Experimenting with Domestic Sodium bi-carbonates for Ceramic Glazing and Decoration.

ABSTRACT

Ceramic glazes are a glassy layer of fused material over the surface of a clay-based product. Glazing is an important technique in the decoration and finishing of ceramic products. It is observed that glaze development is not widely practiced by most indigenous cottage ceramic practitioners in Nigeria due to reasons varying from high cost of importation of processed glaze raw materials, to lack of understanding of glaze chemistry that makes it impossible to exploit the local raw materials which exist in abundance. Even where the knowledge is available, the necessary equipment to process the glaze materials are capital intensive and unavailable. Hence this study was carried out to discover the feasibility of using a locally available, easily assessable materials in simple glaze development. This research focused on achievingceramic glazing, using varying forms ofbicarbonates of soda available in Nigeria, outside of the vapour glazing usually associated with soda glazing in ceramics which requires a dedicated kiln for such processes. The research outcome shows that 60% of baking soda mixed involume ratio with ball clay and water will give a very good mid-temperature glaze when fired in both oxidized and reduced kiln atmospheres.

Key Words - Baking soda, Ceramic decoration, Ceramic glazes, Ceramic practice in Nigeria, Mid-temperature glazes, Soda slip glazes.

1.0 Introduction

Glaze is the glassy coating found on the surface of ceramic articles (Singer and Singer, 1963; Taylor and Bull, 1986; Rado, 1988). It is a suspension of finely intermixed insoluble materials in water which when applied to clay bodies as a thin surface coating and fired to appropriate temperatures, the materials fuse with one another forming a molten solution which on cooling, becomes a glassy coating on the clay body (Emmanuel & Derek 2001). Glazes are not just decorative- adding color and beautiful finish to a piece of ceramic, but they add such function as durability- by making the ceramic impervious to water. It also helps keep the pores of the cermic sealed thereby preventing germs from settling within and making it easier to clean such ceramic surfaces. There are various types and classifications of glazes; some based on the maturing temperature, and others on the main materials used in the making, and the appearance of the glaze (Emmanuel & Derek, 2001).

The earliest known example of vitrified glaze surface is on the statue head from Badari in Upper Egypt dated back to about 5000BC. Other notable developments in ceramic glazes included the introduction of low temperature glazes while high-fired feldspathic glazes continued to be used. Today, glazes have been refined to ensure cost effectiveness and almost perfect quality control

(Wing Kong, 1999).Salt glaze wasdevelopedin the 17^{th} century in the Rhine valley (Germany) where it was used to glaze white stoneware bottles and wares for wine production. Salt glaze was also utilized in colonial America and in many potteries in the U.S. throughout the 18th, 19^{th} and early 20^{th} centuries. Utilitarian wares of all sorts were fired in this way, including sewer pipes in many parts of the United States of America. Salt glazing is a simple way to glaze many pieces quickly and efficiently. The characteristic salt-glazed stoneware pottery with slightly translucent, glossy, and orange-peel surface texturethat enhances natural clay colors and surface marks was formed by throwing common salt into the kiln at high temperatures. In the 1970's, with increased concern for the environment, soda glaze was developed as a way to keep the beauty of the much loved salt-glazed ware without producing the cloud of sodium vapour gas and toxic chlorine gas that were byproducts of salt glazing. Soda ash, sodium bicarbonate, and other sodium products were experimented with.Soda or sodium oxide (Na_2O) is an active ceramic flux known for its bright color response in glaze. Soda glazing, which was developed as a chloride-free alternative to salt glazing, gives interesting surface effects that are quite different from the salt glaze despite the similarities with salt glazing. Soda glazes can range in color from dark plum (persimmon), yellow, brown, to black (Frank, 1975).

