

# Physical and Chemical Analyses of Shabu Clay for Stoneware Ceramics Production

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## ABSTRACT

This is an experimental study that has ascertained the quality of a ceramic raw material discovered in economic value quantity in Nasarawa state, located in the middle belt region of Nigeria. Shabu settlement in the Lafia local government area of Nasarawa State, Nigeria, is the point of concern. This location has one of the largest deposits of secondary clay in the region. The advent of an art school at the Federal University of Lafia, where ceramics is offered as a course of study, has further brought this material of economic value to the limelight for use in ceramics production. For sustainable use in stoneware ceramics production and also in future industrial applications, it is necessary that Shabu clay be carried through the necessary physical and property tests to confirm what type of secondary clay it truly is in terms of chemical analysis, plasticity, shrinkage, throwing ability on the potter's wheel and firing tests. Shabu clay was conducted through all the forgoing tests, and the findings indicate that Shabu clay contains basic oxides that are worthy of being a good working clay but have percentages of oxides that are not the same as any other clay. The plasticity test shows that the clay is plastic enough for good production processes that include hand building, throwing and slip casting. Shrinkage tests indicate higher than recommended shrinkage for good stoneware ceramics production, and as such, Shabu clay will need to be improved upon by adding Kaolin to the body to balance up the shrinkage rate. The throwing test conducted confirmed that Shabu clay had the required strength for throwing and withstood forming and pulling. Finally, Shabu clay, under two different firing tests of earthenware and stoneware temperatures, showed no sign of deforming and melting. This implies that the clay can conveniently be used for stoneware ceramics production.

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## 1. INTRODUCTION

Shabu development area of Lafia, Nasarawa state in Nigeria, is home to one of the largest clay deposit sites in the middle belt region of Nigeria. Apart from the minute usage by local traditional pottery makers, there has not been any form of exploration of Shabu clay in the area of ceramics for studio use or industrial application. The advent of the School of Art at the Federal University of Lafia led to the discovery and possible exploration of the material for stoneware ceramics production in the Department of Visual and Creative Arts by staff and students. Shabu clay cannot be effectively and sustainably used for ceramics production if the necessary standard tests for good workable clay are not carried out. These tests, which include chemical analysis tests, plasticity tests, shrinkage tests and firing tests, are vital components of working with clay for sustainable use.

Nasarawa state, where the sample area (Shabu) is located, is almost in the middle of Nigeria, close to the Federal capital territory- Abuja. Shabu is a development area under Lafia City, the capital of Nasarawa State in Nigeria. The two maps, Plates 1 and 2 shown in [Figs. 1 and 2](#), indicate the location of Nasarawa state in Nigeria as well as the location of Shabu under the Lafia local government area. [Ayuba \(2014\)](#) reveals that Lafia is both the Capital of Nasarawa State and the headquarters of Lafia Local Government Area. The Local Government Area has a land area of 2,797.5 sq. km. [Jibrin \(2021\)](#)



