INVESTIGATING THE POTENTIALS OF PALM KERNEL SHELLS ASH IN CERAMIC GLAZE DEVELOPMENT

ABSTRACT

Wood ash has a long antecedent in the history of ceramic glaze making. Various efforts have been made by potters and researches to obtain ash from other sources apart from wood which include rice husks, bamboo, bones, etc. This study took a step further to obtain ash from palm kernel shells (PKS) to develop ceramic glazes. PKS were sourced, washed, dried and burnt. Chemical analysis test (XRF) conducted on the palm kernel shells ash (PKSA) obtained revealed the presence of silica (23.97%), iron (33.61%), calcium (1.16%), etc. which showed that PKSA could combine with other materials to produce good glazes. Batches of recipes were weighed, mixed, milled, applied on bisque wares and fired in the kiln. Some good glazes were achieved at 1140 C.

Keywords: PKSA, ash glaze, recipe, agricultural waste, ceramic artist.

1.0 INTRODUCTION

The final step or procedure in producing a piece of pottery is that of applying a glaze and firing. It is the glaze that gives a ceramic piece its most dominant characteristic beyond the basic shape. Although there are many types of glazes, they are all basically nothing more than a thin glass-like coating fused to the clay surface of the pot by the heat of the kiln (Nelson, 1960). According to Madan and Tuli (2014), glaze is a layer of coating of a vitreous substance which has been fused to a ceramic object through firing. The process to achieve this is called glazing. Several definitions of glazes are given by different authors but what is core is that it still borders on its functions as, to seal the pores of a pot, create a surface texture that are either glossy or matty, provide colour and make pot resistant to acid (Ologunwa, Akinbogun & Kashim, 2013). Glazes also enhance a design or texture which may be either the natural texture or painted design. Glaze can serve to color, decorate, strengthen, or waterproof an item.

A glaze that employs organic ash (e.g. paper, wood, plant) as a supplier of oxides (e.g. silica, alumina, soda, calcia) is called ash glaze. The use of ash as a glaze ingredient has long historical antecedent; it has been an integral part of the evolution of pottery making in China, and from there played a similar role in the development of high fired pottery in Japan and through other places in Asia. Also, the roasting of PKS usually results in the production of ash (PKSA) (Ikubanni, Oki, Adeleke, Adediran, & Adesina, 2020). Palm kernels are important nuts which are obtained from highly valued oil palm trees (Okoroigwe, Saffron & Kamdem, 2014). After the removal of the mesocarp, which contains the palm oil, the remaining material is termed palm kernel (Anyaoha, Sakrabani, Patchigolla & Mouazen, 2018). When the nut (kernel) is removed from the endocarp, palm kernel shell (PKS) is obtained (Ikumapayi & Akinlabi, 2018). They are agricultural residues that can be generated from crude palm oil processing (Adebayo, 2012). PKS are important biomass sources and are found in abundance in palm oil-producing Asian and African countries such as Malaysia, Nigeria, Brazil, and so on (Ikubanni et al, 2020).

However, Hammed, Sridhar, Ana & David (2017) asserted that a portion of these wastes is used as feed supplements for livestock but most are disposed by burning. Overall, limited quantities of the PKS are used, primarily for fuel. Like many other agricultural wastes, PKS were disposed indiscriminately or burnt haphazardly without energy recovery thereby constituting environmental pollution. Tangchirapat, Saeting, Jaturapitakkul, Kiattikomol, & Siripanichgorn, (2007) also opined that utilization of PKSA is minimal and unmanageable while its quantity increases annually and most of the PKSA are disposed as waste in landfills causing environmental problems. Hence, importance has now been placed on the recycling and valorization of by-products and all manners of wastes emanating from industrial and urban areas to harness them into useful and marketable products at lower cost of production (Owoeye et al. 2019). Efforts to bring solutions to this challenge have increased research activities in finding feasible areas where the PKSA can be utilized (Olutoge et al. 2012).

