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 greater global community. Biomass conversion to energy has shown 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 bio-char production facility in Nigeria. The biomass potential of Nigeria is a promising prospect for pilot and commercial bio-char 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 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 (PO) 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 utilization of PKS has been energy production through direct combustion processes. However, it has been proposed for use as concrete reinforcement in construction industry [7-9], production of palm kernel shell concrete [10-11] production of admixture with Portland cement to form concrete [12] production of activated carbon for industrial use [13] while, for minor considerations, [13] considered it as substitute in 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 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 present 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 characterized with slow biomass heating rates, low temperature and long duration for producing gases and solids, while fast pyrolysis takes place within five seconds at temperatures between 300-500°C [15]. In slow pyrolysis, the temperature increases gradually from room temperature to 300°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 pyrolyzed with appreciable results. Rice, Straw, Sugar cane bagasse and coconuts shell were pyrolyzed at different temperature in an induction – heating reaction [16]. The results show that the liquid product decreased as temperature increased from 400 to 800°C for the three samples. The increase in temperature in this work also resulted in the decrease of char and increase in the water content of the bio-oil for the biomass materials. The effect of reaction temperature on pyrolysis of tea waste [17] was successively carried out using fixed bed tubular reaction at 273-973K (400-700°C). The result shown that char yield decreased from 43.37% to 38.26% while gas yield increased from 19.99% to 38.26%, over that temperature range. The maximum bio-oil yield was at 773K (500°C) and decreased at temperature above this. Reference [18] produce bio-char from cocoa pod waste using improvised reaction, Reference [19] pyrolyzed corn cob rice husk and saw dust using local brick furnace in a slow pyrolysis process. In this work he obtained high percentage of char compared to bio-oil yield with respect to input quantities of feedstock. Reference [20] produce charcoal from wood residues. Reference [21] worked on conversion of corncob to bio-oil and chemical preservative.

Nigeria needs well developed technology for bio-char 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 conversion to energy [22]. Even though Nigeria is a crude oil producing nation there is 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 center 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°C to 300°C, the reaction becomes exothermic and the shells are as red-hot coals in appearance. At this stage pyrolytic processes are favored 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](image-url)
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 of 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 maximizes the products and minimizes its cost and environment impacts.

D. Material Selection

The materials of construction of component 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, a galvanized metal was used.

The furnace is made of a thick metal pipe with 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 galvanized 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

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<tr>
<th>Specification 1: condenser</th>
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<tbody>
<tr>
<td>Height</td>
<td>450mm</td>
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<tr>
<td>Length</td>
<td>750mm</td>
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<tr>
<td>Width</td>
<td>550mm</td>
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<td>Cooling fluid</td>
<td>water</td>
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<th>Specification 2: Furnace</th>
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<td>Height (upper chamber)</td>
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<td>Height (lower chamber)</td>
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<tr>
<td>Diameter</td>
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<td>Heat source</td>
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<th>Specification 3: condenser stand</th>
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<th>Specification 4: Furnace stand</th>
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<td>Height</td>
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<th>Specification 5: Delivering pipe</th>
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<tr>
<td>Diameter</td>
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F. Fabrication Procedures

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

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°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 were 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.

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<th>TABLE I</th>
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<td>Products</td>
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<tr>
<td>a Bio-char</td>
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<tr>
<td>b Distillate (Pyroligeneous acid + Settled tar)</td>
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<tr>
<td>c Uncondensed gas</td>
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B. Observations

During the test and after the test, the following were 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 a 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 favorably with other biomasses as raw materials for distillation. The pyrolysate (distillate) comprises of pyroligeneous acid and settled tar, constitutes about
16.67% of the kernel shell. The pyrolygenic 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, smokeless fire which does not pollute the environment. It finds use for domestic heating.

VI. CONCLUSION

The kernel shell bio-char is useful for domestic and industrial heating. It is thus 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 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 depend largely on imported agents (activated carbon and bleaching earth) for their vegetable oil industries. The production of activated carbon from palm kernel shell bio-char on industrial scale will stem this tide and help in preserving our foreign exchange which is used for funding these imports. Energy production through thermochemical conversion of palm kernel shell biomass is a venture that needs encouragement as the world is going green energy production.

REFERENCES