Potential Utilization of Solid Waste (Bagasse Ash)

V. S. Aigbodion*, S. B. Hassan, T. Ause and G.B. Nyior

Department of Metallurgical and Materials Engineering,
Ahmadu Bello University, Samaru, Zaria, Nigeria.

*Corresponding Author: aigbodionv@yahoo.com

ABSTRACT

Utilization of industrial and agricultural waste products in the industry has been the focus of research for economical, environmental, and technical reasons. Sugar-cane bagasse is a fibrous waste-product of the sugar refining industry, along with ethanol vapor. This waste-product is already causing serious environmental pollution which calls for urgent ways of handling the waste. In this paper, Bagasse ash has been chemically and physically characterized, in order to evaluate the possibility of their use in the industry. X-ray diffractometry determination of composition and presence of crystalline material, scanning electron microscopy/EDAX examination of morphology of particles, as well as physical properties and refractoriness of bagasse ash has been studied.

Key Words: Density; microstructure; particle size; refractoriness

1. INTRODUCTION

Researches all over the world today are focusing on ways of utilizing either industrial or agricultural wastes as a source of raw materials for the industry. These wastes utilization would not only be economical, but may also result to foreign exchange earning and environmental pollution control [1-3].

Bagasse is the matted cellulose fiber residue from sugar cane that has been processed in a Sugar mill. Previously, bagasse was burnt as a means of solid waste disposal. However, as the cost of fuel oil, natural gas, and electricity has increased, bagasse has come to be regarded as a fuel rather than refuse in the sugar mills [4, 5].

Ganesan et al [6] stated that 1 ton of sugarcane generates 280 kg of bagasse, and that based on economics as well as environmental related issues, enormous efforts have been directed worldwide towards bagasse management issues i.e. of utilization, storage and disposal. Different avenues of bagasse utilization are more or less known but none of them have so far proved to be economically viable or commercially feasible [5, 7]. Hence the objective of this present work is to characterize the bagasse in order to explore it use in the metallurgical and materials industry.

2. MATERIALS AND METHOD

2.1 Materials

The bagasse used in this work was obtained from Zongo area of Zaria in Kaduna State of Nigeria. Other materials used are: Arabic gum and cotton wool. The photograph of the bagasse is shown in plate 1[5].

Plate 1: Photograph of the Bagasse

2.2 Equipment

Equipment used in this research are: Meter balance, Crucible, tong, Thermometer, Drying oven, Density bottles, Hydraulic press, Mixer, Hood type furnace, Steel mould and set of sieve, scanning electron microscopy (SEM) and X-ray diffractometry (XRD) machine.

2.3 Methods

2.3.1 Bagasse carbonization

The bagasse was packed in the graphite crucible air tight, and place inside electric control furnace and burnt at a temperature of 1200^oC for 5hours to obtain a black color ash (see plate 2) which is the bagasse ash which was used in this research [5].
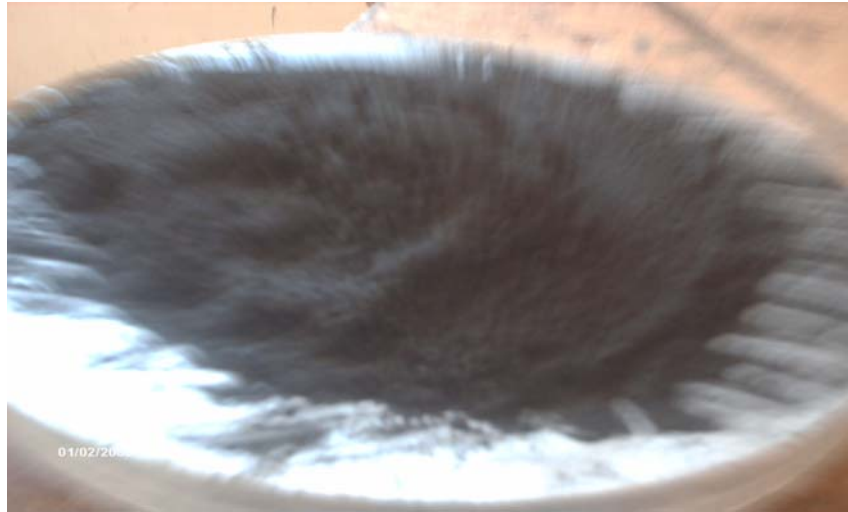
Plate 2: Photograph of the Bagasse after carbonization

