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Production and Quality Analysis of Evaporating Dish Using Local Materials

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Abstract- Evaporating dish was produced using raw materials such as kaolin, quartz, ball clay and talc that were sourced from Agaie, Kutigi, Kagara and Kadna respectively in Niger state. A control sample was produced using 30% feldspar, 5% quartz, 27% kaolin, 37% plastic clay and 1% talc, while all other samples were formulated by varying the compositions to compare with the control sample. The milled and mixed samples were casted and fired at a temperature of 1250°C. Physical examinations such as linear shrinkage, bulk density, water absorption was carried out on all the samples produced, while mechanical test such as failing load was also carried out on all the samples. The outcome of all the tests shows that the locally manufactured evaporating dish satisfied the qualities required of an evaporating dish for laboratory use.

Keywords: Shrinkage; bulk density; temperature; kaolin; plastic clay.

1. Introduction

The development of a nation depends on the quality of its research output. Nigeria is no doubt an oil rich nation and has solely relied on this resource as her economic backbone to the utter neglect of all other huge naturally endowed mineral resources that abound almost everywhere in the country. The development of ceramic raw materials particularly clay minerals in Nigeria and their applications in manufacturing and production of scientific equipment such as evaporating dish will not only boost the nation's economy, but will enhance her technological development, changes the country's status from consumer to producer nation and create employment for the teeming unemployed youths. The production of evaporating dish which is used for gravimetric analysis (determination of the amount of ion being analysed through the measurement of mass) will aid in improving research and save the country foreign exchange which would have been used in importation. There is constant search for new and relevant sources of raw materials to enhance the production of evaporating dish and other scientific products, reduce the cost of production and improve the quality of the products. The future of production of evaporating dish will depend largely on the national will and determination to succeed. This would be possible if the government facilitate the appropriate channel of establishing man power that can contribute positively in the processing of local raw materials to produce evaporating dish [1].

The exploitation, processing of raw materials and production of evaporating dish can influence the development and capacity building among the local miners and other professionals involved in processing of these raw materials. These include the development of ceramic materials for research purposes as well as for production in industries. The production of quality evaporating dish will enhance quality science education in schools, quality research works and generation of much needed foreign exchange for the country. In Nigeria, most of the raw materials for development of evaporating dish are



available in most of the states of the federation. These materials are found in raw state and cannot be used directly for production of evaporating dish.

The lack of milling facilities has hindered research and production of evaporating dish. The present approach to the production of evaporating dish started as experiments to test the locally available raw materials and their suitability for the production of evaporating dish. Therefore, to evaluate raw material composition on the quality of evaporating dish and identify local raw materials for processing and production. Evaporating dish is a small bowl with a spout, usually made of porcelain or borosilicate glass. As its name suggests, it is commonly used to evaporate solvents in a sample. The shape of the evaporating dish makes evaporation easier due to a large surface area with which the solvent is exposed to the atmosphere [2]. Ajakor et al. [3], indigenously produced electrical porcelain from Nigeria mineral. In their study, universal composition of triaxial porcelain (kaolin, 45%; ball clay, 5%; feldspar, 25% and quartz, 25%) were used to produce a test piece. The pulverized and thoroughly mixed composition was compacted and fired at a temperature of 1200°C and the physical and electrical properties were investigated. The results showed that the sample has a breakdown voltage of 26kV/mm, low water absorption and dielectric constant between 9.0 and 10.9 within the frequency range considered. Egbai [4], carried out kaolin quantification in Ukwu Nzu and Ubulu Uku using electrical resistivity method. Ito et, al [5], determined the swelling and shrinkage properties of undisturbed expansive soil. The desire to produce quality evaporating dish for both local consumption and export is what prompted this study.

However, this will help to ignite the Nigeria industrial revolution of the production and good quality evaporating dish using local materials, which is in line with the study carried out by Azeta et al [11] and Salawu et al [12].

2. Materials and Methods

2.1 Materials

The materials and equipment used in this study include digital and mechanical weighing scale, ball mill, electric vibrating sieve, roller pot mill, blunger, spraying gun, moulds, storage tanks/stirrers and the electric kiln. The raw materials for slip preparation like plastic clay, kaolin, feldspar, quartz and talc were beneficiated, milled and used for casting, after which the products were fettled, dried, glazed and fired in the kiln for vitrification to take place.

