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Low Emission, Smoke Free Charcoal from Oil Palm (Elaeis Guineensis) Waste- A Cheap Energy Source for Rural Communities in Nigeria

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Abstract
The use of oil palm (*Elaeis guineensis*) waste as a potential source of soil conditioner in agriculture has long been identified. Its conversion into smokeless and low emission charcoal which is more environmental friendly has not been well investigated. The present study explored conversion of oil palm waste into low emission charcoal. Palm Kernel Fibre (PKF) and Palm Kernel Shell (PKS) were subjected to a pyrolytic process in a Closed Drum Carboniser (CDC). The raw waste and the gaseous emissions that emanated during processing of wastes and during use for cooking were analysed for its mineral composition and emissions of CO, CO_2, SO_2, NO_2 and $PM_{2.5}$ contents respectively using potable digital gas monitoring equipment and gravimetric PM sampler. The PKS had low nitrogen: (0.02 ± 0.03) Ma.-% and phosphorus: (0.18 ± 0.10) Ma.-% required for plant growth but high in potassium: (3.24 ± 2.49) Ma.-% which can be recovered from charcoal ash. The time taken to convert 25 kg of PKF and PKS into charcoal and their percentage volume reduction were: 1h: 13 min (90.00 Ma.-%) and 1h: 19 min (70 .00 Ma.-%) respectively. The charcoal produced from PKS exhibited higher stove value for cooking 200 g of rice within 25 min using 0.35 kg of the charcoal as against 28 min and 0.40 kg observed for conventional wood charcoal. The study showed that PKF and PKS form viable feed-stock to produce charcoal which emits less smoke and reduce greenhouse gas emissions when used as cooking fuels in households.
Keywords: Closed drum carboniser, Low emission charcoal, *Elaeis guineensis*, Oil palm waste, Pyrolytic process, Stove energy value

1. Introduction

In Nigeria, oil palm (*Elaeis guineensis*) is indigenous to the coastal plain, having migrated inland as a staple crop. About 80 % of production comes from dispersed small holders who harvest semi-wild plants and use manual processing techniques. Several million small holders are spread over an estimated area ranging from 1.65 million hectares to 2.4 million hectares and to a maximum of 3 million hectares (Sridhar et al., 2015). The major biomass in oil palm are: Fresh Fruit Bunch (FFB), Empty Fruit Bunch (EFB), Palm Kernel Cake (PKC), Palm Kernel Shell (PKS) and Palm Kernel Fibre (PKF). The biomass are managed in many places through direct combustion that usually result in air pollution. However, biomass has great potential for recycling and many products can be obtained through value chain.

To avert problems of deforestation in the country, alternative sources of energy need to be sought. Wondwossen (2009) converted agricultural wastes (dry leaves, coffee husk, sugarcane trash, grass, etc.) into charcoal briquettes to provide much needed source of cheap fuel that is cleaner in burning as an alternative to wood charcoal. According to Kolade et al. (2005), palm kernel wastes produced from small and medium scale industries pose a serious environmental problem in Nigeria. A portion of these wastes is used as feed supplements for livestock but most are disposed of by burning. Alternative economic disposal methods of palm waste management are therefore necessary and one potential method is to convert the wastes into smoke free charcoal. Smoke free charcoal offers dual advantages: as a source of cheap energy as well as organic fertilizer (as mineral supplement) especially after it is burnt into ash. In Oyo State alone, it is estimated that the following biomass is available from oil palm (per annum): 3,500,000 kg of empty fruit bunches, 2,250,000 kg of oil-pressed fibre, and 1,750,000 kg of palm kernel nuts (Vogel, 2002).

An Ibadan study by AdeOluwa et al. (2007) on EFB and cow dung in varying combinations showed that a mixture of EFB and cow dung (40 per cent) yielded acceptable compost after 8 to 9 weeks. Studies from other researchers have also shown that the production of edible mushrooms is financially viable with EFB based fertilizers. Apart from the EFB, palm kernel also has great potential for organic fertilizer production. The EFB is now used mainly as mulch (Hamdan et al., 1998). Placed around young palms, EFB helps to control weeds, prevent erosion and maintain soil moisture. Kolade et al. (2005) developed a process of converting Palm Kernel Cake (PKC) into compost using poultry manure, and goat manure as supplements. An account of the palm wastes and their potentials for recycling have been given by Sridhar and AdeOluwa (2009).

