OPEN ACCESS

Saudi Journal of Engineering and Technology
Abbreviated Key Title: Saudi J Eng Technol
ISSN 2415-6272 (Print) | ISSN 2415-6264 (Online)
Scholars Middle East Publishers, Dubai, United Arab Emirates
Journal homepage: https://saudijournals.com

Original Research Article

Effects of the Addition of Corncob Ash on the Technological Properties of Ugwuoba Clay, Nigeria

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DOI: 10.36348/sjet.2024.v09i02.009 | **Received:**18.12.2023 | **Accepted:** 25.01.2024 | **Published:** 16.02.2024

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Abstract

An investigation into the effects of combustible materials on the refractory properties of Ugwuoba clay, using corncob ash has been undertaken. Ugwuoba clay was sourced from Ugwuoba town in Oji River Local Government Area of Enugu State, Nigeria, while corncobs were collected at New Artisan Market in Enugu Metropolis. The clay was processed using standard beneficiation and purification procedures at the Ceramics Department of Projects Development Agency (PRODA), Enugu. The corncobs were calcined into amorphous ash by heating in a furnace at 650ºC. The refractory blends were compounded at the ratio of 90:10, 80:20, 70:30, and 60:40 for Ugwuoba clay (UGC) to Corncob Ash (CCA) respectively. These blends were subsequently moulded into the standard test pieces for the various properties determination and subjected to firing at temperatures of 900ºC, 1000ºC, 1100ºC and 1200ºC. Thereafter, the fired samples were characterized for fired shrinkages, total shrinkages, apparent porosities, water absorption coefficients, apparent densities, bulk densities and cold crushing strengths. The results obtained for each of the blends showed that the values were within the tolerable limits for industrial refractories with the 20%CCA blends showing the best results when compared with the other blends. A conclusion is drawn to the effect that corncob ash can serve as good organic admixtures for refractory bricks production for the lining of melting furnaces in the metals industry, hence opening new frontiers for recycling of these agricultural wastes for environmental safety and economic development in Nigeria.

Keywords: Ugwuoba clay, Corncobs, Ceramics, Refractories, Environment, Economics.

INTRODUCTION

The pressing needs in Nigeria and the availability of abundant natural resources demand that the direction of utilization of locally available resources be broadened through scientific and technological research and new or improved technology. Technological development in Nigeria has created the needed awareness and has impacted positively on the standard of living of both urban and rural dwellers, leading to increasing use of modern industrial appliances. If Nigeria is to sustain increased industrial growth, the iron and steel industries must be sustained and new ones established. These iron and steel industries among others like the cement and building materials industries make use of furnaces and the furnaces are by process requirements lined with refractory bricks. The refractories are largely produced using kaolin or other clays or a combination of clays and other admixtures. Clay is a fine-grained rock which when suitably crushed and pulverized, becomes plastic when wet, leather-hard when dried and on firing is converted to a permanent rock-like mass (Nwajagu & Idenyi, 2003). Clays are complex alumino-silicate compounds containing water molecules, with the simplest form of its chemical formula as $Al_2O_3.2SiO_2.2H_2O$ (Singer *et al*., 1963). The various types of clays are distinguished according to their commercial utilities as kaolin (or China clay), ball clay, fire clay, red brick clay, and stoneware clay (Odo & Nwajagu, 2003).

Refractories belong to the class of ceramic materials which are employed for high temperature applications, usually above 1100^oC (Mokwa & Salihi, 2011). Besides being used as furnace linings, refractory materials find applications in kilns, incinerators, and reactors or other heat bearing equipment. They are also used to make crucibles and moulds for casting glass and metals and for surfacing flame detector systems for rocket launch structures (Mokwa *et al.,* 2019).

Kaolin is used as fire bricks because of its unique properties such as natural whiteness, fine particle size, non-abrasiveness and chemical stability. In addition to the general properties mentioned above, it is soft and has low viscosity at high solid contents (Kirabira, Johnson & Byaruhanga, 2003).

The determining factor for refractoriness of furnace bricks is the alumina content of such refractories. The higher the alumina contents of the clay, the higher the refractoriness (Nwajagu & Idenyi, 2003).

