunsina, B.S., Ojolo, S.J., Bamgboye, A.I., Muritala, A.O., Femi- Falade, O., Imoudu, D.E., Fashogbon, S.K., 2009. Thermochemical conversion of cashew nut shells into alternative energy sources. Proceedings of 3rd International Conference of WASAE and 9th International Conference of Nigerian Institution of Agricultural Engineers. OAU Ile Ife. Nigeria.

Ojolo, S.J., Orisaleye, J.I., Ismail, S.O., Abolarin, S.M., 2012. Technical Potential of Biomass Energy in Nigeria. Department of Mechanical Engineering, University of Lagos, Akoka, Lagos, Nigeria.

Rolando, Z., Krister, S., Emilia, B., 2002. Rapid pyrolysis of agricultural residues at high temperature. Biomass and Bioenergy, Pp. 357 – 66. http://dx.doi.org/10.1016/S0961-9534(02)00061-2

Sambo, A.S., 2009. The Place of Renewable Energy in the Nigerian Energy Sector. World Future Council.

Wei, L., Thomasson, J.A., Bricka, R.M., Batchelor, W.D., Columbus, E.P., 2006. Experimental study of a Downdraft Gratifier. ASABE Meeting, Paper No. 066029.

Wihersaari, M., 2005. Evaluation of Greenhouse Gas Emissions Risk from Storage of Wood Residues. Biomass and Energy, 28, Pp. 444-453.

Yobe State Ministry of Environment as quoted in Niasse A, Afouda A, Amani A, Reducing West Africa's vulnerability to climate change impacts on water resources, wetlands and desertification. IUCN Regional office for West Africa; 2004.