FORMULATION OF SOME HIGH-FIRED PORCELANOUS THROWING BODIES AND GLAZE FIT: AKWANGA LOCAL GOVERNMENT AREA - RESOURCES

BY

SOLOMON MAIGARI AUGA MANZUCHE

A THESIS SUBMITTED TO THE POSTGRADUATE SCHOOL AHMADU BELLO UNIVERSITY, ZARIA IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF MASTER OF ARTS IN INDUSTRIAL DESIGN.

DEPARTMENT OF INDUSTRIAL DESIGN
FACULTY OF ENVIRONMENTAL DESIGN
AHMADU BELLO UNIVERSITY
ZARIA.

1991

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DECLARATION

I, Solomon Maigari Auga Manzuche, solemnly declare that the contents of this thesis is the report of my study "Formulation of Some High-Fired Porcelanous Throwing Bodies and Glaze Fit; Akwanga Local Government Area - Resources".

That I procured, processed formulated and tested the materials and also produced samples articles as stated in this thesis. I took and passed the following courses.

Research Technique

Conceptual Definition in History and Philosophy of Design

Business Management

History and Philosophy of Industrial Design in Africa

Principles and Issues in Ceramics

Material Studies

Seminar in Ceramics

Advance Studio Practice

Seminar Presentation

Sign: _____

Date: 22/10/1992

CERTIFICATION

This thesis entitled "Formulation of Some High-Fired Porcelanous Throwing Bodies and Glaze Fit: Akwanga Local Government Area - Resource", by Solomon Maigari Auga Manzuche, meets the regulations governing the award of the degree of Master of Arts Industrial Design of Ahmadu Bello University Zaria.

It had this day been approved for its contribution to knowledge and literary presentation.

Mr, James Ewule Chairman Supervisory Committee	22/10/92 Date
Mr, Mike Aluwong Member Supervisory Committee	9th Dec 92 Date
Dr, Abashiya M. Ahuwan Head of Department	20/12/92 Date
Dean Postgraduate School	24/1/96 Date

DEDICATION

This thesis is dedicated to my beloved wife,
Mrs, Charity Dorcas Solomon Manzuche and my dear Children:

Sera Solomon	-	Daughter.
Sonna Solomon	-	Daughter.
Sari Solomon	-	Son.
Shenne Solomon	-	Son.

ACKNOWLEDGEMENT

I wish to acknowledge the effort of Mr. James Ewule who supervised and made useful criticisms during the period of the study. I also appreciate the co-operation of Mr. Mike Aluwong and the Postgraduate Co-ordinator in the department, Dr. A. O. Aboderin.

I wish to express my sincere thanks and gratitudes to the Head of Department of Industrial Design, Dr. Abashiya Ahuwan for his concern during the period of this study and Dr. S.A. Adetoro who gave me an insight in research technique. Mr. Ezekiel Bahago, the Auditor with Akwanga Local Government Council needs to be specially mentioned for his laudable assistance to me during my pre-test of raw materials in the area.

I am much indebted to the following respondents; Sabatu Audu, Kwate Lakpu, Tagude Ndeni, Shiriya Kawo, and Maimuna Maikoni - Local Potters. Chube Zamwa, Dauda Ajiji and Awaje Maiyaki - Geologists. Barau Mu'azu and Debura Chube - Farmers. Maidoki Mado and Rakiya Michael - Wood dealers.

Inspite of their crowded programmes and engagements, they allowed me sat them down in furnishing me with useful information that led to the procurement of some ceramics Local raw materials found in Akwanga Local Government Area. I am indeed grateful to each and every one of them, because their full co-operation made this study a great success.

Finally, I wish to register my very special thanks to Mrs. Charity Dorcas Solomon Manzuche, my beloved wife for enduring my absence and taking care of the family. Having known the importance of education,

assisted me financially, morally and above all prayerfully throughout the duration of the course. Together, we give thanks and praises to our Lord Jesus Christ.

SOLOMON M.A. MANZUCHE

ABSTRACT

Solomon Manzuche, Formulation of some High-Fired porcelanous throwing Bodies and Glaze Fit: Akwanga Local Government Area - Reources. M. A. Thesis in Industrial Design, Ahmadu Bello University Zaria, 1991. The thesis contains 13 tables, 3 maps , 12 plates, and 30 Bibliography.

The problem of this study is exploring into the Local raw materials in Akwanga Local Government Area of Plateau State for the production of porcelanous throwing Bodies, glaze materials for such bodies and processes in arriving at the correct body and glaze fit.

The objectives among other things are:

1. To identify the local raw materials for the formulation of the porcelanous bodies and glazes.
2. To test the extent to which the local raw materials would be utilised for the formulation of porcelanous throwing wares through experimentation.

The materials used in this study are kaolin, feldspar, quartz, ball clay rice husk ash, and wood ash, procured from Akwanga Local Government A rea in Plateau State. The visual and physical property tests includes blending, kneading, plasticity, throwability, trimming and firing. Other visual and physical property tests conducted include whiteness, translucency, transparence, hardness, strength and smoothness.

The quadrilateral test blends and triaxial test tiles methods were adapted as the basis for body and glaze formulations. Throwing technique is used as a shaping method to produce experimental samples.

The results obtained from the study showed the following summarised findings:

1. Akwanga rice husk ash, wood ash, Kura Falls kaolin, Bayan Dutse ball clay, Buhar feldspar and Ningo Quartz wgre found to be of good quality for porcelanous ware products.

2. The glaze composition selected fitted well on the formulated porcelanous throwing products.

3. Ball milling was found to be an effective means for grinding and mixing of porcelanous materials.

4. The 1300°c temperature range using gas was found to be adequate in yielding hard, white, translucent, transparent and smooth glassy effects with variations of colour effects due to reduction firing.

Therefore, the study certifies that Akwanga Local Government Area of Plateau State is a potential place for good and viable quality raw materials for the production of porcelanous wares and glazes.

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Defination of Terms

ALKALIS: A general term for compounds of sodium and potasium often used to cause bodies and glazes to vitrify.

BALL CLAY: A highly plastic secondary clay usually greyish in colour. It forms the basis of many pottery bodies.

BALL MILL: A machine for grinding rocks and minerals, consisting of horizontal cylinder made from or line with an abrasion - resistant mineral (e.g stone or porcelain) and of some mechanical means of making it to revolve.

BISQUE OR BISCUIT : The name given to a once fired ceramic body on which there is no glaze. A bisque firing usuallly varies in temperature between 950°C and 1100°C but it may be high if vitrification is required.

BODY: The natural clay of which a pot is formed; natural mixed together for the formation of pottery.

CALCINATION: To disintegrate by heat. The strong heating of a material resulting in a physical or mechanical change.

CERAMICS: (Greek - Keramos). A general word for all pottery process. Also used today in connection with industries such as glass and cement.

EARTHENWARE: Pottery which is soft, opaque and porous if unglazed.

FELDSPAR: Generally opaque white rectangular crystals found in granite which on decomposition forms china clay. Feldspar is a major flux in both clay bodies and glaze.

FLUX: A substance which melts and causes other substances to melt inside kiln.

GLAZE: A thin glassy coating melted on the surface of a pot to make it non-porous.

KILN: A structure built to conserve heat used by ceramists to fire ceramic wares through conduction or convention.

LEVIGATION: A method of refining clay by water floatation the heavier particles settling out.

PORCELAIN: High temperature ware which is white and translucent. The body is formed by mixing kaolin, feldspar, ball clay, and quartz together at definite rates.

PORCELANOUS: The ceramics product made in resemblance to true matured and highly finished porcelain.

PUG MILL: A machine consisty of cylinder contracted at one end containing revolving blades which compress, cut and mix plastic clays.

PYROMETRIC CONE: It is made from the mixture of ceramic materials formed into triangular elongated pyramids and designed to melt and bend over or 'squat' at a given temperature. Also called seger cone.

QUARTZ: A crystalline form of silica.

SHORT: The quality of clay that is grainy, sandy, and unable to hold together well; the opposite of plastic.