Energy can be obtained from palm wastes through diverse ways. In the small scale industries PKS, EFB and other wastes are directly used as fuel for boilers and other process stages. A variety of fuels can be produced

from palm biomass resources including liquid fuels such as: ethanol, methanol, biodiesel, Fischer-Tropsch diesel, and gaseous fuels such as: hydrogen and methane. Bio-diesel, Bio-oil, Bio-ethanol and biogas (or methane) are common energy sources derived from palm wastes. Following the determination of optimum operating conditions by two-level fractional factorial design in stirred-tank bioreactor, the highest bioethanol production was found to be 4.6 Vol.-% or 36.3 $g \cdot L^{-1}$ at a temperature of 32 ^{0}C, pH of 6.0, and O_2 of 30 Vol.-% (Alam et al., 2009). In recent years, a novel closed tank methane recovery system and conversion to electricity generation was being planned for Lepar Hilier Palm Oil mill. Kouichi Miura (Kouichi, 2003) reported severally the utilistion of oil palm wastes in which a variety of chemicals were derived.

Smoke free charcoal production and utilisation systems differ from most biomass energy systems because the technology is carbon-negative: it removes net carbon dioxide from the atmosphere and stores it, as stable soil carbon "sinks" (Lehmann et al., 2006). Also, because smoke free charcoal retains nitrogen, emissions of nitrous oxide (a potent greenhouse gas) may be reduced. Turning waste biomass into biochar reduces methane (another potent greenhouse gas) generated by the natural decomposition of the waste. This paper describes our studies on the conversion of PKS and PKF into smoke-free charcoal using an indigenous technology developed locally.

2. Materials and Methods

2.1 Feed-Stock

Oil palm wastes used, including Palm Kernel Fibre (PKF) and Palm Kernel Shell (PKS) were sourced from the palm oil processing unit of the agricultural farm, University of Ibadan, Ibadan, Nigeria. The farm is located approximately at the intersection of longitude 30 55'' East of the Greenwich meridian and latitude 70 23''North of the equator. The temperature range is between 19 °C - 30 °C depending on the season. In the farm, *Elaeis guineensis* is one of the major plants grown on large scale for purpose of palm oil production. The processing plant is located very close to the farm and oil production takes place immediately after harvesting, resulting into accumulation of PKF and PKS regarded as waste.

2.2 Laboratory Procedure

From heaps of PKF and PKS each, samples were taken at various depths and sides and pooled together to form a representative sample. Each sample was then sun-dried to reduce moisture content, milled and analysed for total organic-carbon (C), total Kjeldahl nitrogen (N), C: N ratio, total phosphorus (P), magnesium (Mg), sodium (Na), potassium (K), according to the American Public Health Association [12]. Also measured were iron (Fe), lead (Pb), chromium (Cr), nickel (Ni), copper (Cu), manganese (Mn), zinc (Zn), and cadmium (Cd) using Atomic Absorption Spectrophotometer. For phosphorus determination, 0.2 g of the powdered organic material of each sample was digested with nitric, and perchloric: sulphuric acid mixture in the ratio of 5:1:1 in a 100 ml conical flask (APHA, 2005). The mixture was heated on a hot plate for about one hour until 1ml of clear solution was left in the flask. Large quantity of brownish fume with choking smell was given off. It was allowed to cool and distilled water was added to the clear solution to make it up to 100 ml. The solution was filtered through an ash less filter paper (Whatman No.3) into a volumetric flask. The quantity of phosphorus in each sample was determined spectrophotometrically, using the Mo (molybdo-vanadate) blue colour method of Murphy and Riley (1962). Total carbon content of the samples was determined according to Walkey Black wet oxidation method (Walkley and Black, 1934); total Nitrogen was determined, using regular Macro- Kjeldahl method (Kjeldahl, 1883) while potassium was determined according to Mehlich 3 procedure (Mehlich 1984).

