

The Use of Bagasse Ash as a Source of Silica for Production of Container Glass

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Abstract: The study focused on the feasibility of recycling sugarcane bagasse ash (SCBA) to produce container glass. The bagasse was calcined through a Gallenkamp muffle furnace at 600°C and then held at 700°C for 1 ½ hrs and large amount of bagasse ash was obtained. 30 and 18 mesh sieves were used simultaneously to produce a fine powdered of the materials. 5g of SCBA sieved, calcium carbonate and sodium carbonate were passed through atomic absorption spectrophotometer. The result reveals SiO₂ 76.34wt%, Al₂O₃ 8.55wt%, Fe₂O₃ 2.93wt%, Na₂O 0.12wt%, TiO₂ 0.80wt%, K₂O 1.50wt%, CaO 0.07wt%, SO₃ 2.25wt%, Cr₂O₃ 0.05wt%, Mn₂O₃ 0.06wt% and LOI 6.42wt%. Interestingly, the ash contained high amount of silica of 76.34wt% which could supply all SiO₂ needed to produce soda lime silica glass. A container glass batch composition was formulated from 95.899g of SCBA, 19.220g of CaCO₃ and 25.556g of Na₂CO₃ and fired in muffle furnace at temperature between 1100°C-1200°C for 3 hours. The resulting glass was amber in colour which signifies the presence of iron oxide (Fe₂O₃) and sulphur trioxide (SO₃) in bagasse ash. This implies that the ash can be used to produce amber glass for beverages and storing pharmaceutical drugs especially those which are sensitive to light.

Keywords: Bagasse, Bagasse ash, Glass batch, Container glass, Soda lime silica

I. Introduction

Nigeria industries and energy production always produce waste. Nowadays, there is worldwide consensus that there is a need to recycle and reutilize these waste residues for an efficient utilization of natural resources [1].

A wide variety of industrial residues have been used as a substitute for flux in glassmaking, glass ceramic production, additive in concrete mixture. Rawlings, et al. [4] published a review on the re-use of residues containing silica for the production of glass.

In sugar mill bagasse is a residue after the sugar cane juice extraction. Bagasse is used as a fuel in boilers for thermal power generation in

the industry. The ash produce in the process is called as bagasse ash (BGA). The sugar cane bagasse ash (SCBA) waste can be characterized as a non-biodegradable solid waste materials rich in crystalline silica and aluminum, calcium, iron, potassium and magnesium oxides are the main minor components [2]. In addition to recycling these wastes and preventing them from being discharged in to the environment, natural resources used by industries are saved. Bagasse ash is part of sustainable power from biomass and contributes to the green image, while landfill with bagasse ash may be interpreted as waste of valuable materials.

The search for utilization option must deal largely with bagasse ash. Fuel composition and installation type are the primary factors that influence ash quality. Variations in the inorganic fraction of fuels are directly reflected in ash compositions. A large proportion of it has been recycled as a raw material for cement, glass, and glass ceramics and soil stabilizers.

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Nevertheless, the demand of silica tends to fluctuate periodically with the construction industry while the generation of bagasse ash increases gradually.

Therefore, it is necessary to search for a new option for industry while the generation of ash increases gradually. Therefore, it is necessary to search for a new option for the treatment of the ash. On the other hand, bagasse ash with a silica content of >78 wt. % can be used as a substitute source for silica in the manufacturing process of a silicate glass [3] in [5], in which the glass product can immobilize and stabilize the heavy metals in the glass matrix. Several studies have reported the recycling of bagasse ash as glass-based materials [4] in [5].