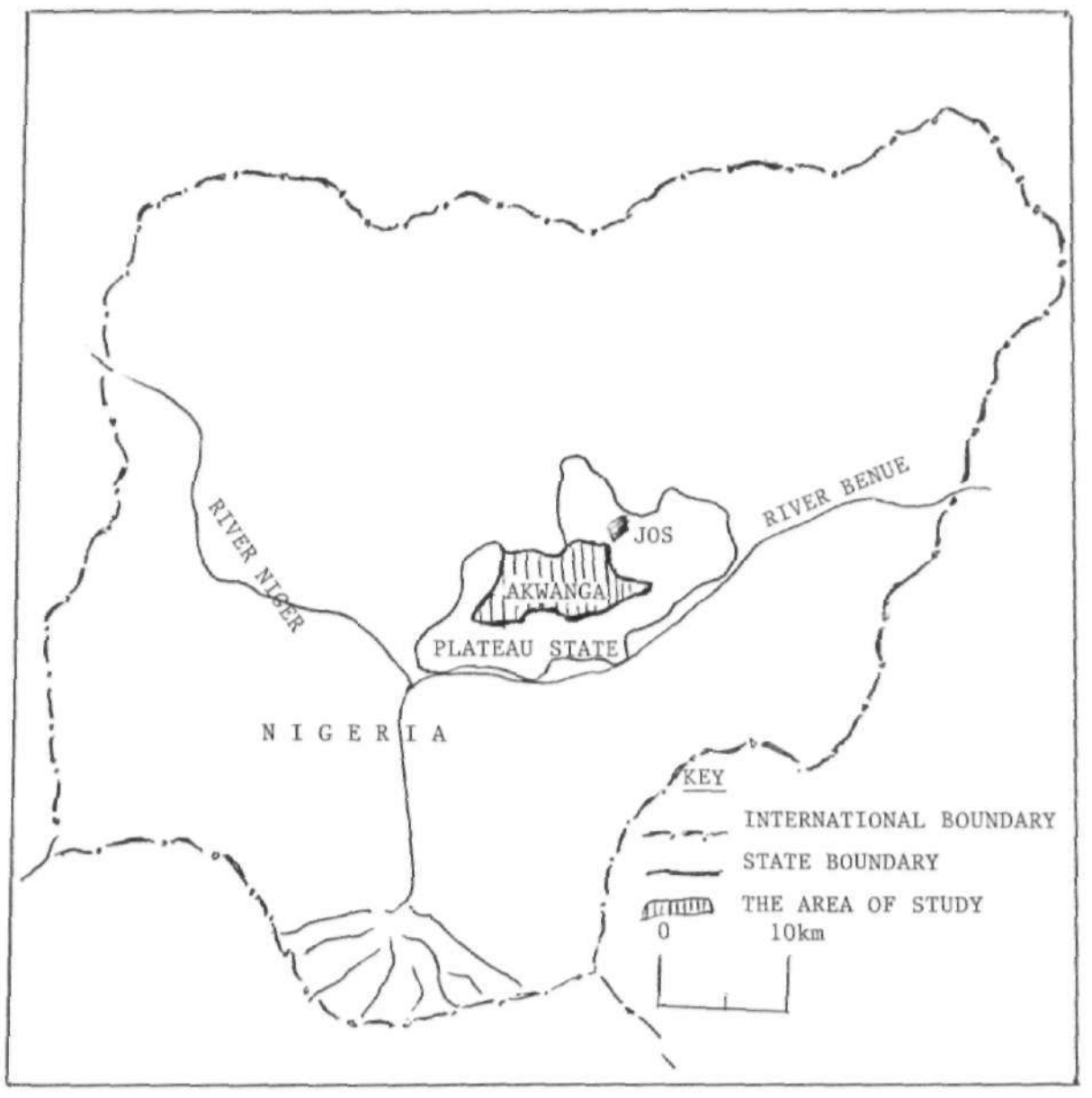
TABLEWARE: A general term for ceramics directly concerned with serving of food and drinks.

THROWING: The method of making clay shapes on a potter's wheel.

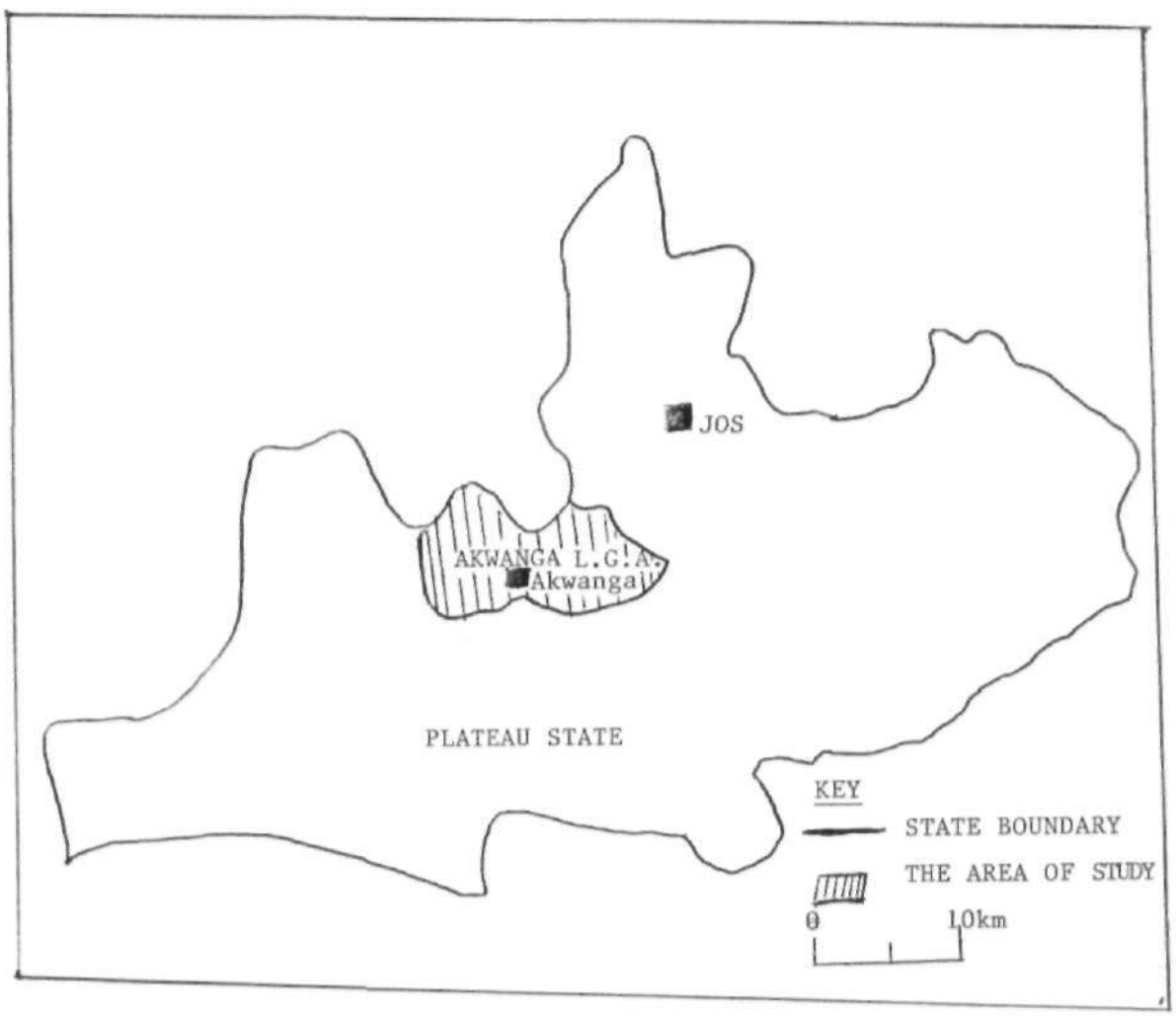
TRIAXIAL: A diagrammatic method of studying the effect of the various mixtures possible with three materials of colours.

VISCOSITY:The resistance of fluid to flow freely on the body.

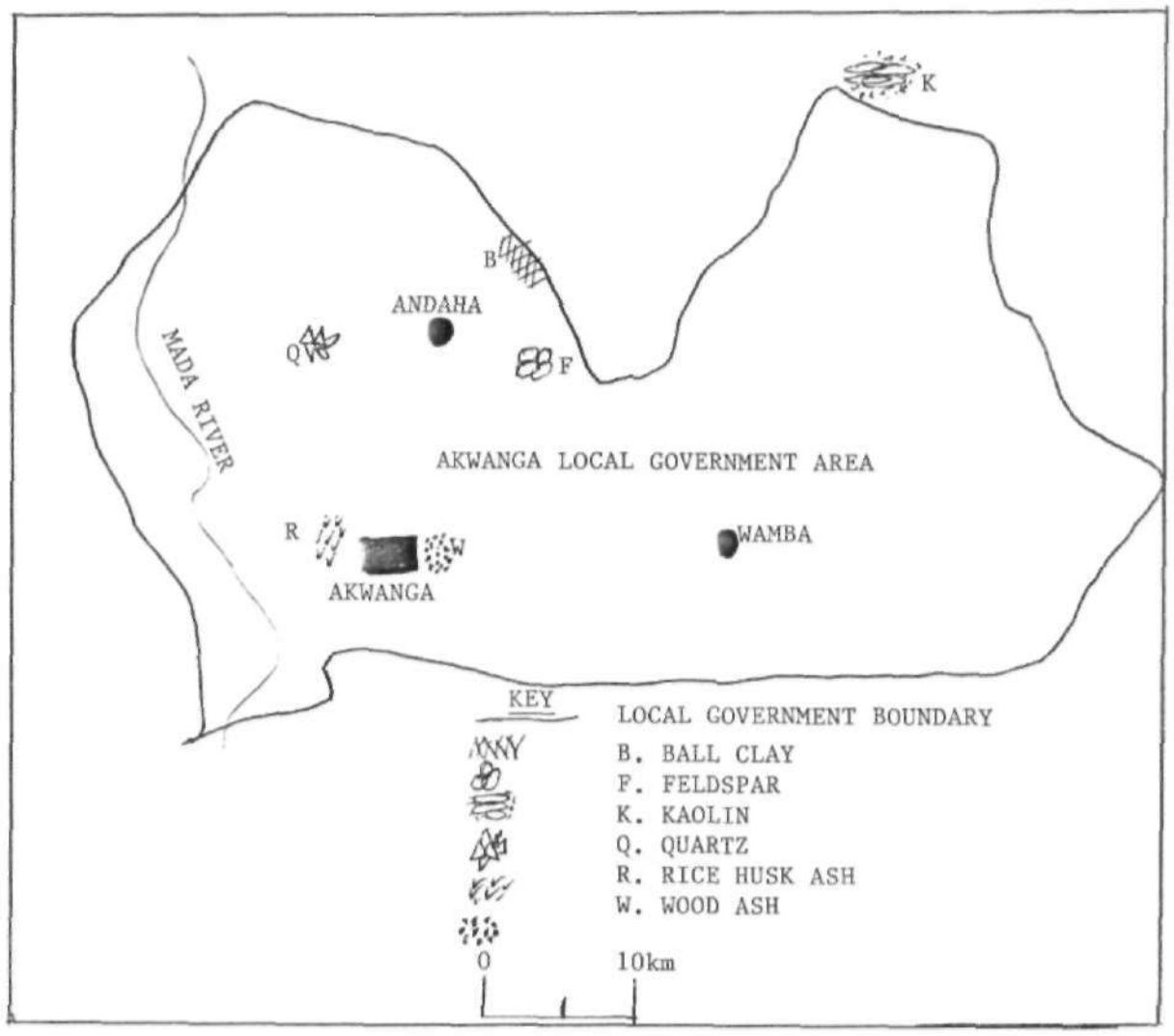
VITRIFICATION:The point at which ceramic materials reach a "glassy" condition under heat.