Thus, as suggested above, this study is poised to investigate the potential of palm kernel shells ash in ceramic glaze making. One of the impact of this study is to convert this waste to useful glazing material considering its elemental composition, abundant supply and cheap cost. Also, the utilization of ash obtained from palm kernel shells will reduce the indiscriminate disposal and poor waste management in the palm oil industry thereby making our environment more habitable.

2.0 MATERIALS AND METHODS

The method of preparation and application of glazes is one of the determining factors governing glaze composition (Akinbogun & Fadairo, 2009). In order to achieve the final result of this study, the processes involved were guided by scientific approach. The processes included:

1. Material processing
2. Formulation of glaze recipes

2.1 **Material processing**

The material required to develop ceramic glazes in this study were ash obtained from palm kernel shells, ball clay, potash feldspar and borax. The chief material in this study, PKS, were sourced from Owena – a border community between Ondo state and Osun state while ball clays were from Ire-Ekiti in Ekiti State of Nigeria. Other materials used such as feldspar and borax were purchased at a ceramic store. In order to make palm kernel shells and the ball clay suitable for use as glaze ingredients, both were made to undergo some characterization processes.

2.1.1 Washing and drying of palm kernel shells

The PKS obtained were washed with water and soap in order to remove the remaining traces of oil in the shell (See figure 1). During washing, the PKS was sorted to remove unwanted materials such as stone, wood and other vegetative matters to avoid possible contamination of the eventual ash. It was then sun-dried for three days so that the moisture inherent in them was dried to aid burning (See figure 2).

2.1.2 Burning of palm kernel shells

The dried PKS were packed and poured into a kiln. This kiln is a makeshift kiln improvised for open air burning outside ceramic studio of Industrial Design Department in FUTA. This kiln type was preferred to normal closed-chambered kiln types because it was observed that this method was more economical, effective and efficient owing to exposure to large supply of oxygen needed for combustion. The heap of the PKS was sprinkled with kerosene to ignite the fire. The burning started in the evening and burnt through the night (See figure 3). In the following morning, the burning was completed and allowed to cool before it was packed inside a bucket for further processes.

2.1.3 Sieving and washing of palm kernel shells ash (PKSA)

The PKSA was sieved through 1800 microns sieve in order to remove any foreign material and bigger size particles; and only the fine ash which passed through the sieve was collected (See figure 4). This sieve size was fine enough to be combined with other processed materials for glaze ingredients. The ash was soaked and mixed thoroughly in plenty amount (three times ash volume) of water. The mixture was allowed to sit for 24 hours after which the top water was carefully decanted and replaced with the same amount of fresh water and sit for another 24 hours. The washing process was repeated three times. This was done to remove the soluble compounds such as sodium and potassium in the ash which would leach out from the glaze when it is used to serve acidic drinks or foods. This washing may not be required if the glaze is developed for decorative wares purpose only.

2.1.4 Drying of the washed palm kernel shell ash (PKSA)

The wet ash was poured into a clean cloth and placed outside in the sun for two days to ensure all the moisture in the ash was removed. Then, it was sieved again and now in powder form suitable for mixing with the remaining materials.

2.1.5 Palm kernel shells ash yield

Palm kernel shells of 15,000 grams were weighed on the scale before burning. It was re-weighed after burning to be 1100 grams. The remaining grams was sieved using the 1800 microns sieve. The table 1 showed that ashing of 15,000 grams palm kernel shells (PKS) led to a loss of about 13,900 grams of shells material representing 93.7% of combustible material. The percentage ash produced from the shell was 2%. This is pretty much close to the 2.11% ash yield obtained by Iregbu, (2015) from pulverised PKS ashed in a porcelain plate over a Bunsen burner. However, the ash yield in this study is highly lower than the 10.88% and 21.12% reported for PSA and

PRA respectively by Nwogu (2013). It is therefore observed in this study that the method employed to generate ash from a parent material determines the ash yield of the material.

