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Production of Bio-Char by Pyrolysis of Palm Kernel Shell

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Abstract—*The need to search for a more environmentally friendly, available and affordable alternative energy source to the conventional fossil energy has been the major heartbeat of a greater global community. Biomass conversion to energy has shown a potential to provide bio-energy for numerous applications where fossil fuel has dominated over the year. This work is an effort to buttress some techniques that have been adopted in this conversion process. There is no existing commercial biochar production facility in Nigeria. The biomass potential of Nigeria is a promising prospect for pilot and commercial biochar production plant. A Pyrotechnic/Distillation Equipment was developed in Delta State Polytechnic, Ozoro. The "Two-Chambered-Furnace" Pyrotechnic/Distillation Equipment, used cracked shells from palm fruits to produce; 56.6% bio-char, 16.67% Pyrolysate (distillate) and 26.16% gas.*

Keywords — *Palm Kernel Shell, Pyrolysis, Biomass, Bio-char, Energy.*

I. INTRODUCTION

The nativity of Oil palm had been associated with the tropical rainforest of West Africa but has spread to most of the equatorial tropics of South East Asia and America [1,2]. It forms part of foreign income earner for most Asian countries such as Malaysia, Indonesia and Thailand. Oil palm is chiefly cultivated for palm oil (P.O.) and palm kernel oil (PKO) [3,4].

A typical fresh palm fruit bunch can produce about 5-7 PKS per bunch [5]. This invariably suggests the relative abundance of PKS per oil palm harvest. Palm kernel shell (PKS) is the fractions that are left in the oil palm mills after extraction of the oil palm from the Mesocarp. The nuts are broken, and the kernel is removed. The hard stony endocarp covering is the PKS which are left as the fibrous shell waste materials [6]. In the developing world, waste PKS is either burned to supply energy at palm oil mill or left in piles to compost.

The major consideration and utilisation of PKS have been energy production through direct combustion processes. However, it has been proposed for use as concrete reinforcement in the construction industry [7-9], production of palm kernel shell concrete [10-11] production of admixture with Portland cement to form concrete [25] production of activated carbon for industrial use [13] while, for minor considerations, [13] considered it as a substitute in the manufacture of auto Lining.

There are many conversion techniques employed in the exploitation of energy potentials in biomass, as shown in figure 1. The traditional combustion is well known and understood while the rest appear to be partially understood.

II. BIOMASS CONVERSION TECHNIQUES

Pyrolysis, gasification and torrefaction are the three common thermochemical processes recently applied to biomass conversion to obtain higher energy density fuels. Pyrolysis is the thermal decomposition in the absence of oxygen, while gasification is the thermal decomposition of biomass in the presence of oxidative substance usually controlled air. Torrefaction is achieved by heating the waste under pressure in the presence of a reactive gas such as hydrogen or carbon monoxide. The current thermochemical processes are preferred to the traditional combustion of PKS because of their environmental-friendly output. Of the above three thermochemical processes, Pyrolysis seems more practicable due to the simplicity of the process and the equipment. Pyrolysis produces a mixture of solid-liquid and gaseous fuels.