A MAP OF NIGERIA SHOWING THE AREA OF STUDY



A MAP OF PLATEAU STATE SHOWING THE LOCAL GOVERNMENT AREA OF STUDY



A MAP OF AKWANGA LOCAL GOVERNMENT AREA
SHOWING THE MAIN DEPOSITS OF SOME HIGH-FIRED CERAMICS RAW MATERIALS

CHAPTER I

INTRODUCTION

I.I Introduction

A number of views have been expressed about the beginning of ceramics. It has, for example, been pointed out by Schofield, (1947), that it is the custom of certain peoples living on the Great Lakes of North America to cover their wicker work baskets with clay, the burning of a basket treated in such manner might have been the basis upon which the ceramic art began many years ago.

Another view suggested that the art of ceramic is said to have come into existence at the time of the Etruscans who were living in the region of Syria in Asia Minor 500 B.C. They started by imitating some natural objects such as shells, and gourds and were most noted in the field of ceramic sculptures. This imitation of natural objects was done through press making of layers of clay and hollow formed. The hollowed of clay was allowed to harden, later fired and used as containers. Supporting this assertion, Mangrock, (1986), states, "This accidental experiment is thought to have been the means by which man learned how to make pottery".

The art of making clay products is one of the man's earliest scientific achievements. They are among the indestructible materials through which early history of man is being traced. Mangrock, (Ibid), alludes that the bowls made constitute the only surviving records of our ancient civilisation. These products have survived the rigours of thousands of years and from their study scientists often visualise the modes of life of our early ancestors.

This art of pottery was further advanced by the Chinese during the discovery of high - fired pottery through refinement of materials and bodies. The strong and persistent effort of the Chinese brought about the beginning of the refinements that seperated porcelain from other kinds of ceramics in the world. Rhodes, (1973), states, "The beginnings of high - fired ceramics are of great antiquity, dating back to about 500BC. in China, prior to this time all pottery the world over, was earthenware - that is porous, non vitrified ware".

The quality of porcelain products as described by Mcmeekin, (1957), is its superior whiteness, hardness, corrosive proof and translucency. These characteristics and qualities according to him are not found in other kinds of ceramic products. These same materials, used for porcelain production are believed to be available abundantly at the door posts, all over, in this country. Cardew, (1956), laments that Nigeria had almost unlimited reserved of all the major raw materials necessary for ceramics and some of them are of excellent qualities. But it is sad to note that these abundant materials have not been investigated to boost the Nigeria economy. Nigeria, thus, needs a better economic policy that would lead her to self sufficiency and economic independent.

It is certain that the present economic hardship is greatly affected by over dependency upon the foreign machinery by the industrial sector. According to Onaji, (1985), Nigeria imported a large consignment of high-fired ceramic products worth 13 million naira in 1978. Therefore ten years of continuous importation of similar ceramic wares would be expected to exceed one hundred and thirty million naira. In similar opinion, Gukas, (1985), reiterates that most of the table wares, stonewares and porcelain seen in our markets today are imported. It is, thus certain that Nigerians have realised that high-fired wares are ideal medium for household utensils. The long term effect of this economic aspect, therefore, will lead the nation into a huge foreign debt. For instance, Umazzayi, (1990), states that heavy weight of foreign debts had made Nigerians suffer from bankruptcy which was due to lack of proper investigation and utilisation of local resources.

It is anticipated that formulation of high-fired porcelanous throwing wares using local raw materials will thus offer some fundamental suggestions for ceramics growth in this country particularly from the area of study.

1.2 Statement Of The Problem

The problem of this study is exploring into the local raw materials in Akwanga Local Government Area of Plateau State for the production of porcelanous throwing bodies, glaze materials for such bodies and processes in arriving at the correct body and glaze fit.

1.3 Objectives Of The Study

The objectives of this study are:

1. To identify the raw materials for the formulation of the porcelanous bodies and glazes.

2. To test the extent to which the local raw materials will be utilised for the formulation of porcelanous throwing wares through experimentation.

3. To produce high-fired porcelanous throwing wares in the country which is fundamental in promoting economic self-reliance.

4. To make a contribution to the academic and technological advancement in this area.

1.4 Basic Assumption

The research was based on the following assumptions:-
That information supplied by the local potters, farmers, geologists, and wood dealers would be useful and helpful in the procurement of the raw materials needed for the study.

That the raw materials identified would have properties and characteristics suitable for the production of porcelanous bodies.

That adequate facilities will be available for the process of the samples collected.

1.5 Limitation And Delimitation

The Research concerns with the formulation of porcelanous throwing bodies and glaze fit, using local raw materials found in Akwanga Local Govenment Area of Plateau State. The insufficient knowledge about the location of raw materials result in limiting the information gathered to the respondents such as local potters, geologists, farmers and wood dealers within the area of study.

The delimitation to this geographical location is for the purpose of thorough tapping of resources for the study. The raw materials in view are: kaolin, feldspar, quartz, ball clay, rice husk ash and wood ash. The use of throwing technique as the means of shaping method in producing experimental samples for the research constitute delimitation.

1.6 Instruments

The instruments for this research will be unstructured interview, diggers, shovels, and hoes for procurement of raw materials from the area of study. Other instruments will include sieves, baskets, water, drums, drying-boards, and head pans to process the raw materials.

Other machines that will be used in the ceramics section will include kiln, ball mill, crusher, pug mill, blunger, shelves and potter's wheel. Others include scale and pyrometric cones, for heat measurement during the test.

1.7 Significance

It is obvious and certain that some Nigerian ceramists produce soft earthenware products, although these products serve the purposes for which they were made; they are indeed brittle having been fired at a low temperature below 1180°C. As a result of this, there is need for more research in the abundant high-fired ceramic raw materials in order to meet the challenges of modern technology. It is anticipated that the study will broaden the public vision on the importance of high-fired ceramics to realise that ceramic does not merely produce pots, but quite a wide range of products which are extremely important. Such products are porcelain insulators, wall and floor tiles, electrical sockets, water sinks, high votage porcelain resistors, glass, engine plugs, tablewares, burnt bricks and refractories, most of which are all imported.

Finally, itis hoped that the outcome of this study will eventually lead to the production of the high-fired porcelanous products, for instance, porcelain water sinks, porcelain insulators and high voltage porcelain resistors in the country. It is also hoped that this study will contribute to the academic advancement in ceramics.

CHAPTER II

LITERATURE REVIEW

2.1 Introduction

The formulation of some high-fired porcelanous throwing bodies and glaze fit calls for a review , high lighten a brief history of porcelain.

The principal raw materials for porcelanous throwing bodies and glazes are also looked into.

2.2 Brief Literature Review

Porcelanous production was in existence long before porcelain was ever made and known during Sui and T'ang periods, (618-906 BC). This assertion was supported by Laufer, (1917), who states:

> From the Sui and T'ang periods onward, the word T'se was applied, for the first time to true porcelain. It is self-evident that prior to that time, it was attached to porcelanous ware, the fore runner of true porcelain which did not plainly describe any pottery; but porcelanous pottery specifically.

Porcelain was not an invention that could be attributed to the efforts of an individual, but rather a slow and gradual processes of finding, groping and experimenting.

The length of time for these developments resulted into a matured and highly finished product (porcelain) which the Chinese gained fame throughout the world. The rising developments of the porcelain from T'ang to the Sung, Yuan and Ming peiods, the high perfection of true porcelain culminated only in the K'an-hi era. It is thus, logical to assume that proceeding the age of the Sui (590-618 BC) there was an initial stage of development which ultimately resulted in the T'ang porcelain.

Considering the formulation of the porcelanous throwing body and suitable glaze fit, Mcmeekin, (1957), suggests that it is important to have a look at the principal raw materials that are involved and the role each plays in the formulation. Such materials in view are kaolin, feldspar, quartz, ball clay, rice husk ash and wood ash. An exception is the incorporation of calcined bone which is called bone china or bone porcelain to which is outside the scope of the research.

2.3 Kaolin

Kaolin ($Al_2 O_3 . 2 SiO_2 . 2H_2O$) is a mixture of quartz, feldspar, and mica and a member of a class of clays. It is the only type that is used for ceramics, taken internally as a medicine and also used in cosmetics. The mineral (Kaolin) is indispensable in ceramics because it is relatively free from iron and other associated mineral impurities as such it can withstand temperature approaching 1750°C. It helps in determining whiteness in which it burns very light colour. It provides strength to the fired wares and because of its refractoriness permits its use in a very high temperature firing. Singer and Singer, (1977), expresses the composition and percentage of Kaolin ($Al_2O_3 . 2SiO_2 . 2H_2O$) to be :-

Silica	-	46.51%
Alumina	-	39.53%
Combined Water	-	13.9%

Leach, (1973), also gives the composition and percentage of kaolin as:-

Silica	-	46.64%
Alumina	-	39.55%
Combined Water	-	13.95%

Rhodes, (1973), states that kaolin by itself is highly refractory and could be softened (melted) at around orton cone 30 (1650°C). He also showed that some kaolin are more plastic than others which could be used for throwing depending on the careful processing and longer ageing.

2.4 Feldspar

The alkali feldspar which this study is much concerned includes potash and soda which fall in number 6 on Moh' scale of mineral hardness. They are valued for the fluxing role they play. They fuse a body into smooth white and glassy mass. For the purpose of this study, the alkali feldspar will be considered.

2.5 Potash Felspar

The appearance of potash feldspar ($K_2O.\ Al_2O_3.\ 6SiO_2$) is a milky white, grey, or often pink translucent mineral, with a pearly lustre on its cleavage planes. Potash feldspar is used in both bodies and glazes as an alkaline flux. Its most valuable charateristics for ceramists is that when it melts, it does so gradually and the melt formed is very viscious. That is why it is so often used in porcelain bodies where the gradualness of the melt gives vitrification unsquatting problem.

