International Journal of Humanities Social Science and Management (IJHSSM)
Volume 4, Issue 2, Mar.-Apr., 2024, pp: 638-647 www.ijhssm.org

Elements, Water Absorption Capacity and Opacity of *Bos Indicus* Bone, Borax, Adobe and Soda Ash Derived Ash Glazes

Akinde Toyin Emmanuel[1, 2*] and Kalilu Razaq Olatunde Rom[1]
[1]Department of Fine and Applied Arts, Ladoke Akintola University of Technology, Ogbomoso, Nigeria
[2]Department of Creative Arts (Visual Arts), University of Lagos, Akoka, Nigeria
[*]Corresponding Author

Date of Submission: 15-03-2024 Date of Acceptance: 30-03-2024

Abstract
This study was conducted with the aim of deriving opacifier from *Bos indicus* bone and combining it with Borax, Adobe and Soda ash to formulate opaque glazes. Elements of all the samples were qualitatively and quantitatively determined through particle induced X-ray emission and Rutherford Backscattering spectroscopy techniques. The samples' water absorption capacity analyses were done using dry base technique. Results showed CaO at 31.41% as the dominant element of *Bos indicus* bone ash, Na_2O at 15.35% for Borax, Si_2O_3 at 40.89% for Adobe and Na_2O at 45.20% for Soda Ash. The water absorption capacities were 22%, 24%, 22% and 0% respectively for *Bos indicus* bone ash, Borax, Adobe and Soda ash. The samples were jar-milled into glaze batches, applied on bisque wares; and fired in a down draught kiln at cone 09 (1120) resulting in successful opaque glazes. The study has identified an organic source of calcium and indicated calcium as opacifier, determined *Bos indicus* bone as a rich source of calcium for glaze opacity, demonstrated the effectiveness of *Bos indicus* bone ash as opacifier and as glaze; and evolved two glazes named Bosinbo Ash Glaze and Bosinboadso Ash Glaze and from which other opaque glaze models can be derived.

Key words: Glaze, *Bos-indicus*, Opacifier, Borax, Adobe, Soda-ash

I. Introduction

Glaze generally is a glassy solution that renders clay host immune to liquid, smooth to touch and colourful to vision; a quality that made it *sine-qua-non* to all ceramics finishes (Peterson, 1998: 9; Kalilu, 2013: 20; Akinde, 2016: 1). Glaze on various household utensils such as kitchen and table wares is prevalent (Singer and Holmyard, 1956: 261; Singer and Singer, 1963: 1089-1102; Kalilu, Akintonde and Ayodele, 2006: 74-80; Abiodun, Akintonde and Akinde, 2013: 103-104). Glaze, by nature, could be transparent, matt or opaque. Opaque surface effect of a glaze also known as opacity is simply the insolubility of chemical crystals in glaze. Opacity, the measure of impenetrability to radiation, prevents light from penetrating glass formation as a result of the presence of tin (Rhodes, 1998: 202; Akinde and Kalilu, 2022: 1-2), zirconium and titanium oxides and as such increase glaze viscosity and accelerate its crawling. Tin oxide is regarded as the best opacifier but glaze opacity is also obtainable by addition of marl, chalk or calcium carbonate (Hughes, 1965: 102). Other means of achieving opacity in glaze are commercially available in frit forms (Rhodes, 1998: 203). Glaze opacifier has equally been derived through organic wastes from animals, particularly from shells and bones as a result of their titanium, zinc, zirconium and calcium contents (Rhodes, 1998: 203).

The use of shells and bones for glaze production has not been of adequate scholarly interest in Nigeria. Ceramic production is at two different levels in Nigeria: industrial and studio practice. The industrial sector, which is relatively at a low capacity, is not supported by active research, while the studio practitioners are largely not scholars or research oriented. In these contexts glaze formulators have therefore largely relied on foreign supplies of imported tin oxide. Nonetheless, there have been some efforts at glaze formulation locally, especially at studio level, in Nigeria. Munai and Halliru (2010) used egg shell as alternative calcium source in glaze. Ologunwa, Akinbogun and Kashim (2013), Kalilu and Akinde (2022) and Akinde and Kalilu (2022) at various times used the combinations of cow bone with imported tin and other synthesized oxides at varying proportions to formulate glaze opacifier. Other studies such as Ogusina (1997), Alasa (2005) Akinde (2009) and Kalilu and Akinde (2023) have not been on shells or bones but on plant materials such as maize sheaths, wood residue from fireplace and fruit peelings. Generally, Ogunsina, Alasa, Kalilu and Akinde's efforts were directed only at glaze formation. Opacity of the glazes derived was not of interest in their studies. Not much interest has therefore been given to research in alternative source of glaze opacifier other than the generally known and imported tin, zirconium, titanium and other related oxides.