Some Nigerian clays are unsuitable for ceramic and many industrial applications because they have intolerable high levels of impurities such as iron oxides. Recent studies have tended towards finding ways of improving on the quality of our existing clays, while efforts continue in exploring new clay deposits. Part of these measures include but not limited to the use of natural organic waste materials that can be benefited as admixtures to the clay to improve on their refractory properties. Therefore, beneficiation of these locally available raw materials in view of upgrading their properties to that of standard commercial clay of various type is of paramount importance. There is need to explore different methods of improving and upgrading the materials including the use of additives (Mohammadu, 2013).

In order to determine the profitability of utilizing clays for any application, it is important to examine the microstructural morphology, determine the mineralogical composition and analyze the various phases in the clay deposits. However, since most of the clays in Nigeria have not been characterized they are deemed unsuitable in terms of meeting requisite properties for industrial applications. A study of the elemental and mineralogical composition of Nigeria clays would reveal their compositions and properties hence their suitability for use as raw material will also be revealed.

The ever increasing demand of clays for industrial application calls for modification by the use of additives to meet the technological and local consumption. Modification of clays will enhance clay properties to meet the requisite requirements for industrial applications hence compete excellently with imported ones (Dansarai *et al.,* 2020).

The industrial utilization of a clay deposit depends on its geological, mineralogical, chemical and physical properties. The assessment of economic potentialities of a clay body must involve the evaluation of the parameters. Some of the commonest and important applications of clays are in the manufacture of paper, paint, plastics, ink, roofing sheets, pottery, bricks, ceramics, floor tiles and rubber. Clays also find various applications in the manufacture of cement, fertilizers and insecticides (Asamoah *et al.,* 2018). They are used in advanced chemical processing because of their reactivity and catalytic activity (Vieira *et al.,* 2010). Clays are also utilized in pharmaceuticals and food processing industries (Murray, 2007). Some of these applications require the processing or the blending with other materials so as to improve on some desired characteristics of the finished product (Emofurieta *et al.,* 1994).

Numerous studies exist on clay deposits that are widely spread in Africa and especially Nigeria (Irabor, 2002; Odo & Nwajagu, 2003). Some clay deposits in Nigeria have been investigated for various applications. Several clay deposits in Southern Nigeria have been evaluated and found potentially suitable for the manufacture of bricks, refractories, tiles and pottery (Akpokodje *et al.,* 1991; Attah *et al.,* 2001; Attah, 2008). The mineralogical, physical, geochemical and economic appraisals of some clay and shale deposits in South Western and North Eastern Nigeria have been discussed (Emofurieta *et al.,* 1994).

A corncob, also called cob of corn or corn on the cob, is the central core of an ear of corn (also known as maize). It is the part of the ear on which the kernels grow. The ear is also considered a “cob” or “pole” but it is not fully a “pole” until the ear is shucked, or removed from the plant material around the ear. When harvesting corn, the corncob may be collected as part of the ear (necessary for corn on the cob), or instead may be left as part of the corn stover in the field. The innermost part of the cob is white and has a consistency similar to foam plastic. To produce ash generally from organic matter requires calcination in a closed atmosphere to a temperature between 600^oC and 700^oC. It is at this range of temperature that the allotropic form of the ash (amorphous) is obtained (Murray, 2006).

Most research work carried out on refractories in Nigeria had centred on testing for their physical and chemical properties to ascertain their suitability in the production of fire bricks for lining furnaces. Characterization of Ugwuoba clays have been carried out by previous researchers (Odo, *et al.,* 2009), but their blends with other materials admixtures are yet to be investigated. This study seeks to address this knowledge gap by compounding various blends of the clay with corncob ash and bagasse ash and subjecting them to characterization processes to establish their industrial suitability. Successful modification of these clay blends for refractory applications will serve as source of refractory materials to the local industries and this may trigger off the establishment of small-scale industries for making refractory bricks, which will create jobs for the locals and help improve the economy.