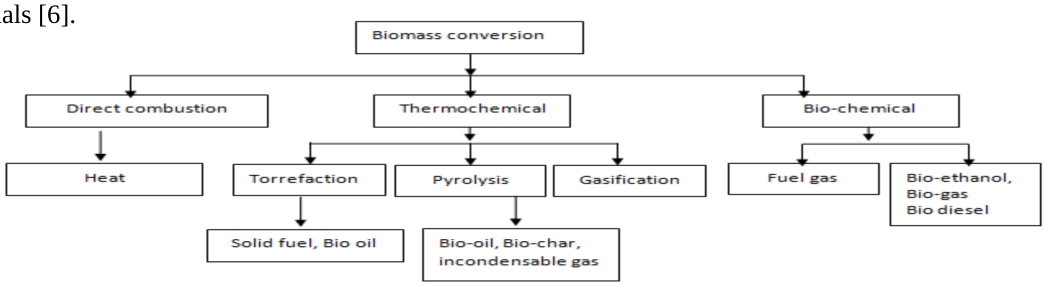

Figure 1: Biomass Conversion Pathways to Energy

There are two main pyrolytic processes viz slow Pyrolysis and fast Pyrolysis. Slow Pyrolysis is characterised with slow biomass heating rates, low temperature and long duration for producing gases and solids. In contrast, fast Pyrolysis takes place within five seconds at temperatures between 300-500^{o} c [15]. In slow Pyrolysis, the temperature increases gradually from room temperature to 300^{o}c.The main product of slow Pyrolysis is charcoal. Fast pyrolysis yields are mainly liquid bio-oil, non-condensable gas (NCG) and bio-char.

Many biomass materials have been pyrolysed with appreciable results. Rice, Straw, Sugar cane bagasse and coconuts shell were pyrolysed at different temperature in an induction – heating reaction [16]. The results show that the liquid product decreased as temperature increased from 400 to 800^{o}c for the three samples. The increase in temperature in this work also resulted in a decrease of char and an increase in the water content of the bio-oil for the biomass materials. The effect of reaction temperature on the Pyrolysis of tea waste [24] was successively carried out using a fixed bed tubular reaction at 273-973k (400-700^{o}c). The result showed that char yield decreased from 43.37% - 38.26% while gas yield increased from 19.99% -38.26%, over that temperature range. The maximum bio-oil yield was at 773k (500^{o}c) and decreased at a temperature above this. Reference [18] produce bio-char from cocoa pod waste using improvised reaction, Reference [19] pyrolysed corncob rice husk and sawdust using a local brick furnace in a slow pyrolysis process. In this work, he obtained a high percentage of char compared to bio-oil yield concerning input quantities of feedstock. Reference [20] produce charcoal from wood residues. Reference [21] worked on the conversion of corncob to bio-oil and chemical preservative.

Nigeria needs well-developed technology for biochar production to be able to compete with the outside world. This can be geared towards equipment development, biomass screening to identify high yielding species, biomass cultivation research and production, analytical and pilot plant development. Nigeria's biomass potential is capable of supporting the thermochemical biomass conversion to energy [22]. Even though Nigeria is a crude oil-producing Nation there is a need for R&D to be encouraged in this technology which will not only assist in energy production but better waste management. This work is geared towards contributing to efficient biomass waste management (oil palm shells in focus).

III. MATERIALS AND METHODS

A. *Description of the Pyrotechnic / Distillation Equipment*

This design, as depicted in figure 2, has two cylindrically-shaped chamber furnace. The upper chamber accommodates the raw materials to be pyrolysed, and the lower chamber is fed with fuel materials through a rectangular slot (furnace door). The sides and base of the lower chamber have perforations for ventilation. The top of the upper chamber is covered with a detachable circular metal plate. Extending vertically from the centre of this plate is a delivering pipe which then travels horizontally through the condenser. The furnace is raised on a rigid tripod stand. The condenser (heat exchanger) is raised on a square stand. The condenser is an "opened-top" rectangular tank through which the delivery pipe passes to terminate in a "T-Junction" with openings at both ends of the "T".

B. *Principle of Operation of the Equipment*

The upper chamber of the furnace which contains the shells, is fired from the lower chamber. The shells are heated up with the fire. At about a temperature of 29^{0}c to 300^{o}C, the reaction becomes exothermic, and the shells are as red-hot coals in appearance. At this stage,pyrolytic processes are favoured, and the various components latent in the shell are liberated in a gaseous form partly condensable and partly incondensable.