II. The Study

This study is an examination of the elements and water absorption capacity of *Bos indicus* bone-derived ash, Borax, Adobe and Soda ash on the one hand and production of opaque glazes with these materials on the other hand. The aim of the study is to derive opacifier from *Bos indicus* bone and combine it with the other glaze materials with a view to formulating opaque glazes. The objectives of the study include: elemental analysis and water absorption capacity test of ash derived from the bone of *Bos indicus*, Borax, Adobe and Soda ash; formulation of opaque glaze batches; and studio application of the glazes.

Bos indicus is the generic and taxonomic name of cattle indigenous to tropical Africa, and breed in Nigeria, especially in the northern part of the country. It is locally known according to types such as Zebu, *Bunaji*, *Ndama*, *Sokoto*, *Gudali*, *White Fulani*, *Yakanaji*. *White Bororo* among other local typological names. An average *Bos indicus* is large, weighing between 147 kg and 1, 363 kg and with a height of between 123 cm and 133 cm. The bones in a typical *Bos indicus* constitute about twenty five percent (25 %) of its total mass. The bones are readily available at abattoir across the country.

The research design for the study is in two folds: scientific and artistic approaches. The scientific approach involved elemental and water absorption capacity analyses of samples. The artistic approach involved the studio application of ash glaze batches derived from the samples.

III. Methodology

The samples, *Bos indicus*, borax, adobe and soda ash were randomly sourced at different places. The *Bos indicus* bones were collected at an abattoir in Ogbomoso, Oyo State, Nigeria. Animal bones as wastes generated in abattoirs, are largely utilized, at subsistence level, in poultry feeds in Nigeria but a small number of them are thrown away to bio-degrade. Adobe on the other hand was mined from a clay deport in Igbon town, Oyo State, Nigeria, while borax and soda ash were imported commodities obtained from a ceramics shop in Lagos State, Nigeria.

The elemental concentrations of the samples were qualitatively and quantitatively determined at the Centre for Energy Research and Development (CERD) in Obafemi Awolowo University, Ile-Ife, Osun State, Nigeria. The analyses were done using Tandem accelerator machine capable of exploring particle induced X-ray emission (PIXE) and Rutherford Backscattering spectroscopic (RBS) techniques. These techniques detect elemental configuration of samples when exposed to ion beam atomic (IBA) excitements giving off electromagnetic (EM) radiation specific to an element (Brower, Wade and Sernau, n.d). The samples' water absorption capacity analyses were done using dry base technique. This implies that the samples were in dehydrated states. These procedures were done at the Food Chemistry Laboratory of the Department of Food Science and Engineering of Ladoke Akintola Unversity of Technology, (LAUTECH) Ogbomoso, Nigeria. The analyses involved using a digitally powered centrifuge machine. These procedures were run thrice, so as to give the benefit of the doubt and to allow for average reading of the values of each sample.

The studio application involved calcinations of the *Bos indicus* bones using down draught kiln at DAPO Art Studio in Oyo town, Oyo State, Nigeria. The Calcine bones were grinded to ashes using mortar and pestle at the Chemistry laboratory of Ladoke Akintola University of Technology, Ogbomoso, Nigeria. The bone ashes and the other samples were jar-milled into batches at the Ceramics Studio of the Department of Fine and Applied Arts of Ladoke Akintola University, Ogbomoso, Nigeria. The batches were applied on bisque wares and fired as glazes in a down draught kiln of the Ceramics Section of the Department of Fine and Applied Art of The Polytechnic Ibadan, Oyo State, Nigeria.

