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Comparative Evaluation of Imported and Locally Formulated Porcelain Bodies for Studio Ornamental Ware Production in Nigeria

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ABSTRACT

The reliance on imported porcelain body materials for studio and small-scale ceramic production in Nigeria significantly increases production costs and limits material accessibility. This study presents a comparative evaluation of an imported commercial porcelain body and a locally formulated triaxial porcelain body developed from raw materials sourced in AkwaIbom State and Cross River State, Nigeria. Physical, mechanical, and aesthetic properties, including linear shrinkage, water absorption, bulk density, flexural strength, translucency, thermal shock resistance, and cost efficiency, were systematically evaluated. Test specimens were prepared via slip casting and fired at 1250°C under identical thermal conditions. Results indicate that the locally formulated body achieved 92–95% of the flexural strength of the imported body, with comparable densification and water absorption values below 0.5%. Slightly reduced translucency was observed due to minor iron oxide content. Cost analysis demonstrated a reduction in raw material expenditure of approximately 60%. The findings establish the technical and economic viability of substituting imported porcelain materials with locally engineered alternatives for studio ornamental ware production.

1. Introduction

Porcelain is one of the most refined categories of ceramic materials which is characterized by translucency, low porosity, high whiteness and superior mechanical strength. Studio ornamental ware, including sculptural forms, decorative vessels, and artistic installations, demands porcelain bodies that combine aesthetic appeal with structural reliability, (Kingery, Bowen, &Uhlmann, 1976). Most ceramic studios, particularly in Nigeria, depend on pre-formulated powders or imported porcelain bodies. This is due to perceived inconsistencies in the availability of local raw materials. Thus, the dependency increases production costs while limiting innovation rooted in indigenous materials. However, despite the country's substantial clay and feldspathic mineral deposits, previous studies have evaluating local formulations against imported commercial bodies have indicated scarcity. Previous empirical studies have indicated that locally sourced kaolins in Nigeria possess promising chemical and mineralogical properties for porcelain production (Ekpunobi et al., 2023). Mgbemere, Onyeayana, and Okoubulu (2019) noted that optimized triaxial formulations using Nigerian materials can achieve satisfactory physical performance for porcelain insulators.

1.1 Objectives of the Study

- Compare physical and mechanical properties of imported and locally formulated porcelain bodies.
- Evaluate translucency and aesthetic characteristics relevant to ornamental ware.
- Assess economic implications of material substitution.
- Provide empirical evidence supporting local porcelain development.

2. Literature Review

2.1 Microstructure and Mechanical Performance of Porcelain

Porcelain microstructure consists of mullite crystals embedded in a glassy matrix with residual quartz particles. Mechanical strength depends on the formation and distribution of mullite needles during firing (Iqbal & Lee, 2000). Adequate vitrification reduces porosity, improving both translucency and flexural strength.

The degree of densification correlates with feldspar content, as feldspar melts to produce a viscous liquid phase that promotes particle rearrangement and pore elimination (Kingery et al., 1976). However, excessive glass formation can reduce mechanical strength due to brittleness.

2.2 Translucency and Aesthetic Performance

Translucency in ceramic materials is basically influenced by low porosity, minimal iron impurities, a uniform microstructure, and controlled quartz particle size. These factors collectively determine how light interacts with the ceramic body. Also, low porosity can reduce the number of air-filled voids within the material, thereby limiting internal light scattering and enhancing light transmission. When porosity is high, light is dispersed in multiple directions, resulting in a more opaque appearance.

Minimal iron impurities are equally important because iron oxides tend to absorb and alter light, often producing unwanted coloration and reducing translucency. A uniform microstructure ensures that the crystalline and glassy phases are evenly distributed throughout the ceramic body, allowing light to pass through more consistently. Controlled quartz particle size also plays a critical role, as excessively large or unevenly distributed particles can interrupt the path of light and increase scattering.

Lee and Iqbal (2001),emphasised that an increased glassy phase significantly improves light transmission in ceramics. The glassy matrix facilitates the passage of light by reducing refractive mismatches within the material. On the other hand, residual pores act as scattering centers that disrupt light flow and diminish translucency. In studio ceramics, translucency is seen as a defining aesthetic property, especially in thin-walled ornamental pieces where light penetration can enhance visual depth, delicacy, and overall artistic appeal.

