Characterisation of Pulverised Palm Kernel Shell for Sustainable Waste Diversification

R.S. Fono-Tamo* and O.A. Koya

ABSTRACT

The paper presents a report on the physico-thermal properties and elemental composition of pulverized palm kernel shell to enhance its use in engineering applications. Clean palm kernel shell were dried, milled and screened to obtain particles 0.23 mm mean diameter. Experiments were conducted to evaluate the physical and thermal properties of the pulverized palm kernel shell and its differential thermal analysis. Its elemental composition was determined by X-Ray Fluorescent analysis. Test results showed that pulverized palm kernel shell consist mainly of non-ferrous metals. Its bulk density was 560 kg/m^3; specific gravity, 1.26. Its thermal properties were characterized by thermal conductivity of 0.68 W/m K; specific heat capacity, 1.98kj/kg K, and phase change at 101.4^{0}C. The report established significant potentials in the diversification of palm kernel shell from waste to fuel in improved combustion systems and as a future element in bio-material composites.

Keywords: Bio-diversity, Combustion, DTA, palm kernel shell, Sustainability, Waste, XRF.

1. INTRODUCTION

The Millennium Development Goals (MDGs) recognize, explicitly, the interdependence between growth, poverty reduction and sustainable development; resting on good governance, toward time-bound and measurable targets, through collective contributions of the developed and developing countries [1]. And , whilst the world's main development challenges are multifaceted, enhancement of environmental sustainability is one of the eight identified goals. Documented potential strategies include a significant reduction in biodiversity loss: such as, reducing loss in green land area, and emission of greenhouse gases.

Researchers have therefore focused on alternative energy or, improved combustion technology, with the view to reducing pollutant emissions [2], [3], [4], [5], [6], [7]. Furthermore, researchers continue to seek alternative uses of agricultural wastes, which had constituted environmental pollution, because they were disposed indiscriminately or burnt haphazardly without energy recovery [3], [8], [9], [10], [11], [12], [13]. However, the common trend in the diversification of these wastes was to focus on one or two bio-materials at a time, for a specific application [12], [14], [15], [16], [17].

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But, it is reasonable to expect increasing exploitation of the numerous agricultural wastes by providing comprehensive data on their engineering properties, to facilitate their selection for use, deductively.

Palm Kernel Shell (PKS) is one of such abundant agricultural wastes, which are not optimally used. Palm Kernel Shell is recovered as residual waste in the extraction of the kernel from the nut, after palm oil had been expressed from the mesocarp of the oil palm fruit. In 2001 alone, an estimated 3.06 million metric tons was produced by the two highest palm oil producing countries: Indonesia and Malaysia [18]. Until 1970, Nigeria produced about 80% of world palm oil, with the attendant PKS wastes; but her production had declined to meagerly 2% by 2001 [18] [19] [20]. Overall, limited quantities of the PKS are used, primarily for fuel.

Recent research efforts have, however, established the suitability of ground PKS (0.2 to 0.4 mean particle diameter) as friction material in the formulation of non-asbestos brake lining [8], [21]. The physical properties of the PKS were prime concern; whilst, its biodegradability gave promise of environmental friendliness when the product wear debris decomposes. Also, in a renewed interest in fluidized bed combustion, coconut milled to between 3.3 and 10.0 mm showed satisfactory thermal combustion characteristics, improving with smaller particle size. Based on the result of the investigation, better performances were anticipated with finer particle sizes [3]. The physical and thermal properties of the shell were the figures of merit. Furthermore, it has been shown [22] that the required suspension velocity of the particle can be estimated from some of its physical properties: its mass, density and mean diameter.

It is, therefore, expected that more engineering applications of PKS will be readily undertaken if it properties are known. Such technological revolution will provide safer and economical disposal of the waste, and a sustainable lifestyle for the developing countries generating such waste. The objective of this contribution, therefore, is to present the elemental composition, and the physical and thermal properties of pulverized PKS, for possible engineering application.