IV. Treatment of Bones Samples

Eleven point three two kilograms (11.32 kg) of *Bos indicus* bones were collected as samples. The bones were washed and dried in an open space to dehydrate physical water contents. The bones were later calcined in an improvised crucible pot with the aid of a front loader down draught wood powered kiln at cone 06 (991 ^{o}C). The calcined cattle bones gave a variance of white, which were thereafter grinded into ash with mortar and pestle. The bone ash was sieved to remove unwanted particles. The water was stirred and allowed to

International Journal of Humanities Social Science and Management (IJHSSM)
Volume 4, Issue 2, Mar.-Apr., 2024, pp: 638-647 www.ijhssm.org

settle for six hours. When the ash settled in the water, the surface water in the container was systematically and carefully decanted with the aid of hand gloves; employed to protect the hands and skin against the toxicity of the soluble water (Figure 1). This exercise was repeated six times until it was evident that the soluble fluxes of the bones as have been removed. After the final decanting, the slurry of the ash was poured into a 30 mm fine mesh suspended by tying the mesh on a bucket. The slurry was thereafter disengaged from the bucket and placed on a plastic tray and dehydrated under intense sunlight for three days and thereafter bagged in nylon (Figure 2).

Figure 1
Sieving *Bos indicus* bone ash slurry with hand gloves
Photograph generated from the field research.

Figure 2
Bagged ash samples
Photograph generated from the field research.

The sample was weighed at each processing level. The varying weight differences of the sample, from the bone through drying to firing, grinding and washing, were recorded and are detailed in Table 1:

Table 1: Statistical weight changes of collected *Bos indicus* bones sample during processing in kilogram (kg)

S/n	Sample	Actual weight (kg)	Dried weight (kg)	Fired weight (kg)	Weight after grinding (kg)	Weight after washing (kg)
1	*Bos indicus bones*	11.32	10.17	6.70	6.55	3.20

5. Elemental Analysis

Elemental analyses of *Bos indicus* bone ash, borax, adobe and soda ash that determined the elemental concentrations from sodium (Na) to uranium (U) were calibrated to pure element standard and NIST geological standard, NBS278. The samples were further grinded in an agate mortar and subsequently pelletized mechanically into tablets of 13mm diameter without binder. The pelletized samples were ionized by particle induced X-ray emission (PIXE) and Rutherford Backscattering spectroscopic (RBS) techniques performed in a 2.5 mega electron volt (MeV) proton beam. The measurements were carried out with a beam spot of 4mm diameter and a low beam current of 3-6Na. The irradiation was about 10 to 20 minutes. A Canberra Si (Li) detector Model ESLX 30-50, beryllium thickness of 25pm, full width hall maximum (FWHM) of 150eV at 5.9keV, associated pulse processing electronics, and a Canberra Genic 2000 (3.1) MCA card interfaced to a PC were used for the X-rays data acquisition (Obiajuwa, 2015). The result is presented in tables 2, 3, 4 and 5 below:

Table 2: *Bos indicus* bone

Element	Symbol	Concentration (ppm)	Concentration Percentage (%)	Oxides	Oxide Concentration Percentage (%)
Magnesium	Mg	7434.6 ±468	0.7434	MgO	1.233
Aluminum	Al	2780.4 ±402	0.2780	Al_2O_3	0.525
Silicon	Si	12443.3 ±399	1.2443	Si_2O	2.662
Phosphorus	P	183884.2 ±570	18.3884	P_2O_5	42.137
Chlorine	Cl	277.0 ±27	0.0277	Cl_2O	-
Calcium	Ca	314759.7 ±252	31.4760	CaO	44.041
Iron	Fe	367.6 ±14	0.0368	Fe_2O_3	0.053
Zirconium	Zr	138.8 ±19	0.0139	ZrO_2	-
Strontium	Sr	353.5 ±48	0.0354	SrO	-
Barium	Ba	30.8 ±9	0.0031	BaO	-

Table 3: Borax

Element	Symbol	Concentratio n	Concentration Percentage (%)	Oxides	Oxide Concentration Percentage (%)
Sodium	Na	-	11.39 %	Na_2O	15.352
Boron	B	-	16.97 %	B_2O_3	-
Oxygen	O	-	43.77 %	O_2	-
Hydrogen	H	-	27.88 %	HO_2	-