2.2 Methods

2.2.1 Raw materials preparation

The raw materials were weighed in different proportions using a digital weighing scale of maximum capacity of 30 kilograms. The raw materials were analysed by means of X-Ray Fluorescent Photometer (XRF) method at National Geological Survey Agency, Kaduna, Nigeria.

2.2.2 Beneficiation of raw materials

The raw materials, plastic clay, kaolin, feldspar, quartz, and talc were beneficiated. This involved series of processes whereby the chemical and physical properties and characteristics of raw materials are modified to render the raw material easier to process. The feldspar was milled for four hours in the ball mill and then sieved using an electric vibrating sieve of 300 mesh size. 50kg of feldspar was collected. Also, 50kg of quartz was collected from Kaduna in Bosso local government area of Niger state. They were broken into chips with the use of metal hammer and then ball milled. The ball milling lasted for six (6) hours. The milled quartz was then sieved using 300 mesh. The kaolin used in this study was milled in the ball mill and then sieved using the vibrating sieve of 300 mesh and sun dried while the plastic clay was milled using the ball mill and it serves as a binder for the other materials.

Finally, the talc was beneficiated using the jaw crusher and then milled using the ball mill. The vibrating sieve of 300 mesh was used for sieving and the materials were weighed after beneficiation.

2.2.3 Mould making

Plaster mould casting technique was used to form the mould for the casting. All measurements of the profile have to allow 10% for an element of shrinkage during production. From the profile a model of the actual shape was made, the techniques used in making the plaster mould to replicate a model were in accordance with the procedure outlined by Okpanachi, et al [6]. Mould soap was used to prevent the plaster from sticking to the model. Place the model into the bottom of the container and carefully seal the edges around the model with plastic clay so the plaster cannot run under the model. The liquid was then mixed plaster over the model to obtain at least 1 inch plasters thickness all-round the model. Once the plaster was set, it was removed from the model and the mixed liquid plaster into a container and observed carefully as it sets. At the point that the plaster begins to become firm, the model was pressed into the surface and held for a little while as the mix hardens. Once the mould is set, the model was removed carefully so as not to disturb details that remains. Also, before the plaster was prepared, a mould box was built by making a box comprising of four sides held together with external cord on a flat bottom base. The sides and bottom joints of the box were sealed with ordinary plastic clay and model placed upside down on the box base, sealing the edges with clay and cover the outside tightly with soap. Finally, the plaster was then prepared by pouring it over the model carefully until the mould box is filled. The mould was thoroughly dried before use. Spraying gun was then used in applying a coating paint, ink, glaze, through the air onto a surface

2.2.4 Test blends for slip production

The test blends used for slip production is shown in Table 1

Table 1: Test blends of materials

S/N	Feldspar	Quartz	Kaolin	Plastic clay	Talc
1	0	0	41.77	57.23	1
2	5	1	39.23	53.77	1
3	10	2	36.7	50.3	1
4	15	3	34.17	46.83	1
5	20	4	31.64	43.36	1
6	25	5	29.11	39.89	1
7	30	6	26.58	36.42	1
8	35	7	24.05	32.95	1
9	40	8	21.52	29.48	1
10	30	5	27.00	37.00	1

2.2.5 Determination of suitable firing temperature

Evaporating dishes (Fig. 1a) produced were used for testing the firing temperature of the glazes. These products were glazed and fired at the temperature ranges of 1106°C, 1156°C, 1206°C and 1256°C.