2.6 Soda Feldspar

In character and appearance, soda feldspar ($Na_2O.\ Al_2O_3.\ 6SiO_2$) is more often white or greyish in colour. It is more fusible than the potash feldspar. It is used for both porcelain bodies and glazes composing material as flux that lowers melting of high-fired temeperature substance in glazes. It is a hard substance to grind. It is thus usually calcined to about 900°C in order to become soft and easy for jaw crushing and ball milling.

2.7 Quartz

Quartz (SiO_2) is hard, sometime clear, but more often translucent, milky or grey with a glassy or vitreous lustre. The silica sold to ceramists for use in bodies and glazes is invariably milled quartz and may be substituted quite directly and satisfactory for flint in nearly every receipe that calls for flint. Quartz is number seven (7) on Moh's scale of mineral hardness and as a source of silica. It is used for both bodies and glazes.

In bodies, it is used as a result of its high-melting point (about 1700°C). It is used as a refractory opening material to cut down shrinkage or to stiffen clays liable to squat at high temperatures (i.e 1250°) and enables glazes to fit into the body. It is also used in bodies because of its thermal expansion characteristic and adjustment of glaze fit.

In glazes it is the principal glass former. It gives strength to the final fired ware. Quartz is a hard substance to grind, therefore it is usually calcined to about 900°C temperature in order that it could become soft and easy for jaw-crushing and ball milling.

2.8 Ball Clay

The ball clay ($Al_2O_3. 2SiO_2. 2H_2O$) is formed by the disintegrating of granite and other feldspathic rocks which decomposed and deposited alumina and hydrous silicates. It can be modelled, pounded, pinched flattened, rolled, coiled, thrown on a wheel or cast into moulds. The clay responds to shaping, bending, smoothing, drying, firing and glazing. Considering these fundamental characteristics and qualities of ball clay, it is indispensable in ceramics and porcelanous throwing body because of its high degree of plasticity (good bonding power) and dry strength. However, Rhodes, (1973), advices that its use in porcelain bodies should be absolutely held down to the minimum so that the whiteness and translucency of the porcelain products be maintained.

2.9 Ashes

Mcmeekin, (1975), states that the natural glaze which contains all the essential ingredients for a glaze is ash of wood or other vegetable ashes. Although they are not always in correct proportions, they give good glazes. Ashes contain alkali in more or less soluble form together with silica. Rhodes, (1973), states that the composition of ashes vary widely, depending on the source. Some ashes are composed almost entirely of silica and contain very little soda, potash or other elements, for example, rice husk ash. Some ashes are quite fusible while others are refractory and difficult to melt. An ash with the right melting characteristics makes a valuable and often very beautiful porcelain glaze material. Cassion, (1977), in similar opinion, says that a very silicious ash will have a very high melting temperature and ash which is low in silica will usually fuse (Melt) at a lower temperature.

Mcmeekin, (Ibid), says that some ashes will produce beautiful glazes without any addition whatsoever on porcelanous wares. Other may require up to 70% or 80% of additional materials such as feldspar and clay. The selection, procuring and preparation of ashes for use in glazes always presents some difficulties. For example, to burn material especially for the purpose of making glaze requires great quantities of wood, rice husk or other materials just to obtain a small amount of ash.

2.10 Formulation of Porcelanous Throwing Body

In formulating porcelanous throwing body, the four principal raw materials involved are kaolin, feldspar, quartz and ball clay.

Kaolin: This material helps in determining the whiteness (with which it burns), refractoriness and plasticity or lack of it as a result of its purity.

Feldspar: This material helps in the fusion of the body into smooth White and glassy mass. It is therefore ideal for high temperature body flux and seems almost to have been made by nature for this purpose.

Quartz: Quartz in the porcelain bodies serves as a glass former, assists the body to become hard, strong and translucent on the finished porcelanous wares through high firing.

Ball Clay: The ball clay in the porcelanous body provides plasticity with which it enables the body to be thrown on a wheel.

In formulating a porcelanous throwing body, it is important to have a look at the composition of other various types of similar bodies that would be of great help to this study. Rhodes, (1973), suggests (assuming that temperature will be for cone 11 and 12), the porcelain bodies should be based on the following composition:-

Clay (devided between kaolin and ball clay)	=	50%
Feldspar	=	25%
Flint	=	25%

Mcmeekin, (1957), suggests that the starting point of a mixture of porcelain bodies composition should be:-

Clay substance (kaolinite)	=	50%
Feldspar	=	35-25%
Flint or Quartz	=	15-25%

In addition, Rhodes, (1973), suggests that a typical German porcelain body composition is:-

Clay	=	54%
Feldspar	=	20%
Flint	=	25%
Whiting	=	1%

The study showed that the constituents of porcelain throwing bodies should total about one half (½) of the body to include both kaolin and ball clay. The composition of clay in the formulation should be held down to the absolute minimum so that the whiteness and translucency of the body be obtained. The remaining one half (½) of the body should be divided about equal between feldspar and quartz. Riegger, (1971), suggests that the exact composition of the throwing bodies should be determined after a careful test and experiment using a quadrilateral test blend method, as contains in table 2.1 below.

1 (K.) KAOLIN 100%	2 K=80% B=20%	3 K=60% B=40%	4 K=40% B=60%	5 K=20% B=80%	6 (B.) BALL CLAY 100%
7 K=80% F=20%	8 K=64% B=16% F=16% Q=4%	9 K=48% B=32% F=12% Q=8%	10 K=32% B=48% F=8% Q=12%	11 K=16% B=64% F=4% Q=16%	12 B=80% Q=20%
13 K=60% F=40%	14 K=48% B=12% F=32% Q=8%	15 K=36% B=24% F=24% Q=16%	16 K=24% B=36% F=16% Q=24%	17 K=12% B=48% F=8% Q=32%	18 B=60% Q=40%
19 K=40% F=60%	20 K=32% B=8% F=48% Q=12%	21 K=24% B=16% F=36% Q=24%	22 K=16% B=24% F=24% Q=36%	23 K=8% B=32% F=12% Q=48%	24 B=40% Q=60%
25 K=20% F=80%	26 K=16% B=4% F=64% Q=16%	27 K=12% B=8% F=48% Q=32%	28 K=8% B=12% F=32% Q=48%	29 K=4% B=16% F=16% Q=64%	30 B=20% Q=80%
31 (F.) FELDSPAR 100%	32 F=80% Q=20%	33 F=60% Q=40%	34 F=40% Q=60%	35 F=20% Q=80%	36 (Q.) QUARTZ 100%

Table 2.1: The distribution of materials in the quadrilateral test blend.

2.11 Formulation of Glaze

In all ceramics, the body and glaze must fit well to make a successful porcelanous throwing ware products. The three principal glaze materials involved in the glaze formulation are, feldspar, rice husk ash, and wood ash. Ruscoe, (1948), says that the formulation of glaze can be achieved through the 'alumina - silica ratio' which are expressed in the molecular formula form based on the percentage composition or by working recipes. Glaze is therefore compounded to fit the maturity of the clay body which usually matures above 1260°C, as in the case of high-fired (porcelain) body. Rhodes, (1973), maintains that feldspar and quartz should form about 70% while the remaining 30% should be composed from the other materials.

The idea of the upper limit is also stressed that it would make glaze and the body melt at the same point and also decreased the expansion of high temperature glazes. He also suggests that for the composition of glazes for the range of cone 9 to 11, which indicates the usual upper limit of the amount of the various materials, could be used.

MATERIALS	COMPOSITION IN PERCENTAGE	
Feldspar	50%	) 70% of Glaze
Flint	20%	)
Clay	0 - 15%	)
Whiting	0 - 15%	)
Barium Carbonate	0 - 10%	)
Magnesium Carbonate	0 - 10%	) 30% of Glaze
Dolomite	0 - 15%	)
Talc	0 - 15%	)
Calemanite	0 - 15%	)
Zinc Oxide	0 5%	)

Table 2.2 : The usual upper limit of glaze materials for use.

The study revealed that feldspar content in a glaze contains 10-15% of potassium, sodium andlime combined. The remaining 85% to 90% is divided between alumina and silica, with silica accounting for 60% or more of the total, which gives the body scratch proof and resistance to acids after glaze firing.

Ash in conjunction with feldspar is generally high in silica. It contains also some alumina and calcium, moderate amounts of fluxes such as potash, soda and magnesia plus iron and small quantity of numerous other compounds in it. It is due to its high silica content that it (ash) is used in high-fired porcelanous glazes. Glenn, (1971), suggests that the starting point for porcelanous ash glaze test, should be 40 parts ash, 40 parts feldspar and 20 parts whiting or 50 parts ash and 50 parts feldspar.

In conclusion, he suggests that the way to arrive at a suitable glaze fit for porcelanous body products, is to test the feldspar first by melting it in the glaze fire without any addition of ingredient. This should be followed with additional glaze materials, such as ashes in certain proportions using triaxial blend method as contains in table 2.3 below.