Table 4: Adobe

Element	Symbol	Concentration (ppm)	Concentration Percentage (%)	Oxides	Oxide Concentration Percentage (%)
Magnesium	Mg	2564.5 ±205	0.2565	MgO	0.425
Aluminum	Al	129123.0 ±439	12.9123	Al_2O_3	24.395
Silicon	Si	191125.9 ±363	19.1126	Si_2O_3	40.891
Chlorine	Cl	315.7 ±55	0.0316	Cl_2O	-
Potassium	K	4823.6 ±47	0.4824	K_2O	0.581
Calcium	Ca	4106.6 ±38	0.4107	CaO	1.221
Titanium	Ti	7317.8 ±46	0.7318	Ti_2O	-
Vanadium	V	325.8 ±35	0.0326	V_2O_3	-
Iron	Fe	105081.7 ±168	10.5082	Fe_2O_3	15.025
Copper	Cu	583.3 ±115	0.0583	Cu_2O_3	-
Zinc	Zn	1172.2 ±167	0.1172	ZnO	-
Zirconium	Zr	287.0 ±57	0.0287	Zr_2O	-
Lead	Pb	138.6 ±95	0.0139	PbO	-

Table 5: Soda ash

Element	Symbol	Concentration	Concentration Percentage (%)	Oxides	Oxide Concentration Percentage (%)
Sodium	Na	-	33.54 %	Na_2O	45.208
Carbon	C	-	14.09 %	CO_2	-
Oxygen	O	-	52.37%	O_2	-

For the tables 2 and 4, a total of ten (10) and thirteen (13) elements were respectively detected and quantified between six (6) and seven (7) major elements (Mg, Al, Si, P, Ca, Ti and Fe) and four (4) and six (6) trace elements (Cl, Sr, Zr, Cu, Ba and Pb) were observed. The concentration result of each element as indicated in the tables 2 and 4 were in part per million (ppm). Calculating their percentages (%) therefore required dividing each element concentration by ten thousand (10,000). Apparently, the cumulative sum of the elements in the samples did not add up to hundred percent (100 %) as a result of PIXE limitation to account for oxygen, carbon and hydrogen of the samples. RBS elemental analyses on the other hand accounted for hundred percent (100 %) as indicated in tables 3 and 5. Consequently, details in Table 6 are percentages reflecting the major elements in *Bos indicus* bone ash and adobe samples:

Table 6: Percentage of the major elemental concentration of samples

Sample	Na_2O	MgO	Al_2O_3	SiO_2	P_2O	K_2O	CaO	TiO_2	MnO	Fe_2O_3
Bos inidcus bone ash	-	.74	.28	1.24	18.39	-	31.48	-	-	.04
Adobe	-	.26	12.91	19.11	-	.48	.41	.73	-	10.51

6. Water Absorption Test

For this water absorption capacity test, small quantities of *Bos indicus* bone ash, borax, adobe and soda ash were separately encased in plastic Petri dishes. The measurement of one gram (1 g) from each of the samples in the Petri dishes was put into filter papers and measured one after the other on the balancing machine to ascertain constant value for all the samples and were then turned in calibrated glass beakers. Thereafter, ten mills (10 ml) of distil water was measured with a calibrated rubber cylinder and added to the samples in each beaker. The combination of each sample and the liquid in each beaker was stirred vigorously to attain solution homogeneity (Figure 3).

Figure 3
Stirring the beaker's content
Photograph generated from the field research.

The sample solutions were immediately poured into silver lining centrifuge text tubes one after the other. The text tubes were placed in the centrifuge machine and operated at 2000 revolution per minute (rpm) for precisely thirty (30) minutes. At the end of the operation, the text tubes were removed from the centrifuge machine. The remaining content of the solutions in the silver lining centrifuge text tubes were then accounted for by measuring their residues. This process was run thrice and tabulated but, in avoidance of table duplications, only the average results of the process were indicated in Table 7;

Table 7: Water absorption capacity

S/n	Samples	Initial Volume 1g+10ml	Final Volume (ml)	Actual WAC in volume (ml)	WAC in percentage (%)
1.	*Bos indicus* bone ash	10	7.8	2.2	22
2.	Borax	10	7.6	2.4	24
3.	Adobe	10	7.8	2.2	22
4.	Soda ash	10	-	-	-

The Table 7 above represents the values of each analysed samples using the formula:

$$A = IV - FV$$

$$A\% = \frac{A}{IV} \times \frac{100}{1}$$

Where: *IV* = Initial Volume
FV =Final Volume
A = Actual Absorption
A% = Actual Absorption percentage.