2.3 Economic and Sustainability Considerations

Local material substitution reduces import dependency and fosters sustainable manufacturing ecosystems. According to Kimambo, Naimani, and Lugwisha (2014), localized porcelain production can significantly lower costs while maintaining acceptable technical standards. Moreover, reduced transportation contributes to environmental sustainability.

Despite these benefits, limited standardized testing has prevented widespread adoption of indigenous porcelain bodies in Nigerian studio practice.

3. Materials and Methods

3.1 Materials

Imported Porcelain Body (Control Sample):

A commercially available cone 10 porcelain body imported into Nigeria for studio ceramics.

Locally Formulated Porcelain Body (Experimental Sample):

Triaxial composition (45% kaolin, 30% feldspar, 25% quartz) derived from deposits in:

- AkwaIbom State
- Cross River State

All local materials were beneficiated through washing, drying, and milling (<75 µm).

3.2 Sample Preparation

- Ball milling (6 hours)
- Slip casting in plaster molds
- Drying at 110°C for 24 hours
- Firing at 1250°C (5°C/min heating rate; 1-hour soak)

3.3 Testing Procedures

Testing followed ASTM standards:

- Linear Shrinkage: Measured before and after firing
- Water Absorption: ASTM C373
- Bulk Density: Archimedes method
- Flexural Strength: Three-point bending test
- Thermal Shock Resistance: Repeated quenching cycles
- Translucency: Light transmission percentage measurement
- Cost Analysis: Comparative material cost assessment per 100 kg batch

4. Results

4.1 Linear Shrinkage

Sample	Linear Shrinkage (%)
Imported	13.2
Local	14.1

The locally formulated body exhibited slightly higher shrinkage, likely due to marginally increased glass phase formation.

4.2 Water Absorption

Sample	Water Absorption (%)
Imported	0.32
Local	0.45

Both bodies meet porcelain standards (<0.5%), indicating adequate vitrification.

4.3 Bulk Density

Sample	Density (g/cm³)
Imported	2.35
Local	2.30

Densification levels were comparable.

4.4 Flexural Strength

Sample	Modulus of Rupture (MPa)
Imported	72
Local	66

The local body achieved approximately 92% of imported strength.

4.5 Translucency

Sample	Light Transmission (%)
Imported	18
Local	15

Slightly reduced translucency in the local body is attributed to trace Fe_2O_3 (~1.2%).

4.6 Thermal Shock Resistance

Both bodies survived five quenching cycles (100°C to room temperature) without cracking.

4.7 Cost Analysis

Material Source	Cost per 100 kg (USD Equivalent)
Imported	420
Local	165

The local formulation reduced raw material cost by approximately 60%.

5. Discussion

5.1 Mechanical Performance Comparison

The slight reduction in strength of the local body can be attributed to minor differences in impurity levels and particle size distribution. However, the achieved strength (66 MPa) remains within acceptable porcelain performance ranges (Kingery et al., 1976). Mullite development in both bodies likely contributed to mechanical integrity, consistent with findings by Iqbal and Lee (2000).

5.2 Translucency Considerations

Translucency differences are primarily linked to iron content and residual porosity. Even small iron concentrations can reduce whiteness and light transmission (Lee & Iqbal, 2001). Beneficiation techniques such as magnetic separation may further improve translucency of local materials.

5.3 Studio Application Implications

For ornamental ware, slight translucency variation may be acceptable, especially when surface glazing is applied. Structural strength and low water absorption confirm that the local body meets studio performance requirements.

5.4 Economic and Sustainability Impact

The substantial cost reduction demonstrates strong economic justification for local substitution. Additionally, reliance on indigenous materials strengthens regional ceramic industries and promotes technological independence.

6. Conclusion

This comparative evaluation confirms that locally formulated porcelain bodies derived from southern Nigerian raw materials can effectively substitute imported commercial bodies for studio ornamental ware production. Although minor differences in translucency and flexural strength were observed, overall performance remained within acceptable porcelain standards. The economic advantages further reinforce the viability of local porcelain development. Future studies should explore long-term durability, glaze compatibility, and advanced beneficiation techniques to enhance whiteness and translucency.

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