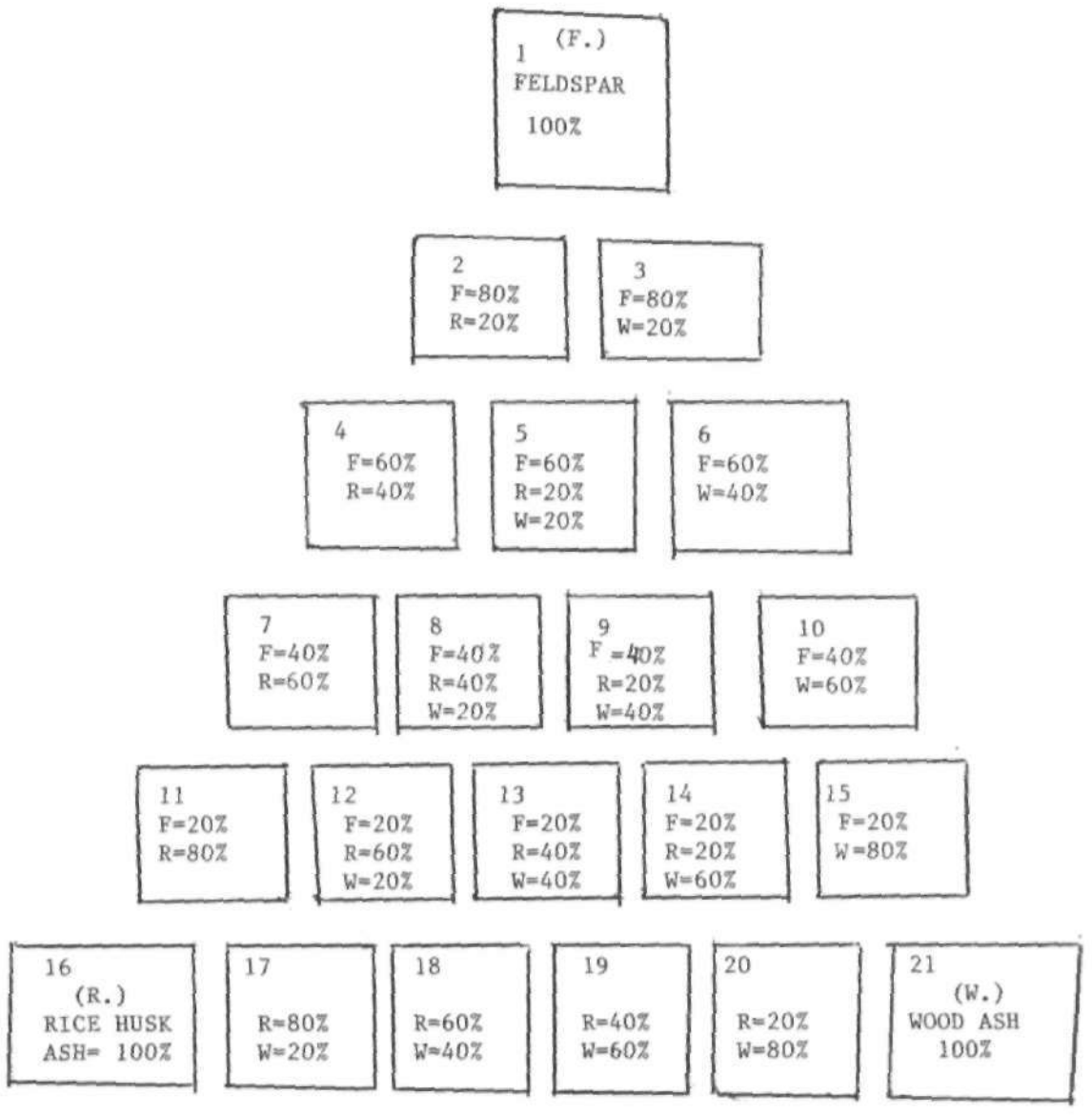


Table 2.3: The distribution of glaze materials in the triaxial blend.

CHAPTER III

RESEARCH PROCEDURE

3.1 Introduction

The chapter covers the samples for the study, the unstructured interview schedule, field trips and sampling and processing of raw materials. In addition, are the formulation of porcelanous throwing bodies and the suitable glaze fit, the procedures for porcelanous throwing wares and glaze application.

3.2 Samples

The samples for the study comprise of kaolin, feldspar, quartz, ball clay, rice husk/and wood ash.

3.3 Unstructured Interview Schedule

The unstructured interview method was used with a total of twelve people at different times who were chosen at random. They were simply asked to identify some areas in Akwanga Local Government Area where kaolin, feldspar, quartz, ball clay, rice husk ash and wood ash could be found in large quantities. These are the four selected groups of related knowledge for the procurements of raw materials.

Traditional Potters: This group comprised of five people within the area of study. The selection was on the assumption that being traditional potters in this area, they would have knowledge of clay deposits.

Geologists: This group comprised of three people within Akwanga Local Government Area. The selection was done on the assumption that being geologist and a miner.

This category of participants here have a wider knowledge of feldspar and quartz in the area.

Farmers: The farmers comprised of two people within the area of study. The selection of this group was on the assumption that being farmers, they would have knowledge where rice was heavily produced and where rice mill centres in the area could be found so that husk could be collected and burnt down to obtain ash.

Wood Dealers: The wood dealers comprised of two people within the area of research. The selection was on the assumption that being wood dealers, they would know where wood ash could be found in abundance in the area so that it (ash) could be collected.

For the purpose of visualisation and clarity on the locations and procurements of local raw materials, the table 3.1 below enhances the data presentation.

RESPONDENTS			LOCATION OF RAW MATERIALS				
S/NO	RESPONDENTS	KAOLIN LOCATION	FELDSPAR LOCATION	QUARTZ LOCATION	BALL CLAY LOCATION	RICE HUSK ASH LOCATION	WOOD ASH LOCATION
1	Sabatu Audu - Potter	Kura Falls	Buhar	Ningo	Bayan Dutse	Akwanga	Akwanga
2	Kwate Lakpu - Potter	Kura Falls	Buhar	Ningo	Bayan Dutse	Akwanga	Akwanga
3	Tagude Ndeni - Potter	Wamba	Buhar	Ningo	Wamba	Moroa	Akwanga
4	Shiriya Kawo - Potter	Kura Falls	Buhar	Ningo	Andaha	Akwanga	Akwanga
5	Maimuna Maikoni - Potter	Kura Falls	Wamba	Rija	Bayan Dutse	Akwanga	Akwanga
6	Chube Zamwa - Miner	Kura Falls	Akwanga	Ningo	Bayan Dutse	Akwanga	Akwanga
7	Dauda Ajiji - Geology Staff	Kura Falls	Ningo	Akwanga	Bayan Dutse	Akwanga	Akwanga
8	Awaje Maiyaki - Geology Student	Kura Falls	Buhar	Wamba	Bayan Dutse	No Idea	Akwanga
9	Debura Chube - Farmer	Nidan	Buhar	Ningo	Bayan Dutse	U/Zaria	Andaha
10	Barau Mu'azu - Farmer	Kura Falls	Buhar	No Idea	Bayan Dutse	Akwanga	Akwanga
11	Maidoki Mado - Wood Dealer	Kura Falls	Gudi	Ningo	Bayan Dutse	U/Zaria	Wamba
12	Rakiya Michael - Wood Dealer	No Idea	Andaha	Ningo	Bayan Dutse	U/Zaria	Akwanga

Table 3.1: The distribution and location of available local raw materials for High-Fired ceramics in Akwanga Local Government Area as indicated by the twelve respondents.

Where a respondent could not/have an idea of location of material in question it is indicated 'No. idea'.

TOWNS	CERAMIC RAW MATERIALS DEPOSITS					
TOWNS & VILLAGES	KAOLIN	FELDSPAR	QUARTZ	BALL CLAY	RICE HUSK ASH	WOOD ASH
Akwanga	-	1	1	-	7	10
Wamba	1	1	1	1	-	1
Andaha	-	1	-	1	-	1
Ningo	-	1	8	-	-	-
Buhar	-	7	-	-	-	-
Moroa	-	-	-	-	1	-
Ungwan Zaria	-	-	-	-	3	-
Nidan	1	-	-	-	-	-
Bayan Dutse	-	-	-	10	-	-
Kura Falls	9	-	-	-	-	-
Rija	-	-	1	-	-	-
Gudi	-	1	-	-	-	-
Total No. of 'No idea'	1	-	1	-	1	-

Table 3.2: The data analysis and distribution of respondents location of raw materials and deposits in the area of study.

S/NO	TOWNS/VILLAGES OF RAW MATERIAL DEPOSITS	AVAILABLE LOCAL RAW MATERIALS	% RESPONDENTS
1.	Akwanga	Wood Ash	83.3%
2.	Bayan Dutse	Ball Clay	83.3%
3.	Kura Falls	Kaolin	75.0%
4.	Ningo	Quartz	66.7%
5.	Buhar	Feldspar	58.3%
6.	Akwanga	Rice husk ASh	58.3%

Table 3.3: The main deposits of raw materials expressed in percentages.

The summary of the data analysis of the location of some ceramics raw materials deposits in Akwanga Local Government Area as indicated by the twelve respondents expressed in percentage.

The areas with high percentages of respondents were selected for the field trips and sampling of the raw materials as contains in table 3.2 and 3.3.

Wood Ash: The result of analysis showed that ten out of twelve respondents (83.3%) located Akwanga as an area where wood ash could be found. One person mentioned Wamba and another mentioned Andaha as areas where wood ash could be found. Akwanga was therefore selected being the area with the highest percentage of respondents.

Ball Clay: Ten out of twelve respondents (83.3%) located Bayan Dutse as an area where ball clay could be found in abundance. One person mentioned Wamba and another mentioned Andaha as areas where ball clay could be located. Hence, Bayan Dutse was selected because it had the highest percentage of respondents.

Kaolin: The data analysis showed that nine out of twelve respondents (75.0%) located Kura Falls as an area where kaolin could be found in abundance. One person mentioned Wamba, another mentioned Nidan as areas where kaolin could be located while another person had no idea of the location. Kura Falls was therefore selected because it had the highest percentage of respondents.

Quartz: The data analysis indicated that eight out of twelve (66.7%) located Ningo as an area where quartz could be found inlarge quantities. One respondent each mentioned Rija, Wamba, and Akwanga as areas where quartz could be found. One respondent had no idea of the location. Ningo was thus selected because the area had the highest percentage of respondents.

Feldspar: From the result, seven out of twelve respondents (58.3%) located Buhar as an area where feldspar could be found in abundance. One respondent each mentioned Wamba, Ningo, Akwanga, Gudi and Andaha as areas where feldspar could be found. Buhar was thus selected because it had the highest percentage of respondents.