2.3.2 Particles size analysis

The particle size distributions of the Bagasse ash were determined using the (AFS) specifications. 100g each of the dried ash was taken and introduced unto a set of sieves arranged in descending order of fineness and shaken for 15 minutes which is the recommended shaking time to achieve complete classification. The weight retained on each sieve was taken and expressed as percentages of the total sample weight. From the weight retained, the grain fineness number (AFS) was computed [5].

2.3.3 Chemical analysis and microstructure of the Bagasse ash

 The X-ray diffraction patterns of the ash sample derived from the bagasse was determine by X-ray diffraction analysis which was carried out with a Siemens D-500 diffractometer using Co-K_c radiation ($K_c = 1.79026\,A$). The microscopic study of the ash were determined by JEOL JSM840A scanning electron microscope (SEM) complemented by EDAX [5].

2.3.4 Production of the test sample

The   ash was mixed thoroughly with Arabic gum and water to enhance plasticity. The mixed blend was each packed into a mould box and pressed using hydraulic jack. A pressure of about $9kg/cm^2$ was applied to enhance excellent mouldability, homogeneity and surface smoothness of the samples [5].
The moulded samples were dried in an open air for 24 hrs at 110°C to expel any moisture and to avoid crack during firing. The dried bricks were then fired in an automatic digital electric furnace (Hood-type furnace) at a preset heating rate of 7°C/min at different temperatures shown below;

200°C for 6hours, 650°C for 4hours, 950°C for 3hours, 1100°C for 8hours and 1400°C for 8hours. After firing, the samples were allowed to cool in the furnace at a cooling rate of 1°C/min [4, 5]. The sample was then removed from the furnace for physical test (see Plate 3)

Plate 3: Photograph of the moulded Bagasse ash after firing

2.3.5 Firing shrinkage

The green weight of the sample was taken after moulding; and weight after firing was taken. The diagonal line across the sample in the green state and fired state were measured using the vernier caliper. The firing shrinkage was then calculated as a percentage of the original wet length as shown below [5, 7];

$$\% \ of \ fired \ shrinkage = \frac{L_B - L_D}{L_B} \times 100 \ (\%) \qquad \text{---------------------------- (1)}$$

Where, L_B = Dimension of green sample, L_D = Dimension of fired sample.

2.3.6 Density

The density of the respective samples was determined basically by measuring the mass and the volume by using the beam balance and the measuring cylinder respectively. It is then estimated from the formula given below [5-8].

$$\text{Density (g/cm}^3) = \frac{Mass \, (g)}{Volume \, (cm^3)} \qquad \text{--- (2)}$$

2.3.7 Refractoriness

The Pyrometric Cone Equivalent (PCE) as recommended by ASTM Test C-24 was   used in the determination of the refractoriness of the sample [5-7].