For clarity, the value of the initial volume of each solution was constant while that of the final volume (suspended distil substance) varied. These differences were used to calculate actual absorption (*A %*) by subtracting initial (*IV*) from final (*FV*), while the value for absorption percentage (*A %*) was determined by dividing (*A*) from (*IV*) and multiply by one hundred (100) over one (1). These absorption results in Table 7 are testimonies to samples capacities to hold and absorb water, except for soda ash that had zero water absorption capacity as a result of its hydroscopic nature and solubility in water. The samples average absorption percentage, apart from that of soda ash, ranged between 22 and 24. These percentages were further detailed in Table 8 below;

Table 8: Water absorption capacity percentage

S/n	Samples	Water Absorption Capacity in percentage (%)
1.	*Bos indicus* bone ash	22
2.	Borax	24
3.	Adobe	22
4.	Soda ash	0

7. Glazing

Glazing in this sense, is a holistic process involving batch formation, application and firing of the *bos indicus* bone ash sample solely and in combination with other samples. Batch formulation methods often and normally employed by ceramists are technically either hand milling or ball milling. Jar mill is however used for this exercise. Jar mills were made for small scale researches because of the massiveness of the ball mills. The jar mill employed for this exercise is electrically powered with maximum water capacity of 4 liters and programmed to run for an average of six (6) hours per batch. In milling the samples to batches, certain measures like measuring the samples in part(s) and weighed in kilogram (kg) were taken using spoonful and Poyear digital scale

Consequently, batch millings were done solely and aggregately. The jar was filled with one and half liters (1.5 ltrs) of portable water, flint pebbles and the aggregated samples. Thereafter, the jar was covered, bolted water tight and then switched on for milling of the batches one after the other. It is important to note that this exercise was in two phases. The first phase was the sole milling of the *Bos indicus* bone ash while the second phase was the combination of *Bos indicus* bone ash, borax, soda ash and adobe at varying proportions as detailed in Table 9:

Table 9: Composition of batches 1 and 2

Time	Weight	Volume	Percentage	Sample
Batch 1: ***Bos indicus* bone (Bosinbo) ash glaze**				
5:50am/12:05pm	0.45 kg	9 parts	100 %	Cattle bone ash
	0.45 kg	**9 parts**	**100 %**	**Bosinbo ash**
Batch 2: ***Bos indicu* bone, Borax, Adobe and Soda ash (Bosinboadso) Ash glaze**				
7:30pm/12:00am	0.46 kg	13 parts	50 %	Cattle bone ash
	0.30 kg	9 parts	35 %	Borax
	0.11 kg	3 parts	12 %	Adobe
	0.11 kg	1 part	3%	Soda ash
	0.98 kg	**26 parts**	**100 %**	**Bosinboadso ash**

The Table 9 above shows details of the batches time duration, weight, volume, percentage and sample combinations of *bos indicus* bone ash and *bos indicus* bone ash mixed with other samples, presented in whole number and one decimal place. Also reflected in the above table are Bosinbo Ash Glaze (sole) and Bosinboadso Ash Glaze (combined). Bosinbo Ash Glaze and Bosinboadso Ash Glaze are our terminologies coined respectively for *Bos indicus* bone ash and *Bos indicus* bone ash, borax, adobe and soda ash glaze batches. Percentages of the sample batches were further presented in Table 10:

Table 10: The percentage of sample batch compositions of Bosinbo Ash Glaze and Bosinboadso Ahsh Glaze

Batches number and name	**1** **Bosinbo Ash Glaze**	**2** **Bosinboadso Ash Glaze**
Bos indicus bone ash	100	50
Borax	-	35
Adobe	-	12
Soda ash	-	3
Total	**100%**	**100%**

8. Batches Application

Before the application of the milled batches on bisque wares as glazes, the bisque wares were numbered. The number of each bisque ware was engraved on it at the base for proper identification (Figure 4). Furthermore, the bisque wares were soaked in water and dried to allow proper alignment of the wares with the batches (Figure 5). Subsequently, the milled dust batches were applied on bisque wares by dipping.

