DEVELOPING LOW GLAZE RECIPE FOR EFFICIENT FUEL USE AND ENVIRONMENTAL SUSTAINABILITY

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Abstract
The concepts of sustainability and efficiency in ceramic practices is now becoming popular as evidenced by the numbers of cutting edge research into the use of sustainable fuel and firing technology as well as the adoption of reuse and recycling. This study reports on the development of low fired glaze using quadraxial blend of ash derived from maize cob, feldspar, and ball clay and glaze cullet. The developed glazed was fired in reduced kiln at atmosphere. Result of the firing indicated a reduction in fuel use, time of firing and exposure to gaseous pollutant and by extension a reduction in C02 emission. The result of the study clearly showed that, fuel efficiency and environmental sustainability is achievable using low fired glazes.

Introduction

Traditionally, ash glazes are fired to high stoneware temperatures, at least 1 280°C. Cone 10 and beyond. This practice is not only energy (fuel), and time consuming but it also has deleterious consequence on human health and the environment due to CO2 emission. However a significant reduction in terms of fuel use and time of firing as well as reduction in the green house gas emission could be achieved if high temperature glazes were replaced low fired ones. For example Malmgren, (2000), reported that fuel saving of 30% can be made by firing to Cone 6 instead of Cone 10. This is in line with the global demand for the shift towards the use of best available materials and technology in the production of goods and services as well as the application of sustainable practices in production and consumption. Although the issues of sustainability has not only found its way into ceramic vocabulary, but it has also being put into good use particularly in the areas of fuels and firing technology as well as the reuse and recycling of ceramic materials. However more data needs to be provided on the key components of sustainability namely: social, economic and environmental as it relates to glaze making and firing. This research, therefore seeks to address the key components of sustainability developing a low fired glaze using agricultural residue with a view to addressing the social, economic and environmental components of sustainability.

Glazes

Apart the general classification of Glazes fired into low, medium and high temperatures; glazes were also classified base on the type of ware, the dominant fluxes, and characteristics such as transparency or matty (Sutherland, 2005). However for ceramic glaze to fall into any of these classifications some basic ingredients needs to be added to the recipe to tune the glaze into behaving in the required pattern. For example in chun glazes, the iron content is normally not more than two percent. Similarly , achieving specific temperature and colour variation will depends on the expertise of a ceramics of the manipulation Si02, AL203, Fe203, Ca0, Mg0, K20, Na20: the key ingredient required for glaze formulation. For example if earthen ware glaze temperature to be achieved, the various ingredients must be manipulated in such a way as to achieve make the glaze fuse within a temperature range of 1040-1080°C, while bone china, stoneware and porcelain glazes must be manipulated to melt within the temperature ranges of 1040-10800C, 1250-13000C and 1300-1450 respectively (Green, 1975). However, producing high temperature glaze will require having high content of silicates and Alumina. In this study, unwashed ash derived from maize cob was used to provide the fluxing action required for low temperature firing. The choice of unwashed ash was

based on its potassium (12.49%), calcium (10.60%) and soda (5.6) content of the ash.

Low fired glazes

Low fired glaze which is the main thrust of this study is described as glaze material that vitrifies below 10000C. Most glazes produce at this temperature are soluble with low resistance to abrasion (Sutherland, 2005). Examples of such fluxing agents used in glaze formulation are lead carbonates, red lead, galena, litharge and alkaline compounds such as borax, colemanite, soda ash and boric acid. These fluxing agents act as catalyst in lowering the melting point of glaze materials. However given the soluble nature of some fluxes used in the formulation of the glazes, it therefore became imperative to manipulate the fluxing ingredients in a cautious manner to avoid the glaze becoming runny (Sutherland, 2015). Examples of such types of low fired glazes are the majorlica, raku, lead and borisilicates glaze. This class of glaze recipe will normally contain large percentage of fluxing agent.

Sustainable Ceramics Production

The concept climate change has raised a lot of debates on whether climate change itself is real or not. However while, politicians argued that, climate change does not have existential threat to humans, environmental policy makers such as IPCC and stakeholders in the environmental sector believed that, climate change is real and man through his activities has played a significant role in creating it. They also believe that made needs to take responsibility and work towards preventing future environmental catastrophe. One way of preventing environmental disaster is to become sustainable in the exploration of raw materials, the processing of goods and the consumption of services. However given the backdrop that Ceramics production is a major player in the exploration and usage natural raw materials; the issue of sustainability is now an integral part of the ceramic production process. An example of such integration is the development of low glaze theory and practice for once fired, mid fire purpose by Englund with the view to saving cost and providing some benefits to the use of natural resources and the ecological system through less use of fuel, less green house has emission and less contribution to global warming (Englund, 1995). Other giant strides made in the making ceramics production sustainable includes the use of environmentally friendly firing fuels as well as the reuse and recycling of the of ceramics products and glaze materials such as the development of the waste glaze system by Shippensburg University where used glaze residue containing heavy metal colorants are combined with recycled clay and fired to cone 1 to form paver blocks (Shippensburg University, 2017).