METHODOLOGY

Sampling of the Clays

Twenty kilograms (20 Kg) of the clay was obtained from the deposit at the outskirts of Ugwuoba, a suburb in Anambra State, Nigeria. The clay deposit sites were dug 1.5 meters deep into the earth at four different locations using an iron digger and samples were collected at same locations mentioned above and thereafter transported to the test location. The clays were allowed to dry naturally under the sun for four (4) days. Since the clays are naturally bonded, no other additive was introduced into it prior to sample preparation. The clay samples were each made into slurry to remove organic matter and sand particles. The slurries were dewatered and the resulting mass air-dried. The hard mass was then subsequently crushed and sieved using BS72.

Sampling of the Corncob

Five Kilograms (5 Kg) of corncobs were sourced around New Artisan Layout Enugu, Nigeria where corn roasters stay to sell corns. The corncobs were dried in the sun, crushed and ground before being loaded into the muffle furnace. The furnace was set at 650°C allowed to stand for sufficiently long period of time to allow for proper calcination into amorphous ash and then allowed to cool in the furnace till the next day. Thereafter the ash was removed from the furnace.

Compounding the Clay-Corncob Blends

The clay and the corncob ash (CCA) samples were then compounded according to the following ratios: 90:10, 80:20, 70:30 and 60:40 in the order Ugwuoba Clay (UC): Corncob Ash (CCA). Test samples were made from the blends and fired at 900°C, 1000°C, 1100°C and 1200°C. The experiments were carryout in the Ceramics Engineering Section of Projects Development Agency (PRODA), Enugu, Nigeria.

Characterization of the Blended Clay-Corncob Samples

The characterization of physical and chemical properties of clay samples were carried out on the blends as follows: Bulk density, apparent density, porosity, water absorption, cold crushing strength, dry compressive strength, refractorines and elemental composition of the clay samples.

RESULTS AND DISCUSSION

Results

Tables 1 and 2 represent the chemical compositions of Ugwuoba clay and Corncob ash respectively; while Table 3 represents the chemical composition of the blended samples of the Ugwuoba clay and Corncob ash correspondingly. Figures 1 – 6 show the various properties of the blends of Ugwuoba clay and Corncob ash accordingly.

Table 1: The chemical composition of Ugwuoba clay

Chemical Compound	Composition (%)
Silica (SiO_2)	64.87
Calcium Oxide (CaO)	0.22
Alumina (Al_2O_3)	20.56
Iron Oxide (Fe_2O_3)	4.75
Magnesium Oxide (MgO)	0.75
Sodium Oxide (Na_2O)	0.15
Potassium Oxide (K_2O)	1.64
Sulphur Trioxide (SO_3)	0.04
Loss on Ignition (LOI)	5.99

Table 2: The Chemical Composition of Corncob Ash and Sugarcane Bagasse Ash.

Chemical Compound	Corncob Ash (%)
Silica (SiO_2)	47.78
Calcium Oxide (CaO)	16.70
Alumina (Al_2O_3)	9.40
Iron Oxide (Fe_2O_3)	8.31
Magnesium Oxide (MgO)	7.80
Sodium Oxide (Na_2O)	1.89
Potassium Oxide (K_2O)	5.42
Phosphorus Oxide (P_2O_5)	N.A.
Sulphur Trioxide (SO_3)	2.70

Table 3: The Chemical Composition of the blends of Ugwuoba Clay with Corncob Ash

Compound	100% UGC	10%CCA	20%CCA	30%CCA	40%CCA
SiO_2	64.87	64.90	64.88	64.91	64.92
CaO	0.22	2.18	1.20	3.15	4.13
Al_2O_3	20.56	18.64	19.60	17.69	16.74
Fe_2O_3	4.75	4.80	4.78	4.83	4.85
MgO	0.75	1.00	0.88	1.13	1.25
Na_2O	0.15	0.15	0.15	0.15	0.15
K_2O	1.64	2.11	1.88	2.35	2.58
SO_3	0.04	0.63	0.34	0.93	1.22
P_2O_5	1.03	1.03	1.03	1.03	1.03
LOI	5.99	5.99	5.99	5.99	5.99