Figure 4
Base numbering of tiles and vases
Photograph generated from the field research.

Figure 5
Aligned batch on bisques tile by dipping
Photograph generated from the field research.

International Journal of Humanities Social Science and Management (IJHSSM)
Volume 4, Issue 2, Mar.-Apr., 2024, pp: 638-647 www.ijhssm.org

Thereafter, excess slips of the glazed wares were allowed to dry properly and then cleaned off. The glazed wares were subsequently fired in a down draught kiln, powered by four gas burners concurrently. Two cones, 06 at 991 ^{o}C and 09 at 1120 ^{o}C, were placed on the bats in the kiln to attest to the firing maturity of the temperature. The kiln was consequently, sealed up with bricks leaving two spy holes as windows into the kiln (Figure 6). The firing commenced at 10:24 AM and was stopped at 6:55 PM.

Figure 6
Concurrent firing of the kiln
Photograph generated from the field research.

The details of the firing as observed on the wares are presented in Table 11 and plates 7 to 8 below:

Table 11: Glaze firing trial log for Bosinbo Ash Glaze and Bosinboadso Ash Glaze

TRIAL NO	1 **Bosinbo Ash Glaze**	2 **Bosinboadso Ash Glaze**
RECIPE	*Bos indicus* bone ash 100	*Bos indicus* bone ash 50 Borax 35 Adobe 12 Soda ash 03
TEST PIECE	A vase and three tiles	A vase and three tiles
GLAZE THICKNESS	Thick	Thick
KILN AND FIRING	Medium Kiln, fires to1120^{o} C	Medium Kiln, fires to1120^{o} C
TYPE	Opaque	Opaque
COLOUR	White	Whitish Sienna
SURFACE	Non-shiny	Non-shiny
NOTES	Glaze fit with little pocket of cracks	Glaze runs with pocket of cracks
ASSESSMENT	Very good	Good
ALTERATIONS	Needed	Needed
NAME	Bosinbo glaze	Bosinboadso glaze

Figure 7
Bosinbo Ash Glaze
Photograph generated from the field research

Figure 8
Bosinboadso Ash Glaze
Photograph generated from the field research

V. Conclusion

Glaze opacity is often attained either by organic, inorganic or heat alteration means. This research however, adopted organic means of obtaining opacity from calcium of *Bos indicus* bone ash. The elemental analysis of *Bos indicus* bone ash showed 31.41 % of CaO as against MgO (.74 %), Al_2O_3 (.28 %), SiO_2 (1.24 %), P_2O (18.29 %) and Fe_2O_3 (.04 %) in the ash sample. This quantitative variable attested to the primacy of calcium. Also the dry base analysis equally attests to the absorption capacities of the samples which were low except for soda ash which was zero (0) and non-absorbent as a result of its hydroscopic nature. The absorption capacity of *Bos indicus* bone ash, borax, and adobe were 22 %, 22 % and 24 % respectively. The fired results of the formulated batches of Bosinbo Ash Glaze (sole) and Bosinboadso Ash Glaze (mixed) are clear indication of successful opaque glazes as they run and fitted well on their bisque hosts. The insignificant pocket of cracks in the Bosinboadso Ash Glaze may be removed in subsequent glazing by adding more binders.

The successful studio production of these opacified glazes has determined an organic source of opacifier other than tin and other related oxides. The study has determined calcium as an effective opacifier in glazes and also determined *Bos indicus* bone as a rich source of calcium for glaze opacifier and determined its effectiveness as opacifier. The study has also evolved glaze batch models from which other glaze batch ratios or glaze models can be derived. Furthermore, it has provided elemental constituents data of *Bos indicus* bone, borax, adobe and soda ash to guide researchers and future researchers. The study has also named two types of opacified glazes; it produced Bosinbo Ash Glaze and Bosinboadso Ash Glaze. Environmental and economic-wise the study has shown avenues for constructive and productive use of bone wastes, improvement of environmental cleanliness and enhancement of industrial and economic development of Nigeria and similar contexts.