The heavy metals: Fe, Pb, Cr, Ni, Cu, Mn, Zn and Cd were determined by placing 1g of each sample in a 250 ml digestion tube to which 10 ml of concentrated HNO_3 was added. The sample was heated for 45 min at 90 ^{o}C, and then the temperature was increased to 150 ^{o}C at which the sample was boiled for at least 8 h until a clear solution was obtained. Concentrated HNO_3 was added to the sample (5 ml was added at least three times) and digestion occurred until the volume reduced to about 1 ml. The interior wall of the tube was washed down with a little distilled water and the tube was swirled throughout the digestion to keep the wall clean and prevent the loss of the sample. After cooling, 5 ml of 1% HNO_3 was added to the sample. The solution was filtered with Whatman No. 42 filter paper and < 0.45 µ millipore filter paper. It was then transferred to a 25 ml volumetric flask by adding distilled water. Various metals were read, using Atomic Absorption Spectrophotometer (AAS, Buck 200 model).

2.3 Carbonisation and Pelletising of Feed-Stock into Smoke Free Charcoal

A Carboniser which was designed and fabricated by the authors (Figure 1c) was used for carbonisation of the dry PKF and PKS into biochar. The carboniser is comprised of waste holder with a chimney and a container for burning the waste. The waste was ignited inside the container without additional fuel as remnant palm oil in the waste served the purpose. The burning waste was covered with the chimney immediately after ignition and left for some time. The chimney was open intermittently to monitor the burning. The fire was quenched with water at the point that all the waste inside the container turned black. The resulting biochar was allowed to cool and

pelletised manually with the aid of binder produced from spoilt cassava flour (Figure 1). The pellets, after air drying, were used to cook rice that was sourced from a local market and compared with conventional wood charcoal for their energy values, as reflected in cooking time.

2.4 Assessment of gaseous emission

During the production of smoke free charcoal in the carboniser and testing of the charcoal pellets for cooking time, potable digital air monitoring equipment were used to determine the level of gaseous emissions. Carbon monoxide was measured by CO10HANDHELD (Extech Instruments Corporation, USA); Carbon dioxide by CO_2 Gas Detector (TELAIRE Product, USA); Nitrogen dioxide by Z-1400 (Environmental Sensors Co. product, USA) and Sulfur dioxide by Z-1300 (Environmental Sensors Co. product, USA). In addition, $PM_{2.5}$ level of substance emission was determined by gravimetric PM sampler during the carbonisation. The air samplers were positioned within a 1 meter radius to the carboniser to determine the levels of the key air pollutants released. The measurements were carried out throughout the period of carbonisation at 15 min interval. The same procedure for gas measurement was repeated for gaseous emissions that emanated during processing and used for cooking. Cooking was done using a charcoal stove in an in-door environment. The weight of wood charcoal and smokeless charcoal used was 0.35 - 0.5 kg to cook 200 g of Rice.