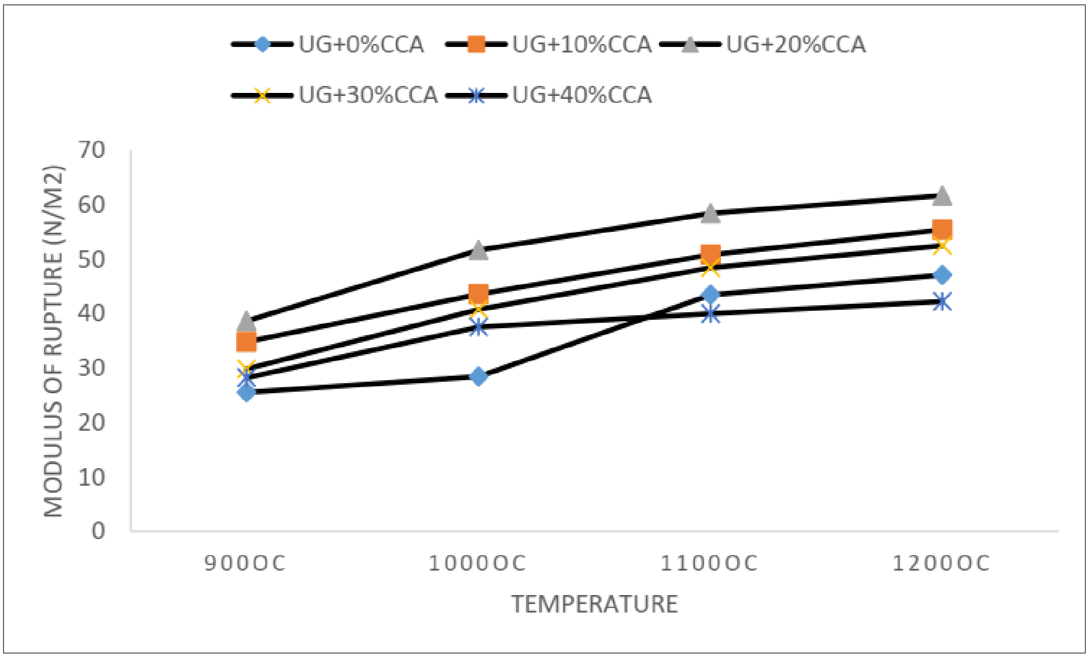

Fig. 1: Compressive strength against temperature of blends of Ugwuoba Clay and Corncob Ash.

