

UTILIZATION OF TIGER NUT (*CYPERUS ESCULENTUS*) CHAFF ASH AS A FLUX IN CERAMIC GLAZE

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Abstract

*This study explores the valorization of tiger nut (*Cyperus esculentus*) chaff ash (TNCA), a fibrous agro-waste by-product, as a sustainable flux material in high-fire ceramic glaze formulations. The research addresses the environmental burden of agricultural waste and the reliance on imported ceramic raw materials in Nigeria. TNCA was produced by calcining dried tiger nut chaff at 800°C and analyzed using X-ray fluorescence (XRF) to determine its chemical composition. The results revealed an unusually high flux content dominated by CaO (24.54%), P₂O₅ (17.73%), Fe₂O₃ (12.54%), and volatile SO₃ (19.83%), with critically low glass-forming oxides: SiO₂ (5.61%) and Al₂O₃ (1.82%). This profile confirmed TNCA's potential as a powerful flux but highlighted its unsuitability for standalone use. Twenty-one glaze formulations were developed using line and triaxial blends with potassium, feldspar and ball clay. Glazes were applied to stoneware tiles and fired at 1260°C. Optimal compositions (40% TNCA, 40% feldspar, 20% ball clay) yielded stable, glossy, impermeable surfaces with warm brown tones. Seger formula analysis confirmed their durability and suitability for high-fire applications. The study demonstrates TNCA's viability as a cost-effective, locally sourced flux, contributing to sustainable ceramics and circular economy goals.*

Keywords: Tiger nut chaff ash, ceramic glaze, flux, agro-waste, sustainability, Serger formula

Introduction

Agricultural waste management is a growing global concern, particularly in developing countries where crop residues are often discarded or burned. Nigeria generates over 30 million tons of agricultural waste annually (FAO, 2025), yet systematic valorization remains limited. Tiger nut (*Cyperus esculentus*), widely cultivated in Northern Nigeria, produces a significant volume of fibrous chaff during milk extraction. This by-product is typically discarded, contributing to environmental degradation. However, its high mineral content suggests potential for industrial reuse. This study investigates the use of tiger nut chaff ash (TNCA) as a flux in ceramic glaze, aiming to reduce reliance on imported materials and promote sustainable practices in ceramic production.

Literature Review

Ceramic glazes are composed of silica (glass former), alumina (stabilizer), and fluxes (melting agents) (Hamer, 2015). Fluxes such as CaO, K₂O, and Na₂O lower the melting point of silica, enabling glaze formation. Historically, plant ashes have been used as fluxes, with origins traced to ancient China and Egypt. Wood ash glazes are well-documented, but other plant ashes remain underexplored. Recent studies have examined agro-waste ashes for ceramic applications, highlighting their chemical richness and fluxing potential (Ologunwa, Akinbogun, & Kashim, 2012; Opoku, 2015; Anto & Akali, 2016). Tiger nuts (*Cyperus*

esculentus) are *tubers*, not true nuts. (Yu, et al., 2022; Souza, 2024). They grow underground like potatoes and are botanically classified as edible tuberous rhizomes of a sedge plant. They are rich in calcium and phosphorus compounds, presents a novel alternative. However, literature on its ceramic application is scarce, indicating a gap this study seeks to fill.

Methodology

The tubers were purchased at Tudun Wada market in Zaria, Kaduna State. The chaff was obtained by soaking, grinding, and sieving to obtain the by-product, followed by sun-drying and burning to produce TNCA. XRF analysis was conducted at the National Geosciences Research Laboratory, Kaduna, to determine oxide composition. Glaze formulations were developed using line blends (TNCA + feldspar) and triaxial blends (TNCA + feldspar + ball clay). Glazes were applied to bisque-fired stoneware tiles and fired at 1260°C with a 2-hour soak. Visual, tactile, impermeability, and acid resistance tests were conducted. Seger formula analysis was used to evaluate glaze chemistry and durability.