2.1.6 X-ray fluorescence (XRF) analysis of palm kernel shells ash (PKSA)

Though, many researchers have worked on palm kernel shells ash especially in engineering and conducted chemical analysis on it. However, due to variations associated with ash as a result of different sources of the palm kernel shells, this study also conducted the XRF analysis to ascertain the elements which are most required in the formulation of ceramic glazes. The table 2 shows the elemental constituents of the ash. This results revealed that silica (23.97%) which serves as a glass former in ceramic glazes is the second most dominant element to iron (33.61%) followed by potassium (6.49%) and alumina (5.11%). Alumina serves as the stabilizer while potassium serve as flux and iron oxide as both flux and colourant in the glaze.

2.2 Formulation of glaze recipes

The three materials which include PKSA, ball clay and feldspar were weighed and batched using 66-point triaxial blend. These recipes were composed in small plastic containers mixed with water, sieved and applied on small bisque test tiles. The test tiles were appropriately numbered from 1 to 66 which represent each recipe (See figure 5).

2.2.1 First firing

The test tiles were dipped, loaded and fired to cone 9 in the gas kiln. After cooling of the kiln, the tiles were offloaded, examined and almost all of them did not melt (see figure 6) except two tiles (7 and 8) which looked promising (see figure 7). Tile 7 represented recipe of 70% ash and 30% ball clay while tile 8 represented recipe of 70% ash, 20% ball clay and 10% feldspar. Therefore, these two tests were picked for further adjustment and tests.

2.2.2 Second firing

The two recipes were adjusted by adding other fluxing materials in other to bring down the maturing temperature of the glaze. Three materials were suggested which include whiting, zinc oxide and borax. PKS ash was observed to be the most refractory among the other materials, thus ash was being reduced by percentage which is being replaced by the fluxing materials introduced in each case. Tables 3 - 8 showed how the recipes were adjusted using the three materials fired to 1140 C in an electric test kiln (see figure 8).

3.0 RESULTS

As the second firing was completed, the kiln was offloaded three days after and the tested tile were physically observed. Out of 24 test tiles tested, tiles $7B_4$ and $8B_4$ melted, glossy and attractive. Both tiles i.e. tiles $7B_4$ (20% ash, 30% ball clay, 50% borax) and $8B_4$ (20% ash, 20% ball clay, 10% feldspar, 50% borax) have borax in their compositions. Other tiles with whiting ($7W_1$, $7W_2$, $7W_3$, $7W_4$, $8W_1$, $8W_2$, $8W_3$, $8W_4$) and zinc oxide ($7Z_1$, $7Z_2$, $7Z_3$, $7Z_4$, $8Z_1$, $8Z_2$, $8Z_3$, $8Z_4$) are matty, rough and did not melt at all. It shows that those tiles with whiting and zinc oxide need to be fired to a more high temperature. The compositions of recipes on both tiles $7B_4$ and $8B_4$ were weighed and prepared in large batches enough to glaze some bisque wares as shown in figure 9. So, glaze $7B_4$ gave a light brown smooth and glossy surface with shades of cream colour while glaze $8B_4$ gave a deep brown, smooth and glossy surface quality (See figure 9).

4.0 DISCUSSION

The two glazes developed from this study possess many characteristics expected of good glazes which include smoothness, gloss and attractive colour. However, as a typical ash glaze which often characterized by running, the two glazes moderately run. An attempt was made to control the running by reducing both the thickness and the melting temperature of the two glazes from 1150°C to 1140°C. By doing this, the running was brought to the barest minimum. It is therefore advised that after dipping of the bisque, an inch or two inches distance up from the bottom of the ware should be cleaned to give room for possible drip and as such prolong the lifespan of the kiln shelves.

5.0 CONCLUSION

This study has been able to successfully establish the potentials of palm kernel shells ash (PKSA) in developing ceramic glazes. The glazes developed are suitable for various applications which include table wares, decorative wares and other utilitarian purposes. Thus, studio potters, researchers and ceramic industries can tap into this opportunity of converting PKS to useful glaze material thereby taking their parts in the management of waste for a serene environment worthy of living.

