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Research Article

Development of Transparent Glaze Using Local Raw Materials

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Abstract

The development of transparent ceramic glazes using locally sourced raw materials offers a sustainable and cost-effective approach to enhancing the aesthetic and functional properties of ceramic wares. This study focuses on formulating and evaluating transparent glazes derived from indigenous Nigerian materials, including silica, lead sulphide, kaolin, and feldspar and quartz. Additives such as bentonite and sodium silicate were incorporated to improve plasticity and fluidity, respectively. The raw materials underwent a series of processing steps: crushing, milling, and batch formulation to create four distinct glaze compositions (Batches A, B, C, and D) with varying ratios of the materials. Each batch was mixed with water to form a uniform suspension, applied to bisque-fired ceramic wares via dipping, and subsequently fired at approximately 1108°C. Analysis of the glaze compositions revealed that silica content ranged from 10% in Batch C to 70% in Batch D, serving as the primary glass-forming agent contributing to transparency and durability. Kaolin varied between 10% (Batch D) and 30% (Batch C), acting as a suspending agent and influencing viscosity and adhesion. Lead sulphide, a potent flux, was present from 20% in Batch D to 60% in Batch C, effectively lowering the melting point and enhancing the glaze's fluidity and glossiness. The study observed that higher silica concentrations, as in Batch D, resulted in glazes with increased transparency and surface smoothness, while elevated lead sulphide levels, as in Batch C, produced glazes with enhanced fluidity and a glossy finish. However, excessive lead content may pose health and environmental concerns, necessitating careful optimization. These findings underscore the potential of utilizing local Nigerian raw materials in developing transparent ceramic glazes, promoting sustainability, reducing reliance on imported materials, and fostering economic growth within the local ceramics industry.

Keywords	*Transparent Glaze; Local Raw Materials; Cost-Effective Approach; Sodium Silicate*
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Introduction

Ceramic glazing plays a crucial role in enhancing the aesthetic and functional properties of ceramic wares. A glaze is a layer or coating of a vitreous substance that has been fired to fuse onto ceramic ware, serving the purposes of coloring, decoration, and strengthening while improving water resistance. Without a glaze, ceramic wares remain porous and susceptible to wear, aging, and deterioration. The development of transparent glazes using local raw materials is a significant area of study in ceramic engineering, as it aligns with the sustainable use of indigenous resources and reduces reliance on expensive imported materials. (Richardson, 2024).

Glazing is a crucial process in ceramics, involving the application of a vitreous coating to pottery to enhance aesthetics and functionality. Unglazed ceramic wares often suffer from porosity, leading to deterioration and reduced utility over time. Glazes not only render earthenware vessels impermeable to liquids but also protect surfaces from wear and aging. The use of locally sourced raw materials in ceramic glaze development is not only cost-effective but also environmentally sustainable. Various studies have identified feldspar, quartz, kaolin, and other locally available minerals as potential sources for glaze formulation (Hamer and Hamer, 2004).

The chemical composition and mineralogical properties of these materials influence the transparency, durability, and aesthetic quality of the final glaze. By optimizing the formulation, it is possible to achieve transparent glazes that meet industry standards for ceramic applications. Transparent glazes serve multiple purposes in ceramic production. They protect the ceramic body from moisture absorption, enhance the visual appeal by revealing underlying patterns, and improve the mechanical properties of ceramic products. According to Kingery et al. (1976), glazes reduce the permeability of ceramics, making them suitable for both decorative and utilitarian purposes. Furthermore, the transparency of the glaze allows for intricate designs and color variations to be displayed vividly.

Industries that rely on ceramic products, such as pottery, tile manufacturing, and sanitary ware production, benefit significantly from advancements in glaze technology. Transparent glazes can be formulated to achieve different surface finishes, including glossy, matte, and satin textures, depending on the composition and firing conditions (Norton, 1970). The development of transparent glazes using local materials offers economic benefits by reducing production costs while maintaining high-quality standards.

The selection of raw materials is fundamental to glaze formulation. Key components of a transparent glaze include silica (SiO_2), alumina (Al_2O_3), and fluxes such as feldspar and calcium carbonate. These materials contribute to the glaze's viscosity, melting temperature, and surface texture. Rhodes (1973) emphasizes that the balance of these components determines the final properties of the glaze, such as its transparency, thermal expansion, and adherence to the ceramic body. Local sources of silica, feldspar, and kaolin have been identified in various regions, making them viable alternatives to imported raw materials. The beneficiation of these raw materials through processing techniques such as calcination and sieving enhances their suitability for glaze production (Hamer and Hamer, 2004). Research has demonstrated that properly refined local materials can produce glazes with comparable or superior properties to those made with imported materials (Singer and Singer, 1979).

Despite the advantages of using local raw materials, challenges such as impurities, inconsistent chemical compositions, and variability in mineral sources must be addressed. These factors can affect the reproducibility and quality of the transparent glaze. Advances in materials characterization techniques aid in the precise analysis and modification of raw materials to achieve desirable glaze properties. (He, Zhang, and Zhang, 2015).