3. RESULTS AND DISCUSSION

3.1 Particle Size

Figure 1 shows the particle size distribution of the sample. The sample has a Grain Fineness Number (GFN) of 85.07, and based on this value, the sample can be considered to be fine as GFN value of 100 is ranked the finest.
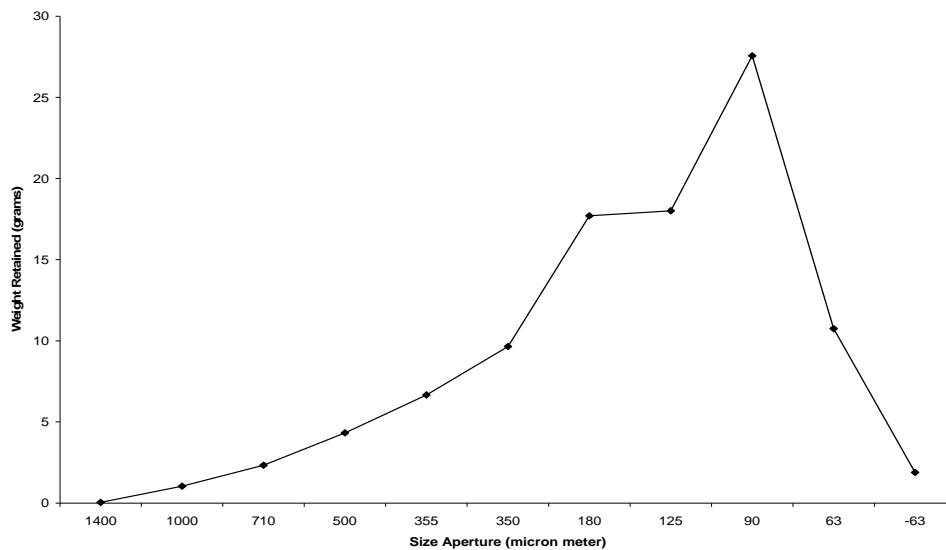

Figure 1: Particle size analysis of the Bagasse ash

Also, the sample can be considered to have met the AFS specification since four sieve-size, has the bulk of the retained sample on four consecutive sieves corresponding to 250μm, 180μm, 125μm, and 90μm size fractions (see Figure 1) respectively [5].

