View metadata, citation and similar papers at core.ac.uk
brought to you by CORE
provided by International Institute for Science, Technology and Education (IISTE): E-Journals

Arts and Design Studies
ISSN 2224-6061 (Paper) ISSN 2225-059X (Online)
Vol.7, 2013
www.iiste.org

Developing Opacified Stoneware Ceramic Products through Experimentation with Waste Bones from Abattoirs in Akure, Nigeria

Temitope. P. Ologunwa* Tolulope. L. Akinbogun Isah. B. Kashim
Department of Industrial Design, School of Environmental Technology, The Federal University of Technology, P.M.B 704 Akure, Ondo State, Nigeria
*topsybond@gmail.com (Corresponding Author)

ABSTRACT

Most small scale ceramic industries depend on imported raw materials among which are opacifiers because locally sourced ones are not adequately processed. It has been observed that refined tin oxide is expensive despite the fact that it is abundantly availability in Nigeria while a lot of bone laid wastes which can be recycled to produce opacifier. A comparative study was made on the physical properties of opaque glaze produced locally with bone ash and that of processed tin oxide when mixed with transparent glazes at different percentages using tri-axial blend. The result proved that 7 to 9 % of cow bone ashes with transparent glazes made a good composition in achieving an opaque glaze. The success of this experiment has reduced the dependency on tin oxide as ceramic glaze opacifier which has been expensive to procure and has given ceramic artist the platform that would allow paintings using ceramic oxides that could be attractive and competitive which is seldomly used in the country

Keywords: Bone Ash, Opacifier, Stoneware and Sustainability.

1.0 INTRODUCTION

The word ceramic derives its name from the Greek ***keramos***, meaning "pottery", which in turn is derived from an older Sanskrit root, meaning "to burn". The Greeks used the term to mean "burnt stuff" or "burned earth". Thus the word was used to refer to a product obtained through the action of fire upon earthy materials. The art of embellishing clay pot with materials such as ceramic stains, oxides which when heated on the clay pot, leads to fuse glasses are of great antiquity. These ceramic stains can be applied to the surface of clay products, and after heating, it gives a vitrified surface in form of glass. The vitrified surfaces in form of glass on ceramic pot are referred to as "glaze". Several definitions of glazes are given by different authors but what is core is that it still border on its functions as, to seal the pores of a pot, create a surface texture that are either glossy or matty, provide colour and make pot resistant to acid. Different glaze surfaces are described as been matt (not shiny), gloss (shiny), satin (semi-shiny), transparent (see through), translucent (barely not see through), opaque (not see through), and textural (visual or actual).

Opaque glazes are glazes that are sufficiently low in light transparency so as to effectively hide the body from direct view. They are usually white, but this is not a requirement. Opacity in glazes is caused by the reflection and refraction of light phases and particles suspended in the clear matrix. Opacifiers are finely ground materials that do not enter the glaze melt but remain as small white particles suspended throughout the glaze. They reflect light and make the glaze opaque. The commonest and easiest way of creating opacity is to use an opacifier such as Tin oxide and Zirconium oxide as asserted by Emodah (2006). Zirconium oxide is rarely found in Nigeria. Ceramists usually import it to be used in the studio and the cost of importation is very high. However, tin oxide which is readily available in Nigeria is also expensive due to its usage as protective coating for copper vessels, and various metal used in manufacturing of tin cans. The use of opacifiers in tableware, dinnerware, sanitary wares and in decorative ceramics is very paramount and must be encouraged for competitive ceramic production that will attract local market.

Bone Ash is a common name given to dibasic di-calcium phosphate dehydrates ($CaHPO_4$ -H_2O). This material is derived from a ground ash. The average chemical composition is 25%-Calcium with a phosphorus content of 18.5% at minimum. Fluorine is an inherent impurity in natural bone ash, but it contained to a maximum concentration of 0.05%. This ground ash also known as natural bone ash is grainy in nature with a mean particle size of 100 mesh while Synthetic bone ashes are processed to a much finer particle size. However synthetically derived bone ashes used in the industry have a primary chemical composition of tri-calcium phosphate. (Http/MSDS – CHBONE – boneash crude. pdf).