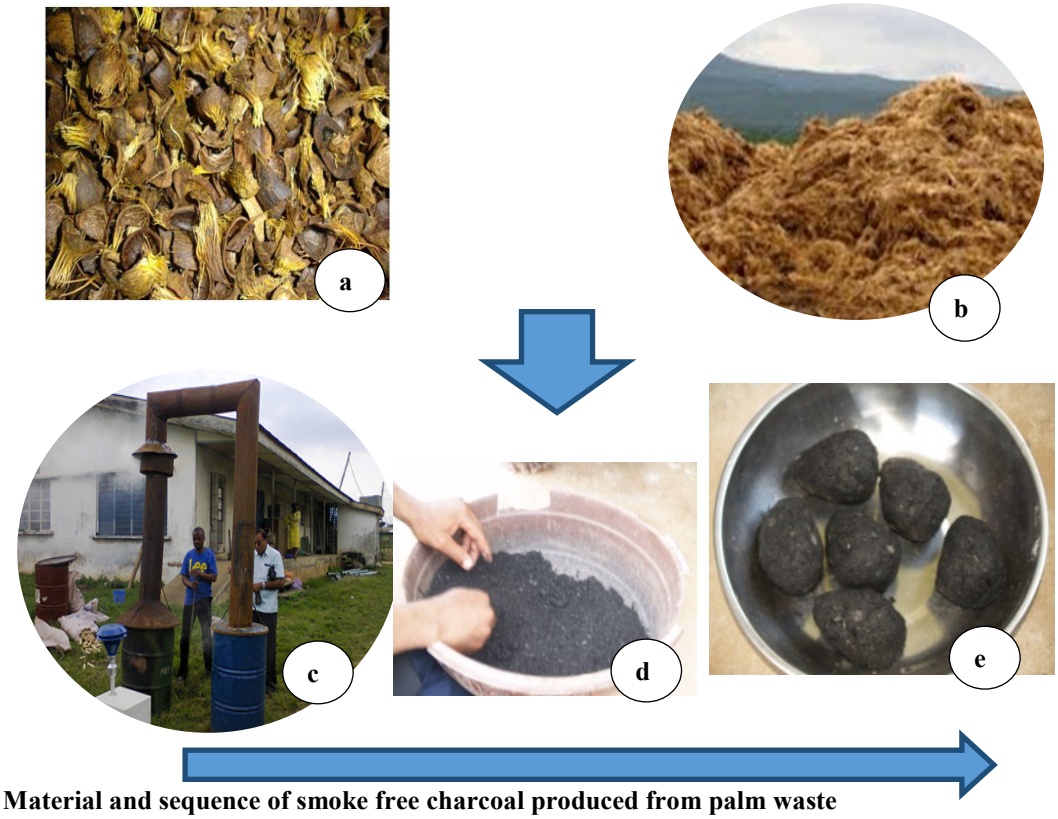

Figure 1. Material and sequence of smoke free charcoal produced from palm waste
(a – palm kernel shell; b- palm kernel fibre; c- carboniser; d- biochar; e- hand crafted charcoal pellets)

3. Results and Discussion

Tables 1 and 2 show the chemical composition and heavy metal contents of the PKS prior to carbonisation. It is very rich in carbon (75.68 ± 0.01) Ma.-% which imparts high energy on charcoal and favours selection of biomass for charcoal production. Some heavy metal contents in the sample such as Pb (2.59 ± 0.11) mg•kg-^{1} and Zn (7.09 ± 0.35) mg•kg-^{1} seem to be very high. However, as at present, there is a paucity of information on the minimum allowable heavy metal concentrations in the biomass that should be converted to charcoal.

Table 1. Mineral composition of PKS (Ma.-%) prior to carbonisation

S/N	Parameter	Value
1	Na	1.57 ± 0.45
2	K	3.24 ± 2.49
3	Mg	0.05 ± 0.13
4	C	75.68 ± 0.01
5	N	0.02 ± 0.03
6	Available P	0.18 ± 0.10

Table 2. Heavy metal composition of PKS ($mg \cdot kg^{-1}$) prior to carbonisation

S/N	Parameter	Value
1	Pb	2.59 ± 0.11
2	Cr	0.60 ± 0.04
3	Zn	7.09 ± 0.35
4	Cd	3.28 ± 0.01
5	Fe	8.71 ± 0.03

Gaseous emissions during the carbonisation and pyrolitic process of the waste were: CO (29.5 $mg \cdot m^{-3}$ and 11.33 $mg \cdot m^{-3}$); CO_2 (217.8 $mg \cdot m^{-3}$, 131.67 $mg \cdot m^{-3}$) and, SO_2 (0.62 $mg \cdot m^{-3}$, 0.12 $mg \cdot m^{-3}$) for PKF and PKS respectively (Table 3). In all, higher values of gaseous emissions were recorded for PKF than PKS. This might probably be due to high ligno-cellulosic and carbon contents of the PKS that slowed down its carbonisation and gaseous emission. This reason could have also resulted into higher temperature observed in the carboniser and more time taken when producing charcoal from PKS compared to PKF. It has been reported earlier (Kuhlbusch, 1995; Chun et al., 2004) that degree of carbonisation is described by the H: C ratio, because these elements are primarily associated with plant organic matter. Hence, the temperature generated during and time required for carbonisation of a waste may be a function of the level of carbon in the waste.