In some salt glazing, the salt mixture of sodium chloride and water is introduced into the kiln when the appropriate temperature is reached, typically around 900^{oc}. As the kiln reaches higher temperatures, typically 1100-1200^{oc}, the sodium chloride vaporizes and reacts with steam to form hydrogen chloride and soda. A glaze of fairly high alumina content (0.6 molecular parts) and a relatively low silica content (2.6 molecular parts) with soda as main base is formed. Salt glazes have been improved by the addition of borax, and sometimes sodium nitrate, to the salt mixture. Sometimes, colouring oxides are incorporated in the soda mixture to give decorative effects Reactions in salt glaze firing is given as such:

$$2NaCl + 2H_2O \rightarrow 2NaOH + 2HCl \text{ (gas)}$$

$$2NaOH \rightarrow Na_2O + H_2O$$

Sodium from the salt reacts with silica in the clay body to form a glassy coating of sodium silicate. Both the hydrogen chloride and the carbon dioxide are gases; they do not react with the sodium oxide that binds with the silica and other components of the clay body. Hydrogen chloride leaving the kiln will form a hydrochloric acid vapor on contact with moisture in the air or kiln exhaust gases.

$$Na_2CO_3 \rightarrow Na_2O + CO_2 \text{ (gas)}$$

Soda glazing involves introducing sodium carbonate or bicarbonate into the kiln at a high temperature to create soda vapor. Various techniques are used to introduce soda onto the ceramic wares in the kiln, including spraying a water and soda solution, dropping small amounts of powdered sodium carbonate into the kiln or introducing a solid plaster-like paste made from a mixture of sodium carbonate and bicarbonate, whitening and water. Behrens (1974) described the application technique of dropping dry sodium carbonate/bicarbonate into the firebox using a piece of steel angle; recommending that frequent introduction of small amounts of soda, dropped from the highest point above the firebox, gives the best results. This is claimed to allow time for the soda compound to vaporize during its fall. Another method, suggests that, Sodium carbonates be introduced to the kiln through a burner-blower unit. This method was proved to be efficient in dispersing sodium carbonate vapor, but Zamek (1999) noted some resulting dark patches on white clay bodies, which was blamed on the corrosion of the burner/blower unit. Other techniques involve the dissolution of Sodium carbonate in water and spraying the solution into the firebox. This spray method is proved to have good results, but excess sodium carbonate in the solution would cause the spray nozzle to clog up (Zamek 1999). However the limitation of these methods is that it requires that a kiln be dedicated to soda firing because of the reaction of the vapour with the alumina in kiln walls and furniture, making it unsuitable for other glaze firing.

As with salt glazing, the soda reacts with the alumina silicate surface of the clay, creating a glaze. This reaction, however, also occurs with other surfaces in the kiln since the soda is in vapor form, causing some irreversible changes to the kiln thereby making it unsuitable for other glaze applications. This research therefore sought to overcome this challenge, among other, by testing the effect of direct application of soda mix/slip onto the ceramic wares to create the glazing effect. The study also involved the exploration of locally available, easily assessable sources of soda for glazing of ceramic wares. This is expected to encourage the practice of glazing amongst local potters, who may lack adequate knowledge of glaze chemistry and hence have limited ability in composing successful glaze recipes; and ceramic practitioners who may not have the wherewithal to import processed glaze materials to compose glazes.

1.1 Research Problem

Ceramic glazing is both an art and a science and requires a clear understanding of both the chemistry of materials and chemical reactions during firing. Ceramics in Nigeria is mostly studied as an art and most successful potters excel in practice based on experience acquired through the years. Contemporary pottery practice in Nigeria is burdened with a poor understanding of the chemistry of glazes, hence most ceramic practitioners, lackingthe knowledge for glaze development, leave their work unglazed (bisque fired) or apply acrylic paints to add colour to the wares.

There is also the challenge of lack of adequate infrastructure for the mining, processing and beneficiation of ceramic raw materials. It is known that Nigeria is blessed with earth minerals in large quantities, many of which as useful as glaze materials. However the challenge is to get these materials from their raw impure forms to usable forms which are of higher concentration of purity. This requires processing with heavy machinery such as crushers, mixers and agitators, mills and furnaces, which most indigenous ceramic studios and cottage industries, lack the funding to acquire.

All of these have left potters, ceramic practitioners and students in Nigeria with little option than to purchase processed materials for glazing their ceramic wares. The feasibility of this however is very low because of the high cost of importation considering the foreign exchange rates and shipping costs. This has made it extremely difficult for indigenous ceramics industries in Nigeria to practice glazing of ceramics wares, thereby leaving their works looking unfinished and mostly unappealing to prospective consumers of these wares. This has encouraged the dearth in the demand of locally made ceramic wares in Nigeria.