The future of transparent glaze development using local raw materials lies in continued research and technological innovation. With the increasing demand for sustainable and cost-effective ceramic production, the optimization of local resources offers a promising pathway for growth in the ceramics industry. Historically, Nigeria has relied on imported glazes, unaware of the abundant local raw materials suitable for glaze production. This study explores the development of transparent glaze using three indigenous raw materials, namely, Orhionmwon river sand (silica), Abakiliki galena (lead sulphide), Nsu clay (kaolin), feldspar and quartz.

Methods

The primary raw materials utilized were; Silica, sourced from Orhionmwon River sand in Edo State; Lead Sulphide (Galena), obtained from Abakaliki in Ebonyi State; Kaolin gotten from Nsu in Imo State, Feldspar and Quartz, gotten 0from Abeokuta in Ogun State. Other additives include bentonite to enhance plasticity and sodium silicate to improve fluidity.

Processing

These raw materials were processed individually, following the steps below;

Crushing: This process involves breaking down large chunks of the raw materials into smaller, manageable sizes. A hammer mill is typically used for this purpose, as it applies mechanical force to shatter hard raw materials. The efficiency of the crushing process is crucial because it determines the ease of subsequent milling and affects the uniformity of the final glaze composition. Properly crushed materials facilitate better homogenization in the later stages of glaze preparation.

Milling: After the crushing stage, the raw materials underwent milling to achieve a finer particle size. This step is essential to ensure the smooth texture and homogeneity of the glaze. A ball mill is employed, where the crushed materials are loaded into a rotating cylindrical drum along with grinding media such as ceramic balls. The continuous impact and friction reduce the particles to micron-sized powders. The degree of fineness achieved in this process directly influences the glaze's surface finish, adhesion properties, and melting behavior during firing. Extended milling times often result in finer particles, leading to improved glaze stability and aesthetic appeal.

Batch Formulation: Once the raw materials are finely milled, they are weighed and combined in specific proportions to create different glaze compositions. In this study, four batches (A, B, C, and D) were formulated with varying ratios of silica, kaolin, and lead sulphide, as outlined in Table 1. The formulation process is critical because it determines the physical and chemical properties of the final glaze. The presence of silica contributes to the formation of a glassy phase, kaolin acts as a suspending agent, and lead sulphide serves as a flux to lower the melting point and enhance the glaze's glossy finish. Careful batching ensures that each composition meets the desired aesthetic and functional requirements.

Mixing: The next step involves mixing the formulated batches with water to create a uniform glaze suspension. A roller mill is used to ensure thorough blending of the components. This wet mixing process aids in achieving a consistent particle distribution, preventing settling, and enhancing the adhesion of the glaze to ceramic surfaces. The mixture is then sieved to remove any coarse particles or impurities, ensuring that the glaze has a smooth and homogeneous consistency. Proper mixing is crucial to prevent defects such as pinholes or uneven coatings in the final product.

Application: After achieving a well-mixed glaze suspension, the application process begins. Bisque-fired ceramic wares (Figure 1) are dipped into the glaze suspension for approximately 10 seconds. This duration allows for an even coating of the glaze on the ceramic surface. The dipped wares are then removed and left to air-dry before firing. The application process is vital, as inconsistencies in glaze thickness can lead to defects such as crawling, cracking, or uneven color development after firing. Factors such as glaze viscosity, dipping time, and drying conditions influence the success of this step.

Firing: The glazed ceramic wares (figure. 1) were heated to approximately 1108°C in a kiln. During firing, the glaze undergoes several transformations: the volatile components evaporate, the fluxing agents lower the melting point, and the silica forms a glassy network that bonds with the ceramic body. The firing temperature and duration must be carefully controlled to prevent defects such as blistering, crazing, or incomplete vitrification. At the optimal temperature, the glaze forms a smooth, transparent, and durable surface, enhancing the ceramic's aesthetic and functional properties.

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Figure 1: Image of glazed ceramic wares with a glossy and colorful finish

Table 1: Glaze Batch Compositions

Raw Material	Batch A (%)	Batch B (%)	Batch C (%)	Batch D (%)
Silica	*30*	*20*	*10*	*70*
Kaolin	*20*	*25*	*30*	*10*
Lead Sulphide	*50*	*55*	*60*	*20*