The use of bone ash in glaze compositions is not arbitrarily done but based on careful considerations as opined by Anon, (1983) and Bridges, (1976). Bone ash contain about 58% of calcium phosphate ($Ca_3 (PO_4)_2$) in additions to calcium carbonate ($CaCO_3$), fat and organic matter containing nitrogen. The chemical and physical properties of phosphorous pent oxide as reported by Ayilaran, (2005) earns for it a pre-eminent position as constituents of glazes which is essentially a group of materials characterized by low fusion points, low viscosity and with low thermal expansion coefficient, high resistance to thermal shock and durability. The large amount of phosphorous pent oxide supplied by bone ash makes it function as a flux and opacifier without rapid loss of chemical resistance which is associated with increasing alkali contents. Phosphorous pent oxide, exerts a very pronounced effect on the expansion of glazes and replacement of alkali by Phosphorous pent oxide bringing about low viscosity, rapid setting and good surface gloss of glaze.

Izedomi (2005) admitted that scientific research is directed towards acquiring information that is to contribute to knowledge so as to be able to harness available materials in the immediate environment to accomplish and resolve conflicts. This study explicitly shows the processes involved in producing a good bone ash that is carbon free, the chemical analysis of the bone ashes and how it was mixed with transparent glaze at different percentage using a simple line blend to produce an opacified glaze. The scope of this study is limited to cattle bones in Akure Abattoirs. The choice of location in sourcing these materials such as Kaolin, flint, and whiting used to formulate the transparent glaze recipe was based on its availability and accessibility within Ondo, Ekiti and Edo States in Nigeria.

This study resolves to enquire through the waste bones from abattoirs in Akure, Nigeria to developing an opacifier that can be used as alternative to tin and zirconium oxides which are expensive to procure. The major impact of the study is to aid the artistic technique in painting with different identified oxides or colour stains which had been difficult to achieve on celadon glazes with dark colours characteristics. The use of bone as opacifier for this study also served as a means of converting waste to wealth enhances solid waste management and encourages innovative practice especially for the development of cottage level ceramic production and institutional practice.

2.0 METHODOLOGY

The processes involved in carrying out this study were approached scientifically in order to achieve the final result. These processes were divided into two parts:

1 Materials processing
2 Formulation of opaque glazes through Experimentation.

2.1. Materials processing

The materials processed to produce stoneware ceramic products in this study were cow bone, kaolin, flint, whiting, and potash feldspar. The Cow bones which were the major material experimented with transparent glaze to produce opaque glaze were gathered from abattoirs within Akure metropolis. Other materials such as Kaolin, flint, whiting, and potash feldspar needed for the formulation of transparent glaze, were sourced at Ijero Ekiti in Ekiti State, Akure in Ondo State and Auchi in Edo States of Nigeria. Tin oxide which was used comparatively with bone ash was sourced from Jos in Plateau State and it meant to affirm the quality of opacity of opaque glaze produced with bone ash. In order to make these materials suitable as glaze constituents, the following steps were undergone to process them;

1. Soaking and Washing of the bones
2. Boiling of the bones
3. Calcination of the bones
4. Crushing and grinding of the bones
5. Pulverization of the bones into powder
6. Formulation of Transparent Glaze used

2.1.1 Soaking and Washing of the bones

This is the act of softening and saturating the bones gathered by immersing them into water. The immersion in water was carried out for two days in order to remove the dirt, soften the beef and contaminants that were present in the bones. The bones were removed from water on the third day, rinsed and sundried. The bones were poured into a bath and washed with thread sponge in order to remove the adhered beef. (See plate 1)

2.1.2. Boiling of bones

In order to further remove impurities such as unwanted liquids in the bone marrow, adhere beef and most especially the fat present in the bone, the bones were boiled at 100^0C in the water with the addition of soda potash ($Na_2.Al_2O_6.SiO_2$) to help soften the adhere beef for easy remover. Fats and glue were seen boiling out of the bone at 100^0C later which the bones were de-beefed, rinsed and sundried. This is expressed in plate 2 and 3.

2.1.3. Calcination of the bones

This is the process of heating a substance below its melting temperature in order to remove organic matter including chemically combined water in the substance and to create a fine network of cracks on the substance for easy grinding. By calcination, traces of carbon and also small amount of water within the material were burnt off. The most important essence of calcinations was to weaken the structure. The volume changes associated with the heating and cooling of the material resulted in the development of network of fine cracks throughout the material. At about 500^0C to 600^0C, chemically combined water is driven out. At about 900^0C and above, Igbinedion (1995) asserted that most or all organic compounds are said to be totally removed.

The bones used for the study were calcined above 1000^0C in order to ensure that all chemically combined water and organic matters are all removed.