Both the condensable and incondensable gases are conducted through the delivery pipe, which passes through the condenser (tank). In the condenser, heat exchange takes place between the gas, delivery pipe and cooling medium by process of conduction and conversion. As the heat is removed, the temperature of the condensable gas drops below the

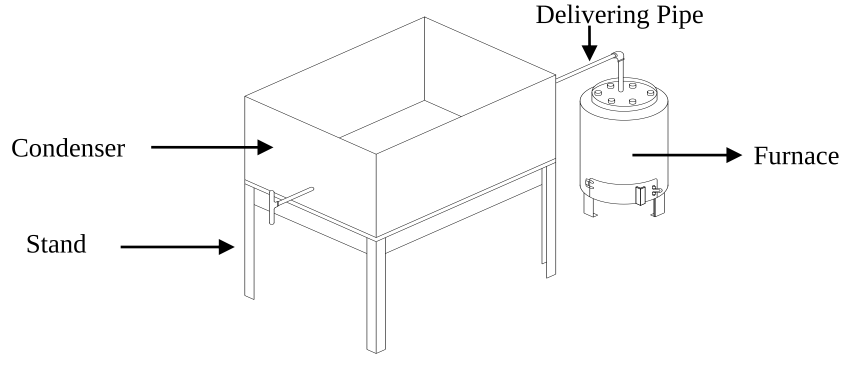

Figure 2: Pictorial View of the Shell Pyrotechnic/Distillation Equipment

Condensing temperature and, thus condensed. In this way, the condensate gas is separated from the non-condensate.

C. Design Considerations

Equipment configuration and heat transfer mode are put off the major parameters considered in designing pyrolysis systems. A clear understanding of the processes involved in Pyrolysis will aid in the design of a suitable system that maximises the products and minimises its cost and environment impacts.

D. Material Selection

The materials of construction of part of the equipment were locally source and selected based on material suitability, cost and availability.

The Delivery pipe is made of a non-corrosive metal of relatively high thermal conductivity with a suitable diameter. Hence, galvanised metal was used.

The furnace is made of a thick metal pipe with a high melting point and low thermal expansivity. Hence, a mild steel pipe was used due to its relative cheapness.

The material for the tank (condenser) is thermally conductive and resistant to corrosion. Thus, a galvanised sheet is used for this purpose.

A 2-by-2 mild steel angle bar is used for the stand due to its toughness, rigidity and ability to resist or withstand Loading stress.

E. Design Specifications

Specification l: condenser

Height -	-	450mm
Length -	-	750mm
Width -	-	550mm
Cooling fluid	-	water

Specification 2: Furnace

Height (upper chamber)	-	270mm
Height (lower chamber)	-	150mm
Diameter	-	260mm
Heat source	--	wood fuel

Specification 3: condenser stand

Height -	-	550mm
Length -	-	760mm
Width -	-	560mm

Specification 4: Furnace stand

Height -	-	100mm

Specification 5: Delivering pipe

Diameter	-	20mm
Length -	-	1450mm

F. Fabrication Procedures

Each part was marked to the required specified sizes and shape using scriber. Marked out sections of parts were cut out using hacksaw and shear cutter various components were welded with gauge 12 electrodes.

Assemble of parts was done with fasteners (bolt and nuts)

G. Testing Procedures

For the testing process, the condenser was filled with water. 7.13kg of palm kernel shells was fed into the upper chamber (full Loading). Wood fuel was loaded into the lower chamber and ignited. The shell was subjected to Pyrolysis by the firing process, which was by continuous feeding of wood fuel into the lower chamber. Firing continued to a temperature of about 310^{o}c when the distillation products were completely recovered. The equipment was tested at the polytechnic mechanical workshop, and the process lasted for about 3 hours. The palm kernel shells and used have abstained from local palm oil processors in Isoko North Local council of Delta State Nigeria.

IV. RESULTS AND DISCUSSION

A. Results From Test

The table below shows the percentage by Mass of products obtained from the test.

