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A Nature Based Solution: Production and Characterization of Biomass Derived Catalyst from Nigerian Baobab Fruit Shell Powder (*Adansonia Digitata*)

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ABSTRACT

Work on biomass synthesized catalyst from Nigerian Baobab fruit shell powder was thermally treated at 550^{o}C for 6 hours using a muffle furnace. The resultant calcined powder and the un-calcined were characterized using Fourier Transform Infrared spectroscopy (FTIR), Scanning Electron Microscopy (SEM) and X-ray Diffraction (XRD) and further compared with the un-calcined form (baobab fruit shell powder). The FTIR revealed the presence of functional groups matched as alkenes with carbon-hydrogen and nitrogen-hydrogen bonds for baobab fruit shell powder (BFSP). With C-O, a carbon stretch at 1118 & 670 cm^{-1} and C-H alkyne for the biomass derived catalyst (BDC) from baobab. The morphology of the samples using SEM indicated the presence of higher porosity in the calcined sample when compared to the uncalcined. The superimposed graph of intensity vs 2 theta, of the BFSP and BDC showed no crystallinity during phase determination causing differing diffraction peak counts with no width from 20^0 – 45^0, characteristic to biomass of plant or animal origin. Related outcome was seen for XRD results.

Keywords
Biomass, Catalyst, Baobab shell, Characterization.

Introduction

The increase in population across the globe has overtime resulted to industrial evolution to meet the needs of human consumption. As a result, numerous production processes have employed the use of catalyst to improve time of production, and quality of product in order to enhance the economics involved with production [1].

Catalysts are chemical or biological species used in a chemical reaction, It operates by reducing the activation energy but does not take part in the reaction; examples are homogenous and heterogeneous catalyst [2]. Positive and negative catalyst have both found uses in a chemical-thermodynamic reaction, by hastening the reaction time or reducing the reaction time to promote the said process [3]. Petroleum purification, detergents, fertilizers, paints, plastics, herbicides and pesticides production are presently reported as few of the processes requiring catalyses [4].

As technological advancement progressed, there have been increased need for catalysed aided production, from photo catalyses, bio-catalyses to electro-catalyses and most trending biomass derived catalyses [5,6]. Chemical based catalysts have found wide usage in production processes. However, their general characteristics stand out including toxic, flammable, exorbitant and corrosive. The continuous use of homogenous catalyst leads to effluent generation of soapy products that require treatments on a large scale and then proper disposal. However, heterogeneous catalyst is an improvement on the homogenous catalyst, though chemically synthesised is still stable and quite expensive. The trendy use of biomass derived heterogeneous catalyst surfaced, from renewable or sustainable feedstocks. These catalysts are less toxic, inexpensive and require less wastewater treatment, and possess high catalytic activity, as they are reusable.

Catalysts generated from waste and plant material origin have been reviewed severally by researchers, as sustainable process of catalysis originated from the use of materials of plants and animal waste of renewable origin. Studies have shown the use of animal hides, seashells of clams, periwinkles and or the stones found in fish mouth for use in catalysis reaction; as a sustainable management practice for the earth [7]. Specifically, plant materials for the production of biomass-based catalyst mostly gave calcium and magnesium oxide in nature when characterized [8]. Calcination or thermal treatment of plant waste and animal materials according to [9], exist as benefit; as an enhanced way for food fortification and transform waste to wealth from a controlled environment of a muffle furnace; with respect to time and temperature. Further details showed that the replacement of these materials by the earth connotes the process as a greener energy solution, environmental quality have been preserved as the materials are converted to non-polluting substances [10].

Baobab fruit tree are highly sought out locally and worldwide because of the nutritional and medicinal properties of the plant [11]. The fruit shell itself is relegated for fire-woods and sometimes used for dipping of water or food collection, owing to the hardy nature of the shell [12]. Research has shown that the shells of fruit like baobab has been used in water purification as with other plant materials [13]. The use of green chemistry is a nature based solution, suggesting that catalyst from biomass derived materials are among the group of solutions of which are environmentally safe and nature friendly [14].