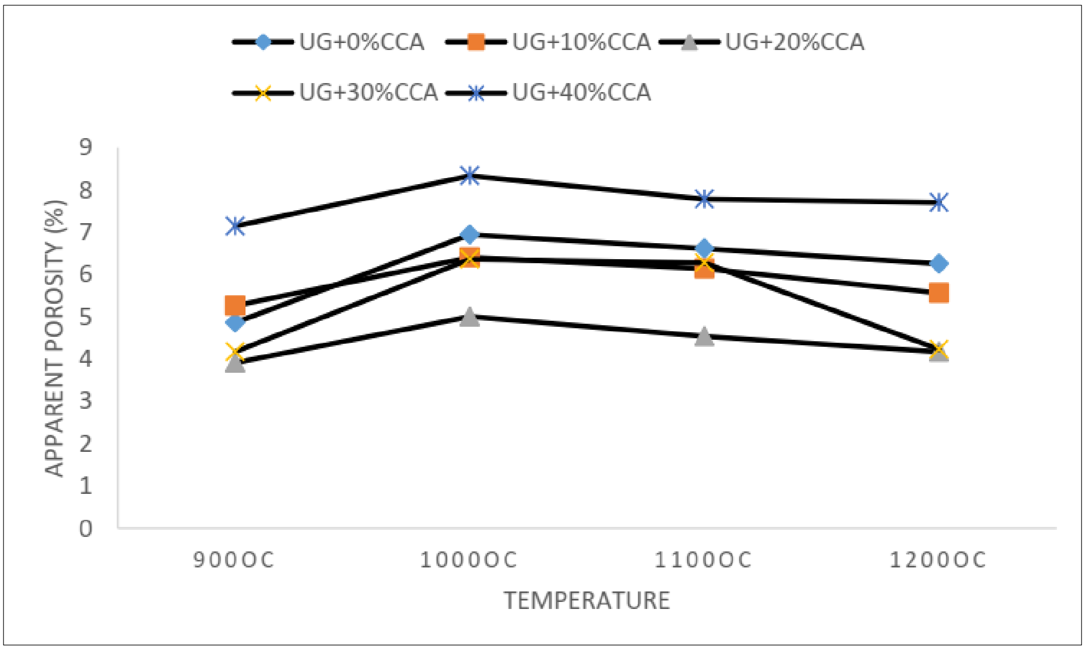

Fig. 2: Apparent Porosity against temperature of blends of Ugwuoba Clay and Corncob Ash.

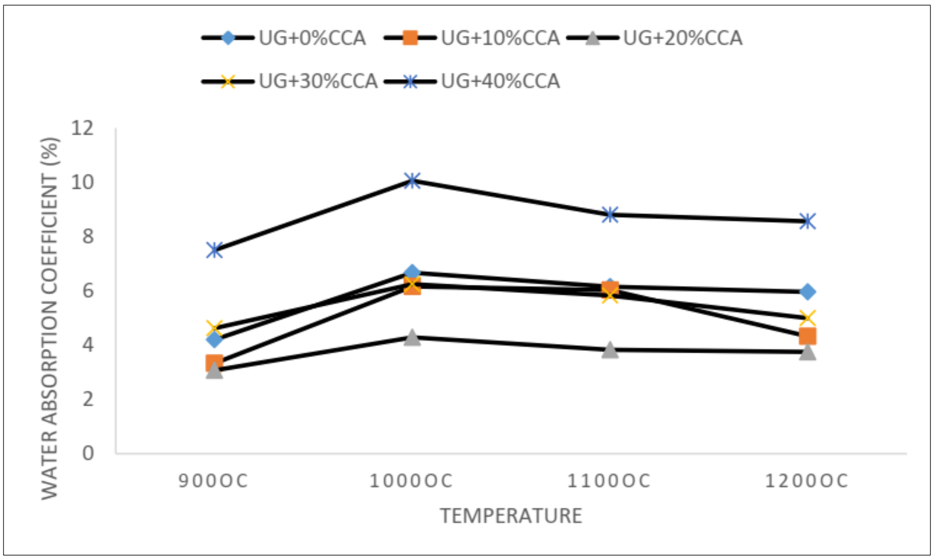

Fig. 3: Water Absorption Coefficient against temperature of blends of Ugwuoba Clay and Corncob Ash.

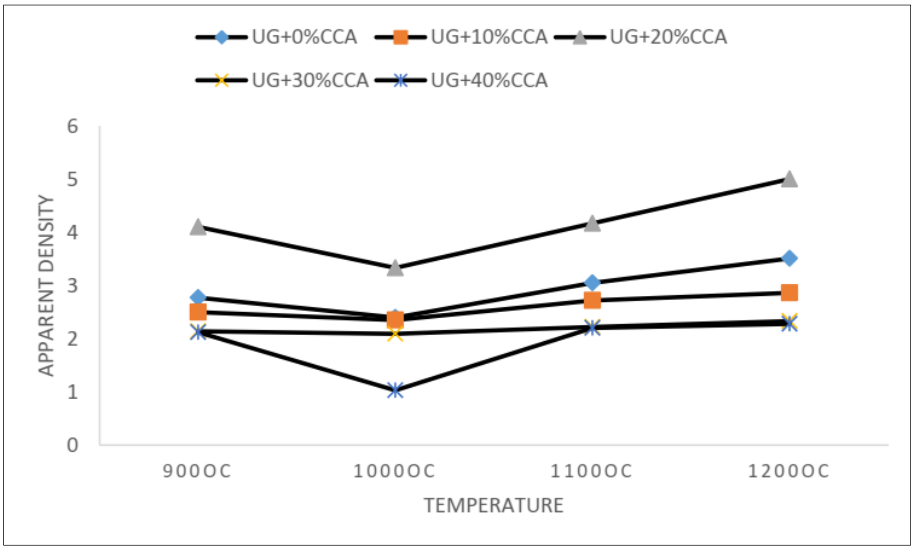

Fig. 4: Apparent Density against temperature of blends of Ugwuoba Clay and Corncob Ash.