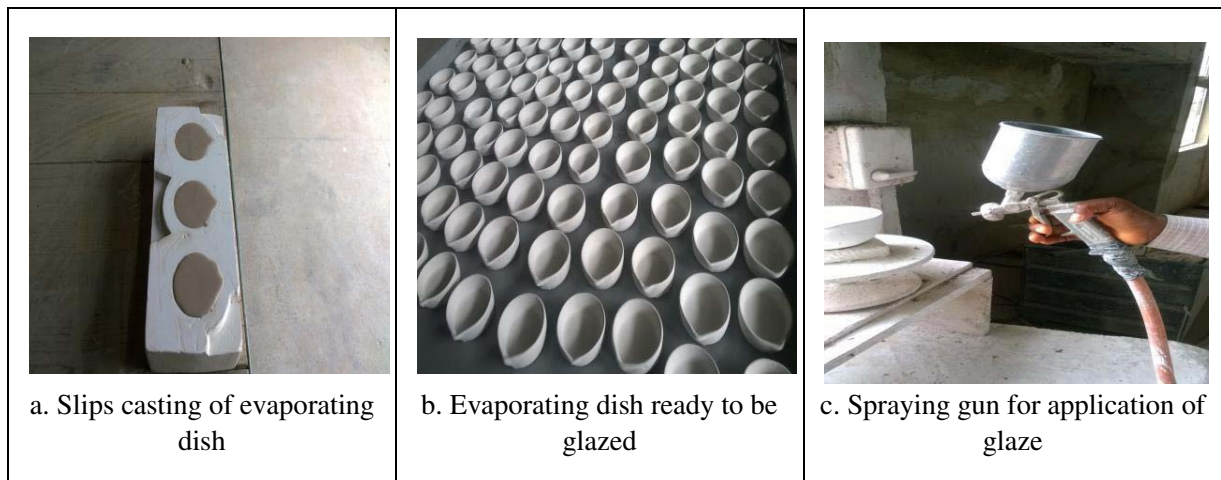


Fig. 1: Experimental Set up

2.2.6 Determination of densification parameters

The densification parameters of the evaporating dish were obtained after firing in the firing kiln. The densification parameters of the fired piece were obtained by measuring the linear shrinkage, bulk density and water absorption capacity and failing load was obtained after the ASTM C20 – 00 FORM. The linear shrinkage was determined using the Equ. 1 – 3 [7; 8; 9]. The boiling method was used in water absorption test at 100°C for 2 hours and was calculated using Equ. 4.

$$\text{Drying shrinkage} = \frac{L_W - L_d}{L_d} \times 100 \tag{1}$$

$$\text{Fired shrinkage} = \frac{L_W - L_f}{L_d} \times 100\% \tag{2}$$

$$\text{Total shrinkage} = \frac{L_W - L_f}{L_w} \times 100\% \tag{3}$$

Where L_W = Wet length, L_F = Fired length and L_D = Dry length.

$$\text{Water Absorption} = \frac{W_s - W_d}{W_d} \times 100\% \tag{4}$$

Where W_s = Soaked weight after boiling for 100°C for 2 hours and W_d = Dry weight.

The strength of the porcelain insulators was investigated by determining their failing load according to ASTM, [8]. The insulators were coupled on the tensile machine and allowed to be loaded up to 20KN until failure occurred. The force at which the materials failed were recorded. The failed load was determined using Equ. 5. [10]. The Loss on Ignition (LOI) was calculated using Equ. 6. Finally, the percentage residue was determined using Equ.7;

$$\sigma_T = \frac{p}{A} \tag{5}$$

where $A = b * t$ and $\rho = \sigma_T(b * t)$.

Where σ_T = tensile strength, p = Maximum load, b = width and t = thickness.

$$L. O. I = \left(\frac{m_2 - m_1}{m_2 - m_1} \right) \times 100 \quad (6)$$

Where m_1 is the mass of the porcelain, m_2 is the mass of crucible and sample weighed while m_3 is mass of the crucible and its contents cooled in a desiccator.

$$\%Residue = \frac{Dry\ Weight \times 100}{A} \quad (7)$$

Where A, is the mass of the sample obtained using; A = Litre. Weight – 1000dm³ x 1.625.

3. Results and Discussions

3.1 Chemical and percentage compositions of constituent and Evaporating Dish

The percentage composition of the evaporating dish is shown in Table 2 and it was observed that, specimen 10 served as a control specimen and the percentage composition of kaolin as well as plastic clay for other specimens were calculated based on the percentage of composition of the clay (plastic and ball clay) and the percentage composition of others were calculated thereafter. The XRD results are shown in Table 3.

Table 2: Constituent percentage compositions of Evaporating Dish

Specimen	Feldspar (%)	Quartz (%)	Kaolin (%)	Plastic Clay (%)	Talc (%)
Specimen	%	%	%	%	%
1	0	0	41.77	57.23	1
2	5	1	39.23	53.77	1
3	10	2	36.70	50.30	1
4	15	3	34.17	46.83	1
5	20	4	31.64	43.36	1
6	25	5	29.11	39.89	1
7	30	6	26.58	36.42	1
8	35	7	24.05	32.95	1
9	40	8	21.52	29.48	1
10	30	5	27.00	37.00	1