In Nigeria today, sugarcane waste (bagasse) is found littering in the streets, causing the prevalence of flies. It constitutes environmental nuisance as they form refuse heaps in areas they are disposed and resulting in the general contamination of the environment. In order to prevent this, a lot of investigation had been made by some authors such as [1, 5, 6, 7] on utilization of bagasse, it was reported that the major components of bagasse ash is silica greater than 78%. As a student of Glass and Silicate Technology, silica is a major raw material used to manufacture glass, ceramics and glass ceramic products which have led to high demand of silica materials in the development of glass. As a consequence there are massive destruction of land which has been one of the major costs of landslides and flashfloods during earthquakes and typhoons resulting to loss of thousands or even millions of lives. The result of this study is to provide an alternative means of using bagasse ash as a substitute for silica. This study will encourage them to study other materials that can be used in glass making material and awaken their minds regarding environmental protection. It is against this background that

the study explored the following research objectives: analyze the composition of bagasse ash, formulate and design container glass batch using bagasse ash as a source of silica and test-melt the formulated glass batch.

II. Methodology

A. Materials and Equipment

The raw materials that were used in carrying out the research includes: Bagasse ash (BGA), Limestone and Soda ash, Muffle furnace, AAS Machine, Sieve and Weighing Scale.

i. Bagasse Ash (BGA)

Bagasse was collected from Samaru Sabon Gari Zaria. The bagasse was carefully beneficiated which means that it was thoroughly washed with water to do away with dirt and some unwanted particles that came with it. Typically the bagasse was dried and burnt in an open atmosphere, the ash formed contained a lot of carbon on it. It was further calcined through a Gallenkamp muffle furnace through a heating rate of 600°C and then held at 700°C for 1 ½ hrs. At 700°C the organic compounds decomposed off and large amount of bagasse ash with high active silica content was obtained. This process took place at Department of Chemical Engineering Ahmadu Bello University Zaria. Small amounts of powdered ash were characterized using Atomic Absorption Spectroscopy (AAS) at National Research Institute for Chemical Technology (NARICT) Bassawa Zaria to determine its chemical composition.

ii. Calcium carbonate (CaCO_3) and Sodium carbonate (Na_2CO_3)

In this work, a material which is widely available and affordable (such as calcium oxide and sodium carbonate) was sought in order to make the process viable on an industrial scale. Therefore, SCBA was mixed

with (calcium carbonate) and a fluxing agent (sodium carbonate) to obtain a glass material with properties comparable to those which



Plate 1: Bagasse Sample



Plate 2: Burning Process



Plate 3: Bagasse Charcoal



Plate 4: Bagasse Ash

would be useful to the construction industry. The result analyses were used in formulation of a container glass batch. Sample of SCBA, calcium carbonate and sodium carbonate was pass through 18 mesh sieve (1mm); calcium carbonate (CaCO_3) and sodium carbonate (Na_2CO_3) gotten from Department of Glass and Silicate Technology Ahmadu Bello University Zaria (analytical grade), were used as source of calcium oxide (CaO) which act as a Stabilizer to modify the property of the glass and Sodium oxide (Na_2O) act as a flux to lower the melting temperature of the glass respectively. The result of the analysis was used in formation of glass batch.

iii. Chemical Analysis

The essence of the chemical analysis is to find the percentage of iron oxide impurities and amount of silica as well as other oxides in the sample. The analysis was carried out using AAS which is an energy dispersive microprocessor controlled analytical instrument designated for the detection and measurement of elements in a sample (liquid). Oxygen normalization method was used to convert each elements present to their respective oxides.

iv. Sieve, Weigh and Furnace

The bagasse ash was sieved with 30 mesh ($<0.59\text{mm}$) simultaneously to produce a fine powdered of the materials. The other raw materials like calcium carbonate and sodium carbonate were passed through 18 mesh sieve (1mm) and also weighed on analytical weighing scale at Department of Glass and Silicate Technology Ahmadu Bello University Zaria. The SCBA were used as a source of silica to obtain the container glass. The glass was prepared mixing SCBA ($<0.59\text{mm}$) with (1mm) mesh of calcium carbonate (CaCO_3) (stabilizer) and sodium carbonate (Na_2CO_3) (fluxing agent) using melting method. The mixtures were melted at 1400°C in an

electrical laboratory furnace at National Metallurgical Development Centre (NMDC), Jos.