3.2 Morphology

The results of the X-ray diffractogram technique is presented in Figures 2-3, and Tables 1-2.
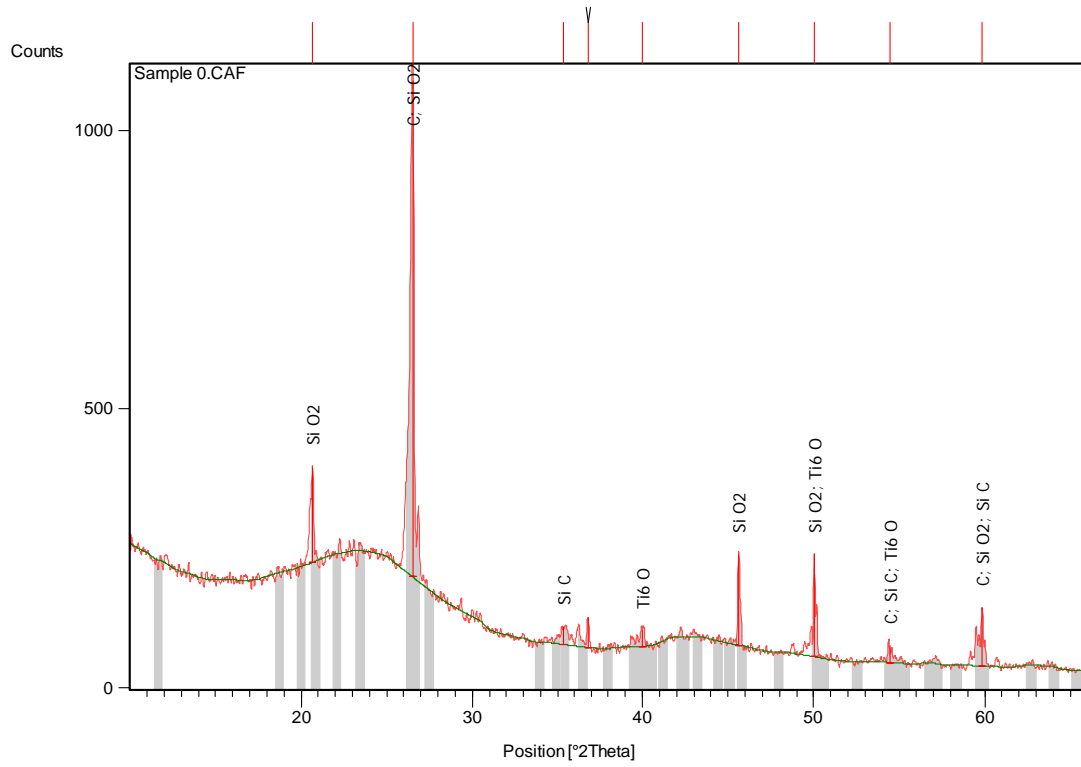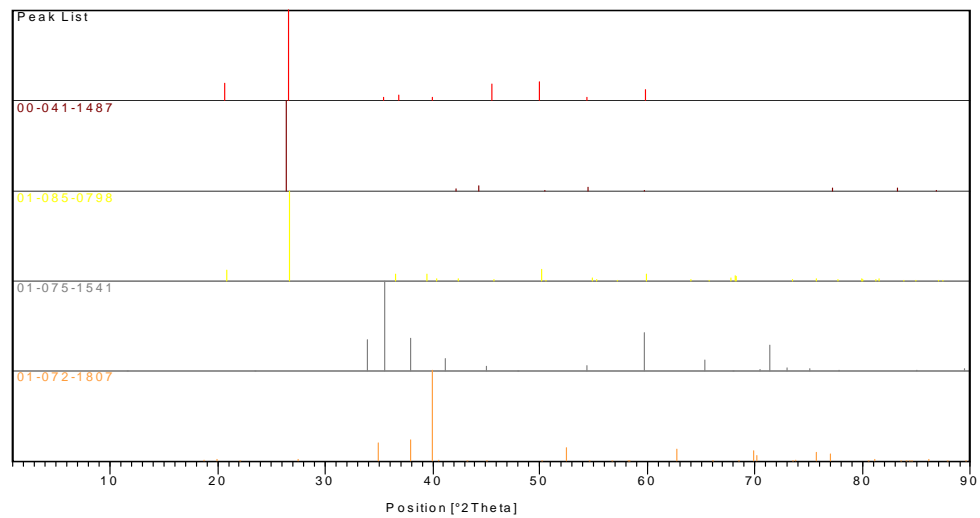
Figure 2: XRD pattern of the Bagasse ash

Figure 3: Plot of Identified Phases of the XRD

From the result obtained it was observed that, the major diffraction peaks are 20.68°, 26.53°, 35.41° and 40.00° and their inter-planar distance, 4.29Å, 3.36 Å, 2.54 Å and 2.26 Å, and their relative intensity of X-ray scattering are 19.17, 100.00, 3.59, and 3.26 and phases at these peaks as Quartz (SiO_2), Cliftonite:(C), Moissanite:(SiC) and Titanium Oxide:(Ti_6O), while each of these phases have a score of 30, 31, 19 and 18 respectively (see Tables 2-3). The result shows that carbon has the highest percentage of all the compound and element present as revealed by the XRD analysis [5].

Table 1. Identified Patterns List of the XRD.

| Visible	Ref. Code	Score	Compound Name	Displacement [°2Th.]	Scale Factor	Chemical Formula
*	00-041-1487	31	Cliftonite	0.000	0.657	C
*	01-085-0798	30	Quartz	0.000	0.084	SiO_2
*	01-075-1541	19	Moissanite	0.000	0.044	SiC
*	01-072-1807	18	Titanium Oxide	0.000	0.045	Ti_6O

Complete mineralogical analysis of bagasse ash carried out by X-Ray also revealed that the ash contains each of these elements C, O, Si, Ca, Ti, Al, Fe and Zr and none of these other elements H, Zn, Ga, Ge, As, Se, Br, Kr, Rb, Sr, Y, Nb, Mo, Tc, Ru, Rh, Pd, Ag, Cd, In, Sn, Sb, Te, I, Xe, Cs, Ba, La, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu, Hf, Ta are presented.