Table 3: Chemical characterization of the materials

Oxide Composition %	Feldspar	Quartz	Kaolin	Plastic Clay	Talc
SiO ₂	68.4	94.5	66.7	58.75	52.9
Al ₂ O ₃	17.9	0.06	23.71	27.6	17.38
SO ₃	ND	3.07	ND	1.2	ND
K ₂ O	9.33	0.39	0.31	0.38	0.31
CaO	0.19	0.6	0.8	0.16	2.1
Fe ₂ O ₃	0.73	0.422	0.478	0.637	8.4
MgO	0.16	ND	0.08	ND	3.73

SrO	0.032	ND	0.024	0.014	0.088
PbO	0.017	0.015	ND	0.019	ND
BaO	0.065	0.03	ND	0.08	ND
MnO	0.08	0.025	0.005	0.018	0.37
TiO ₂	0.12	0.11	0.133	0.11	0.559
V ₂ O ₅	0.01	ND	ND	0.035	0.02
Cr ₂ O ₃	ND	0.01	ND	0.032	0.772
CuO	0.02	0.029	0.016	0.024	0.077
Cl	ND	ND	ND	0.604	ND
ZnO	ND	0.055	0.002	0.004	0.01
Na ₂ O	2.13	ND	0.23	ND	0.02
ZrO ₂	0.022	0.054	0.02	0.171	ND
Ta ₂ O ₅	ND	ND	ND	ND	0.07
NiO	ND	ND	ND	ND	1.28
L O I	0.73	0.63	7.49	10.16	11.91

ND = NOT DETECTED

From Table 3, it can be observed that the silica content of the clay varies between 58.75% and alumina content of about 27.6% and this therefore shows that is type of clay can be classified as aluminasilicate type of clay [13]. The entire chemical compositions are in qualitative agreement with the requirements of ceramic wares [14]. Quartz with a percentage silica content of 94.5% is highly desirable since it serve as the refractory skeleton and it is usually desirable at a composition of nearly 100%.

3.2 Physical test carried out on the produced specimen

The results of the physical test conducted on each of the specimen is presented in the Table 4, which shows that the values of total shrinkage for all the specimen is within the recommended values for evaporating dish wares [13], though, the shrinkage values for specimen 3, 4 and 9 are a bit high. In the case of specimen 9, it is as a result of the high fluxing i.e. feldspar present in the charged materials as well as high amount of quartz resulting to high liquid flow during firing and consequently. Table 4: Physical properties of the produced Evaporating Dish

Properties	3	4	5	6	7	8	9	10
Total Shrinkage (%)	7.3	6.9	3.52	3.7	3.2	3.07	8.6	2.9
Water Absorption (%)	4.30	3.71	2.68	2.69	2.65	2.63	4.78	2.61
Bulk Density (g/cm ³)	1.21	1.23	1.24	1.27	1.30	1.31	1.35	1.28
Failing Load (kN)	0.43	0.67	0.93	0.95	0.95	0.97	0.62	1.10

Also, from Table 4, it can be seen that the water absorption is higher for specimen 3 and specimen 9. In the case of specimen 3, it is as a result of too small feldspar content i.e. 10%, leads to immature evaporating dish formation and high porosity which consequently leads to more water absorption [1516], while in the case of specimen 9, the water absorption was high as a result of too much feldspar i.e. 40%, as it also allows for reaction with impurities to form slag which are burnt off at elevated temperatures

during firing, hence creation of more porosity which automatically results in higher water absorption this also result in thermal shock upon cooling. Similarly, as shown in Table 4, the bulk density experienced slight reduction as with increasing amount of kaolin and reduction in feldspar. This phenomenon was exhibited as a result of kaolin's higher tendency for loss of ignition compared to feldspar. From, Table 4, the failing load ranges between 0.43kN to 1.10kN which is in accordance with the standard requirement of an evaporating dish wares [17].

4. Conclusions

Kaolin, ball clay, feldspar, quartz and talc, were sourced locally from Niger state province (Agai, Kutigi, and Kagara and Kaduna state). These materials were then formulated in different compositions and then used in the production of evaporating dish. From this study, it can be concluded that;

- i. The control Specimen (Specimen 10) possesses the optimal properties. Thereafter, formulated specimens (specimen 8) with composition 24.05% kaolin, 32.95% plastic clay, 35% feldspar, 7% quartz and 1% talc, was found to possess the highest failing load of about 8.0kN, corresponding to water absorption 2.63%, bulk density 1.31g/cm^3 and total shrinkage of 3.07%.
- ii. The raw material used is good for a successful production of high quality evaporating dish.
- iii. And among the produced evaporating dish, specimen 4 to 8 possesses the best constituent formulation.

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