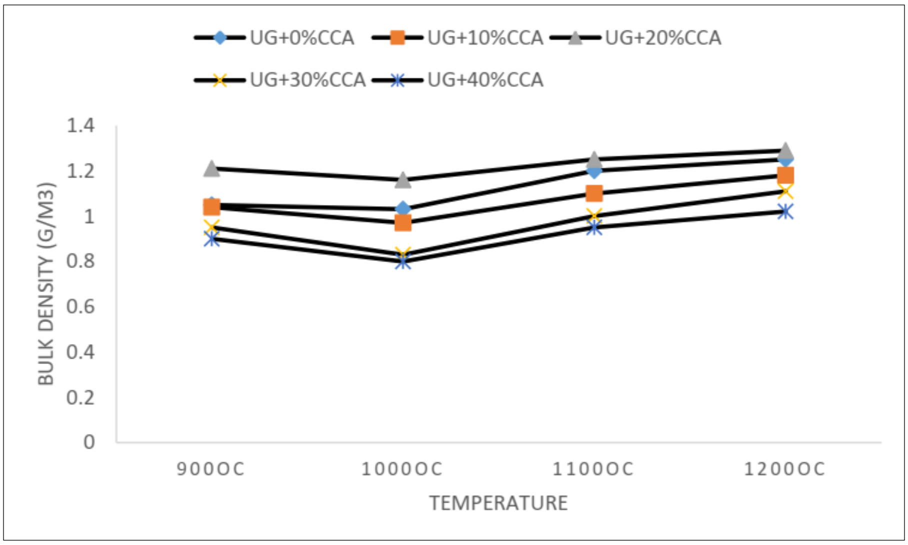

Fig. 5: Bulk Density against temperature of blends of Ugwuoba Clay and Corncob Ash.

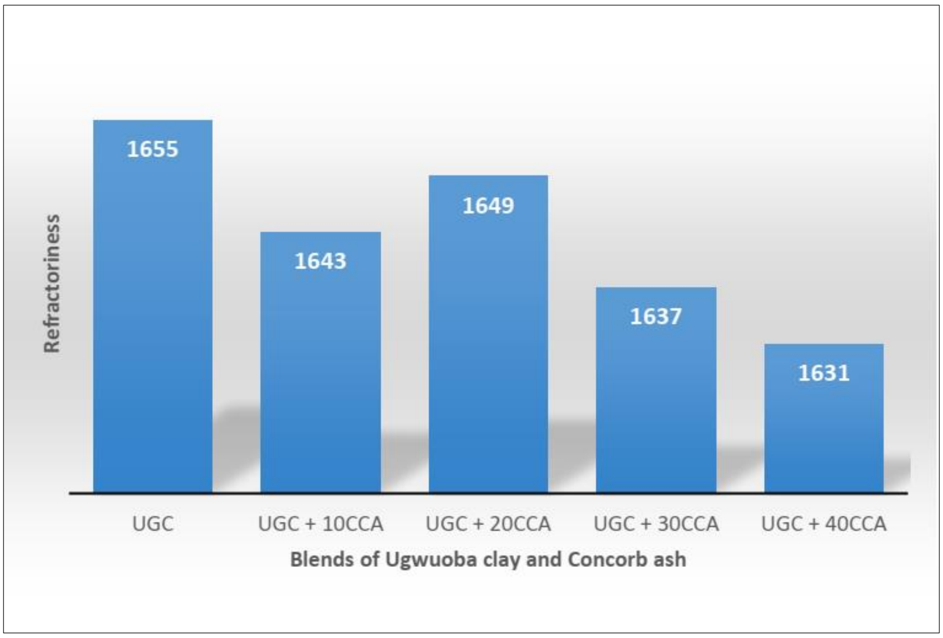

Fig. 6: Refractoriness values of the blends of Ugwuoba clay and Corncob ash.