Tables

Table 1: Ash Yield of Palm Kernel Shells

Parameters	Values
Initial weight of palm kernel shell (g)	15000
Weight of burnt palm kernel shells produced (g)	1100
Weight of material lost (g)	13900
Weight of ash produced (g)	300
Weight of unburnt (residue) material (g)	800

Percentage of ash yield (%)	2.0
Percentage of residue (%)	5.3
Percentage combustible material (%)	93.7

Table 2: Chemical composition of palm kernel shells ash

Element	Oxide	Percentage of oxide (%)
Si	SiO_2	23.97
Al	Al_2O_3	5.11
K	K_2O	6.49
Ca	CaO	1.16
Fe	Fe_2O_3	33.61
P	P_2O_5	0.39
Ti	TiO_2	1.50
Mn	MnO	0.50
Co	CoO	1.94
Zn	ZnO	1.03
Ni	NiO	0.27
S	SO_3	1.52
	Others	22.51

Table 3: Tile 7 (70% ash, 30% ball clay) with whiting

Tile label	Ash (%)	Ball clay (%)	Whiting (%)
$7W_1$	50	30	20
$7W_2$	40	30	30
$7W_3$	30	30	40
$7W_4$	20	30	50

Table 4: Tile 7 (70% ash, 30% ball clay) with zinc oxide

Tile label	Ash (%)	Ball clay (%)	Zinc oxide (%)
$7Z_1$	50	30	20
$7Z_2$	40	30	30
$7Z_3$	30	30	40
$7Z_4$	20	30	50

Table 5: Tile 7 (70% ash, 30% ball clay) with borax

Tile label	Ash (%)	Ball clay (%)	Borax (%)
$7B_1$	50	30	20
$7B_2$	40	30	30
$7B_3$	30	30	40
$7B_4$	20	30	50

Table 6: Tile 8 (70% ash, 20% ball clay, 10% feldspar) with whiting

Tile label	Ash (%)	Ball clay (%)	Feldspar (%)	Whiting (%)
$8W_1$	50	20	10	20
$8W_2$	40	20	10	30
$8W_3$	30	20	10	40
$8W_4$	20	20	10	50

Table 7: Tile 8 (70% ash, 20% ball clay, 10% feldspar) with zinc oxide

Tile label	Ash (%)	Ball clay (%)	Feldspar (%)	Zinc oxide (%)
$8Z_1$	50	20	10	20
$8Z_2$	40	20	10	30
$8Z_3$	30	20	10	40
$8Z_4$	20	20	10	50

Table 8: Tile 8 (70% ash, 20% ball clay, 10% feldspar) with borax

Tile label	Ash (%)	Ball clay (%)	Feldspar (%)	Borax (%)
$8B_1$	50	20	10	20
$8B_2$	40	20	10	30
$8B_3$	30	20	10	40
$8B_4$	20	20	10	50

Figures

Figure 1PKS obtained were washed with water and soap

Figure 2 Drying of PKS

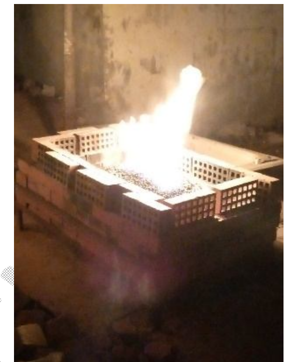

Figure 3 Burning of PKS

Figure 4 Sieving of PKSA

Figure 5Test tiles

Figure 6 Glazed tiles

Figure 7 Almost melted tiles.

Figure 8 Firing process

Figure 9 Glazed pots

REFERENCES

Adebayo, O. (2012). Assessment of Palm Kernel Shells as Aggregate in Concrete and Laterite Blocks. J. Eng. Stu. Res. Vol. 18. Pp. 88-93.

