# *Original Research Article*

## REVOLUTIONIZING CERAMIC ARTISTRY: HARNESSING THE POTENTIAL OF COW BONE ASH AS A SUSTAINABLE OPACIFIER IN ENAMEL PRODUCTION


### ABSTRACT

This study explored the feasibility of utilizing cow bone ash as a sustainable alternative opacifier in enamel production for ceramic applications. Through a process of recycling cow bone, enamel was synthesized and subjected to a comprehensive comparative analysis with standard tin oxide enamel. The investigation encompassed an evaluation of both chemical and physical properties, with a focus on clarity and resistance to chemical degradation. Results indicated that the enamel derived from cow bone ash exhibits comparable clarity and chemical stability to traditional tin oxide enamel when applied to ceramic ware. This breakthrough offers a promising avenue for reducing the reliance on tin oxide, a costly and sometimes scarce opacifier. Moreover, it transformed discarded cow bones into a valuable resource for ceramists and chemists, presenting an eco-friendly solution that mitigates environmental concerns associated with waste disposal. This research not only contributes to the optimization of ceramic manufacturing processes but also aligns with sustainability goals, offering a practical and economically viable alternative in the realm of enamel production.



**KEYWORDS:** Bio-ceramics; cow bone; enamel; glaze; opacifier


### INTRODUCTION

Ceramic industries use opacifiers as enamel for ceramic production and most small-scale ceramic industries depend on imported raw materials including opacifiers which are expensive. Opacifiers are finely ground materials or substances added to another material to make the ensuing system opaque. In ceramic production, opacifiers are mixed with transparent glaze using a line blend. They do not enter the glaze melt but remain as small white particles suspended throughout the glaze [1]. They reflect light and make the glaze opaque, hence forming enamel.

Enamel is an opaque, glassy, and decorative substance that can be applied to metallic or other hard surfaces for ornament or as a protective coating [2]. The process of enameling includes applying a thin coat to metal and other hard surfaces at high temperatures, when the enamel melts, it fuses to the object. Enamel is useful in the production and decoration of many laboratory equipment and household goods and appliances such as cooking vessels, cooktops, sinks toilet bathtubs, wall tiles, dishwashers, and laundry machines. Enamel is also used architecturally as a coating for wall panels and can be used externally to provide weather resistance and desirable appearance, or internally to provide wear resistance [3].

Bone ash is the white powdered material (ash) left from the burning (calcination) of bones. Typical bone ash consists of about 55.82 % calcium oxide, 42.39 % phosphorus pentoxide, and 1.79 % water [4, 5]. The exact composition of these compounds varies depending upon the type of bones being used, but bone ash is primarily composed of calcium phosphate with formula $(Ca_3(PO_4)_2$. It usually has a density of around 3.10 g/ml and melts at temperatures above 1670 ℃ [6]. Bone ash has been found useful as a raw material for ceramic applications and other allied industries. In ceramic, calcium acts as a stiff glass-former. The calcium oxide present in the bone ash gives strength and stability to ceramic wares and also serves as a fluxing agent in high-temperature glaze [4, 7].

This study was designed to develop an opacifier from bone ash that can be used as alternative enamel to tin and zirconium oxides which are expensive to procure, scarce, and sometimes unavailable. The major impact of this study is to aid the artistic technique in painting with different identified oxides of colour stains which had been difficult to achieve on celadon glazes with dark colour characteristics. The use of bone as an opacifier for this study will also serve as a means of converting waste to wealth, enhance solid waste management, and encourage innovative practice, especially for the development of cottage-level ceramic production and institutional practice.

## EXPERIMENTAL

**Sample Collection and Preparation:**Cow bones were collected from abattoirs in Afikpo, Nigeria. They were immersed in water for 48 hr., washed thoroughly, rinsed, and sun-dried. They were boiled in water with the addition of soda potash, washed, rinsed, and dried again. The bones were calcined at 1100 ℃ in an electric kiln (Type-P5900, England) until chemically combined water and organic matters were all removed. To achieve a finer particle size, the calcined bones were milled with an Egde milling machine (Pascal Engineering, England) with a porcelain jar.

**Chemical Analyses:** Chemical analysis of enamel produced from bone ash was done to determine elements such as silicon, aluminium, iron, calcium, sulphur, magnesium, potassium, zirconium, sodium, barium, and phosphorus with atomic absorption spectrophotometer (Bulk Scientific). The elements were later converted into their respective oxides.

**Enamel Formulation:** Approximately 100 g of the pulverized sample was weighed with an electric weighing balance (Mettler PN163) thoroughly mixed with 40 $cm^3$ of water so that it could stick to the body of the ware. The slurry product formed was smeared on ceramic wear. The smeared items were subjected to firing under full oxidation and atmospheric conditions at 1100 ℃. For comparison, tin oxide (reference) was prepared and applied in the same manner.

**Durability Test:**The test ceramic ware imprinted withenamels from bone ash and tin oxide was soaked in 1.0 $moldm^{-3}$ solutions of hydrochloric acid and sodium hydroxide separately overnight.

## RESULTS AND DISCUSSION

The cow bone after calcination is presented in Figures 1 and 2, respectively are the cow bone ash after crushing and the control sample (tin oxide), which was used for comparison.