I. TABLE I
MASS PERCENTAGE OF PRODUCTS FROM TEST

	Products	Quantity	% Mass
a	Bio-char	4.08	56.67
b	Distillate (Pyroligeneous acid + Settled tar)	1.2	16.67
c	Uncondensed gas	1.92	26.67

B. Observations

During the test and after the test, the following was observed.

i. The first drop of the distillate emerged eighty-four (84) minutes after firing begun.
ii. The incondensable gas (seen as white fumes) began spouting at about 125mins after firing begun.
iii. The gas, when ignited born freely with non-sooty flames.
iv. The Pyrolysate (distillate) separated into a light-clear fraction and a thick dark fraction when left to stand.

C. Discussion

The palm kernel shell is seen to compare very favourably with other biomass, as raw materials for distillation. The Pyrolysate (distillate) comprises of pyroligeneous acid and settled tar, constitutes about 16.67% of the kernel shell. Pyroligeneous acid is the top layer of the distillate and has a brown colour. Palm kernel shell tar is the fraction of the distillate, which settles at the bottom of the container.

The gas evolved during the Pyrolysis of kernel shell constituted 26.67% of the shell. The gas was noted to burn freely. The gas could be channelled for heating purpose in the premises where the kernel shell is being Pyrolysis. However, as an alternative, it could be cleaned, purified, bottled and sold as domestic gas.

The bio-char which results from the destructive distillation of palm kernel shell constitutes about 56.67% of the kernel shell. This kernel shell bio-char gives neat, the smokeless fire which does not pollute the environment. It finds a use for domestic heating.

V. CONCLUSION

The kernel shell bio-char is useful for domestic and industrial heating. It is thus the renewable source of energy, unlike petroleum and coal, which are huge wasting energy of sources. The fact that Nigeria has a potential kernel shell bio-char is a great asset. This would when applied for domestic heating purposes largely replace the use of firewood as a heating medium in both rural and urban communities. In this way, the pressure on wood for domestic heating which is largely responsible for current large-scale deforestation of Nigeria forests might be checked. Nigeria still depends largely on imported agents (activated carbon and bleaching earth) for its vegetable oil industries. The production of activated carbon from palm kernel shell bio-char on an industrial scale will stem this tide and help in preserving our foreign exchange which is used for funding these imports. Energy production through the thermochemical conversion of palm kernel shell biomass is a venture that needs encouragement as the world is going green energy production.

REFERENCES

[1] Hartay, CWS. *"The oil palm 3rd Ed. Longman, Scientific & Technical New York"*,1988.

[2] Lavagekiattikhun P, Tangsathitkulchai C. Tangsathitkulchai M. "*Nun-Isothermal Thermogravimetic Analysis of Oil-Palm Solid Wastes*", Bioresource Technology, vol. 99, 2008, pp. 986-997.

[3] Obeng K, Ocran KAG, Anaba D (1997). "*Palm Kernel as Fuel for Burning Bricks*". Build Res. Info 25: 131-136.

[4] Lartey R.B, Acquah F, Nketia KS (1997). "*Developing National Capability for Manufacture of Activated Carbon from Agricultural Wastes*". The Ghana Engineer.

[5] FAO. *"Small Scale Palm Oil Processing in Africa"*. FAO Agriculture Services Bulletin, Vol 148, pp 1-56.

[6] Zafar S. (2015). Biomass Pyrolysis Process. *"Retrieved from http: //www.bioenergyconsult.com /biomass pyrolysis process"*.

[7] Okafor F.O. (1988). "*Palm Kernel Shell as a Lightweight Aggregate for Concrete*". Cement and Conc. Research, vol. 18, number 6, pp. 901-910.

[8] Okpala D.C. (1990). "*Palm Kernel Shell as a Lightweight Aggregate in Concrete*". Building and Environment, vol. 25, number 4, pp 291-296.

[9] Alangaram U.J. M.Z. Jumaat and H. Mahmud (2008). *"Ductility Behavior of reinforced palm kernel shell concrete Beams"*. European Journal of Scientific Research, Vol 23, number 3, pp 406-420.