Rice Husk Ash: Seven out of twelve (58.3%) respondents located Akwanga as an area where rice husk could be abundantly found. Three respondents (25.0%) mentioned Ungwan Zaria and one mentioned Moroa River while one had no idea. As a result, Akwanga being the highest percentage of respondents was selected. However, Ungwan Zaria near River Mada where rice was heavily produced and transported to Akwanga for milling was also visited.

The researcher used the greater percentages of respondents as the basis to determine the areas for the Field Trips and Sampling.

3.4 Field Trips and Samplings

This part comprised of Field trips to some selected areas within the area of study for sample collections. The materials collected were based on the information gathered from literature review on High-Fired Porcelanous raw materials. Below is the list of towns and villages where raw materials were procured for the research.

S/NO	RAW MATERIALS	TOWNS VILLAGES OF RAW MATERIALS DEPOSITS	LOCATION OF RAW MATERIALS DEPOSITS AND DISTANCE FROM AKWANGA TOWN
1	Wood Ash	Akwanga	Within Akwanga town in Mada District
2	Ball Clay	Bayan Dutse	North East of Akwanga town and distance of 20km from Akwanga in Mada district.
3.	Kaolin	Kura Falls	East of Akwanga town and a distance of 159km from Akwanga, in Barkin Ladi Local Government Area.
4.	Quartz	Ningo	North of Akwanga town and a distance of 14km from Akwanga, in Mada District.
5.	Feldspar	Buhar	North of Akwanga town and a distance of 15km from Akwanga, in Mada District.
6.	Rice husk ash		Within Akwanga town in Mada Disitrict.

Table 3.4: The field trips and sampling of Local raw materials.

The local raw materials from the area of study, were found to be in abundance and of high quality materials for porcelain.

Wood Ash: The wood ash was procured directly from the college of Education Akwanga, Mada Hills Secondary School Akwanga, and Government Girl's College Akwanga.

The ash was found in abundance in the area which was thrown away as kitchen wastes, including saw-dust from the mill-centres at Akwanga town.

Ball Clay: The ball clay was obtained through digging up of the raw materials from the ground. It was from the old local mining pit where the deposits were found. Diggers were used to dig up the material and head pans to carry it at Bayan Dutse, 20km from Akwanga town in Mada District.

Kaolin: This material was dug up from the already mined pit, full of raw kaolin material deposit. Diggers, and shovels were used to dig up and to collect the materials into head pans where the deposits were found at Kura Falls, 159km from Akwanga town.

Quartz: The quartz was collected through hand picking and digging up where the deposits were found. This material was commonly found all over the area but heavily deposited at Ningo, 14km from Akwanga in Mada District.

Feldspar: Feldspar was also collected through hand picking and digging up where the deposits were found in abundance. The material was found all over the area of study at Buhar hill, 15km from Akwanga town in Mada District.

Rice Husk Ash: The rice is heavily produced in the area and is taken to the rice mill centre where the husks are thrown away as wastes in heaps at Akwanga. The rice husk was collected from the rice mill centre at Akwanga town, burnt down and the ash obtained.

S/NO	RAW MATERIALS	KITCHEN WASTE	MILLING WASTE	DIGGING	PICKING
1.	Wood ash	✓	-	-	-
2.	Ball Clay	-	-	✓	-
3.	Kaolin	-	-	✓	-
4.	Quartz	-	-	✓	✓
5.	Feldspar	-	-	✓	✓
6.	Rice husk ash	-	✓	-	-

Table 3.5: The method of collection of raw materials from the area of study.

3.5 Preparation of Samples Collected

Some of the materials collected were prepared from the area of study to avoid carrying unnecessary impurities with the samples on a long journey to the Ceramics Studio, Ahmadu Bello University, Zaria. The samples collected and prepared were kaolin, ball clay, rice husk ash and wood ash.

Kaolin Sample: The kaolin sample was soaked in water overnight in a drum after it was thoroughly stirred. The impurities were removed and seived using mesh 120. It was allowed to settle down and water on top was discarded. Finally kaolin was dried on a clean board ready for tests and experiments.

Ball Clay Sample: The ball clay sample collected was soaked in water overnight in a drum and thoroughly stirred. The impurities were removed and sieved using mesh 80. It was allowed to settle down and water on top discarded. Finally the ball clay was dried on the cemented floor ready for experiments.

Rice Husk Sample: The rice husk sample collected from the rice mill centre was burnt down and the ash was obtained ready for tests and experiments.

Wood Ash Sample: Wood ash was collected from the main cooking centres of the institutions of learning, soaked in water and stirred in a drum. The impurities in the ash were removed and the ash allowed to settle down. The water on top discarded. The process was repeated twice a day, which lasted for one week till the slurry texture and taste/bitterness were eliminated. The washed ash was then sieved using mesh 80. The sieved ash was allowed to settle down and water on top thrown away and ash dried on a clean board ready for experiments.

3.6 Studio Preparations of Sample Collected

The raw materials, brought from Akwanga Local Government Area to b processed in the Ceramic Studio, were feldspar and quartz. They were seperately prepared in the studio. At this stage, kaolin, ball clay, rice husk ash and wood ash had been prepared already at the area of study and were ready for various tests and experiments.

Feldspar and Quartz Samples: The feldspar and quartz samples were calcined using electric kiln to about 1000°C temperature, cooled and broken down into smaller particles (using a hammer) that would be convenient for crushing. After crushing the feldspar and quartz, were ball milled seperately for about 24 hours each. The grounded materials were removed from the ball mill into their labled bins to setttle down. The water on top was poured away. Finally the feldspar and quartz were seperately dried ready for the tests and experiments.

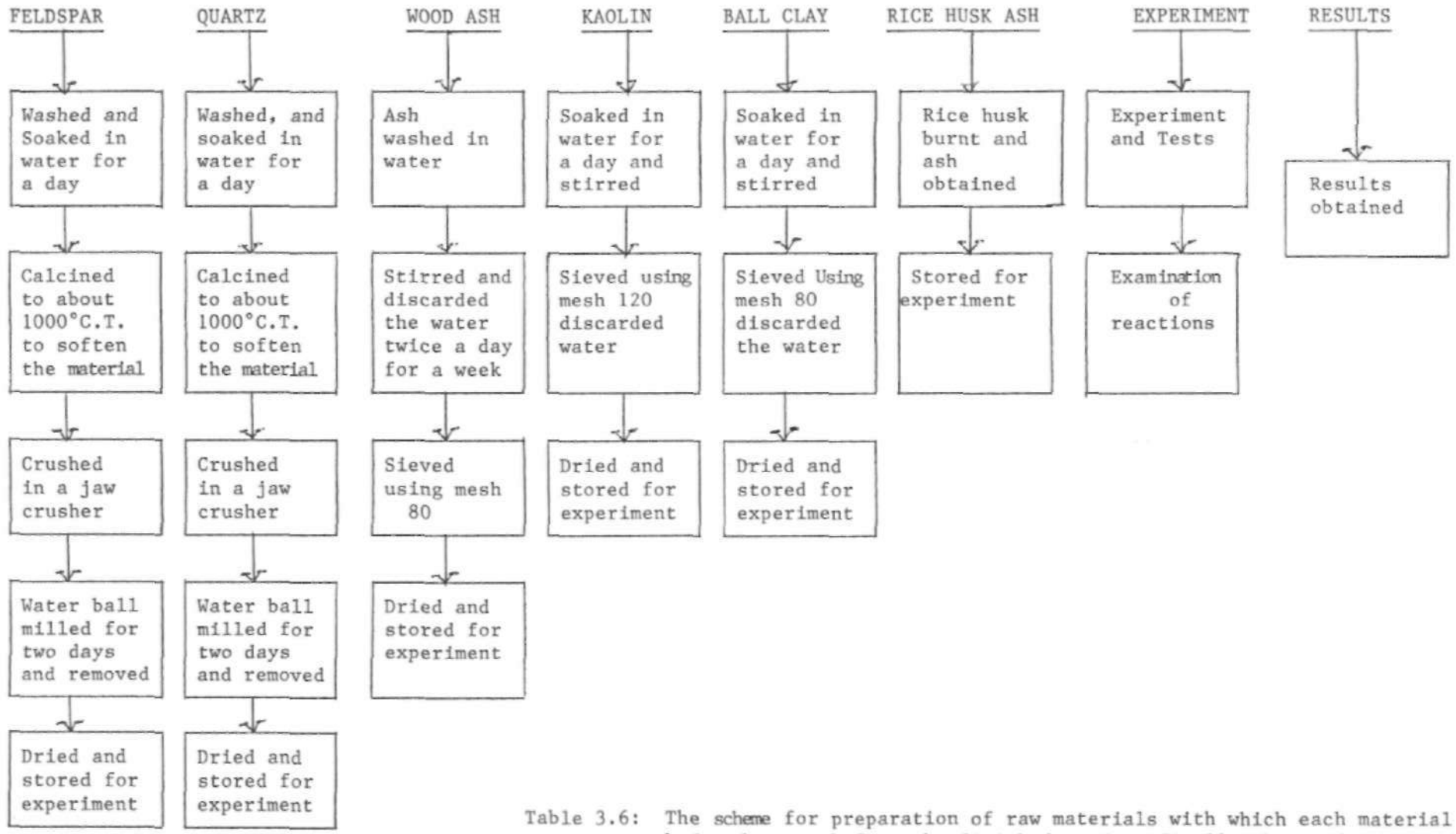


Table 3.6: The scheme for preparation of raw materials with which each material had undergone before the finished product finally obtained.

3.7 Formulation of Porcelanous Throwing Bodies

The information gathered from the literature review, revealed that the formulation of porcelanous throwing bodies involved the combination of different materials such as kaolin, feldspar, quartz, and ball clay.