Fig. 1: Cow bone after calcination

Fig. 2: Bone ash (left) after crushing and commercial tin oxide (right)

Figure 3 presents the chemical analysis of bone ash. From the result obtained, the calcium oxide content of the bone ash was 78.079 %. This high value of calcium oxide would give more strength and stability as ascertained by Ayilaran [6] to ceramic wares when compared to those produced with tin oxide. The percentage content of phosphorus pentoxide ($P_2O_5$) was 0.087 %; this showed that the enamel produced from cow bone had the characteristics of low thermal expansion coefficient, high resistance to thermal shock and durability; high chemical resistance, rapid setting, and good glossy surface [8]. Aluminium oxide also increases the viscosity, chemical, and thermal resistance. It helps in reducing the expansion coefficient and favours an opaque finish [4].

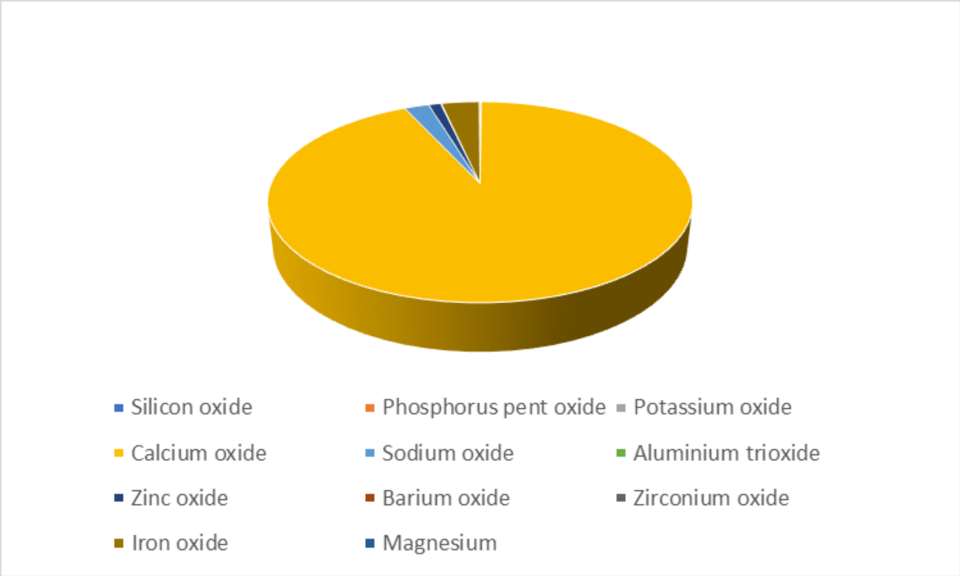


Figure 3: The chemical analysis (oxides) of bone ash

Zirconium oxide content represents the property of bone ash as an opacifier. The zirconium oxide content as obtained in this research was 0.041 %. This oxide also improves resistance to acid [9]. The % silica component was very low. This is expected since low silica content helps to harden the vitreous system and increases the mix viscosity [8, 10]. Both magnesium and barium oxide performed the same functions of integrating anti-acid enamels, increasing enamel resistance and viscosity. Zinc oxide is an excellent flux that lowers the expansion coefficient and improves brilliance and surface quality [9, 10]. Potassium and sodium oxides lower the elasticity and increase enamel brilliance. Phosphorus oxide alters the opacity of the finish (shining), improves colour stability, and reduces chemical resistance. Calcium oxide is a very good adherent agent [4, 10].


Fig. 4:Enamels from bone ash (left) and tin oxide (right) print on ceramic cups

Physical examination of enamel produced from bone ash had a low bloating when compared with that of tin oxide. Also, the samples decorated with bone ash enamel had a low tendency of crawling. In terms of opacity, the ceramic cups decorated with bone ash and zinc oxide enamels came out brilliantly (Fig. 4). This indicated that cow bone ash is a good enamel opacifier as tin oxide. The durability test of the opacifier produced and that from tin oxide was excellent as the ceramic cups were resistant to acidic and basic attack.

## CONCLUSION

This research highlighted the promising potential of cow bone ash as a sustainable opacifier in ceramic enamel production. Through rigorous comparative analysis, it was established that theenamel derived from cow bone ash exhibits commendable clarity and resistance to chemical deterioration, akin to the industry-standard tin oxide. The successful application of this alternative not only provides a cost-effective solution but also addresses concerns related to the scarcity of tin oxide. By embracing cow bone ash as a viable substitute, ceramists and chemists gain access to a resourceful platform that not only contributes to cost efficiency but also mitigates environmental impact. This research thus marks a significant stride towards promoting sustainable practices within the ceramics industry. The utilization of cow bone, once regarded as waste, not only enhances the industry's economic viability but also underscores the importance of innovative, environmentally conscious approaches in material sourcing. This study has opened avenues for further exploration and implementation of alternative materials in ceramics, fostering a sustainable and eco-friendly future for the industry. The successful integration of cow bone ash as an opacifier heralds a shift towards responsible and innovative practices in ceramic enamel production and provides a platform for artistic painting on ceramic wares.



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