Morphologies of the bagasse ash by SEM with EDAX are show in Micrograph 1. The structure reveals that the size and shape of the particles vary; however, they can be sorted into three main groups — prismatic, spherical and fibrous [5].

The prismatic particles consist mainly of Si and O. The spherical ones contain Si and O as well as Ca, Al, Ti and Zr with small amounts of Fe. The fibrous ones consist of only C and SiC as a result of the EDAX scan in rectangle label A (see Micrograph 1). The results are consistent with XRD analysis of bagasse ash. Silica appears in prismatic particles or retained features of epidermal layer has been observed in other bagasse fly ash powders [5, 6].

Table 2. Peak List of the XRD

Pos. [°2Th.]	Height [cts]	FWHM [°2Th.]	d-spacing [Å]	Rel. Int. [%]	Tip width [°2Th.]	Matched by
20.6783	170.60	0.2362	4.29552	19.17	0.2400	01-085-0798
26.5272	890.09	0.1378	3.36021	100.00	0.1400	00-041-1487; 01-085-0798
35.4083	32.00	0.4723	2.53512	3.59	0.4800	01-075-1541
36.8181	53.84	0.1181	2.44122	6.05	0.1200	
39.9694	29.00	0.6298	2.25573	3.26	0.6400	01-072-1807
45.5970	161.25	0.1181	1.98956	18.12	0.1200	01-085-0798
50.0251	182.40	0.0960	1.82183	20.49	0.0800	01-085-0798; 01-072-1807
54.4399	31.76	0.2362	1.68545	3.57	0.2400	00-041-1487; 01-075-1541; 01-072-1807
59.8377	105.46	0.1200	1.54439	11.85	0.1000	00-041-1487; 01-085-0798; 01-075-1541
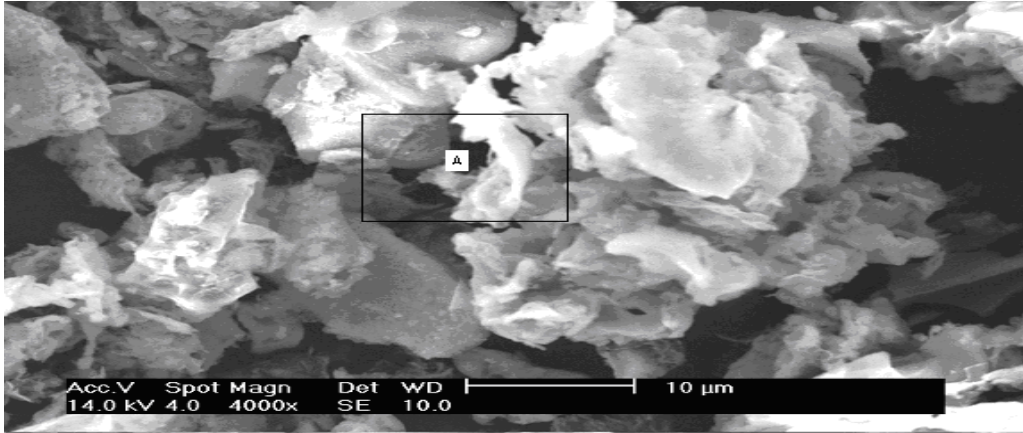
Micrograph 1: The structure of the bagasse ash as revealed by SEM/EDAX

The SEM result shows that both SiO_2 and carbon have a fine structure, the latter having a finer one. This could be associated with pore size of 4.29 Å (see Table 2) against carbon which has significant surface area in the range of hundreds of square meters per gram and microspores with pore size maxima around 3.36Å [5]. This is similar to bagasse ash obtained in other studies [4-6].