Although literature abound in the use of biomass as a catalyst [3] for egg shell waste, [7] in silver croaker stone and [8] for pawpaw stem, its derivative from baobab have not yet been reported. Hence, this study produced a biocatalyst derived from baobab shell and characterized using FTIR, SEM, and XRD.

Materials and Methods

Baobab fruit shell was collected from Bange Village of Tudun Wada Local Government Area of Kano State, Nigeria. The experiment was carried out in Department of Food Science and Technology and National Centre for Energy Research and Development both in University of Nigeria Nsukka, Enugu State.

Preparation of baobab fruit shell

The shells of the baobab fruit were cracked opened (Figure 1) using a cutlass, the shell was further broken into pieces with the cutlass, oven-dried for 24 hours at 60 ^{O}C, milled and packed prior to usage [15,16].

Calcination of baobab shell

The oven dried powdered baobab shell as shown in figure 2 was weighed (25 g) each into crucibles and placed in a muffle furnace for 6 hours at temperatures of 550 ^{O}C until completely calcined. Then the crucibles transferred to a desiccator for 1 hour, and subsequently weighed and the obtained ash were packed for characterization [9,8].

Characterization of biomass derived catalyst

The derived biomass catalyst was passed through the Fourier Transform Infrared Spectroscopy, to check for the functional groups present in the compound on a wavenumber array of $4000 - 650\ cm^{-1}$ (Name: Agilent, Model: Cary 630 FTIR, Manufacturer: Agilent technologies, Country: United States) the prepared ash was placed in optimal contact with the attenuated total reflectance and spectra collected in the range at 32 scans.

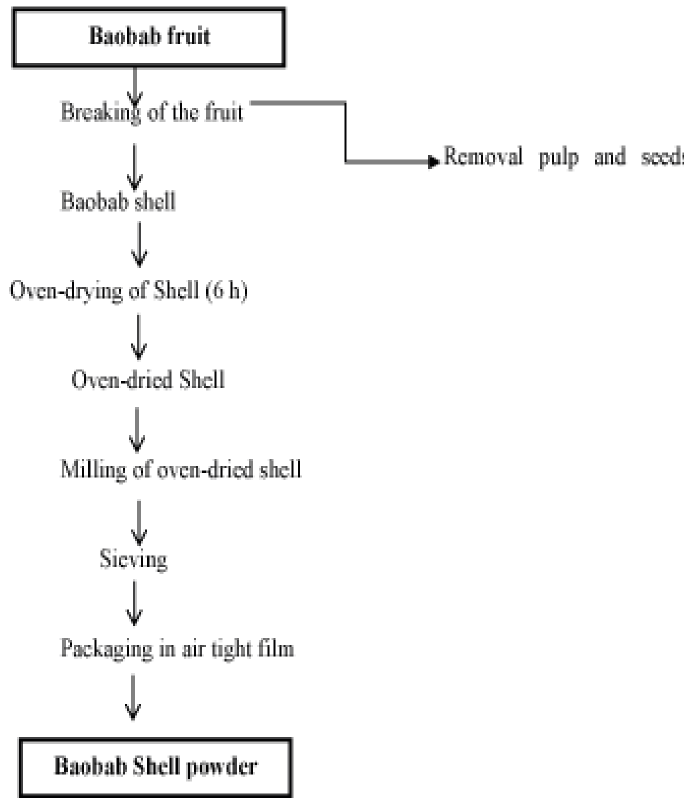

Figure 1: Preliminary Preparation of Baobab Fruit.

Figure 2: Preliminary Preparation of Nigerian Baobab Fruit Shell for Calcination.

Scanning Electron Microscopy SEM (Name: Phenom SEM, Model: Phenom Pro X, Manufacturer: Phenom World Eindhoven, Country: Netherlands)$20\ kV \times 1000 \times 10\ \mu m$, was used to give the surface morphology.

The X-ray diffractograms (Model: Rigaku miniflex 600 Manufacturer: Rigaku Cooperations, Country: Japan) enabled at $2°$ scanning rate to x-ray and give a mirror image of the compounds in $10-80°$ degrees. The characterised biomass derived catalyst of baobab shell origin were then packed in an air-tight proof bag at room temperature.