Note: under-calcination may contain so much organic materials that result to frothing which may lead to glaze fault. (see Plate 4 & 5)

2.1.4. Crushing and grinding of the bone

This is the process of reducing a substance into small pieces or particles by pounding or abrading. The bones were grinded in the grinding machine to make the bone into fine particle size. Nevertheless, the grinding machine was not completely tightened in order to avoid the bones been contaminated with iron oxide. To achieve a pulverized or finer particle size, the calcined bones were then ball milled using a porcelain jar in the Department of Industrial Design, Federal University of Technology, Akure. Plate 6 and 7 indicate these procedures:

2.1.5. Pulverization

Pulverization is an act of grinding substances into powder or fine particle sizes. Glaze ingredients are usually pulverized into powder. The finer the particle size, the glossier the glaze melts on ceramic ware. Sometimes, the finer particles help to lower the eutectic point due to the surface area of the material.

Plate 8 and 9 shows how the bone used for the study was pulverized in the porcelain ball mill to make the material suitable in composing glaze recipes. The time taken to pulverize a batch of the bone took between 12 – 24 hours.

2.1.6. Formulation of Transparent Glaze use

The transparent glaze used for this study was from a known glaze recipe derived from studio experiment by Segun Fatuyi, (2010) who happens to be a lecturer in the Department of Industrial Design, and this served as a good base glaze for the study. The recipes used and their percentage compositions in part by weight are stated below:

Feldspar	50
Whiting	25
Flint	20
Kaolin	5
	100%

2.2. Experimentation and Formulation of opaque glazes

The cow bone ash was mixed with a transparent glaze to compose an opacified glaze using line blend. The bone ashes were mixed with transparent ranging from 1-15 % (see table 1) to produce 10grammes of each sample. In other word, One percent (1%) of cow bone ash was mixed with nine – nine percent (99%) of transparent glaze, 2% of cow bone ashes with 88% of transparent glaze, until fifteen percent of cow bone ashes were mixed with eighty – five percent of transparent glaze to produce fifteen levels of opacified glaze samples. 10grammes of each samples produced were thoroughly mixed with 4ml of water in order to have a uniform quantity.

The same procedure was carried out for tin oxide, thereby having thirty samples in all that were examined by applying them on the test tiles produced using brush after mixing them properly and fired. See plate 10 and 11. The samples were subjected to firing using an electric kiln under a full oxidation firing atmospheric condition at 1200^0C and were monitored with a thermocouple and Orton cones (08, 03, 4) to ascertain the temperature.

3.0 RESULT OF FINDINGS

3.1.1. Assessment of opacified glaze produced using cow bone ash in term of glaze melt

Plate 12 shows the samples of opacified glaze produced using cow bone ash as opacifier. From the physical examination conducted on the samples, it was observed that the level of glaze melt of cow bone ash with transparent glaze was satisfactorily good without showing any flaw when compared with opacified glaze produced using processed tin oxide. The level of the glaze melt of the 15 samples produced is expressed in the table 2 below as the whole samples prepared melted very well.

3.1.2. Assessment of opacified glaze produced using cow bone ash in term of glaze Bloat

It was also observed that 5 (i.e. 33.33%) of cow bone ash samples out of 15 samples have low bloating, 2 (13.33%) is highly bloated and 8 (53.33%) did not bloat. It was inferred from the observation that cow bone ash in term of glaze bloat, had a very low tendency to bloating. Though the higher the percentage increase in cow bone the higher the tendency to bloating. A good opacity that is less prone to bloating was achieved between the ranges of 7 – 9 %. Plate 12 and the table 3 below indicated the degree of glaze bloat in the opacified glaze produced from bone ash.

3.1.3. Assessment of opacified glaze produced using cow bone ash in term of glaze Crawl

The physical examination of the samples of cow bone ash in terms of glaze crawl shown that 7 (i.e. 46.67%) out of 15 samples have low glaze crawling, 2 (13.33%) out of the samples highly crawl and 6 (40%) did not crawl. As earlier stated that crawling can result from the glaze material content such as flux in the glaze which increases the viscosity and surface tension, it can therefore be inferred in essence that cow bone ash is moderately viscous as glaze material and has shown low tendency to crawling when used as an opacifier with transparent glaze. Table 4 below indicate the level of glaze crawl using cow bone ash as opacifier.

3.1.4. Assessment of opacified glaze produced using cow bone ash in term of glaze opacity

It was observed that 8 (i.e. 53.33 %) samples of cow bone with transparent glaze out of 15 samples is highly opaque. 3 (20%) out of the samples were low in opacity and 4 (26.67%) were insignificantly different from the transparent glaze. It was inferred that cow bone ash is a good opacifier with transparent glaze. See plate 12 and table 5 as discussed.

4.0. DISCUSSION AND FINDINGS FROM THE SECOND FIRING

Six (6) samples were recomposed based on the assessment of the result of samples tested above. This test was conducted in order to improve the brilliancy of the opacified glaze samples produced from cow. Therefore, three to four percentage of zinc oxide was introduced into the composition.