B. Formulation of Batch

Batch formulation is defined as the proportion or weight of particular quantities of glass containing the individual component calculated for a previously defined total quantity. Composition of the bagasse ash as and all other raw material were calculated by percentage to formulate a batch.

The glass composition adopted was that of soda-lime glass. Due to the high presence of silica in BGA which is evident in the result from the AAS analysis and the silica content requirement of such soda-lime silicate glass as deduced from literature. The batch formulation was prepared using a ternary phase diagram of three component system (SiO_2 - CaO - Na_2O).

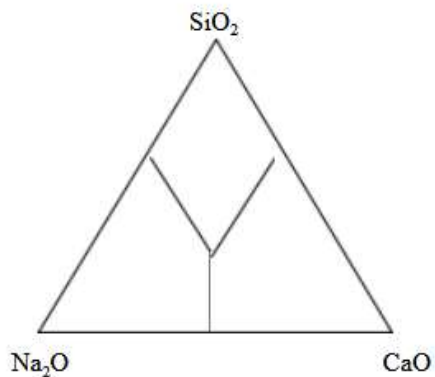


Figure 1: Ternary Phase Diagram

The composition of the soda-lime silicate glass which forms the basis of the calculation is as follows:

SiO_2 - - - - - 73.21wt%

Na_2O - - - - - 15.96wt%

CaO - - - - - 10.83wt%

Bagasse ash (BGA) was analysed to contain the following oxides in their percentages: 76.34wt% SiO_2 ; 8.55wt% Al_2O_3 ; 1.93wt% Fe_2O_3 ; 0.12wt% Na_2O ; 0.80wt% TiO_2 ;

1.50wt% K_2O ; 0.07wt% CaO [LOI = 6.42wt%]

C. Calculation

From the result of the analysis the calculation is this:

100g of BGA introduces 76.34g of SiO_2 (1)

Xg of BGA will introduce 73.21g of SiO_2 ..2)

$$= \frac{100 \times 73.21}{76.34} = \frac{7321}{76.34} = 95.899 \text{ g of BGA (3)}$$

Next stage is to calculate the quantity of the Al_2O_3 ; Fe_2O_3 ; Na_2O ; TiO_2 ; K_2O ; and CaO will the 95.899 of BGA contained.

Al_2O_3 : since 100g of BGA introduces 8.55g of Al_2O_3 , therefore 95.899g of BGA will introduce;

$$\frac{95.899 \times 8.55}{100} = \frac{819.936}{100} = 8.199 \text{ g of } \text{Al}_2\text{O}_3 \text{ (4)}$$

Fe_2O_3 : since 100g of BGA introduces 1.93g of Fe_2O_3 , then:

$$95.899 \text{ g of BGA will introduce } \frac{95.899 \times 1.93}{100} = \frac{185.08507}{100} = 1.851 \text{ g of } \text{Fe}_2\text{O}_3 \text{ (5)}$$

Na_2O : since 100g of BGA introduces 0.12g of Na_2O , then 95.899g of BGA will introduce;

$$\frac{95.899 \times 0.12}{100} = \frac{11.50788}{100} = 0.115 \text{ g of } \text{Na}_2\text{O} \text{ (6)}$$

TiO_2 : since 100g of BGA introduces 0.80g of TiO_2 , then 95.899g of BGA will introduce;

$$\frac{95.899 \times 0.80}{100} = \frac{76.7192}{100} = 0.767 \text{ g of } \text{TiO}_2 \text{ (7)}$$

K_2O : since 100g of BGA introduces 1.50g of K_2O , then 95.899g of BGA will introduce;

$$\frac{95.899 \times 1.50}{100} = \frac{143.8485}{100} = 1.438 \text{ g of } \text{K}_2\text{O} \text{ (8)}$$

CaO : since 100g of BGA introduces 0.07g of CaO 95.899g of BGA will introduce;

$$\frac{95.899 \times 0.07}{100} = \frac{6.71293}{100} = 0.067\text{g of CaO} \quad (9)$$

i. For Sodium Carbonate (Na_2CO_3)