Plate 4: Dried Tiger nuts



Plate 5: Soaked Tiger nuts ready for milling



Plate 6: Dried tiger nut chaff ready for burning

Source: Research Photograph, Aigbudume (2025)



Plate 7: Buring of the chaff



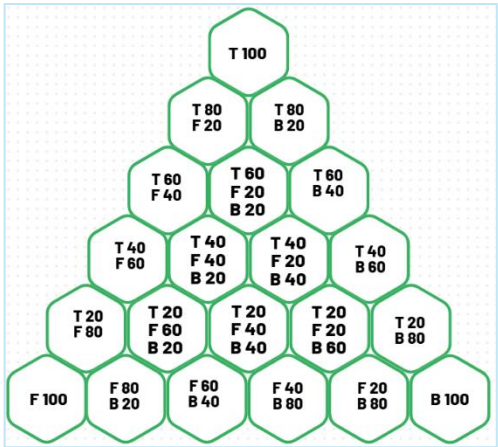
Plate 8: Test Tiles After Bisque Firing

Source: Research Photograph, Aigbudume (2025)

Table 1: Line blend comprising Tiger Nut Chaff Ash and Potassium Feldspar.

Tiger Chaff Ash (%)	Nut Ash	0	10	20	30	40	50	60	70	80	90	100
Feldspar		100	90	80	70	60	50	40	30	20	10	0

Tiger Nut Chaff Ash (TCNA)



Potassium Feldspar (F)

Ball Clay (B)

Figure 1: Triaxial Blending of Tiger Nut Chaff Ash (TCNA), Feldspar (F) and Ball clay (B).

Source: Research Figure, Aigbudume (2025)

Result

XRF analysis reveals TNCA’s high flux content: CaO (24.54%), P₂O₅ (17.73%), Fe₂O₃ (12.54%), and SO₃ (19.83%), with low SiO₂ (5.61%) and Al₂O₃ (1.82%). 100% of TNCA glazes exhibited crawling and excessive flow due to premature melting. Stable, glossy, and impermeable surfaces were achieved in blends containing 20–60% TNCA. The optimal formulation—40% of TNCA, 40% of feldspar, 20% of ball clay—produced warm brown tones and excellent surface quality. Seger analysis showed a balanced flux ratio and appropriate Si: Al molar ratios (7.1–10.7), confirming glaze stability and durability.

Table 2: Overview of chemical analysis of Tiger nut chaff ash, Ball clay and Potassium Feldspar

Oxides	% presence in (TCNA)	% presence in (Ball clay)	% presence in (Potassium Feldspar)
SiO ₂	1.93	56.72	68.46
P ₂ O ₅	17.73	0.10	0.03
SO ₃	19.83	0.20	ND
K ₂ O	12.63	4.60	6.30
MgO	7.47	ND	ND
Na ₂ O	0.80	0.30	0.10
CaO	24.54	ND	0.30
Fe ₂ O ₃	12.54	4.38	0.80

Source: National Geosciences Research Laboratory (NGRL) 24/2025, Aigbudume 2025



Plate 9: Line Blend Comprising Tiger Nut Chaff Ash and Feldspar

Source: Research Photograph, Aigbudume (2025)



Plate 10: Triaxial Blend Comprising Tiger Nut Chaff Ash and Feldspar

Source: Research Photograph, Aigbudume (2025)

Serger Unity Formulas

This is otherwise known as Serger empirical formula. It is a molar representation of glaze composition in which the sum of fluxing oxides ($RO + R_2O$) is normalized to 1.0, allowing prediction of melting behaviour and surface quality (Seger, 1902; Eppler & Eppler, 2000)

Simply put, a serger unity formular is a way of simplifying glaze recipes by showing the balance of ingredients in terms of their chemical building blocks, making it easier to understand how a glaze will behave. It helps potters predict whether a glaze will melt smoothly, stay matte, or fit well on the clay body.

Find below the Serger unity formulas for the suitable glaze recipes and their interpretations.