Results and Discussion

Characterization

Characterization of an unknown compound or catalyst as described by [4] often yield a clearer picture of the functional group, surface area morphology, and compounds composition available. According to [17], solid catalysts have been described as the metals found in the alkaline-earth metals or transition metals, these metal description tallies with that of biomass derived catalysts. These biomass derived catalyst are renewable in nature.

Fourier Transform Infrared Spectra Analysis

The FTIR is a known technique for functional group identification of an unknown material. The spectra or peaks of the calcined baobab shell powder and baobab fruit shell powder are given in figures 3 & 4 respectively. The spectrum of transmittance versus wavenumber (cm^{-1}), displayed the spectrum of each peak, marked by elaborate complexity of the biomass derived catalyst and raw material.

Spectra analysis of baobab fruit shell powder (BFSP) as shown in figure 3, the broad spectrum around 3265 cm^{-1} is suggestive of the presence of bonded O-H and N-H groups on the surface of raw material. The biomass is of plant origin and the presence of nitrogen is evident [18]. The peak detected at 2915 cm^{-1} and 2218 cm^{-1} were matched as alkenes to the stretching vibrations of C-H bond in the methyl group. The spectrum of 1636 cm^{-1} was assigned to C=C. The deformations associated with C-H and N-H bonds were evident with weak to moderate spectra.

Spectra analysis of calcined baobab fruit shell powder (CBFSP), from figure 4 the bands in the region of 2915 is stretch bond C-H and asymmetric in nature. The 1647 C=C, C=N, moderate peak. 1453 C-H with bending and scissors with a methyl group. 1371 bonded C-H bending with methyl group. 1118 C-O is a carbon stretch, 861 C-C weak bond. 670 C-H bend with alkyne.

By reasonable assumption, the decrease in the number of peaks after calcination leading to the disappearance of the certain transmittance spectra, shift in the functional group and development of new spectrum are attributed to complexities of the binding sites of catalyst [19].

Scanning electron microscope (SEM) analysis

The basis for the determination of physical properties and surface morphology of a catalyst is the use of the instrument known as SEM [20]. This analysis has been shown to provide the particle orientation, porosity, and size distribution of a catalyst [21]. The three-dimensional imagery derived were used to observe the (CBFSP) and (BFSP). From figure 5, the image had large number of holes which is technically a good surface area when compared to the image of figure 6 having orthogonal or rhombic shapes. It can be concluded on the basis of morphological structure and form that the calcined baobab fruit shell powder (CBFSP) in figure 5 has sufficient surface area for chemical reaction. Furthermore, the catalyst surface area is moderately rough containing pores of various sizes [8].