The required amount of Na_2O in the batch is 15.96g. But 0.115g has been introduced by BGA respectively. The required amount of Na_2O from Sodium carbonate (Na_2CO_3) will be:

$$15.96\text{g} - 0.115\text{g} = 15.845\text{g}$$

$$\text{Na}_2\text{CO}_3 \rightarrow \text{Na}_2\text{O} + \text{CO}_2 \quad (10)$$

100g of Na_2CO_3 will give 62g of Na_2O ,
Xg of Na_2CO_3 will be 15.845g of Na_2O ,

$$X = \frac{100 \times 15.845}{62} = \frac{1584.5}{62} = 25.556\text{g of}$$

$$\text{Na}_2\text{CO}_3 \quad (11)$$

ii. For Calcium Oxide (CaO)

The required amount of CaO in the batch is 10.83g. But 0.067g has been introduced by BGA respectively. The required amount of CaO from calcium carbonate (CaCO_3) will be:

$$10.83\text{g} - 0.067\text{g} = 10.763\text{g}$$

$$\text{CaCO}_3 \rightarrow \text{CaO} + \text{CO}_2 \quad (12)$$

100g of calcium carbonate will give 56g of CaO ,
Xg of calcium carbonate will be 10.763g of CaO ,

$$X = \frac{100 \times 10.763}{56} = \frac{1076.3}{56} = 19.220\text{g of CaCO}_3 \quad (13)$$

D. Batch Composition

From the result AAS analysis, it can be seen

that the oxides present in the bagasse collected from Samaru location were used in the formulation of glass batch as shown in Table 1.

E. Melting process

A melting test was carried out to evaluate the suitability of bagasse ash as the main source of silica in the glass batch. The raw material was accurately weighed out and mixed thoroughly in order to facilitate homogeneity in the glass. The batch was then transferred into crucibles for melting in an electric muffle furnace at a temperature of 1400°C . A test melting was carried out to determine the suitability of bagasse ash as the main source of silica in the glass batch. The next reason for test melting is to ascertain the accuracy of the result of chemical analysis of the bagasse ash.

The analysis of the raw materials used for the glass batch provided data for the formulation of the batch. The batch formulated is a three-component system ($\text{SiO}_2\text{-CaO-Na}_2\text{O}$), which is acquired from Bagasse ash, calcium carbonate and sodium carbonate

III. Results and Discussion

The chemical analysis of the bagasse ash (BGA) is shown in Table 2 below. This composition was obtained from the AAS machine analysis. As shown in the Table sugarcane bagasse ash contained silica as the major compound with minor concentration of aluminum, sodium oxide, calcium oxide

Table 1: Summary of Raw Materials and Oxides Supplied

Raw materials	Amount of raw materials (g)	Oxides (g)						
		SiO_2	Al_2O_3	Fe_2O_3	Na_2O	TiO_2	K_2O	CaO
Bagasse ash	95.899	73.210	8.199	1.851	0.115	0.767	1.438	0.067
Calcium carbonate	19.220	—	—	—	—	—	—	10.763
Sodium carbonate	25.556	—	—	—	15.845	—	—	—
Total	140.675	73.210	8.199	1.851	15.960	0.767	1.438	10.830

and iron oxides. The obtained results are similar with the results reported by [8].

Table 2: Chemical Analysis of Bagasse Ash (BGA)

Oxides	Weight (wt)%
SiO ₂	76.34
Al ₂ O ₃	8.55
Fe ₂ O ₃	2.93
CaO	0.07
Na ₂ O	0.12
TiO ₂	0.80
K ₂ O	1.50
SO ₃	2.25
Cr ₂ O ₃	0.05
Mn ₂ O ₃	0.06
LOI	6.42



Plate 5: Formulated Batch composed of 95.899g of SCBA, 19.220g of CaCO₃ and 25.556g of Na₂CO₃



Plate 6: Melted Glass

The raw materials that were used in the preparation of this batch are silica from bagasse ash, soda ash and calcium carbonate. These glass batch was fired in muffle furnace at National Metallurgical Development Centre (NMDC), Jos. in a small refractory crucible to the temperature 1100°C - 1200°C instead of 1400°C due to lack of furnace facility in the environment available to fired at that temperature.