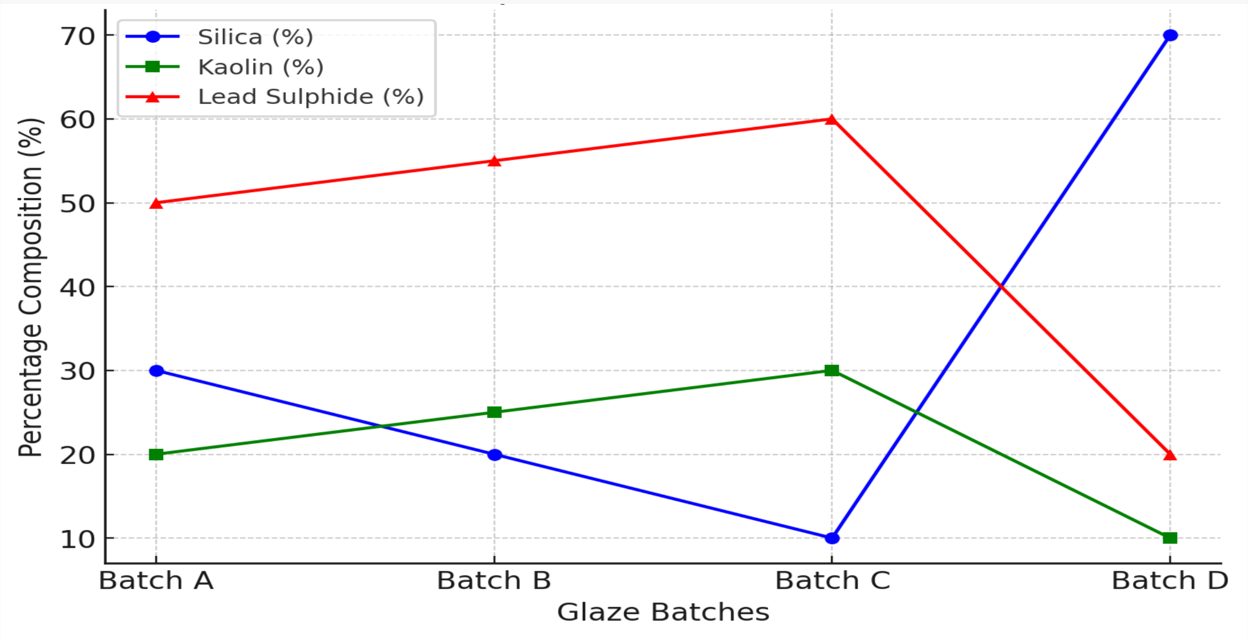

Figure 1: Raw Material Composition in Different Glaze Batches

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Results and Discussion

From table 1 and figure 1 above, the composition of raw materials—Silica, Kaolin, and Lead Sulphide—in four different glaze batches (A, B, C, and D) were shown. This formulation is a critical step in the development of transparent glazes using local raw materials. Each raw material plays a distinct role in determining the final properties of the glaze, such as transparency, adhesion, surface smoothness, and resistance to chemical and thermal degradation.

The table illustrates the varying percentages of the three raw materials across the four glaze batches: For the silica, the content is highest in Batch D (70%) and lowest in Batch C (10%). It acts as the primary glass former in glazes, contributing to the transparency and durability of the final coating. The significant variation in silica content across batches indicates an attempt to evaluate the effect of high and low silica concentrations on glaze properties. For the kaolin content, it ranges from 10% in Batch D to 30% in Batch C. Kaolin functions as a suspending agent and contributes to the glaze's viscosity, adhesion, and stability during firing. Its variation in different batches aims to determine the optimal proportion that enhances glaze application and consistency. For the Lead Sulphide, the content is highest in Batch C (60%) and lowest in Batch D (20%). It is a powerful flux that lowers the melting point of the glaze, improving its fluidity and adhesion to the ceramic body. The variations in Lead Oxide percentages suggest an exploration of how flux content influences glaze transparency, smoothness, and fusion with the ceramic surface.

From the line graph, it can be visualized how the composition of each raw material fluctuates across different batches. The following observations were made:

i. **Silica's pattern**: The curve for Silica shows a sharp increase in Batch D, indicating a significant rise in glass-forming content compared to the other batches. This suggests that Batch D is designed to achieve a glaze with high transparency and a smooth surface.

ii. **Kaolin's trend**: The Kaolin curve remains moderate across the batches, peaking in Batch C. This controlled fluctuation suggests that the study aims to determine the effect of slight variations in Kaolin concentration on glaze suspension and application properties.

iii. **Lead Sulphide's influence**: The Lead Oxide curve shows a downward trend in Batch D. Since Lead Sulphide enhances melting and adhesion, its low concentration in Batch D suggests that this batch relies more on Silica for vitrification. Conversely, the high Lead Sulphide content in Batch C implies an effort to achieve a lower melting point glaze with enhanced fluidity.

Conclusion

The study successfully developed transparent glazes using locally sourced materials in Nigeria. The high-quality silica and kaolin, combined with lead from galena, produced effective glazes. The variations in the raw material compositions in each batch highlight an experimental approach to optimizing glaze properties. The high Silica content in Batch D is produced a highly transparent glaze, whereas the high Lead Sulphide content in Batch C yielded more fluid, low-melting glaze. The Kaolin content, remaining within a moderate range, helps maintain suspension stability. This formulation approach allows for a comparative study of different glaze behaviors, ensuring that the most suitable composition is selected for practical ceramic applications. Addressing impurities in raw materials could further enhance glaze quality. This initiative promotes the utilization of indigenous resources, fostering self-sufficiency in the Nigerian ceramics industry.

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