Making available a low-cost and easily accessible resource which can empower the local potter/ ceramist to beautifully finish his/her works in colorful glaze, without requiring the acquisition of a new kiln for such glazing, became the drive of this research.

The objectives of this study included; the sourcing for various forms of sodium bicarbonates available in Akure, the formulation and testing of glaze compositions from the locally sourced soda by firing at varying temperatures to create glazing effect.

2.0 Methodology

This study involved a comparative visual assessment of the outcomes of varying the methods of application of soda in glazing in the following manner:

i. soda was mixed with water to form slurry

ii. soda was mixed with clay slip which was composed of kaolin (50%) and ball clay (50%)

iii. soda was dry mixed with ball clay

The study also involved varying the forms (sources) of soda tested. The tested types included baking soda (bicarbonate of soda), baking powder and soda ash (sodium carbonate).

Types of soda used in the research

1 Baking Soda (Sodium bicarbonate)

2 Baking powder

3 Soda ash (Sodium carbonate)

Baking Soda (Sodium bicarbonate) is also known as bicarbonate of soda ($NaHCO_3$). It is an alkaline compound which is commonly used as a leavening agent in baking. It is inexpensive and readily available in the local food market or from a bakers' supplier.

Baking powder is a chemical leavening agent used in baking which constitutes of bicarbonate of soda, calcium carbonate, tartaric acid and sometimes corn starch. It is also inexpensive and readily available for purchase in the local food market or from a bakers' supplier in Akure, Nigeria.

Soda Ash (Na_2CO_3), also known as sodium carbonate, is the water-soluble sodium salt of carbonic acid and is an alkali chemical. It is mostly used in glass manufacturing and as water softeners amongst other applications. Soda ash is also inexpensive and readily available in chemical retail shops or pharmaceutical suppliers.

a.  b. 

c. 

Figure 1: Forms of soda used in the research; a) baking soda, b) baking powder, c) soda ash

Experimental Procedure

STEP1: Sourcing for the raw materials (soda)

Soda ash (sodium carbonate), baking powder and baking soda (bicarbonate of soda) were sourced in powdered form from chemical and baker's retail shops in Akure, Nigeria.

STEP2: Produce sample ceramics wares.

Sample ceramic wares were shaped using the slip casting technique for test sampling the glazing techniques.

STEP 3: Application of Soda

The methods of application of soda tested are as follows;

1) Soda-Water mixture: The various types of soda (all in powdered forms) were individually mixed with water into a slurry and the test samples were dipped into the mixture to coat the outer surface.

2) Soda-Clay slip mixture: The soda powders were mixed in varying blend ratios with prepared clay slip. The clay slip was prepared by weighing kaolin and ball clay in ratio 1:1, and adding just enough water to mix it into a thick slurry. The sample ceramic wares were dipped in the soda-clay slip mix to coat the outer surface.

3) Soda-Ball clay mixture: The soda powders were dry mixed with powdered ball clay. Water was added to it to form a slurry and then the sample ceramic wares were dipped in the slurry to coat the outer surface.

Dipping is the most common glazing technique among the studio potters, because there is room to maneuver the pieces, and it is the earliest method of glaze application. Ceramic objects are dipped or immersed into a bucket of glaze. The form is dipped into the glaze and withdrawn immediately. The piece can be dipped severally, the layer of glaze can produce different fired results and can create a range of decorative effect. Dipping is as easy as it sounds, it can be applied on dried (green) ceramic wares or bisque fired wares. A pair of tongs can be used to hold the piece as it is being immersed into the glaze (Cooper and Royle, 1992).

STEP 4: Firing using a ceramic test kiln

The samples were dried on the shelves and observed. When fully dried, they were loaded inside the kiln and fired at a maturing temperature of 1160^{oc}

Figure 2: Cast ceramic pieces for the glaze testing

3.0 Results and Discussions

This is presented according to the different stages of experimental findings.

FIRST FIRING TEST (soda slurry only) firing temperature

With no significant success from the first firing, the following tests were carried out with only soda and water mixed into slurry. The different forms of soda were mixed with water into a slurry and the ceramics wares dipped and fired at 1160^{oc} in an oxidized kiln atmosphere. The tests were carried out with green wares in triplicates.

