CHARACTERIZATION OF CARBONIZED WOOD CHARCOAL FOR ENERGY GENERATION AND UV RADIATION DETECTOR

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Abstract
Mangifera indica (mango) tree of over ten years in existence was used to produce wood charcoal via incomplete combustion process. The carbonized wood charcoal was subjected to different characterizations analysis; the X-ray diffraction, the UV-Visible spectroscopy and water absorption capacity test. The X-Ray diffraction analysis revealed that the charcoal produced exists in a largely amorphous state, though partly crystalline and has its grain size in nanoscale. Its grain size is estimated to 25.42 nm. The charcoal absorbed radiation in the ultraviolet region of electromagnetic radiation with absorption peaks between 200 nm to 290 nm and has very high rate of water absorption of over 100 % with final weight of 50 g sample to be 132.5 g in water, due to its low-density properties. The charcoal can be used for energy generation, composite of nanomaterials for application in sensing devices and other reasonable applications.

Keywords: Charcoal, Carbonization, Energy, Ultraviolet radiation, X-ray diffraction

Introduction

The world's most important form of non-fossil energy burning is the wood fuel (FAO, 1999). Roughly half of the wood harvested from forests is used to generate energy (Wood and Baldwin, 1985); primarily for cooking and heating in developing nations, but also for electric power generation in developed countries. Half of the world's population, and up to 95 percent in poor countries, rely on solid fuel including biomass fuel and charcoal to meet their energy needs (Rotowa *et al.,* 2019). Due to rising demand in urban areas and by businesses, as well as insufficiency of readily available alternative energy sources, charcoal manufacturing is on the increase.

Although, along the charcoal value chain, unsustainable wood harvesting and manufacturing of charcoal result in forest degradation and deforestation, as well as the emission of greenhouse gases (GHGs) (AFREA, 2011). However, the charcoal produced using sustainably managed resources and improved method is a low net emitter of GHGs, helping to reduce climate change while simultaneously expanding means of energy generation and giving income-generating opportunities (Liyama *et al.,* 2014; Schure *et al.,* 2014).

Charcoal is a light black carbon residue made by extracting water and other volatile elements from animal and plant matter. Slow pyrolysis, the heating of wood or other organic materials in the absence of oxygen, is the most universal method for producing charcoal. Charcoal is largely pure carbon that is produced by heating wood in a low oxygen environment, a process that can take days and removes volatile molecules such water, methane, hydrogen, and tar. Burning takes place in massive concrete or steel silos with very high temperatures in commercial operations (William, 2005).

Carbonization is a process that involves heating biomass feedstock in a kiln or retort (pyrolysis) at temperatures of around 400 °C (generally between 300 °C and 900 °C) in the absence of oxygen. The wood is heated in a closed ground, away from the oxygen in the air that would otherwise cause it to ignite and burn to ashes. This so-called wood gas has a poor calorific value (around 10 percent of that of natural gas). The technique is known as

Low Temperature Carbonization when the coal is burnt to temperatures ranging from 4000-700 °C. High Temperature Carbonization occurs when the temperature of the coal is between 900 and 1300 degrees Celsius. The goal is to create a carbon-rich, robust, glossy, and cohesive coal mass. As the wood structure decomposes to generate charcoal, there is also an exothermic production of heat during carbonization (Marsh & Rodriguez-Reinoso, 2006).

Despite the fact that the world is becoming awakened to harnessing of renewable energy sources, like solar energy, the exploration of charcoal for energy generation is still much relevant. Though several researchers have reported the carbonization of wood for charcoal production, a few work is reported on the X-Ray Diffraction (XRD) analysis of the produced charcoal and most likely none on the UV radiation absorption potential of charcoal in relevant materials science field. Without the use of chemicals in preparation or synthesis, is there a natural material which can be used in fabricating UV radiation detector or as its composite? Hence this study focuses on the simplified process of charcoal production and the charcoal granules' characterization for studying its crystallinity, porosity property and ultraviolet radiation absorption potential. Also, this research is economically and environmentally viable compared to the use of chemicals in designing a UV radiation detecting devices.