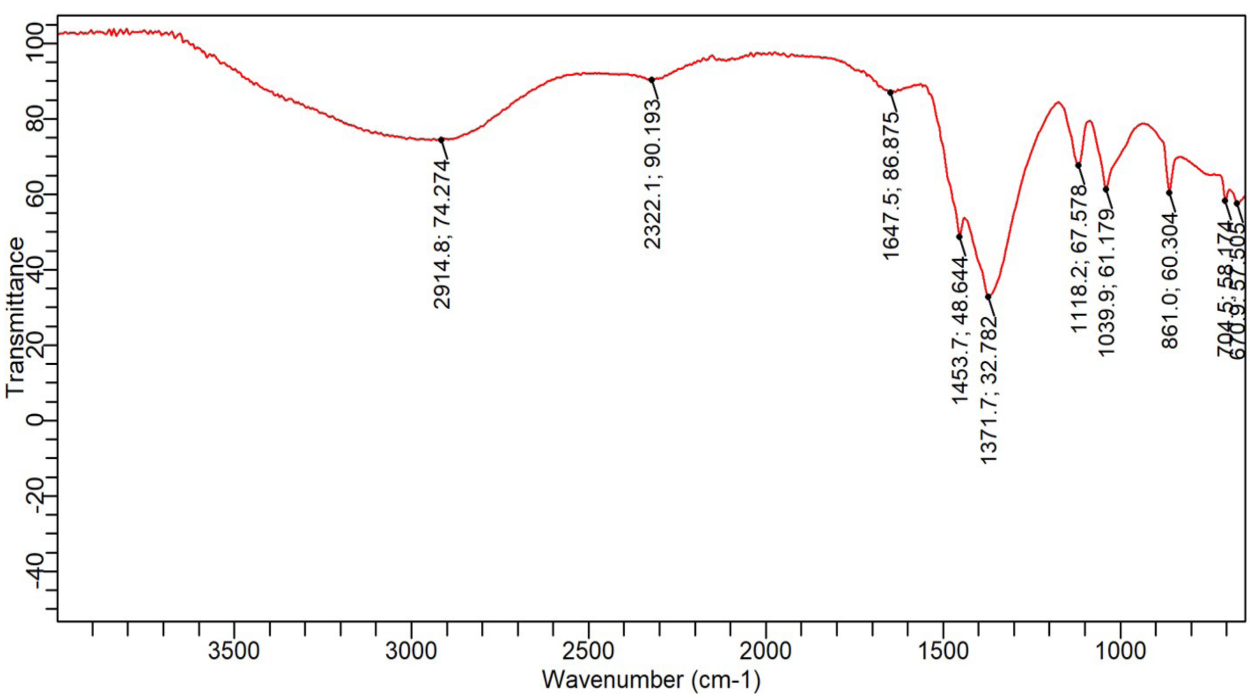

Figure 3: Fourier Transform Infrared spectrum of Baobab Fruit shell powder.