2. MATERIALS AND METHODS

2.1 Materials Preparation

About 150 kg of PKS was obtained from a local palm oil processing mill in Abagboro village, in Ile-Ife. The shells were cleansed by sorting to remove whole nuts, kernels and other extraneous materials; and by elutriation in soapy and clean water, in sequence, to eliminate traces of oil and other fine particles adhering to the shells. The PKS was then sufficiently sun-dried before it was ground in the mill, in two stages, using a hammer mill (Samtag Flour Mill Ltd., Ile-Ife) and a conventional burr mill. The ground PKS was graded using a set of BS 410 Standard sieves (Endecotts Ltd, London, England) with apertures of 0.212, 0.425 and 0.6 mm. the fraction passing through the 0.425 mm sieve, but retained on the 0.212 mm sieve was used in the experiments, to exclude fines and granular particles [23]. The sample was kept in desiccators, to eliminate moisture re-absorption; while its actual moisture content at the time of experiments was determined using the oven method, as recommended in Standard S352 [24].

2.2 Physico-Thermal Characterisation

The bulk density of the pulverized PKS was determined using the mass/volume relationship [25], [26]. A cylindrical container of specified diameter and height was used. The measurements of the diameter and height were done using a Vernier caliper with ±0.001 mm accuracy. The empty container as well as the container filled with the material was weight on a table top digital balance (Melter Toledo) to determine the mass of the sample. Measurements were replicated five times and, the average standard deviation of the measurements was computed. The relative density was determined using a specific gravity jar, to divide the weight of the sample by the weight of water occupying the volume taken up by the sample, based on Archimedes' principle.

The specific heat capacity and other thermal attributes of the pulverized PKS were evaluated using a computer integrated differential thermal analyser (DTA 404 PC H Eos, NETZSCH). A corundum crucible holder in the DTA was filled with the required quantity of the sample, and the equipment was operated at 0-150^{0}C, for 30 minutes. Air was used as the inert gas in the experiments. The heating rate was in the range of 15-23 k/m. the resulting DTA was generated

The thermal conductivity of the sample was computed based on Fourier law of heat transfer which is given [27] as,

$$k = \frac{\Delta Q}{\Delta t} \times \frac{L}{A \times \Delta T} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where, k is the thermal conductivity in W/m k; ΔQ, the quantity of heat transmitted in J, during the time Δt in s; L is the thickness of the material in m, in a direction normal to A; A is the surface of area in m^2 and ΔT, a temperature difference in k, under steady conditions, assuming that the heat transfer is only on the temperature gradient.

Sample of the pulverized material was placed in a cylindrical dish (90 mm diameter and 12.7 mm high) on a hot plate, which had been prepared for 3 minutes. The hot plate was disconnected from the power source and a thermocouple was used to measure the temperature at the bottom of the pan and also at the surface of the material contained in the pan. Thus, the variables required in the evaluation of Equation 1 were determined.

2.3 Determination of Elemental Composition

The elemental composition of the PKS particles was determined based on the X-Ray Fluorescence (XRF) analysis. Samples of the material were formed into pellets in a pelletizer with hydraulic press (Carver Inc). The pellets were then sealed into the chamber of the XRF (Amptek Inc) and allowed to run for 1000 s at a voltage of 25 kV, and a current of 50μA. The resulting spectrum measured the elemental composition of the material.

3. RESULTS AND DISCUSSION

The observed moisture content of the sample at the time of the experiments was 13.4% (w.b). A summary of the physic-thermal properties of the pulverized PKS is shown in Table 1.

Table 1: Summary of Physico-thermal properties of the pulverized palm kernel shell

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Property	Mean value ± SD
Bulk Density (kg/m³)	560 ± 17.4
Specific Gravity	1.26 ± 0.07
Thermal Conductivity (W/mK)	0.68 ± 0.05
Specific Heat (kJ/kgK)	1.983 ± 0.10

The ground shell exhibited a bulk density of 560 kg/m³ and a specific gravity of 1.26, indicating a porosity of 56%. This shows that the pulverized PKS holds a good promise of high compressibility, which is desirable in constituents of fuel briquettes [28]. The voids may also embed other ingredients in the formulation of bio-material composites, as being currently investigated in the development of non-asbestos brake pads [8].