Materials and Methods

(a) Carbonization process for charcoal production

The *Mangifera indica* (mango) tree was cut from a residential compound at Tanke, Ilorin, Nigeria (Lat. 8.4928^0 N, Long. 4.5962^0 E). The image in Figure 1 shows the mango tree which was cut down with an electric saw machine in the residential compound. The tree has been in existence for over ten years. The choice of such food crop tree for charcoal production in this research is because it is hardwood and can be carbonized for excellent charcoal yield efficiently (according to Sumrit and Vijitr, 2015), as compared to other types of wood that may be regarded as softwood.

The entire mass of the fallen tree was combusted in a locally-structured kiln, as shown in Figure 3, (with sand and fresh leaves), without taking the carbonization temperature or the kiln temperature into consideration. The focus is the charcoal's characterization for potential applications.

The fallen tree pieces are shown in Figure 2. Afterward, the incomplete combustion process of obtaining the wood charcoal was done by putting heap of sand on the wood pieces and covered with fresh leaves, as shown in Figure 3. After about 48 hours the pieces of charcoal, via incomplete combustion of the fresh wood, was obtained as shown in the image presented as Figure 4. Exothermic heat production occurs during carbonization as the wood structure decomposes to make charcoal.

Fig. 1: Cutting down of the wood

Fig. 2: Processing into smaller logs

Fig. 3: Conventional Carbonization Chamber

Fig. 4: Charcoal Product of Carbonization

(a) Water absorption study

The water absorption of the charcoal specimens was directly related to apparent porosity and ranged from 50 g to 200 g for initial charcoals masses and 132.5 g to 468.3 g for final masses. The charcoal was submerged in water for seven days. The purpose of soaking the charcoal is to determine its porosity.

(b) Characterization techniques

UV-Vis Spectrophotometer (Model VWR: UV-6300PC Double beam spectrophotometer) was used to determine the charcoal granules' optical properties. The sample was prepared with distilled water of pH of around 6.9 and at room temperature. The charcoal powder was subjected to X-ray diffraction for the structural properties, by using powder X-ray diffractometer (Model: EMPYREAN) with Cu-K radiation. The test circumstances were 50 kV tube voltage, 80 mA tube current, and a scanning speed of 4°/min.

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Results and Discussion

X-Ray Diffraction Analysis

The XRD pattern of the produced charcoal powder is presented in Figure 5. It can be seen that the charcoal has a reasonably narrow peak around 2 Theta values of 29.27°, though with evidences of being amorphous, as a result of the presence of noise that characterized the XRD pattern. It is expected to be largely amorphous with such noise in the pattern, because the major composition of the charcoal which is carbon is not crystalline, except for the traces of crystalline graphite that may be present. The powder X-ray diffraction analysis indicates a mostly amorphous and partially crystalline product with a prominent diffraction peak at 29.27°.

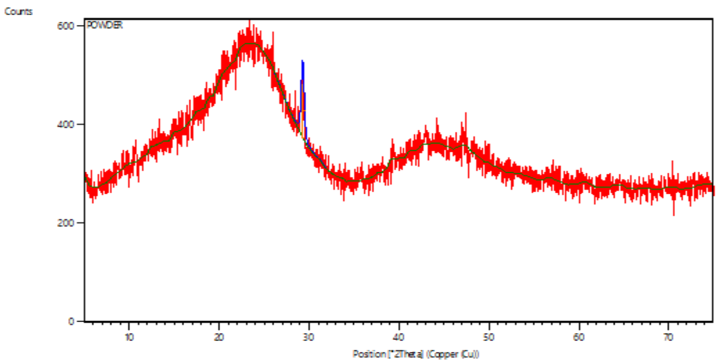

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Figure 5: XRD pattern of ground charcoal sample

The Table 1 gives the summary of the XRD analysis result.