Observations

At the end of firing, the samples containing baking soda melted and ran and it was observed to have a glossy appearance. The samples containing soda ash also melted and ran, giving a glossy appearance. However, the samples containing baking powder were cracked and peeled off leaving a brown trace on the sample.

The results of the firing indicates that the additional constituents in the baking powder affected the reaction of the soda with the clay body. While the baking soda and soda ash which are bicarbonates and carbonates of soda respectively, melted because there were no interruptions to the reaction of soda with the alumino-silicates in the clay.

However, the results were not satisfactory because the glaze ‘ran’ in both the soda ash and baking soda samples.

Figure 3: Result from the first firing

SECOND FIRING TEST1160^{oc}

Each source of soda was mixed with clay slip composed of kaolin and ball clay (50:50) using a line blend formula.Firing temperature was 1160^{oc}.The tests were carried out with green wares (unfired wares). The samples were fired under an oxidized kiln atmosphere.

Table 1: Sample formulation using clay slip.

	10% :90% clay slip	20% : 80% clay slip	30% : 70% clay slip	40% : 60% clay slip	50% : 50% clay slip
Soda ash	SA 1	SA 2	SA 3	SA 4	SA 5
Baking soda	BS 1	BS 2	BS 3	BS 4	BS 5
Baking powder	BP 1	BP 2	BP 3	BP 4	BP 5

Observation

At the end of firing, the samples containing baking soda 1, 2, 3, 4 and 5 had dull matt appearance. The samples containing soda ash 1,2,3,4 and 5 was chalky, the glaze coating on the samples flaked and removed easily after firing, and this could imply that they were under fired. While the samples containing baking powder 1,2,3,4 and 5 were cracked and peeled off leaving a flash of brown on the sample.

At the end of the firing none of the samples melted.

Figure 4: Result for Baking powder

Figure5: Result for Baking soda

Figure 6: Result for soda ash

Based on the result of the second firing, changes were made by varying the ratios of the mix of soda with clay slip of kaolin and ball clay (50:50). At ratios ranging from 80:20 mix of soda to clay, to 40:60. Baking powder was removed as it was judged unsuitable for the purpose of the experiment. The samples were fired a third time at a lower temperature of 1040^{oc}. At the end of this firing, the samples containing baking soda had a dull matt appearance, those containing soda ash appeared burnt and the glaze coating on the samples removed easily, indicating they might be underfired. The result was unsatisfactory.

Further testing was done in which the firing temperature was increased to1160^{oc}using extended ratios of up to 20:80 of soda to clay (equal parts of kaolin to ball clay). The observation showed no difference from the third firing test in which the samples containing baking soda had dull matt appearance, while those containing soda ash had the glaze coating removing easily from the ceramic sample pieces leaving a brown trace on the sample. At the end of the firing none of the samples showed satisfactory glaze melt.

Figure7: Result for third firing test

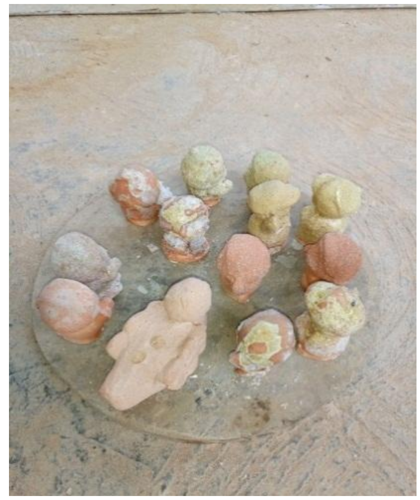

Figure8: Result for fourth firing test

THE FIFTH FIRING TEST

Based on the result of the previous firing tests, the formula was adjusted by mixing powdered ball clay with soda separately from kaolin as well as varying the soda to kaolin/clay ratios to form slurries into which the ceramic pieces were dipped and fired. The tests were carried out with green wares and fired to 1160^{oc}