High $PM_{2.5}$ level of 3.86 $\mu g \cdot cm^{-3}$ was measured for PKF than 0.71 $\mu g \cdot cm^{-3}$ that was measured for PKS. However, both levels were found to be below the 25 $\mu g \cdot cm^{-3}$ for 24 h mean set by WHO (2014). By reducing particulate matter (PM_{10}) pollution from 70 to 20 $\mu g \cdot cm^{-3}$, air quality related deaths will be reduced by around 15 Vol.-% ; hence more percentage reduction of deaths is possible by reducing particulate matter ($PM_{2.5}$) that was measured in this study. The quantities of NO_2 and SO_2 observed for all types of charcoal pellets were far below the guidelines: NO_2 (200.00 $\mu g \cdot cm^{3}$ in 1 h mean) and SO_2 (20.00 $\mu g \cdot cm^{-3}$ in 24 h mean and 500.00 $\mu g \cdot cm^{-3}$ in 10 min mean). According to these guidelines, a SO_2 concentration of 500.00 $\mu g \cdot cm^{-3}$ should not be exceeded over average periods of 10 min duration. Studies have shown that a proportion of people with asthma experience changes in pulmonary function and respiratory symptoms after periods of exposure to SO_2 at short interval of 10 min (WHO, 2014).

Values obtained for other parameters such as mass reduction after carbonisation, amount of binder used per kilogram powdery charcoal produced, number of charcoal pellets produced from 1 kg of each raw waste and weight of charcoal pellets were higher in PKF than PKS. The results indicated that PKF has more surface area that was exposed to pyrolysis than PKS, leading to total carbonisation and more mass reduction (90.00 Ma.-%). In essence, the higher the surface area of the initial waste, the higher the carbonisation, amount of binder used, and weight and number of pellet produced. In a similar study, Odesola and Owoseni (2010) observed 79.90 Ma.-% reduction for cocoa pod husk in a charcoal fired reactor for small-scale production of biochar.

Table 3. Characteristics of charcoal and emissions during its production from Palm wastes

Parameter	Palm Kernel Fibre (PKF)	Palm Kernel Shell (PKS)
CO ($mg \cdot m^{-3}$)	29.50	11.33
CO_2 ($mg \cdot m^{-3}$)	217.80	131.67
SO_2 ($mg \cdot m^{-3}$)	0.62	0.12
$PM_{2.5}$ ($\mu g \cdot cm^{-3}$)	3.86	0.71
Temperature for combustion (^oC)	740.00	750.00
Time taken for charcoal production, using 25 kg of palm wastes) (h)	1.22	1.32
Mass reduction (Ma.-%)	90.00	70.00
Amount of binder used for 1 kg powder charcoal (kg)	0.02	0.01
Number of charcoal pellets produced from 1 kg of waste	36.00	27.00
Weight of charcoal pellets (kg)	1.26	1.05

Note: The moisture content of the waste was set at 17 %

Table 4 compares the charcoal produced from the two types of oil palm waste with that of conventional wood charcoal. It was observed that PKF produced lowest levels for both CO (86.50 $mg \cdot m^{-3}$) and CO_2 (429.67 $mg \cdot m^{-3}$) while PKS gave the highest values (CO: 124.22 $mg \cdot m^{-3}$ and CO_2: 710.00 $mg \cdot m^{-3}$). These results indicate that the nature and quantity of the gases emitted during cooking is related to the contents or chemical make-up of the feed-stock or initial materials. When compared to selective international guide lines, gaseous substances emitted during the utilisation of the charcoal pellets were below emission guidelines (WHO, 2014).

Table 4. Gaseous emissions and cooking parameters during charcoal utilization

Variables	Palm Kernel Fibre (PKF)	Palm Kernel Shell (PKS)	Wood Charcoal
CO ($mg \cdot m^{-3}$)	86.50	124.22	102.11
CO_2 ($mg \cdot m^{-3}$)	429.67	710.00	575.89
SO_2 ($mg \cdot m^{-3}$)	0.34	0.17	0.09
NO_2 ($mg \cdot m^{-3}$)	0.03	0.01	0.09
Time taken for cooking 200 g of rice (min)	49.00	25.00	28.00
Quantity of charcoal used for cooking 200 g rice (kg)	0.50	0.35	0.40
Presence of smoke	Not noticeable	Not noticeable	Noticed