Akinbogun, T.L. & Fadairo, O.O. (2009). Developing Ash Glazes from Agricultural Waste Materials in Ondo and Ekiti States. Ashakwu Journals of Ceramics. ISSN: 1597-3182. Vol. 6. Pp. 30.

Anyaoha, K.E., Sakrabani, R., Patchigolla, K. & Mouazen, A.M. (2018). Critical Evaluation of Oil Palm Fresh Fruit Bunch Solid Wastes as Soil Ammendments: Prospects and Challenges. Resource Conservation Recycling. Vol.136. Pp. 399-409. https://doi.org/10.1016/j.resconrec.2018.04.022.

Fadairo, O.O. (2019). Developing Low Temperature Glazes from Nigerian Sweet Beans *vigna unguiculata* Pod Ash. Egghead: A Journal of Art. ISSN: 2636-4921. Pp. 112.

Hammed, T.B., Sridhar, M.K.C., Ana, G.R.E.E. & David, A. (2017). Low Emission, Smoke Free Charcoal from Oil Palm (Elaeis Guineensis) Waste – A Cheap Energy Source for Rural

Communities in Nigeria. Journal of Resources Development and Management. ISSN 2422-8397 An International Peer-reviewed Journal Vol. 34.

Hardjasaputra, H., Fernando,I., Indrajaya, J.,Cornelia,M.& Rachmansyah. (2018).The Effect of Using Palm Kernel Shell Ash and Rice Husk Ash on Geopolymer Concrete. MATEC Web of Conferences 251, 01044. https://doi.org/10.1051/matecconf/201825101044

Ikubanni, P.P., Oki, M., Adeleke, A.A., Adediran, A.A., & Adesina, O.S. (2020). Influence of Temperature on the Chemical Compositions and Microstructural Changes of Ash formed from Palm Kernel Shell. Elsevier B.V. https://doi.org/10.1016/j.rineng.2020.100173

Ikumapayi, O.M. & Akinlabi, E.T. (2018). Composition, Characteristics and Socioeconomic Benefits of Palm Kernel Shell Exploitation – An Overview. Journal of Environmental Science and Technology. ISSN: 1994-7887. 11 (5): 220-232

Iregbu, U.G. (2015). Evaluation of the Energy and Combustion Values of Pig Dung in its Pure and Combustion Accelerants Blended State. Msc. Thesis. Federal University of Technology Owerri, Nigeria.

Madan, R.L. & Tuli, G.D. (2014). Inorganic Chemistry. S. Chand & Company Pvt. Ltd. 6th Revised ed. New Delhi. Pp. 694.

Nelson, G.C., (1971).Ceramics A Potter's Handbook. Holt, Rinehart and Winston. Inc., New York pp. 219-318.

Nwogu, C.M. (2013). Physiological responses of pullets fed commercial diets supplemented with varying levels of plantain stalk and root base ashes. MSc. Thesis, Federal University of Technology, Owerri, Nigeria.

Okoroigwe, E.C., Saffron, C.M. & Kamdem, P.D. (2014). Characterization of Palm Kernel Shell for Material Reinforcement and Water Treatment. J. Chem. Eng. Mater. Sci. Vol. 5. Pp. 1-6. https://doi.org/10.5897/JCEMS2014.0172.

Ologunwa, T.P. (2018*)*. Production of High-Strength Electrical Porcelain Insulator from Processed Ceramic Raw Materials in Nigeria. Phd Thesis in Industrial Design Department, The Federal University of Technology Akure, Nigeria.

Olutoge, F.A; Quadri, H.A; Olafusi, O.S. (2012). "Investigation of the Strength Properties of Palm Kernel Shell Ash Concrete". Engineering, Technology & Applied Science Research Vol. 2, No. 6, 2012, 315-319

Owoeye, S. S., Toludare, T. S., Isinkaye, O. E., & Kingsley, U. (2018). Influence of waste glasses on the physico-mechanical behavior of porcelain ceramics. *https://doi.org/10.1016/j.bsecv.2018.07.002*