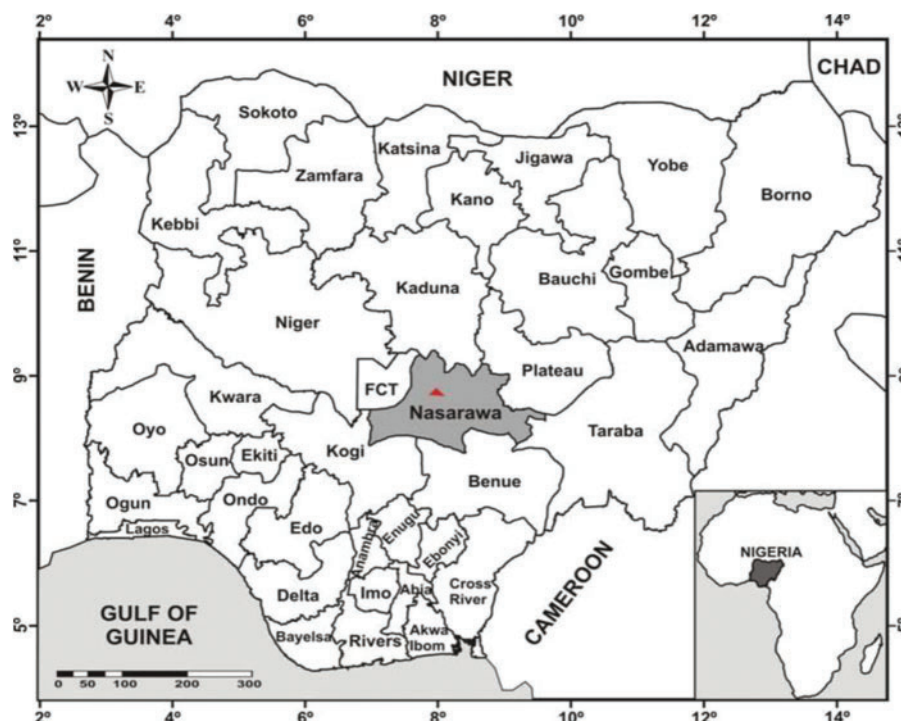


Fig. 1. Map of Nigeria showing the location of Nasarawa state (Source: [Akaamaa et al., 2023](#)).

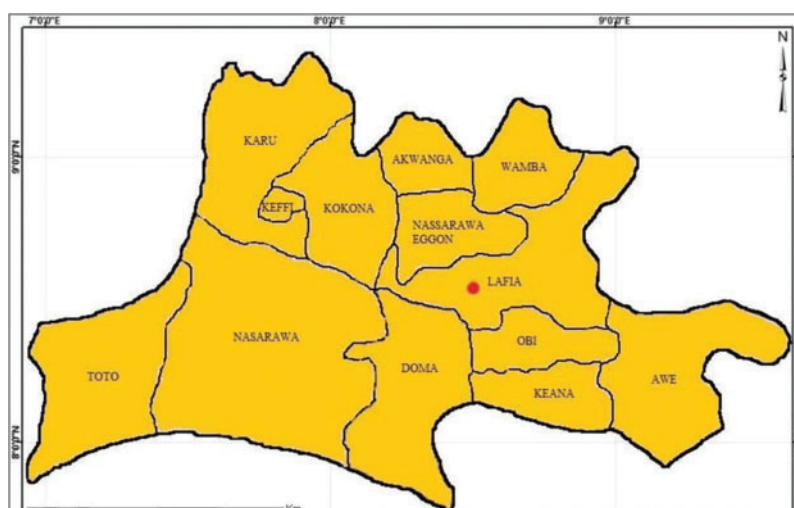


Fig. 2. Map of Nasarawa state showing sample area (Source: [Ayiwulu et al., 2020](#)).

gave the distance between the Lafia and Shabu settlements to be about thirteen kilometres apart. The revelation of the distance between the sample area and Lafia city tells a lot about the proximity to the site of Shabu clay deposit users and would-be users.

Shabu region is made up of vast alluvia plains with abundant clay materials in their numerous valleys, which can ensure sustainable ceramics production. According to [Obaje et al. \(2021\)](#), the mapped industrial minerals in Shabu, which include clay, occur in economic quantities, although the exact reserves have not yet been measured. Despite its high proportion, clay materials from Shabu are only exploited for traditional pottery and local bricks. This is primarily because the potentialities of these clays have not been tested. To date, no study that evaluates the potential application of these materials has been reported. Considering the large expanse of land, quantity and volume of clay in Shabu, and the fact that no two clays are exactly the same, it is necessary that this kind of study be carried out. This will test and ascertain the chemical and physical properties in order to ameliorate the use of Shabu clay in ceramic production. This will also open the way for other potential industrial applications.