It was observed that more gaseous emissions were generated during the utilisation of the pellets than carbonisation of both PKS and PKF. This is a clear indication that after the thermal decomposition of waste in the carboniser, the resulting char retains some of the components of the initial material, particularly nitrogen and carbon that emitted during utilisation as nitrous oxide and carbon dioxide respectively Johannes and Stephen (2009). Other major findings of this study were the time taken for cooking 200.00 g of rice (as test) and the quantity of the charcoal pellets used. Palm kernel shell cooked faster, indicating increased stove energy value as compared to others used. It is evident that the higher the CO_2 emitted by a pellet the higher is the stove energy value.

Both PKF and PKS charcoal pellets produced no smoke during their use for cooking. The main benefit of the pyrolysis is that it offers clean heat, which is needed to develop cooking technology with lower indoor pollution due to smoke (Bhattacharya and Abdul Salam, 2002) than is typically generated during the burning of fire wood (Bailis et al., 2005). Pyrolitic waste loses its smoke inside the carboniser during carbonization process and the resultant briquetted charcoal does not have smoke and burns cleanly due to very low sulphur content (Wondwossen, 2009). Unlike wood charcoal, pyrolitic or carbonised charcoal pellets are smokeless fuel, due to the fact that during carbonisation smoke is removed under controlled conditions. It was observed that among the three types of charcoal tested, the wood charcoal with lowest sulfur content produced smoke. Thus the type of technology used determines the amount of smoke in the final charcoal pellet. Smoke free charcoal could be better than wood charcoal as it has been shown that smoke produced by wood charcoal or fire wood in an indoor cooking environment can lead to multiple respiratory illnesses (Bouros and Samiou, 2001; Da. Costa et al., 2004).

Conclusions

The study revealed that production of smoke-free charcoal is viable using oil palm (*Elaeis guineensis*) wastes. Palm kernel fibre emitted more gaseous substances during the carbonisation than palm kernel shell while palm kernel shell emitted more of these substances during the use for cooking food as pellets. The temperature generated in the carboniser and time required for carbonisation of a waste depended on the level of carbon in the waste. In addition, palm kernel fibre released more $PM_{2.5;}$ required the use of more binder use and gave more volume reduction as well as number and weight of charcoal pellets than the palm kernel shell during the charcoal production. However, palm kernel shell showed highest stove energy value of the three pellets with the least time taken for cooking rice and lesser quantity of pellets used. Although, more gaseous emissions were generated during the use of the pellets than carbonisation of both palm kernel shell and palm kernel fibre, the levels were found to be below the WHO guideline limits.

References

AdeOluwa, O. O., Adeoye, G. O. and Sridhar, M. K. C. 2007. “Adoption of oil palm (*Elaeis guineensis* Jacq.) empty fruit bunch (EFB) as organic fertilizer in oil palm plantations.” In: J A Okogun., O O. AdeOluwa and J A Adediran (eds): *Proceedings of the 2nd National Conference on Organic Agriculture in Nigeria. 27th November - 1st December, 2006 at the Faculty of Agriculture and Forestry*, pp. 30-34, University of Ibadan Press: Ibadan, Nigerian.

Alam, M. Z., Kabbashi, N. A. and Hussein, S. N. I .S. 2009. “Production of bioethanol by direct bioconversion of oil palm industrial effluent in a stirred-tank bioreactor.” *J. Ind. Microbial Biotechnology,* Volume 36, pp. 801-808.

American Public Health Association (APHA). 2005. *Stand-ard methods for the examination of water and wastewater.* 21st edition, Eaton, A.D. Clesceri, L.S. Rice, E.W. Greenberg, A.E. Franson, Eds. M.A.H. APHA: Washing-ton. pp. 400-1960.

Bailis, R., Ezzati, M. and Kammen, D. M. 2005. "Mortality and greenhouse gas impacts of biomass and petroleum energy futures in Africa." *Science,* Volume 308, pp. 98–103.

Bhattacharya, S. C. and Abdul Salam, P. 2002. "Low greenhouse gas biomass options for cooking in the developing countries." *Biomass and Bioenergy,* Volume 7 (22), pp. 305–317.