Table2: Sample formulation

Sample 1	40% ball clay	60% baking soda
2	40% ball clay	60% soda ash
3	60% kaolin	40% baking soda
4	60% kaolin	40% soda ash
5	20% ball clay	80% soda ash
6	20% kaolin	80% baking soda

Observation

At the end of firing, all the samples glazed with slip containing baking soda and ball clay melted and gave a glossy surface finish. The same as the samples glazed with slip containing soda ash and ball clay. While all the samples containing kaolin did not give a good melt and gave a dull appearance on the surface. It was indicated by the results at the end of the firing tests that the samples with ball clay melted and did not 'run' because the ball clay reduced the action of the soda and hence limiting its action to only a fluxing agent. The samples containing kaolin did not melt successfully because kaolin is a more refractory material and would require higher temperatures to melt and is therefore unsuitable for mid-temperature glaze applications.

In another firing attempt, feldspar was added to the soda and ball clay mixtures at 10% of the total weight of materials and fired to 1040^{oc}in an oxidized kiln atmosphere. The resultant effect were dark brown glossy glazed surface. The feldspar reduced the maturing temperature of the glaze as well as altered the colour.

Sample Two, with a formula of 60% ball clay and 40% bicarbonate of soda (baking soda), gave the best visual appearance/finish.

Figure9: Results of fifth firing

Figure10: Results of added feldspar to slip

Figure11. More products of the experiment.

4.0 CONCLUSION

This study dealt with experimenting the use of different types of soda in the glazing of ceramics, by applying the glaze directly onto the ware by dipping in a soda-mix slip rather than by introducing soda into the kiln atmosphere as commonly practiced in vapour glazing.

The research outcomes shows that;

- Baking soda and Soda ash has potentials to react with clay body to give a good glaze melt and glossy surface finish at1160^{oc} when dipped. However, at that temperature the glaze ‘ran’.
- Baking powder did not give as good a glazing effect on the tested ceramics as baking soda and soda ash. It cracked and peeled off leaving a brown trace on the wares. It can be concluded that this may be due to the fact that the baking powder is not a pure bicarbonate of soda substance but contains other substances that may affect the chemical interaction of the soda with the aluminosilicates of the clay body.
- The addition of ball clay to carbonates and bicarbonates of soda gave better glaze finishing results when tested. This would also reduce the cost of using this glazing method by reducing the quantities of soda used in the glaze composition.
- It was important to note that the addition of feldspar at 10% of the total body composition weight resulted in a reduction in the maturing temperature of this soda glaze. And also resulted in a good gloss finish in a different colour.
- The study has provided a basis for the glazing of ceramics in small scale and cottage ceramic industries.This glazing technique do not require the acquisition and use of material processing equipment as thorough hand mixing is sufficient to make the glaze slip.
- The glaze derived from these experiments are expected to be useful on utilitarian household drink and cookwares without any concern for health hazards arising from poisioning by the use of harmful materials as with lead glazes. The materials used in composing this glaze are used in food and pharmaceuticals thereby showing their suitability and safety for wares for storing/ containing human consumables.
- This soda glazing technique can be used to glaze ceramics without the environmental health hazards involved in vapor glazing that involves the release of gas by-products into the atmosphere. As well as without the extra cost of building a dedicated kiln for glazing as with the vapour glazing technique.
- The raw materials required for this soda glazing technique are both ubiquitous and low-cost, offering the ability to stimulate a trend of production glazed ceramic wares in Nigeria. This will encourage and pave way for employment for ceramic graduates. This research demonstrates a stable and reliable means of glazing ceramics wares with materials that can be easily accessedbyceramic practitioners. This could liberate small scale and cottage ceramic industries, studio potters and ceramic students in various tertiary institutions to effectively produce glazed ceramics, using baking soda and soda ash.

In conclusion, these set of experiments displayed the characteristics of carbonates and bicarbonates of soda and ball clay and how they behave at mid-range temperatures. Although there are scientific methods for calculating glazes and proven theories, but there are very few people who have access to this knowledge both in theory and practice. And while it is important for a potter/ceramist to become familiar with glaze behavior so that they can better utilize it, it is also important to be able to access these glaze materials easily and affordably. It is hoped that this experiment will benefit many ceramicists by helping them to expand their palette and inspire them to test the possibilities in soda glazing of ceramics.

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