Clays are natural materials abundantly found and largely used for the production of ceramics in various industries, institutions of learning and by traditional potters. Clay is the oldest known ceramic material, and it is still considered the main feeding material for conventional ceramic products. It is a soft, loosed, earthy material that is plastic when wet and hardens when dried or fired. [Gukas and Datiri](#)

(2001) describe clay as an earthy, malleable substance that is soft when wet but hard and rocklike when fired to high temperatures. They can also be referred to as fine-grained natural, earthy material that develops plasticity, can be shaped when wet, and becomes hard, brittle, and non-plastic upon drying and firing. Okewu (2014) also describes clay as an earthy plastic material that is different from the inelastic earth. He further stressed that the ability of clay to be shaped into different forms makes it important in the field of ceramics and the entire human life. Clays are used to make both utilitarian and decorative wares and to construct walls, bricks, and floor tiles. Objects such as cooking pots, dishware, art objects, smoking pipes, and even some local musical instruments are produced from clay.

The fine particles of clay are formed from the decomposition or breakdown of igneous rocks. These processes occur as a result of certain geological actions. Gukas and Datiri (2001) reveal that the decomposition of the igneous rock which forms clay is a result of some hypogenic actions which result from the mixture of gasses and vapour in the interior of the earth's crust over a very long period of time. This action leads to the breakdown of the different minerals in an igneous rock, which in turn forms clay. It is a very common substance that is distinguished from other fine-grained soils due to its size and mineralogy. Clay is a rock formed from a compound which is made up of three major oxides. These are aluminium oxide (alumina), silicon oxide (silica), and hydrogen oxide (water). Kumari and Mohan (2021) summarise that clay minerals are mainly known as the complex silicates of various ions such as aluminium, magnesium and iron. Clay from different deposits may look like most of the time but have different and unique behaviours when used for ceramics production. This is due to its unique characteristics, both physical and chemical. These characteristics cannot be predicted just from their physical appearance; this is because the different clays are formed from different rocks with different mineral aggregates and also have come in contact with different contaminants. The mineral contents in most clay may be the same, but they carry different percentages of such minerals. Any clay used based on trial or assumption is most often problematic to work with due to the lack of prior knowledge of the clay's behaviour during production. The behaviour of clay cannot be fully predicted by mere observation unless the components of the clay and its level of purity are ascertained. Peterson (2003) disclosed that it is particularly important to pre-think and find answers before working with clay. As a matter of fact, the location, excavation, and evaluation of clay suitability play vital roles in successful ceramic practice. Clay testing also saves the artist some time and builds up confidence in him or her as the raw material is being handled for production.

Ceramic practice in the Federal University of Lafia is not different, as clay has been the basic material for production in the Department of Visual and Creative Arts. This material has before now been sourced randomly from different clay sites and has been deployed into the ceramic studio for production. The clays have been used for production based on trial and assumption, and no appropriate test or evaluation has been done on the clay to check on their physical and chemical properties or ascertain their suitability for ceramic stoneware production. The act of random usage of unverified clay usually results in wastage of resources as well as ceramics faults such as warping, cracking, and even melting in the kiln. This study has subjected Shabu clay to different quality tests for chemical analyses, shrinkage, plasticity, throwing and firing to ascertain its suitability for sustainable ceramics production both in the studio and for industrial application. The aim of this study, therefore, is to subject Shabu clay to standard tests to ascertain the suitability of the clay for sustainable ceramics stoneware production through the following objectives: conduct chemical analysis on Shabu clay, conduct Shrinkage, plasticity, throwing and firing test.

## 2. METHODOLOGY

This study went through experimental research processes to actualize its aims and objectives. The population of the study is a large group of members selected from a sample. Clay is of two types: primary and secondary clay. The population of this study is secondary clay. Sampling is a subgroup drawn from the population, and it is an important part of the population. The sampling technique used for this study is the purposive or subjective technique, which gave this study the opportunity to focus on particular qualities of a population that are very relevant to this study. The sample for this study is Shabu Clay.