References

[1]. Abiodun, S. O., Akintonde, M. A. and Akinde, T. E. 2013. Small Scale Ceramic Industry in Oyo State: Challenges and Prospects. Journal of Economics and Sustainable Development, Vol. 4, No. 11, pp.103-111.

[2]. Akinde T. E. 2009. Fruit Peelings as Ash Glazes. Unpublished M.Tech Thesis. Ladoke Akintola University of Technology, Ogbomoso, Nigeria. pp. 1-101.

[3]. Akinde, T. E. 2016. Comparative Study of the Strength of Glazes Derived from Horticulture and Animal By-products. Doctor of Philosophy (Ph. D.) Thesis. Department of Fine and Applied Arts, LAUTECH. Ogbomoso, Nigeria. pp. 1-225.

[4]. Akinde, T. E. and Kalilu, R. O. R. 2022. Derivation of Ash Glazes from Cattle Bone. Science Focus. An International Journal of

Biological and Physical Sciences, Vol. 27, pp. 1-11.
[5]. Alasa S. 2005. Fundamentals of Ceramics. Benin City, Nigeria: Mara Mon Bros.
[6]. Black S. A. W. 2005. Domesticating the Crystal: Sir Lawrence Bragg and the Aesthetics of X-ray Analysis. Configuration. Vol. 13, no. 2.
[7]. Brower K, Wade J and Sernau L. n.d. PIXE/XRF: Identifying Element Concentrations by Exciting the Target's Atoms. An online power point presentation.
[8]. Hughes G. B. 1965. The Country Life Collector's: Pocket Book of China. New and Revised edition. London: Country Life.
[9]. Kalilu R. O. R, Akintonde M and Ayodele O. 2006. Ceramics: Art and Technology in the 21st Century South Western Nigeria. Agege: Pemilter Publishers.
[10]. Kalilu R. O. R. 2013. Art from Art for Art: Conceptualising Existence in the Space of the Visual Arts. Presented at the Tenth Inaugeural Lecture Series of Ogbomoso: Ladoke Akintola University of Technology.
[11]. Kalilu, R. O. R. and Akinde, T. E. 2022. Elemental Comparison of Bones of Red Sokoto (Capra Hiraacus) and West African Dwarf (Capra Aeaguru) Goats for Production of Glazes. LAIJOCES: LAUTECH Journal of Civil and Environmental Studies, Vol. 8, Is. 2, pp. 58-69.
[12]. Kalilu, R. O. R. and Akinde, T. E. 2023. Derivation of Ash Glazes from Orange and Sugarcane Peelings. ITS: Art and Design. Vol. 6, Is. 1, Hong Kong, pp. 77-85.
[13]. Manai and Halliru . 2000. Egg Shell as Viable Alternative Commercial Whiting or Calcium Souce in Glaze.
[14]. Obiajunwa E. I. 2015. PIXE Experimental: Samples Preparation and Methods. A power point presentation delivered at the Center for Energy and Research Development, Obafemi Awolowo University, Ile-Ife, Nigeria.
[15]. Ogunsina E. D. 1997. Maize Sheath Ash: A Possible Ingredient for Ceramic Glaze. USO: Nigerian Journal of Art. Vol. 2, nos. 1 and 2
[16]. Ologunwa P. T, Akinbogun T. L and Kashim I. B. 2013. Developing Opacified Stoneware Ceramic Products through Experimentation with Waste Bones from Abattoirs in Akure, Nigeria. Arts and Design Studies. Vol. 7. www.iiste.org
[17]. Peterson S. 1998. Working with Clay: An Introduction. London: Laurence King Publishers.
[18]. Rhodes D. 1998. Clay and Glazes for the Potter. Revised Edition. Wisconsin: Krause and London: A and C Black.
[19]. Singer F and Singer S. 1963. Industrial Ceramics. London: Chapman and Hall Ltd.
[20]. Singer H and Holmyard. 1956. History of Technology: Volume II. London: Ely House and Oxford University Press.