Materials and Method

Experimental design was adopted for the formulation of the glaze recipe using quadraxial blends method. The method was used to arrive at a suitable glaze recipe using the following tools and equipment: cutting knife, small plastic containers, kiln shelves, props stands, kerosene, masking tape, marker, wooden boards, ruler, and test tiles, jaw crusher, milling machine model No: BB 51, ball milling machine model 1679-VS-A, electric kiln, x-ray fluorescent machine mini pal model 4 version pw 430, and a digital scale model PGS002.5

Sourcing of materials

Maize cob ash, glass cullet, ball clay and feldspar were used in the formulation of the low temperature glaze recipe. These materials were sourced from ATBU farm, Ram, Dirr/Bayara and studio ATBU Bauchi all in Bauchi L.G.A.

Processing of materials

The materials used in the glaze formulation were processed based on the standard procedures as recommended by AS TM—

Glaze formulation

Quadraxial Technique

Various methods and techniques and approaches such as the linear approach, blanket coverage and block blends have been have been used for the development of glaze recipe (Currie, 1986; Sutherland, 2005; Scott, 2001; De Montmollin, 1997; Metcalfe, 2008 & Smout, 2013). However, given that four materials were selected for use in this study for the formulation of test tiles; quadraxial method of

glaze development prescribe by Smout (2013) was found appropriate for use in this study. The method is described here:

A total of 81 tiles were used to produce the quadraxial blend. Batches of equal weight and volume for each of the four glaze ingredients werepreprared and placed at the four corners of a quadraxial. At these corners, designated (maize cob ash, feldspar, cullet and ball clay) there is a 100% of the allocated ingredient. The ingredient at each corner is systematically mixed with each other in predetermined proportions, based on the number of rows in the quadraxial as shown on figure 3

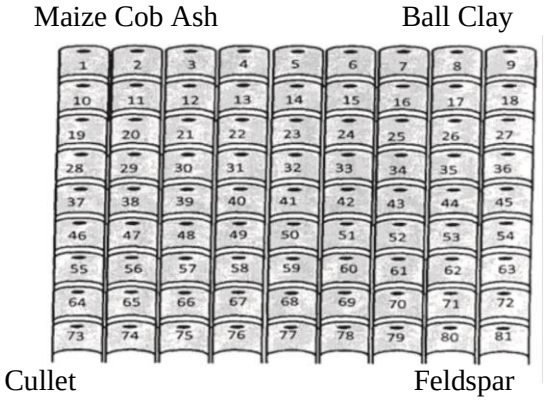


Figure 4: Quadraxial fired test tiles

Firing

Bisque firing

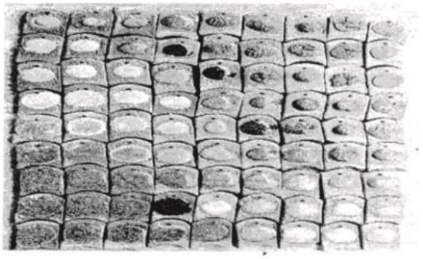
Before the application of glazes, the test tiles were bisque fired to 700°C. This was done to change the green body into hard, strong and chemical resistant product, prior to the application of glaze to ensure that the changes in the clay did not affect the glaze behaviour.

Glaze firing

The glaze recipe developed from the quadraxial blend technique was fired to 9000C in 5 hours in an oxidizing kiln atmosphere.

Result and Discussion

The fired result of glaze recipe developed using the quadraxial blend technique is shown on figure 4.



Of the total number of 81 test tiles used in the quadraxial blend, the result of the firing results showed that 74 were fused, of the 74, 55 tiles produce smooth glaze, 29 tiles showed runny glaze while 29 tiles produce glossy glaze. The number of fused tiles translates 20%, 37%, 15% and 28% for glossy, fused, runny and smooth respectively as indicated in figure 5.