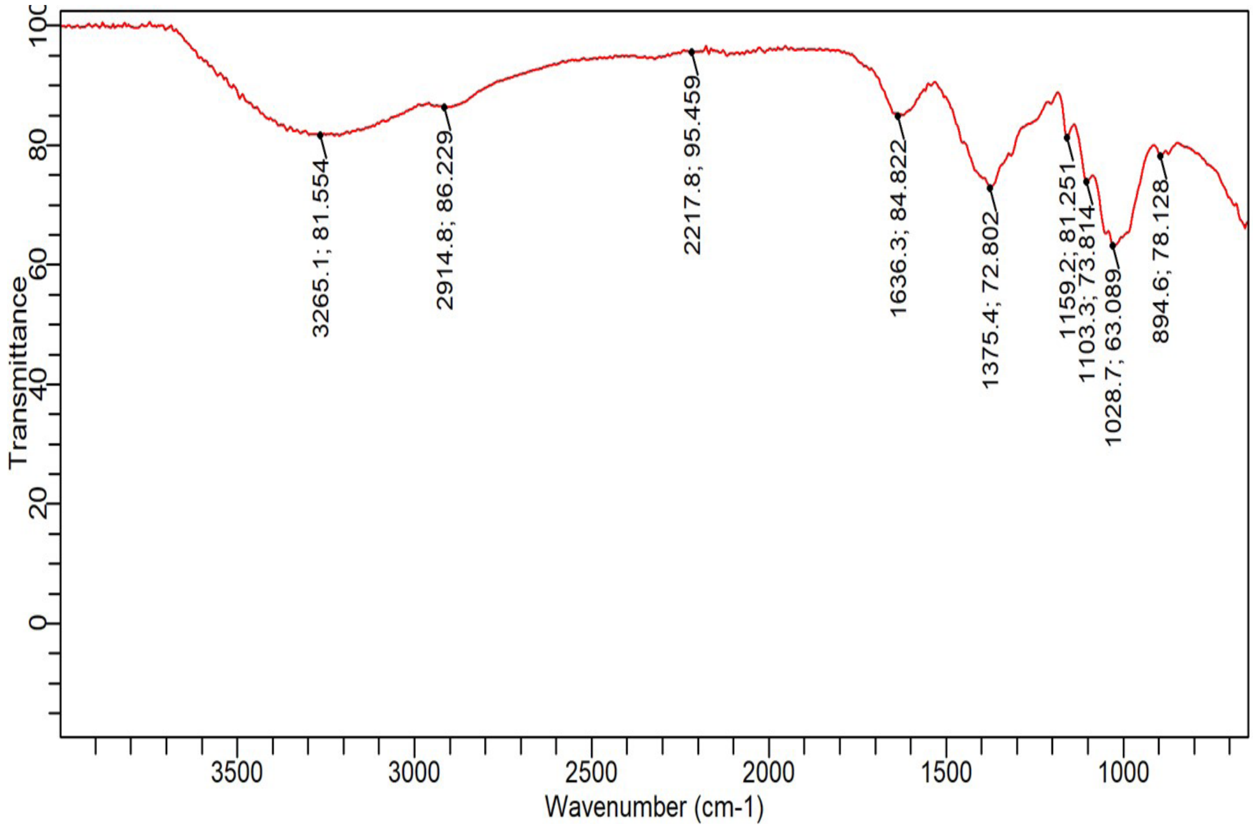

Figure 4: Fourier Transform Infrared Spectrum of Calcined Baobab fruit shell Powder.

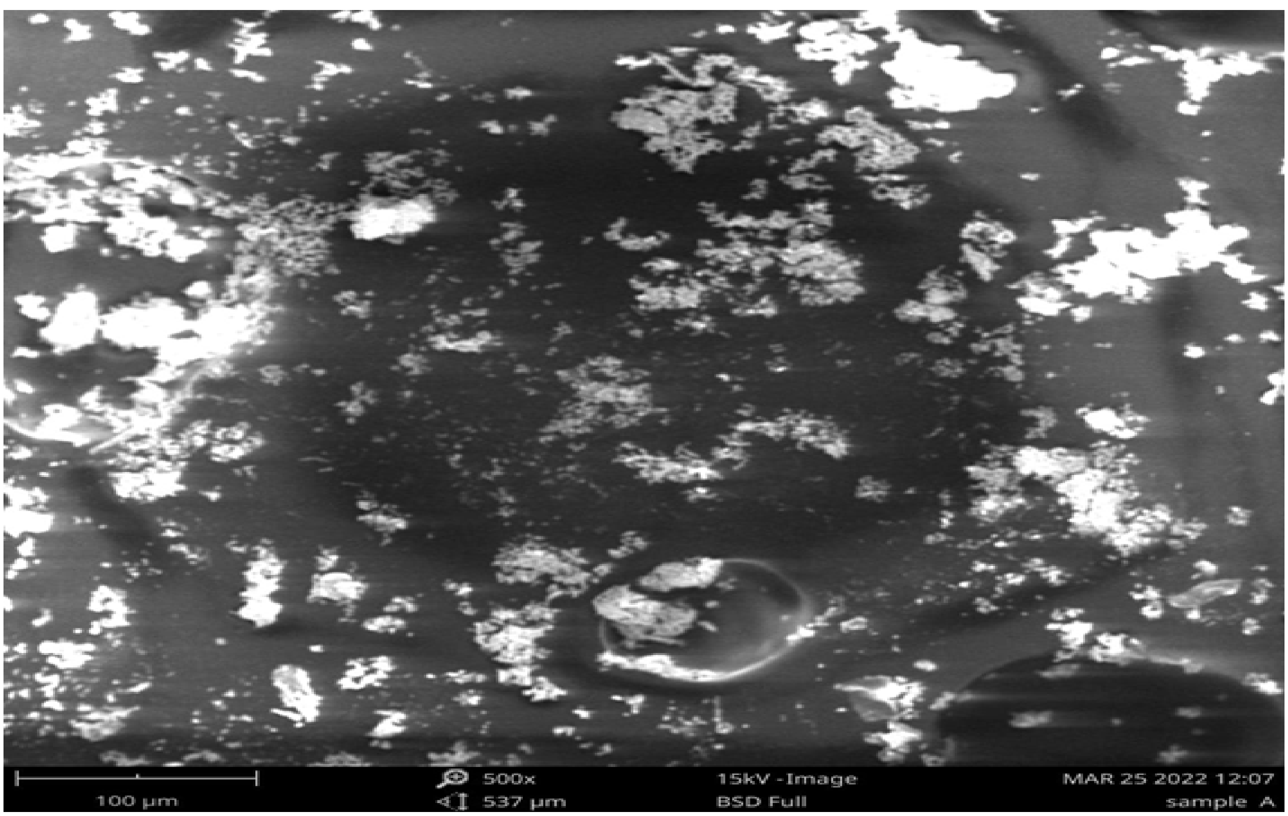

Figure 5: Scanning Electron Microscopy of Calcined BFSP (sample A).