Bouros, D. and Samiou, M. F. 2001. "Short-term effects of wood smoke exposure smoke exposure on the respiratory system among charcoal production workers." *CODEN CHETBF*, Volume 119 (4), pp. 1260-1265.

Chun, Y., Sheng, G., Chiou, C.T., Xing, B. 2004. "Compositions and sorptive properties of crop residue-derived chars." *Environ. Sci. Technol*., Volume 38, pp. 4649-4655.

Da. Costa, J. L., Navarro, A., Neves, J. B. and Martin, M. 2004. "Household wood and charcoal smoke increases risk of otitis media in childhood in Maputo." *Int J Epidemiol.,* Volume 33(3), pp. 573-8.

Hamdan, A. B., Tarmizi, A. M. and Tayeh, M. D. 1998. "Empty fruit bunch mulching and nitrogen fertilizer amendment: The resultant effect of oil palm performance and soil properties." *PORIM Bull. Palm Oil Res. Inst. Malaysia*, pp. 37.

Johannes, L. and Stephen, J. 2009. "Biochar for Environmental Management: An Introduction." *ES_BEM_*, Volume 16 (2), pp. 17: 23

Kjeldahl, J. 1883. Neue méthode zur bestimmung des stickstoffs in organischen körpern. *Z. Anal. Chem.* 22: 366–382.

Kolade, O. O., Coker, A. O., Sridhar, M. K. C. and Adeoye, G. O. 2005. "Palm Kernel Waste Management through Composting and Crop Production." *The Journal of Environmental Health Research, UK,* Volume 5(2), pp. 81-85.

Kouichi, M. 2003. "Efficient Use of Oil Palm Wastes as Renewable Resource for Energy and Chemicals." Kyoto University, Japan, March Kyushu Institute of Technology, FELDA Lepar Hilir Palm Oil Mill, Biogas Project in Malaysia, *Project Design Document*, Ver. 2.1, pp. 1-43.

Kuhlbusch, T. A. J. 1995. "Method for determining black carbon in residues of vegetation fires." *Environ. Sci. Technol*., Volume 29, pp. 2695-2702.

Lehmann, J., Gaunt, J. and Rondon, M. 2006. "Bio-char sequestration in terrestrial ecosystems – a review." *Mitigation and Adaptation Strategies for Global Change*, Volume 11, pp. 403–427.

Mehlich, A. 1984. Mehlich-3 soil test extractant: A modification of Mehlich-2 extractant. Comm. *Soil Sci. Plant Anal.* 15:1409-1416.

Murphy, J. and Riley, J. P. 1962. Method of phosphorus determination 36 in soil samples. *Anal. Chem. Acta* 2. 27: 31.

Odesola, I. F. and Owoseni, T. A. 2010. "Development of Local Technology for a Small-Scale Biochar Production Processes from Agricultural Wastes." *Journal of Emerging Trends in Engineering and Applied Sciences (JETEAS),* Volume 1 (2), pp. 205-208.

Sridhar, M. K. C. and AdeOluwa, O. O. 2009. "Palm Oil Industry Residues." In: P. Singh nee' Nigam, A. Pandey (eds.): *Biotechnology for Agro-Industrial Residues Utilisation*., Volume 18, pp. 343-357.

Sridhar, M. K .C., Hammed, T. B, and Anthony, O. (Eds) (2015) *Entrepreneurship in Waste Recycling*, Nigeria: Book builders. pp 301-325,

Vogel, J. H. 2002. A Palm Oil Mill in Oyo State, A Draft Proposal for a Private Venture Submitted to Oyo State Government (Governor Lam Adesina), January 12, 2002, pp.1-10.

Walkley, A. and Black, I. A. 1934. Method of total organic carbon determination in soil samples. *Soil Science* 37: 29-38.

WHO 2014. Air quality guidelines of 2005. Availlable at http://www.who.int/mediacentre/factsheets/fs313/en/ (accessed on 02/028/2014).

Wondwossen B. (2009) Preparation of charcoal using agricultural wastes. *Ethiop. J. Educ. & Sc.* 5 (1), pp. 84.