Kaolin: Being the main component in the making of white ware, enhances refractories and colour to the body.

Feldspar: *Increases translucency, reduces porosity and lowers* the fusion point of the bodies.

Quartz: Provides the resistance to shrinkage, improves translucency and body strength. Feldspar and quartz, thus are non-plastic materials.

Ball Clay: Provides plasticity with which it enables the bodies to be thrown on a wheel.

Literature revealed that a half ($\frac{1}{2}$) of the total porcelanous throwing bodies should be divided between kaolin and ball clay, and ball clay should be held down to the minimum so that characteristics and qualities of the porcelain be obtained. The remaining half ($\frac{1}{2}$) of the bodies be divided between feldspar and quartz.
Riegger (1978) suggests that the distribution of porcelanous throwing body materials should be done through the use of quadrilateral test blends method. This is to obtain the correct compositions that would be suitable for throwability. A 36 member blends of the main constituents which are kaolin, feldspar, quartz and ball clay was adapted. The diagram below contains the distribution of the materials. In each rectangle of the quadrilateral, which has been numbered from 1-36 contains as follows:

The rectangular on top left hand corner represents 100% kaolin. The rectangle on the right hand corner, represents 100% ball clay. The rectangle at the bottom left hand corner represents 100% feldspar while the rectangle at the bottom right hand corner represents 100% quartz. For instance on the test blend No. 20 in the quadrilateral blend, the blend composition comprises of 32% kaolin, 8% ball clay, 48% feldspar and 12% quartz as indicated in table 3.7 below.

1 (K.) KAOLIN 100%	2 K=80% B=20%	3 K=60% B=40%	4 K=40% B=60%	5 K=20% B=80%	6 (B.) BALL CLAY 100%
7 K=80% F=20%	8 K=64% B=16% F=16% Q=4%	9 K=48% B=32% F=12% Q=8%	10 K=32% B=48% F=8% Q=12%	11 K=16% B=64% F=4% Q=16%	12 B=80% Q=20%
13 K=60% F=40%	14 K=48% B=12% F=32% Q=8%	15 K=36% B=24% F=24% Q=16%	16 K=24% B=36% F=16% Q=24%	17 K=12% B=48% F=8% Q=32%	18 B=60% Q=40%
19 K=40% F=60%	* 20 K=32% B=8% F=48% Q=12%	21 K=24% B=16% F=36% Q=24%	22 K=16% B=24% F=24% Q=36%	23 K=8% B=32% F=12% Q=48%	24 B=40% Q=60%
25 K=20% F=80%	26 K=16% B=4% F=64% Q=16%	27 K=12% B=8% F=48% Q=32%	28 K=8% B=12% F=32% Q=48%	29 K=4% B=16% F=16% Q=64%	30 B=20% Q=80%
31 (F.) FELDSPAR 100%	32 F=80% Q=20%	33 F=60% Q=40%	34 F=40% Q=60%	35 F=20% Q=80%	36 (Q.) QUARTZ 100%

Table 3.7: The distribution of porcelanous throwing body materials in the quadrilateral test blend.

*The best test blend considered for the study.

Blending: The successful blends that formed lumps were the test blends No. 1-30 of table 3.7. The test blends No. 31-36 could not form lumps. They sedimented immediately they were mixed with water. The blended materials became hardened at the bottom of containers while water settled on top.

Kneading: The successful kneading test blends in table 3.7 were test blends No. 1-18, 20-24, 27-30 which came as a result of their abilities to form lumps. The test blends Nos. 19, 25 and 26 proved extremely difficult. Attempts made to knead the blended materials resulted into spreading of the mixture on the kneading table as they could not form workable lumps.

Throwing: The test blends Nos. 1-18, 20-23, 27-29 were quite successful during throwing as they responded to centering and pulling easily.

The test blends Nos. 19, 24, 25, 26 and 30 were able to be thrown on a potter's wheel but could not withstand the strain of pulling. As a result, they slummed The thrown products were thick and could not makethedesired shapes; while the test blends Nos. 31-36 could not form lumps, as a result they could not be thrown at all.

Trimming: The successful trimming thrown body wares were the test blends Nos. 1-6, 12, and 20-24. They were trimmed without difficulty which resulted them into some considerable defined shapes. Trimming the thrown bodies when they were already green wares (almost hardened and dried with very sharp tools) proved more successful than when they were in leather hard.

The test blends Nos. 9-11, 14-15, 25, 27-30 were fairly good and much more easy to trim. The thrown test blends Nos. 19, 25, 26, were very difficult to trim. During the trimming operations, the products were tearing off deforming the shapes. These bad effects were as a result of inadequate ball clay in the body compositions, because it was held down to the minimum, so that qualities of porcelain be obtained such as whiteness and translucency.

Firing: The green porcelanous thrown wares were loaded into the kiln and on the last two shelves being the hotest region. Gas was used for the firing to cone 10 (1300°C) to determine the maturing temperature. A slow pre-heating of the test green wares was adapted which lasted for two hours.

The full firing lasted for about 11 hours Cone 10 started bending when the firing was about 10 hours. About 11th hour of the firing, cone 10 was fully bent and fire was then put off. In these blended test porcelanous thrown body materials on table 3.7 responded to firing. All these test thrown pieces came out sucessfully from the firing which were heated to 1300°C tempera ture except test blend No. 19 and 25 that squatted during the firing. Each fired piece was thoroughly examined and the best blend considered.

From the quadrilateral test blends table 3.7 the bodies that yielded the most expected qualities and characteristics of porcelain such as fusion, whiteness, hardness, translucence and trength was test blend No. 20 which contains the following local materials from the area of research.

Kaolin	-	32%
Ball clay	-	8%
Feldspar	-	48%
Quartz	-	12%

This composition was selected and considered best for the porcelanous throwing body. The twenty-one (21) triaxial thrown test tiles, a low thrown cylinder, cut into 'L' shapes for the purpose of examining glaze effects on both vertical and horizontal areas, were made out of the above composition and bisque fired/to cone 04 (1020°C) temperature. This was to make the pieces possible for glaze absorption and to get the pieces a bit hardened for easy handling during glaze application.

Shrinkage And Porosity Tests: From the test bar, an over all shrinkage was calculated to be 15%. Also an apparent porosity of 0.02 gram was got by doubling the water absorption.

3.8 Formulation of Glazes

Based on the information gathered from the literature review, for any successful ceramic product made, the body and glaze ought to fit well. In view of this, glazes were compounded from materials that were insoluble in water to commensurate with the body.

The glaze materials were grounded (ball milled) to fine powder and mixed together with correct proportion which were expressed in percentage. The three principal local raw materials used for the study were feldspar, rice husk ash and wood ash using triaxial test blends as illustrated in table 3.8 below.

		1 (F) FELDSPAR 100%				
	2 F=80% R=20%		3 F=80% R=20%			
4 F=60% R=40%		5 F=60% R=20% W=20%		6 F=60% W=40%		
7 F=40% R=60%		8 F=40% R=40% W=20%		9 * F=40% R=20% W=20%		10 F=40% W=60%
11 F=20% R=80%		12 F=20% R=60% W=20%		13 F=20% R=40% W=40%	14 F=20% R=20% W=60%	15 F=20% W=80%
16 (R) RICE HUSK ASH 100%	17 R=80% W=20%	18 R=60% W=40%	19 R=40% W=60%	20 R=20% W=80%		21 (W) WOOD ASH 100%

Table 3.8: The distribution of glaze materials in the triaxial test blen

* The best test tile considered for the study.

Each batch of glaze materials was measured according to the prescribed triaxial test blend ratio, blended in the ball mill for about two hours. The blended slip poured into a bowl and each thrown bisque tile was dipped into the glaze slip according to the prescribed triaxial test blends. For instance the test blend ratio of number 9 contains 40%feldspar, 20% rice husk ash and 40% wood ash. The glaze on the base of each thrown bisque test tile was neatly wiped off to avoid sticking into the shelves. The glazed test tiles were loaded into the kiln and fired to cone 10 (1300°C).

Gloss Firing: Three different firings were carried out on the wares. The first firing of the thrown wares was 1300°C temperature. This was to enable the researcher determine the qualities and characteristics of the porcelain, such as fusion, hardness, whiteness, and translucency.

The second firing of the thrown triaxial tiles (in 'L' shapes) was the bisque firing using gas to cone 04 (1020°C). This was to enable the wares absorb glaze and for easy handling during glaze application. After glazing, these bisque test tiles were loaded into the kiln and fired using gas to cone 10 (1300°C). The pre-heating of test tiles took one hour each time of the firing while full firing of glazed wares took about 11 hours firing. Cone 10 bent at the 10th hour of firing and fell about 11th hour. Firing was then put off, cooled and unloaded. This formed the third (gloss) firing.

The triaxial glazed tiles were carefully examined. The tile found to be the most matured and the most suitable for the porcelanous glaze fit on table 3.8 was test blend No. 9 containing the following glaze materials.

Feldspar	-	40%
Rice husk ash	-	20%
Wood ash	-	40%

This test tile was result/picked and considered for the study.

Two more tests were conducted, to be more certain about the correct glaze fit from this first 21 triaxial test blends result above. They were the possible test tile results on table 3.8, and the use of kaolin in place of wood ash, still maintaining triaxial test blends method.

The three possible test tile results that were close, were picked for further test namely tile number 6, tile number 9 and tile number 20 from table 3.8. Their glaze compositions as appeared on the triaxial blend were blended. The 21 test tiles were dipped into the glaze slip, loaded into the gas kiln and fired to cone 10 (1300°C). The result was carefully examined. All the 21 test tiles fused well and produced good glazes. Tile number 5 produced close effect and good quality as tile number 9 in table 3.8. The glaze composition of tile number 5 was calculated and the result was found to be the same glaze composition as tile number 9 which contains.