3.3 Firing Shrinkage

The firing shrinkage value of the bagasse ash is very low with a value is 0.85%. This result confirm with the structure observed in the microstructure which is mainly carbon, silica and silicon carbide, since silica and graphite (C) expand during firing [9].

3.4 Density

Density of the sample is $1.95g/cm^3$ which means that bagasse ash is very light material. The value obtained fall within the range of density of carbon and silica which is 1.8 and 2.2 g/cm^3 respectively [7, 9, 10].

3.5 Refractoriness

The sample was observed to have Seger Cone No. 23, with equivalent temperature of 1600^oC. This means bagasse ash can withstand operating temperature of 1600^oC without load [5, 9, and 11]**.**

4. CONCLUSIONS

From the analysis of the results given above, the followings conclusions can be made:
1) XRD analysis of the ash reveals Quartz:(SiO_2), Cliftonite:(C), Moissanite:(SiC) and Titanium Oxide:(Ti_6O) as the primary compounds
2) SEM/EDAX analysis reveals the presence of prismatic, spherical and fibrous structure, which also have similar compound with the XRD analysis.
3) The ash can withstand a temperature of up to 1600^oC with a density of $1.95g/cm^3$
4) Based on the above properties, it is clear that presence of oxides and carbon in the ash will make it suitable for refectory and ceramic products such as insulation, membrane filters and structural ceramics. Also with fine particle size characteristics, implies that this bagasse ash can be used as facing sand moulding during casting operations.

REFERENCES

[1] Balogun S.:Potential of cassava liquid extract as a quenching medium for ferrous metal, M.Sc thesis, Dept. of Metallurgical and Material Engineering, Ahmadu Bello University, Zaria, Nigeria, 2009, pp 12-40.

[2] Magudu .I.A, Abdulwahab .M, Aigbodion V.S: Effect of iron fillings on the properties and microstructure of cast fiber-polyester/iron filings particulate composite Journal of Alloys and Compounds, 476 (2009) 807–811.

[3] Aigbodion.V.S, Hassan.S.B, Olajide.S,O, Agunsoye.O.J, AbdulRahaman.A.S. Okafor.G.E, The use of rice husk ash as an aggregate for foundry sand production in Nigeria, Proceedings of the Nigerian Metallurgical Society (NMS), (2008) Annual Conference & Annual General Meeting, pp 16-22.

[4] Payá J, Monzó,.J , Borrachero .M V, Díaz-Pinzón .L, Ordóñez .L M: Sugar-cane Bagasse ash (SCBA): studies on its properties for reusing in concrete production Journal of Chemical Technology & Biotechnology , 2007, Volume 77 Issue 3, pp. 21 – 32.

[5] Aigbodion.V.S: Potential of using bagasse ash particle in Metal Matrix Composite, PhD work on-going, Department of Metallurgical and Materials Engineering, Ahmadu Bello University, Samaru, Zaria, Nigeria, 2008

[6] Barroso J, Barreras F, Amaveda H, Lozano A: On the optimization of boiler efficiency using bagasse as fuel. Fuel 2003;82:1451–63

[7] Osinubi.K.J and Alhassan.M: Bagasse ash modification of Shika laterite, Nigerian Journal of Engineering, 2007, Vol 14, No Pp96-74104

[8] Aigbodion V.S and Asuke,F: Effect of Kankara clay on some refractory properties of Igbokoda silica sand "Inter-Research Journal on Engr. Sci and Tech. 2007, vol.4, No.2, 66-73.

[9] Hassan, S.B: Modern Refractories: Production, Properties, Testing and Applications, 2005, pp 23-25

[10] Kevorkijan V: American Ceramic Society Bulletin, 2003, Vol. 82, p60.

[11] Chesti, A.R, .Refractories Manufacture, Properties and Application. Prentice Hall of private limited, London, 1986, 1-140.