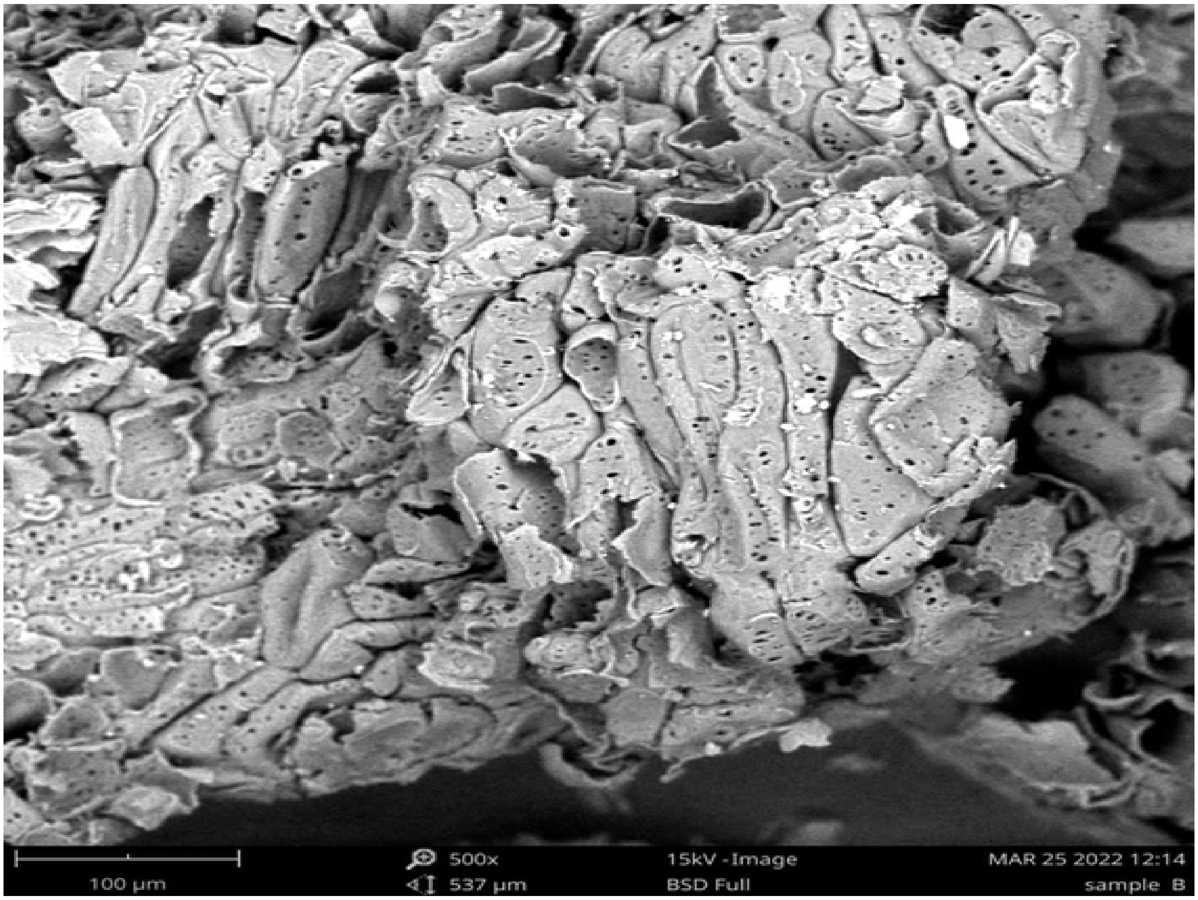

Figure 6: Scanning Electron Microscopy BFSP (sample B).