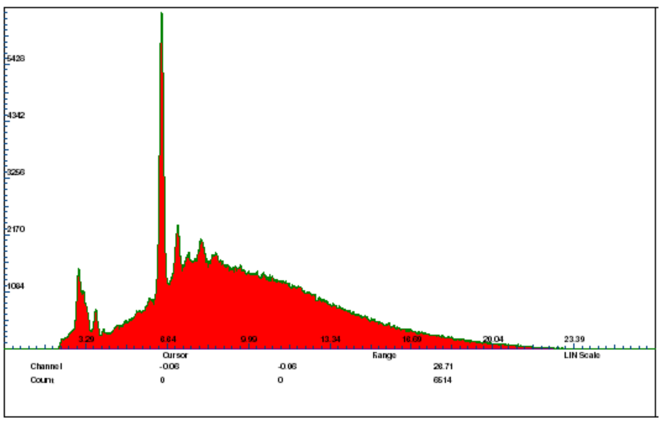

Figure 1: Spectrum of the pulverized palm kernel shell

Figure 1 is the spectrum of the pulverized PKS particles containing about 13 elements, mainly non ferrous-metals. These elements are either insulators, or weak conductors. The only element which might have been increased due to contribution from grinding equipment is the Fe particles, because of the contamination from wear of the hammer and the burr mill during grinding; albeit, all the elements are degradable and non-carcinogenic. The proportion of elements is shown in Table 2.

Table 2: Major elemental composition of the pulverized palm kernel shell

Elements	Conc Value	Conc Error	Unit
K	34.3586	±0.8308	wt.%
Ca	16.0318	±0.5872	wt.%
Ba	2.5319	±0.0100	wt.%
V	2593	± 401	Ppm
Cr	6034	± 100	Ppm
Mn	2.1327	±0.0100	wt.%
Fe	29.2421	±0.0100	wt.%
Ni	4.2829	±0.0100	wt.%
Cu	4.5568	±0.0100	wt.%
Zn	2.3982	±0.0100	wt.%
Se	5408	± 100	Ppm
Sr	3205	± 100	Ppm
Br	6328	± 100	Ppm

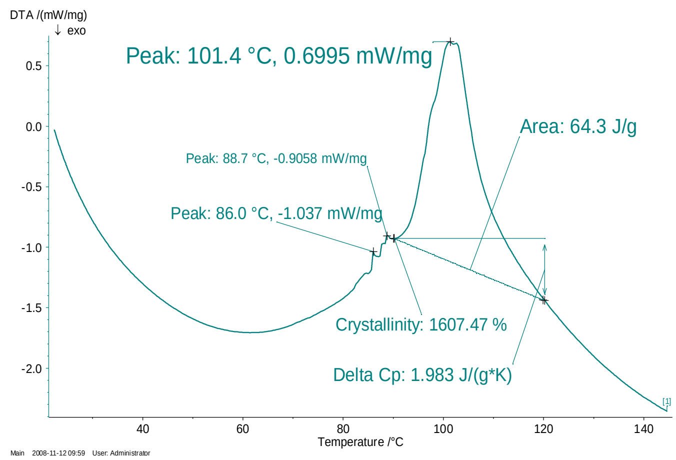

Figure 2: Differential thermal analysis of the pulverized palm kernel shell

From the DTA curve in Figure 2, the specific heat capacity is 1.98 kJ/kg k and it is higher than the values for asbestos, coal, wood and coconut shell [3],[8],[29]. This parameter is important in the consideration of the material as primary fuel in fluidized bed combustion, swirl burner, or other improved combustion technology [3],[6],[30]. It is also required in determining its degree of hotness when employed as an insulator in heat conduction systems; but, since it experiences a phase change at 101.4°C, it must be fortified against thermal degradation in such applications. The observed thermal conductivity is 0.68 W/m K and this complements its requirement for use as insulators, such as glass, wool, asbestos fibres and wood; but lower for plaster, glass and asphalt [29]. Apparently, the Fe contamination might have contributed to increase the observed value.

4. CONCLUSION

The physical and thermal properties and elemental composition of pulverized palm kernel shell were evaluated to enhance its diversification from waste, or environmental pollutant to a viable engineering material. In view of its constituent bio-degradable elements, bulk density of 560 kg/m^3, porosity of 56%, specific heat capacity of 1.983 kJ/kg K, and thermal conductivity of 0.68 W/m K, PKS showed a strong potential for use both as particulate and environmentally friendly bio-fuel and as an ingredient in bio-material composites. Pulverized PKS, thus, provides stimulation for sustainable lifestyle change in waste diversification.

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