A. Melted Glass

The melted glass shown in Plate 6 above is an evidence of an achievement of a largely homogeneous melt, but not without the presence of whitish scum at the corners. A good melt is one which is homogeneous. Compatibility of the constituents is essential for a system in order to obtain a homogeneous glass.

The appearance of whitish scum might be due to lack of stirring at regular interval or might also results from the rapid melting of alkali i.e. when alkali melts too rapidly, it prevents proper sequence of glass forming reactions; foam or silica scum prevents heat from penetrating into the glass thus hindering refining and homogenizing. Whitish scum can occur as a result of rapid firing, the required temperature is about 1400°C.

The resulting glass obtained from the test-melting process was fired at temperatures between 1100°C - 1200°C for 3hours; an amber colour was also observed signifying the presence of iron oxide and sulphur trioxide in the ashes. This glass can be used to produce amber bottles for beverages and for storing pharmaceutical drugs especially those which are sensitive to light of certain wavelengths.

IV. Conclusion

Based on findings of this work, the study concludes that the major component of SCBA is SiO_2 (a glass network former) while Al_2O_3 , CaO and Na_2O which are generally used in glass melting process were found in ashes. Certain transition metal oxides particularly Fe_2O_3 , Mn_2O_3 and Cr_2O_3 were found in minor quantities in the bagasse ash. Further test carried out through the formulation of glass batch and test melting, confirmed that bagasse ash can be used as a substitute for silica in glass making. Glass produced from SCBA was amber in colour due to the presence of iron oxide and sulphur trioxide in the ashes and is recommended for the production of container glass for beverages and for pharmaceutical drugs especially those which are sensitive to light of certain wavelengths.

References

- [1] Bahurudeen, A. and Santhanam, M., "Performance Evaluation of Sugarcane Bagasse Ash Cement for Durable Concrete", *Proceedings of the 4th International Conference on the Durability of Concrete Structures (ICDCS'14)*, 2015, pp. 275-281.
- [2] Hariharam, V., Shanmugam, M. and Amutha, K., "Preparation and Characterization of Ceramic Products Using Sugarcane Bagasse Ash Waste", (*ISC-2013*), vol. 3, 2014, pp. 67-70.
- [3] Park, J.S., Taniguchi, S. and Park, Y.J., "Alkali Borosilicate Glass by Fly Ash From a Coal-fired Power Plant", *Chemosphere*, vol. 74, no. 2, 2009, pp. 320-324.
- [4] Rawling, R.D., Wu, J.P. and Boccaccini, A.R., "Glass-Ceramic: Their Production from Wastes A Review", *J.Mater.Sci.*, vol. 41, 2006, pp. 733-761.
- [5] Sales, A. and Lima, S.A., "Use of Brazilian Sugarcane Bagasse Ash in Concrete as Sand Replacement Sand Waste Management", vol.30, 2010, pp. 1114-1122.
- [6] Tagwoi, J.T., "Investigation of Bagasse Ash for Glass Making". *M.A Thesis, Department of Glass and Silicate Technology*, Ahmadu Bello University Zaria, 2009.
- [7] Teixeira, S.R., Romero, M. and Rincon, J., "Crystallization of SiO_2 - CaO - Na_2O Glass Using Sugarcane Bagasse Ash (SCBA) as Silica Source", *Journal of the American Ceramic Society*, vol. 19, 2010, pp. 450-455.
- [8] Teixeira, S.R., Romero, M. and Rincon, J., "Glass-Ceramic Material from the SiO_2 - Al_2O_3 - CaO System Using Sugarcane Bagasse Ash (SCBA)", *IOP Conf. Series Materials Science and Engineering*, vol. 18, 2011, pp. 112020.