It was observed that the introduction of zinc oxide into the composition lowers the eutectic point, increase the brilliancy of the opaque glaze in comparison to tin oxide and also remove bloating. The addition of zinc oxide into the glaze stabilizes the glaze composition and makes the result to be close to that of tin oxide. The results were found to be very good in the absence of glaze crawl, glaze bloat and glaze opacity. Table 6 and plate 14 expresses the result from the firing in term of glaze crawl, glaze bloat and glaze opacity.

Conclusively, the new glaze formulated with the bone ash was subjected to the same firing condition in the gas kiln with the glaze that had the same percentage of a processed tin oxide at 1160^0C. After the firing, the optical quality of both glazes was observed in terms of maturity of glaze, colour whiteness, hardness and brightness. The two glazes shared all the above character in similar ways except that the opacified glazed ware with bone ash shows slight transparency at the edges of the wares. For a sculptural ceramics, it may give an illusion of design but where a perfect colour finishing is desired, it may require further adjustment to correct the defect. However, the new glaze is a successful because it has created a baseline for a home grown opacified glaze development.

4.1. The Artistic Technique Impact on Local Artist

The impact of the artistic technique invented in this study using bone ash as opacifier is explicitly highlighted below;

1. The discovery that cattle bone can substitute tin oxide and zirconium oxide would largely assist at producing an attractive pottery that will compete with imported ones. For instance, the composite demand of tin oxide in allied industries as greatly affected the cost of producing opaque glazes. The use of bone ash as substitute will eventually reduce the cost of producing opaque glazes which will encourage local producer of pottery who rely solely on celadon glazes which have limitations in the utilization of colouring oxides for artistic manipulation and creativity.

2. The use of bone ash as opacifier in producing opaque glaze would break the monotony of Tenmoku and Celadon glazes derived from wood ash which are the common ceramic glazes used in producing wares in the country. The basic problem with this is that it is not competitive and attractive at competing with the imported ones from China produced using opacified glazes.

3. This opacified glaze from bone ash has created a platform for paintings of scenes or landscape on ceramic wares with colours, oxides and stains on opaque glaze thereby creating a good contrast in artistic treatment of pottery which hitherto is not in vogue in the country.

4. Ceramist who have drifted from pottery production due to some of this unique problem faced such as production of opaque glazes might change their mind to start its production again as this discovery has given room for low production of opaque glaze which economically viable, compare to using tin oxide. An opacified glaze of tea pot with similar decoration is shown on plate 15.

5.0. SUMMARY OF FINDINGS

Based on the field assessment when bone ashes from cow were used in substituting the opacifier used in ceramic glaze (tin oxide), the following findings were discovered:

1. Cow produced a good melt when used as part of glaze material mixed with transparent glaze between the ranges of 4 – 15 %.
2. Cow bones are less prone to bloating and crawling when mixed with ceramic transparent glaze.
3. Cow bone produced better opacity in ceramic glaze with the addition of 7 - 9% opacifier when mixed with transparent glaze.
4. The quality/brilliance of cow bones could be improved with the addition of 3 – 4% of zinc oxide to make opaque glaze closer in its result compare to Opaque glaze produces from tin oxide. This had eventually reduced the cost of producing opaque glaze.
5. Cow bones produced few flaws when used as an opacifier on ceramic transparent glaze in respect to texture, brilliance and opacity when compared to tin oxide, though their differences are insignificant. Hence, cow bone could as well serve as a good expedient opacifier, with little addition of zinc oxide to improve the brilliancy.
6. The use of bone ash as part of ceramic glaze material composition has the tendency to check glaze running by the action of the Phosphorous pent oxide which produces a stiff melt.

6.0. CONCLUSION

The research has successfully proved the expediency of bone ash at producing opaque glaze when added as part of glaze composition with transparent glazes. The study further shows that the volume of bone available in abattoirs and those loitering on the streets are enough to be used as opacifier at little or no cost. The result of this study could act as catalyst at liberating large and small scale ceramic industries, studio potters and ceramic students in various tertiary institutions to effectively produce opaque glaze, using bone ash as opacifier.

This study has also assisted at converting waste that was supposed to have created environmental problem to wealth and subsequently reduced the dependency on tin oxide as ceramic glaze opacifier which has always been very expensive to procure by ceramist in Nigeria and provides platform for artistic painting on ceramic wares.

REFERENCES

Anon (1983): *Raw Materials in the Glass Industry*. Ashee Publishing Co.Inc. New York.