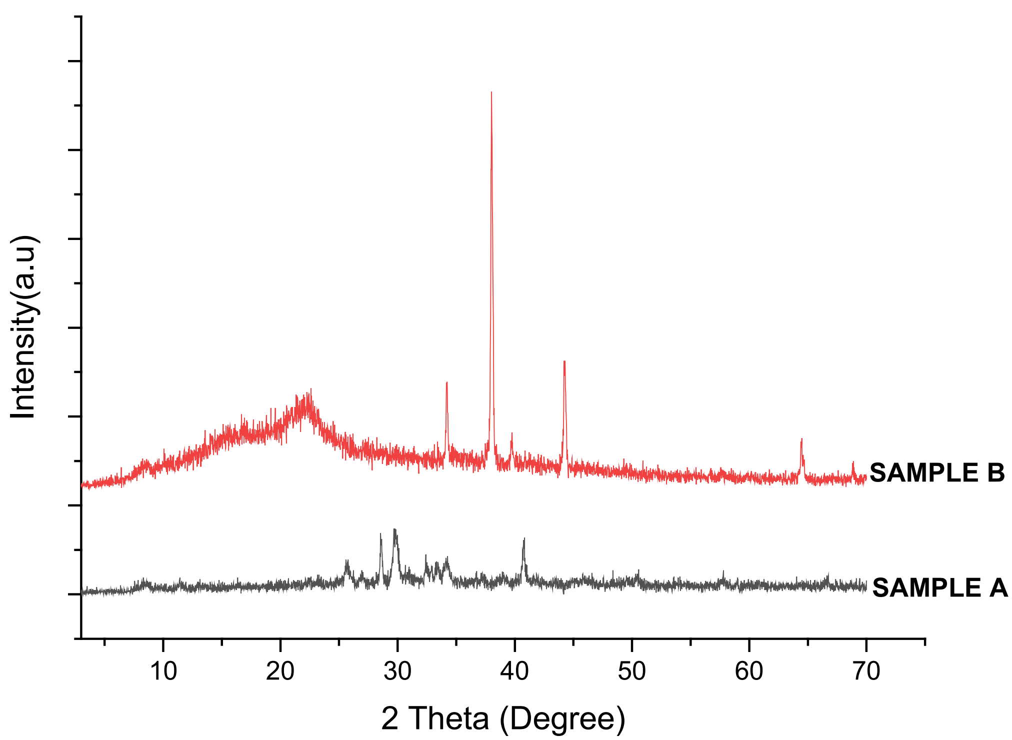

Figure 7: XRD superimposed pattern for BFSP and CBFSP.

X-ray diffraction (XRD) analysis

The crystalline size was seen from the XRD analysis, the superimposed patterns for (sample A) the calcined baobab fruit shell powder and (sample B) the baobab fruit shell powder are shown in figure 7. The obtained characteristics diffraction peaks for the catalyst (sample A) and (sample B) are consistent with patterns reported by [22].

Therefore, based on characterization, the superimposed pattern of BFSP and CBFSP appeared to have slightly dissimilar pattern. This showed that the calcining temperature and time treatment of the (BFSP) does transform the components cells of the derived catalyst; thereby affecting the crystallite peak positions of the calcined form (CBFSP) [23].

Conclusion

From the result obtained from the FTIR, SEM and XRD. It is evident that the FTIR provided an excellent means to identify the functional groups (chemical properties) present in the baobab fruit shell powder and the calcined baobab fruit shell powder. The SEM result of the (CBFSP) showed presence of large pore space (dark patches) compared to the baobab Fruit shell powder which had little or no pore spaces. From literature, a catalyst should be as porous as possible. For the superimposed XRD outline, the calcined form of BFSP did not exhibit a sharp peak with respect to the intensity, count and width. No clear mineral peak was detected in the calcined sample. Therefore, the calcined powder from baobab fruit shell powder could be a feasible catalyst.

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