The experiment started with chemical analyses of Shabu clay to determine the different percentages of oxides inherent in the clay. X-ray Fluorescence (XRF) was carried out on Shabu clay. This is a technique that uses X-rays to measure the elemental composition of a material; it reveals the concentrations of major and trace elements present in a sample. The XRF test was carried out at Chemical Lab, National Steel Raw Materials Exploration Agency (NSRMEA), Malali Kaduna State, Nigeria. This was followed by conducting a plasticity test to ascertain if Shabu clay is suitable for forming into shapes without breaking. Here, a clay string was made out and coiled around the index finger to observe if there would be breakage or tearing (see Fig. 3 for this process). Shabu clay was also



Fig. 3. Physical structure of Shabu Clay sample.

subjected to shrinkage testing. Test Slabs were produced with measurement marks (see Fig. 4) to read the changes at intervals in terms of size at the wet stage and to ascertain the shrinkage rate of Shabu clay when dried and when fired. This is important in order to determine the extent of shrinkage of the clay. Any clay with a high percentage shrinkage needs to be further manipulated by other additions to be ideal for ceramics production. This testing was carried out at the wet stage of the clay, the dried state of the clay and the fired state of the clay.

In the area of building forms, Shabu clay was subjected to a throwing test. This involves the use of the potter's wheel to shape the clay to see if it could withstand shaping on the potter's wheel. Throwing on the potter's wheel is a vital production method in ceramics that needs to verify the throwing ability of Shabu clay. Lastly and very importantly is the firing test on Shabu clay. It is important to determine what temperature Shabu clay can withstand without deforming or melting. Firing temperatures of both earthenware (1000 OC) and stoneware (1200 OC) were used to fire Shabu clay in an electric kiln (see the process in Fig. 6).

### 3. RESULTS

#### 3.1. The Chemical Analysis

Chemical analysis of Shabu clay reveals that, like every other clay, five oxides are inherent in the sample. These oxides, as shown in Fig. 4, are of different percentages in the sample. Quartz which is also referred to as silica or glass former as it is present in shabu clay is the highest portion of 30%. Orthoclase is present in Shabu clay with 29%, Kaolin occupies 20%, albite has 12% while the least oxide—muscovite in Shabu clay occupies 9%.

#### 3.2. The Plasticity Test

The clay coil went around the finger without breaking or indicating numerous cracks (see Fig. 5). The clay is therefore considered plastic enough for form formation and its ability to withstand forming.

#### 3.3. The Shrinkage Test on Shabu Clay

The dried and fired shrinkage tests were carried out, and the results were calculated (see Fig. 6). The difference between the original (wet stage) length and the dried length is the shrinkage in length or size. This is calculated below:

Original length in wet state of test bar as recorded = 14 cm

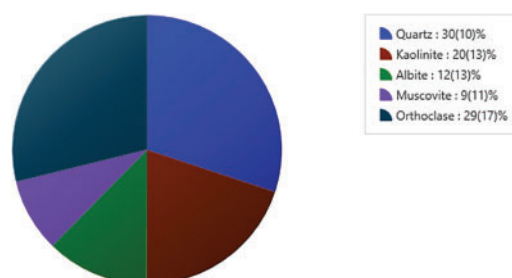


Fig. 4. X-ray Fluorescence (XRF) chemical analysis of Shabu Clay.





Fig. 5. The plasticity test.



Fig. 6. The shrinkage test.

Dried length = 12.5 cm

Shrinkage recorded = 14 cm – 12.5 cm = 1.5 cm

Therefore, the shrinkage recorded at dried stage = 1.5 cm.