Table 3: Optimal Glaze: TNCA 60% + Feldspar 20% + Ball Clay 20%

<i>Oxide</i>	<i>Moles (from 100g batch)</i>	<i>Unity Contribution</i>
Fluxes		
CaO	0.2628	0.786
K₂O	0.0138	0.124
MgO	0.0311	0.077
Na₂O	0.0029	0.013
Σ Flux = 1.000		
Al₂O₃	0.0805	→ 0.25
SiO₂	0.5731	→ 1.78
P₂O₅	0.0750	→ 0.23 (as glass former)
Fe₂O₃	0.0472	→ 0.15 (colorant)

Interpretation

- **High CaO** → strong flux, low melt (completely melts at 1260°C)
- **Low alumina (0.25)** → fluid glaze → risk of running if overfired
- **SiO₂: Al₂O₃ = 7.1** → glossy, transparent potential
- **P₂O₅** → opacifier & phase separation → subtle clouding
- **Fe₂O₃** → warm brown tone



Plate 1: Stoneware fired at 1260°C with glaze formular TCNA 60% Potassium Feldspar 20% Ball clay 20%

Source: Research Photograph, Aigbudume (2025)

Table 4: Optimal Glaze: TNCA 40% + Feldspar 40% + Ball Clay 20%

<i>Oxide</i>	<i>Moles</i>	<i>Unity</i>
<i>Fluxes</i>		
<i>CaO</i>	0.1585	0.524
<i>K₂O</i>	0.0360	0.357
<i>MgO</i>	0.0195	0.097
<i>Na₂O</i>	0.0081	0.022
$\Sigma = 1.000$		
<i>Al₂O₃</i>	0.1170	→ 0.39
<i>SiO₂</i>	1.0520	→ 3.50
<i>P₂O₅</i>	0.0500	→ 0.17
<i>Fe₂O₃</i>	0.0308	→ 0.10

Interpretation

- Balanced flux: CaO + K₂O → stable melt
- Al₂O₃ = 0.39 → ideal for durability
- SiO₂: Al₂O₃ = 9.0 → glossy, hard glaze
- Best overall: most durable, least defect-prone



Plate 2: Stoneware fired at 1260°C with glaze formular TCNA 40% Potassium Feldspar 20% Ball clay 40%
Source: Research Photograph, Aigbudume (2025)

Table 5: Optimal Glaze: TNCA 20% + Feldspar 60% + Ball Clay 20%

<i>Oxide</i>	<i>Moles</i>	<i>Unity</i>
<i>Fluxes</i>		
<i>K₂O</i>	0.0522	0.592
<i>CaO</i>	0.0826	0.298
<i>Na₂O</i>	0.0114	0.064
<i>MgO</i>	0.0088	0.046
$\Sigma = 1.000$		
<i>Al₂O₃</i>	0.1340	→ 0.51
<i>SiO₂</i>	1.4320	→ 5.45
<i>P₂O₅</i>	0.0250	→ 0.10
<i>Fe₂O₃</i>	0.0158	→ 0.06

Interpretation

- K_2O -dominant $\rightarrow$ higher melting temperature, more refractory
- High silica (5.45) $\rightarrow$ very hard, stable, craze-resistant
- $Al_2O_3 = 0.51 \rightarrow$ excellent durability
- Least colour $\rightarrow$ beige/clear tone (tending towards transparent)
- Most like commercial high-fire glaze



Plate 3: Stoneware fired at 1260°C with glaze formular TCNA 20% Potassium Feldspar 60% Ball clay 20% fired at 1260°C

Source: Research Photograph, Aigbudume (2025)

Discussion

The results confirm TNCA's effectiveness as a flux in high-fired ceramic glazes. Its high CaO and P_2O_5 content contribute to early melting and gloss development, while feldspar and ball clay provide necessary silica and alumina for structural integrity. The study aligns with previous research on plant ash glazes and expands the scope by introducing a novel agro-waste material. The findings support the integration of TNCA into ceramic practice, offering economic and environmental benefits. Moreover, the use of locally sourced materials promotes sustainability and reduces production costs for potters in Nigeria.

Conclusion

This study demonstrates that tiger nut chaff ash, an abundant agro-waste, can be effectively utilized as a flux in ceramic glaze formulations. The optimal blend of 40% TNCA, 40% feldspar, and 20% ball clay yields durable, aesthetically pleasing glazes suitable for high-fired applications. The research contributes to sustainable ceramics, waste valorization, and import substitution in Nigeria.

Recommendations

1. Further research should explore TNCA's performance in mid-fire and low-fire glaze systems.
2. Comparative studies with other agro-waste ashes could broaden material options for ceramic fluxes.

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