Table 1: Summarized result of the XRD pattern

Position (2Theta)	Height (Counts)	FWHM	d-spacing	Rel. Int (%)
29.27	108.72	0.374	3.05	100.00

By using Debye-Scherer's equation, $g = \frac{k\lambda}{\beta Cos\theta}$, (Akinsola *et al.,* 2017), the crystallite size of the charcoal granules was obtained as 25.42 nm. λ is the X-ray wavelength = 1.54 x 10^{-10} nm, β is the Full width at half maximum (FWHM). The charcoal particle size is of nanoscale. It shows that it can find application in making composite nano materials for fabricating electronic sensors or as photo catalytic substances, especially since it absorbs solar radiation in the ultraviolet region (the discussion under optical analysis section explains further).

Optical Analysis

The absorption spectra of the ground charcoal sample are presented in figure 6. The electromagnetic spectra range from radio waves to Gamma rays. Each of the spectra has distinct wavelength band attached to them. The charcoal in this study absorbs radiation in the Ultraviolet region, which is from around 200 nm – 380 nm. There are three major classifications of UV radiations. There is the UVA, UVB and UVC, all within this wavelength range. The absorption peaks observed in the spectra span from about 200 nm to 290 nm. Also, there is a little peak seen at around 370 nm. In the visible region, the absorption spectra exhibit a progressive fall.

All these confirm the fact that the material being studied has the potential of absorbing solar radiation in the UV region and this can be incorporated into fabrication of UV detectors. This is highly essential, especially in this present age of obvious depletion of ozone layer which has actually increase the amount of UV penetration into the earth surface.

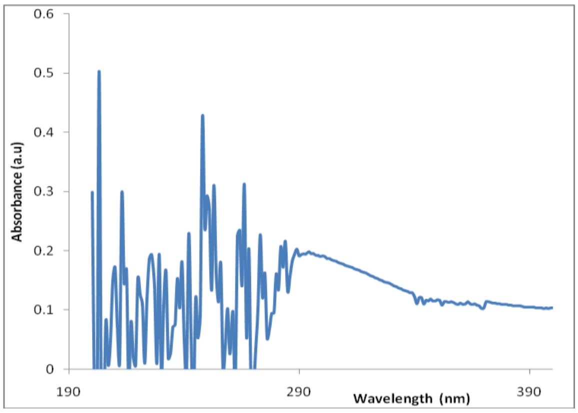

Figure 6: Absorption Spectra of the ground charcoal sample

Water Absorption Analysis

The summarized analysis of the water absorption capacity of the carbonized wood charcoal is presented in Table 2. Four different samples of different masses were tested for the charcoal's water absorption capacity, ranging from 50 g to 200 g. As shown in Table 2, the duration of being soaked in water is the same for all samples, which is 168 hours. It was observed that the weight of the dry charcoal is proportional to the final weight of the wet/soaked one. The implication of this is that the quantity of matter, i.e. the particulate in the charcoal determines the water absorption rate. The higher the mass of the dry charcoal, the higher the quantity of water to be absorbed. Hence its porosity depends on the quantity of matter present which is actually depicted by the sample mass. This can be attributed to the fact that it is a low-density compound and possess low mechanical strength properties. Also, the large surface area of carbon charcoal structure could be responsible for its high porosity in a polar solvent, like water used.

Table 2: Analysis of the water absorption study of the charcoal

Initial Weight (G)	Final Weight (G)	Time (Hours)
50	132.5	168
100	240.7	168
150	352.1	168
200	468.3	168

The result shows that the product is highly porous. The weight of the products increased by more than 100 % within 168 hours.

Conclusion

The charcoal produced by incomplete combustion of fresh wood via carbonization process was discovered to be partly crystalline and has its grain size in nanoscale. The charcoal showed potential of absorbing solar radiation in the ultraviolet region of electromagnetic radiation by absorbing between 200 nm and 300 nm and it has very high rate of absorbing water of over 100 % in water. The charcoal can be used to make composite of nanomaterials for application in sensing devices and other reasonable applications.

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