% shrinkage at dried stage =  $\text{dried shrinkage} / \text{original length} \times 100 = 1.5 \text{ cm} / 14 \text{ cm} \times 100 = 10.7\%$

At fired state of the test bars, the difference between the original (wet state) length and fired length is the fired shrinkage in length and size (see Fig. 7). Ten test bars created were shared into two parts of five each for two different temperature firing of 1100 °C and 1200 °C on two separate occasions in electric kiln. fired, 5 of it were subjected to 1100 °C while the remaining 5 were subjected to 1200 °C. Their results are presented below:

Original (wet state) length of test bars = 14 cm

Fired shrinkage length at 1100 °C = 12 cm

Fired shrinkage length at 1200 °C = 11.7 cm

1100 °C fired shrinkage = 14 cm – 12 cm = 2 cm

1200 °C fired shrinkage = 14 cm – 11.7 cm = 2.3 cm

% fired shrinkage of 1100 °C =  $2 \text{ cm} / 14 \text{ cm} \times 100 = 14.2\%$

% fired shrinkage of 1200 °C =  $2.3 \text{ cm} / 14 \text{ cm} \times 100 = 16.4\%$

Different clay bodies shrink at different rates which can be as little as 4%, or as much as 15% for some clay bodies (Lake Side Pottery, n.d.). These findings about the different shrinkage of clay simply affirms the fact that clays must be worked on in other to attain a specific target and this is possible through testing of clay as is the case in this study. Shabu clay with 16.4% shrinkage at fired state would need addition of “opener” to maintain recommended shrinkage for stoneware ceramics production. An opener is additional material added to clay to be able to reduce shrinkage to recommended standard in ceramics production. Zamek (2024) claims that “knowing which material to use as a replacement is important. Keep in mind that each contributes its own set of qualities and acts in a specific way in conjunction with other materials. The fired color, shrinkage, absorption and forming characteristics of the clay body are dependent on this combination” (para. 1). In this instance, adding Kaolin to Shabu



Fig. 7. The firing test.

clay will remedy the excess shrinkage rate of the clay and make it very suitable for stoneware ceramics production.

#### 3.4. The Throwing Test

Clay is considered plastic and good for production due to its ability to respond when punched, pressed, squeezed, moulded, flattened, or rolled without difficulty in response and maintain its shape thereafter (see Fig. 8). The throwing test conducted resulted in wares that maintained a good response to centering, pulling and shaping on the potter's wheel without falling or showing cracks. This means the clay can comfortably be used for throwing method of ceramics production.

### 4. DISCUSSION

- Chemical analyses of Shabu clay reveals that just like any other clay, it contains basic oxides worthy to be called a good working clay but has percentages of the oxides that are not the same as any other clay. The high percentage of quartz in Shabu clay suggest that the clay will need a slight increase of Kaolin in the clay body to improve the clay.
- Plasticity test conducted on Shabu clay shows that the clay is plastic enough for good production processes that include hand building, throwing and slip casting.
- Shrinkage test carried out on Shabu clay shows that the clay has shrinkage rate that is higher than recommended shrinkage for good stoneware ceramics production and as such, Shabu clay will need to be improved upon by adding Kaolin to the body to balance up the shrinkage rate.
- Throwing test conducted confirmed that Shabu clay has the right quality for production on the potter's wheel. Wares produced through throwing withstood forming and pulling.
- Finally, Shabu clay under two different firing tests of earthenware and stoneware temperatures showed no sign of deforming and melting. This implies that the clay can conveniently be used for stoneware ceramics production.



Fig. 8. The throwing test.

## 5. CONCLUSION

The study was prompted by the fact that Shabu clay is available in a large scale that can service not just studio production but also industrial application. The Physical and Chemical Analyses of Shabu Clay for Stoneware Ceramics Production as carried out in this study has ascertained and proved the clay to have the necessary quality for sustainable application for ceramics practice. This study has helped in alleviating the uncertainties in the random usage of Shabu clay to know precisely type of clay they are using and how to use it without time and resources wasting.

## CONFLICT OF INTEREST

The authors declare that they do not have any conflict of interest.

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