DISCUSSION

Cold Crushing Strength (CCS)

Cold crushing strength refers to the ability of a material to withstand a compressive load without breaking or crumbling. It is often used in assessing the strength of refractory materials like ceramics or bricks under compression (Carter & Norton, 2007; Kingery *et al*., 1976; Wachtman, 2009). Cold Crushing Strength (CCS) and Dry Compressive Strength increase with firing temperature. From Figure 1, it is evident that among all the blends, the 80:20 blend of UC: CCA in that order of ratio presented the highest values for the strength at the various firing temperatures.

Apparent Porosity

Apparent porosity quantifies the fraction of the volume of pores or voids in a material concerning its total volume, expressed as a percentage. Apparent porosity directly impacts the material's quality and performance. Lower apparent porosity indicates a denser material with fewer voids, usually translating to better mechanical strength, resistance to thermal shock, and enhanced performance in various applications (Balczar *et al*., 2015; Machmud *et al*., 2016). This trend is clearly seen to be obeyed by the blends studied and from Figure 2, it can be clearly seen that the 80:20 blend had the least values of apparent porosity across all range of firing temperatures, thereby making it the best blend for use in the industry.

Water Absorption Coefficient

This property refers to the percentage of water absorbed by the clay when immersed or exposed to water for a specific duration. It is an essential indicator of the quality and porosity of clay. Lower absorption often indicates a denser and less porous material, which generally leads to better mechanical strength, durability and resistance to environmental factors like freeze-thaw cycles (Bomberg *et al*., 2005; Mukhopadhyaya *et al*., 2002). Water absorption coefficient is affected by such factors like, clay mineralogy, particle size distribution, processing and firing conditions among others. In the construction industry, clay bricks, tiles and ceramics with controlled water absorption coefficients are used to ensure durability and resistance to weathering (Sicakova *et al*., 2017; Feng & Janssen 2018). Although all the blends obeyed this behavior, it can be shown from Figure 3 that the 80:20 blend has the lowest water absorption coefficients at all the firing temperatures, making it the preferred blend for use.

Apparent Density and Bulk Density

These are measures of the mass of the clay per unit volume. But while apparent density refers to the mass of a unit volume of a material, including both the solid material and the pores or voids within it, bulk density, on the other hand is the mass of the material per unit volume, excluding the volume occupied by the pores or voids (Chepil, 1950; Ituma *et al*., 2018). It is important to note that lower apparent density values, often indicating higher porosity, might suggest reduced mechanical strength, increased water absorption or decreased resistance to thermal shock. This study suggests that all the blends followed this established trend and judging from Figures 4 and 5, the 80:20 blend showed the best results for these densities among all the blends investigated.

Refractoriness

Refractoriness refers to the ability of a material to withstand high temperatures without deforming or softening. The refractoriness of ceramics is influenced by factors such as composition, crystal structure, and fabrication process. Materials with high melting points, such as alumina (Al_2O_3), silica (SiO_2), and zirconia (ZrO_2), exhibit excellent refractoriness. However, despite their excellent refractory properties, ceramics might experience limitations under certain conditions. Factors like thermal shock, sudden temperature changes, or exposure to corrosive environments can compromise their refractoriness leading to cracking or degradation (Singer *et al*., 1976; Murray, 2004). When critically examined from Figure 6, the 80:20 blend shows the highest values of refractoriness under the conditions tested.

CONCLUSION

It can be concluded from the research findings that Ugwuoba Clay is suitable for refractory bricks production based on the values of the its chemical composition and the values of apparent porosities, water absorption coefficients, apparent densities, bulk densities and cold crushing strength of the various blends with corncob ash. Significantly, the 20%CCA is adjudged the best under the prevailing circumstances within which the study was conducted. Based on the foregoing, it is recommended that further research be carried out on Ugwuoba clay using combustible materials as corncob ash but fired at higher temperatures up to 1500^oC. This will ensure the reliability of the refractory especially by determining its refractoriness at that temperature.

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