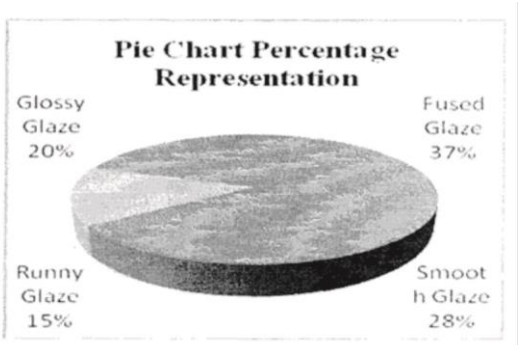


Figure 5: Percentage representation of fused glazes

Percentage representation of maize cob ash in quadraxial blend format with glossy, fused, runny and smooth denoted by 20%, 37%, 15% and 28% respectively. Some of the glossy glaze displayed some crazing features (plate 1). This feature is attributed to high percentage of maize cob ash (75%). However, its glossy nature suggested the ability of the recipe to higher proportions of MCA at the higher temperature. It is also expected that, the addition could reduce crazing. Similarly the quadraxial test with equal percent of the various ingredients showed flakes of paler crystals floating above the underlying pale khaki gloss where the glaze is thickest (Plate 2). The glaze recipe containing 70% feldspar felt slightly drier to touch, and less reflective (plate 3).

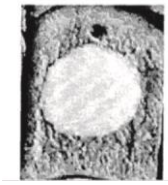


Plate 1: Glossy glaze with crazy features

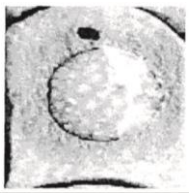


Plate 1: Flakes of pale crystals underlaying Khaki gloss

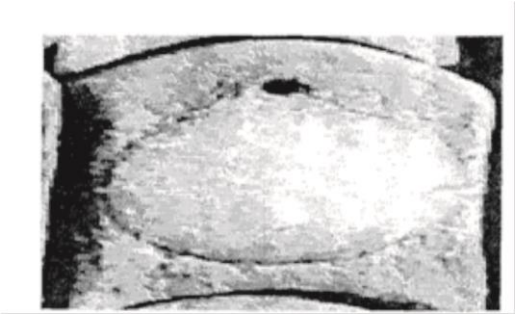


Plate 3: Drier and less reflective glaze

Behaviour of the constituent materials

Maize Cob Ash

The results of the study also showed that ash has a very strong influence on the lowering the melting temperature of the samples. The highest ranking among element of the ash was silica (Si02) with 41.31%; this was because the ash used for the research was unwashed, thus responsible for the high potassium and sodium, their strong fluxes content of the ash. This finding is consistent with the studies of (Carol 2015; Ajala, 2009; Mellon, 1980). According to Rogers (1991), the soluble alkalis removed by washing are mainly potassium and sodium, which are strong fluxes, useful in glazes. The other elements that show prominence in MCA include: - Aluminum (Al203) 13.86%, potassium oxide (K20) 12.49%,so as to retain the soluble alkalis as strong fluxes Calcium (CaO) 10.60%, Sodium (NaO) 5.63%, Manganese (MnO) 5.63%, Iron (FeO3) 3.96%, Zinc (Zn) 0.02%, and Lead Oxide (PbO) 0.00 1%.

Ball Clay

Ball clay also had the highest silica oxide (Si02) content, with 47.90%, the remaining constituents are; Aluminum oxide (A12O3) 27.10%, Iron oxide (FeO3) 11.61%, the 11.61 of iron oxide it possessed invited the brown coloration of the fired test results.

Cullet

The cullet is quite rich of Silica oxide with about 72.0% and Sodium oxide 14.0%, which used along with the maize cob ash (Smout, 2013). The silica and Sodium content therefore was responsible for it fusing at low temperature along as glaze in the tests. The cullet Contains Calcium oxide (CaO) 9.0%, Magnesium oxide (MgO) 4.0%, Aluminum oxide (Al2O3) 0.3%, Iron oxide (FeO3) 0.5%, and potassium oxide (K2O) 0.l respectively.

Fuel Efficiently and Sustainable Firing

The result of the firing also indicated a reduction in fuel consumption and time from 40 to 20 liters of kerosene and from 4 hrs to 2 hrs of firing. The reduction in fuel consumption means a reduction in the amount of CO2 emission into the climate system. Overall the reduced cost of fuel, and time could now be channelled into other aspect of the social and economic life of the ceramicist. It pertinent to also suggest that a reduction in emission of CO2 will also translate to a reduction in exposure to the gaseous pollutions (CO2) which are known to cause respiratory problems and fatalities. The development and use of low fired glazes will surely address key issues of sustainability (social, economic and environmental).

Conclusion

Ash derived from maize cob, alongside feldspar, ball clay and cullet blending using quadraxial technique has proved to be an excellent recipe for low temperature ceramic glazes capable of vitrifying at 9900C. This has also shown a reduction in both times of firing, cost of fuel and the emissions of gaseous pollutant into the climate system. The produced low fired glaze exhibited a stronger resistance to abrasion a quality lacking in most low fired glazes.

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