[10] Alengaram, U.J., M.Z. Jumaat and H. Mahmud (2008). *"Influence of Cementitious Materials and Aggregates Content on Compressive Strength of Palm Kernel Shell Concrete"*, Journal of Applied Sciences, Vol. 8, pp 3207 – 3213.

[11] Mahmud H, M.Z. Jumaat and U.J Alangaram (2009). "*Influence of Sand/Cement Ratio on Mechanical Properties of Palm Kernel Shell Concrete*". Journal of Applied Science Vol. 9, pp 1764 -1769.

[12] I.B. Ologunagba, A.S. Daramola, A.O. Aliu*"Feasibility of using Rice Husk Ash as Partial Replacement for Concrete"*, International Journal of Engineering Trends and Technology (IJETT), V30(5),267-269 December 2015.

[13] Adewumi, I.K and M.O. Ogedengbe (2005). *"Optimising Conditions for Activated Charcoal Production from Palm Kernel Shells"*, Journal of Applied Sciences, vol. 5, pp 1082-1087.

[14] Ibhadode AOA, DagwaIm (2008). "*Development of Asbestos Free Friction Lining Material from Palm Kernel Shell"*. J. Braz. Soc. Mech. Sci. Eng. 30:166-173.

[15] Bridgewater A.V. and G.R. Peacocke (2000). *"Fast Pyrolysis Processes for Biomass"*, Renewable and Sustainable Energy Review, 4 (1); 1-73

[16] Tsai W.T, M. K Lee and Y.M. change (2006): "*Fast Pyrolysis of Price Straw, Sugarcane Bagasse and Coconut Shell in an Induction-Heating Reactor*". Journal of Analytical and Applied Pyrolysis, vol 76: pp. 230-237.

[17] SaiyedFarhana,ParmarBhumika, PrajapatiJayesh, Prof. JayeshkumarPitroda. *"A Study on Utilization Aspects of Stone Chips as an Aggregate Replacement in Concrete in Indian Context"*. International Journal of Engineering Trends and Technology (IJETT).

[18] Odesola I.F and Owoseni T.A (2010). "*Development of Local Technology for a Small-scale Bio-char Production Processes from Agricultural Wastes*". Journal of Emerging Trends in Engineering and Applied Sciences (JETEAS) l (2): 205-208.

[19] Oladeji J.T. (2010): *"Investigation into Pyrolysis of few selected Agro-Residues Commonly Found in Nigeria"*. The Pacific Journal of Science and Technology, Vol. 11 Number 2, pp. 450-452. http://www.akamaiuniversity.us/PJST.htm

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

[21] Bamigboye A.I. and Oniya 0. (2003). *"Pyrolytic Conversion of Corncobs to Medium Grade Fuels and Chemical Preservatives."* FUTAJEET. 3(2): 50-53.

[22] Okoroigwe E.C., Anyanwu C.N. and Oparaku O.U. (2007). *"Status of Biomass Gasification in Nigeria. Proceedings of International Workshop on Renewable Energy for Sustainable Development of Africa"* (IWRESDA, 2007). July 30 – August 1, pp. 132-136.

[23] SaiyedFarhana,ParmarBhumika, PrajapatiJayesh, Prof. JayeshkumarPitroda. *"A Study on Utilization Aspects of Stone Chips as an Aggregate Replacement in Concrete in Indian Context"*. International Journal of Engineering Trends and Technology (IJETT).

[24] Uzun B. B., Esin A., Funda A., Nurgul O. and Ayse P. (2010). "*Synthetic Fuel Production from Tea Waste, Xtisatum of Bio-oil and Bio-char Fuel"*, vol. 89: pp. 176-184.

[25] A.W Otunyo (2011). *"Palm kernel Husk Ash (PKHA) as an Admixture (Accelerator) in Concrete"*. Nigerian Journal of Technology, vol. 30, pp 60-66.