Ayilaran A (2005): *Utilization of Cow Bone Ash as an Opacifier for Enamel production*. M.A Thesis, Department of Industrial Design, A.B.U. Zaria.

Bridges F. (1976): *Raw Materials and Batch Calculation*. Presented at working with Hot Glass. An International Conference by Craft Advisory Comzmittee and Royal College of Art, London.

Emodah , C.S (2006*): An Approach to Ceramic Decoration and Enameling*. Mara Mon Bros. Ent. Benin City.

Igbinedion, S.J.E (1995): *Introduction to Industrial Ceramics*. Uri Publishing Limited, Benin City.

Izedomi, F (2005): *A Manual for Academic and Professional Research*. Lagos, Nigeria: El-Fazek Publishers & Communication.

http://www.continentalclay.com/images/MSDS-CHBONE - BoneAshCrude.Pdf. Retrieved Dec., 2010

ISSN 2224-6061 (Paper) ISSN 2225-059X (Online)
Vol.7, 2013

LISTS OF PLATES

Plate 1: Washing and Sun-drying of the bones

Plate 2: Bones at room temperature

Plate 3: Bones at 100^0C

Plate 4: Bones before Calcination

Plate 5: Bones after Calcination

Plate 6: Crushing of the bones

Plate 7: Grinding of the bones

Plate 8: Charging of bone into mill jar

Plate 9: Placing the jar on ball mill machine

Plate 10: Brushing glaze samples on test tiles.

Plate 11: Glaze samples before firing.

Plate 12: Opacified glazed samples produced using Cow bone ash with transparent glaze.

Plate 13: Opacified glazed samples produced using tin oxide with transparent glaze.

Plate 14: Results from the firing in the kiln

Plate 15: Painting using metallic oxide on the tea pot with opacified glaze using bone ash.

LIST OF TABLES

Table 1: Line blend of transparent glaze with cow bone ash

Transparent glaze (%)	99	98	97	96	95	94	93	92	91	90	89	88	87	86	85
Cow bone ash (%)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

Table 2: Assessment of opacified glaze produced using cow bone ash in term of glaze melt

Variable (Glaze melt)	Good	Fair	Poor	Total
Frequency	15	0	0	15
Percentage	100	0	0	100

Table 3: Assessment of opacified glaze produced using cow bone ash in term of glaze Bloat

Variable (Glaze bloat)	Nil	Low	High	Total
Frequency	8	5	2	15
Percentage	53.33	33.33	13.33	100

Table 4: Assessment of opacified glaze produced using cow bone ash in term of glaze Crawl

Variable (Glaze crawl)	Nil	Low	High	Total
Frequency	6	7	2	15
Percentage	40	46.67	13.33	100

Table 5: Assessment of opacified glaze produced using cow bone ash in term of glaze opacity

Variable(Glaze opaque)	Nil	Low	High	Total
Frequency	4	3	8	15
Percentage	26.67	20	53.33	100

Table 6: Opaque glazes composed and there Assessment

Sample ID	Transparent Glaze (%)	Bone Ash (%)	Zinc Oxide (ZnO)(%)	Crawl	Bloat	Opacity
Cow (C)1	90	7	3	Nil	Nil	Good
C 2	89	8	3	"	"	"
C3	88	9	3	"	"	"
C4	89	7	4	"	"	"
C5	88	8	4	"	"	"
C6	87	9	4	"	"	"

This academic article was published by The International Institute for Science, Technology and Education (IISTE). The IISTE is a pioneer in the Open Access Publishing service based in the U.S. and Europe. The aim of the institute is Accelerating Global Knowledge Sharing.

More information about the publisher can be found in the IISTE's homepage:
http://www.iiste.org

CALL FOR PAPERS

The IISTE is currently hosting more than 30 peer-reviewed academic journals and collaborating with academic institutions around the world. There's no deadline for submission. **Prospective authors of IISTE journals can find the submission instruction on the following page:** http://www.iiste.org/Journals/

The IISTE editorial team promises to the review and publish all the qualified submissions in a **fast** manner. All the journals articles are available online to the readers all over the world without financial, legal, or technical barriers other than those inseparable from gaining access to the internet itself. Printed version of the journals is also available upon request of readers and authors.

IISTE Knowledge Sharing Partners

EBSCO, Index Copernicus, Ulrich's Periodicals Directory, JournalTOCS, PKP Open Archives Harvester, Bielefeld Academic Search Engine, Elektronische Zeitschriftenbibliothek EZB, Open J-Gate, OCLC WorldCat, Universe Digtial Library , NewJour, Google Scholar