Feldspar	-	40%
Rice husk ash	-	20%
Wood ash	-	40%

This composition re-affirmed tile number 9 result to be the most appropriate glaze fit for the porcelanous throwing ware products as contains in table 3.9 below.

1 (T6) FELDSPAR=60% WOOD ASH=40% 100%					
2 T6=80% T20=20%	3 T6=80% T9=20%				
4 T6=60% T20=40%	5 T6=60% T20=20% T9=20%	6 T6=60% T9=40%			
7 T6=40% T20=60%	8 T6=40% T20=40% T9=20%	9 T6=40% T20=20% T9=40%	10 T6=40% T9=60%		
11 T6=20% T20=80%	12 T6=20% T20=60% T9=20%	13 T6=20% T20=40% T9=40%	14 T6=20% T20=20% T9=60%	15 T6=20% T9=80%	
16 (T20) WOOD ASH = 80% RICE HUSK =20% = 100%	17 T20=80% T9=20%	18 T20=60% T9=40%	19 T20=40% T9=60%	20 T20=20% T9=80%	21 (T9) FELDSPAR = 40% RICE HUSK ASH=20% WOOD ASH = 40% = 100%

Table 3.9: The distribution of close test tile results in triaxial test *blends*.

The third test was the use of kaolin in place of wood ash while feldspar and rice husk ash maintained their former glaze blending positions in the triaxial test. The 21 test tiles were dipped into the glaze slip loaded into the gas kiln and fired to cone 10 (1300°C). The result was again examined. the test tiles numbers 1-21 could not fuse well to make any good porcelanous glaze fit, as contains in table 3.10 below.

		1 (F.) FELDSPAR 100%			
	2 F=80% R=20%		3 F=80% K=20%		
4 F=60% R=40%		5 F=60% R=20% K=20%		6 F=60% K=40%	
	7 F=40% R=60%		8 F=40% R=40% K=20%		9 F=40% R=20% K=40%		10 F=40% K=60%
11 F=20% R=80%		12 F=20% R=60% K=20%		13 F=20% R=40% K=40%		14 F=20% R=20% K=60%		15 F=20% K=80%
16 (R.) RICE HUSK ASH=100%	17 R=80% K=20%		18 R=60% K=40%		19 R=40% K=60%		20 R=20% K=80%		21(K.) KAOLIN 100%

Table 3.10: The distribution of glaze materials in triaxial test blends using kaolin in place of wood ash.

CHAPTER IV

ANALYSIS OF RESULTS, DISCUSSION AND FINDINGS

4.1 Introduction

This section contains the analysis of the results, discussions and findings of the data based on the studio tests and experiments conducte

4.2 Result From Quadrilateral Test for Body Formulation

The raw materials involved in the thirty-six (36) member quadrilateral blend test are kaolin, ball clay, feldspar and quartz.

Test blend number 1 has 100% kaolin being one of the main components. It is understood to be considerably free from iron, thereby resulting into white wares and also refractoriness.

Test blend number 6 has 100% ball clay, it is the main component that provides plasticity, this enables the body to be thrown on a potter's wheel.

The test blend number 31 has 100% feldspar. It also serves as one of the main components in the body and acts as flux which increases translucency and reduces porosity.

The last test blend number 36 in the body test blend has 100% quartz. It is resistant to shrinkage, improves translucency and body strength.

The test blends were formulated, blended according to the prescribed test blend ratios, kneaded, thrown, dried and fired to 1300°C using gas.

The results of the test blends numbers 1 - 2, 7 - 8 and 13 - 15 had common characteristics. They had difficulties in throwing, though with similar qualities of porcelain such as whiteness and hardness after firing. The throwing difficulties experienced, were due to the insufficient ball clay in the body composition which should have improved throwability.

The result of test blends numbers 4- 6, 10 - 12, 16 - 13 and 22 - 24 had good qualities in throwing and produced good shapes during throwing and after firing. However, they showed poor qualities of porcelain. This was as a result of too much quantity of ball clay in the composition which diminished the qualities of porcelain that were to be noticed.

Test blends numbers 19, 25 - 30 slummed and hardly stood the strain of the pulling during throwing. The pieces produced were thick and quite heavy. This was due to too little kaolin and a very high feldspar content in the blend.

The test blend number 20 within the range had good results in both throwing and firing. In throwing, good and desired shape was produced. In firing, it withstood the temperature and yielded excellent qualities of porcelain, such as whiteness, hardness, translucency, strength and smooth appearance. This was due to the correct proportion of the thrown material body which enabled them to fuse well.

Test numbers 31 - 36 contain a blend of feldspar and quartz only. They sedimented immediately after the body materials were mixed with water. As a result of their sedimentation which is a normal behaviour of rocks, they could not form lumps with which to be thrown. Thus throwing of any form using test blends numbers 31 - 36 proved practically impossible. This was as a result of lack of clay substances in the composition.

The body composition considered the most appropriate for the porcelanous throwing is test blend number 20. It yielded the most expected characteristics of porcelanous throwing ware. It vitrified with smooth translucency, strong, hard and white appearance.

It comprises of:-

Kaolin	-	32%
Ball Clay	-	8%
Feldspar	-	48%
Quartz	-	12%

4.3 Result from Triaxial Test for Glaze Formulation

The raw materials involved in the twenty-one (21) member triaxial test blends consist of feldspar, rice husk ash and wood ash.

Test tile number 1 has 100% feldspar being one of the main fluxes for glaze formulation. Tile number 16 has 100% rice husk ash while test tile number 21 in the triaxial blend has 100% wood ash which are anxilary fluxes for glaze formulation.

The glaze materials were blended and test tiles dipped into the glaze slip according to the prescribed ratios and fired to 1300°C.

The result of test tile number 1 fused into a viscous white mass which is a normal characteristic of alkali feldspar. Tiles numbers 2 and 4 had matt appearance while test tile 3 - 5 and 6 fused with blueish appearance. This was as a result of sufficient main flux present in the composition.

Tiles numbers 7 - 8 and 11 - 12 had similar crawling characteristics. Some of the unfused glazes on the tiles peeled off. This was due to the high silica content in the rice husk ash which dominated the glaze composition and thus could not fuse well.

Tile number 9 fused and yielded the most expected characteristics of porcelain. Such characteristics are translucency, whiteness, hardness, strength, transparence and a very smooth white appearance.

The results of tile numbers 10, 13 - 15 had common good fusion and colour effects (green and brown). This was due to potash in wood ash. Tiles numbers 16 - 18 could not fuse well. This might be due to the high silica content in the rice husk ash, which was common phenomenum to all tiles that were dominated by rice husk ash in this glaze test. Tiles numbers 19 - 21 had a very good melt with light brown and green colour as a result of potash in wood ash.

Tile number 9, therefore has good melt with cool white, transparent translucent, hard and smooth appearance. The smooth glassy effect was due to the correct proportion of glaze materials in the composition which comprises of:

Feldspar	-	40%
Rice husk ash	-	20%
Wood ash	-	40%

This test tile is considered best for the porcelain samples as contain in table 3.8 on page 31.

Further tests were conducted to be more certain about this result. The result of the second test in table 3.9 on page 34 was very successful.

Test tile number 1 has 100% T6 which combined feldspar and wood ash. Test tile number 16 has 100% T20 which combined rice husk ash and wood ash. While the last test tile number 21 has 100% T9 which combined felspar, rice husk ash and wood ash.

The result of test tile numbers 1 - 4 had good melt with light brown colour. Test tile number 5 melts very well and yielded the most expected characteristics of porcelain such as cool and smooth white, translucent and transparent glaze just as test tile number 9 in table 3.8.

The results of tile 6 - 15 had good melt with light green and brown colour effects, while tiles numbers 16 - 21 had fused well and produced beautiful light brown glazes. All the test numbers 1 - 21 in table 3.9 produced

good melt and formed good glazes.

The attractive test tile number 5 had good porcelain qualities just as test tile results of number 9 in table 3.8. Its (tile 5) glaze material composition was calculated and found to be exactly the same glaze composition of tile 9. This glaze composition comprises of 40% feldspar, 20% rice husk ash and 40% wood ash, affirming tile number 9 to be the most appropriate glaze fit for the porcelain samples.

The result of the third test in table 3.10 on page 35 with the use of kaolin in place of wood ash was not successful. Tile number 1 has 100% feldspar being the main flux in the glaze formulation. Tile number 16 has 100% rice husk ash while tile number 21 has 100% kaolin. The glaze materials were blended accoring to the prescribed triaxial blend ratios, and new 21 tiles were dipped into the glaze slip based on the ratio of each tile and fired to 1300°C.

The result of tile number 1 fused into a viscious white mass which is the most valuable characteristic of feldspar. Tiles number 2 - 6 had dull appearances to matt glazes while tiles numbers 7 - 21 could not fuse well. This was due to the excess silica content in both rice husk ash and kaolin.

4.4 Discussions

Based on the analysis and observations during the formulation of the porcelanous throwing bodies and glaze, the six principal raw materials used for the study are kaolin, feldspar, quartzs, ball clay, rice husk ash and wood ash. The selection of these local raw materials out of many other ones found in the area of study, was based on the fact that they are available in abundance at all times, easy to be processed, and fundamental to survive ceramic industry. They were all procured from Akwanga Local Government Area of Plateau State.

The test blends from quadrilateral numbers 1 - 30 were found workable while test blends numbers 31 - 36 could not form lumps and thus could not be thrown on the wheel at all. This result formed the basis in ascertaining that the inclusion of ball clay as a binder could be used to produce successful porcelanous throwing wares. It was observed that the correct amount of ball clay at least 8% of the total throwing bodies contributed to the effectiveness of the throwability of the porcelain.

In the areas where kaolin and feldspar dominated quartz in proportions, the characteristics of porcelain were clearly visualised. While the area where feldspar and quartz dominated kaolin, the characteristics of porcelain could not stand out clearly.

The materials used in triaxial test blends to determine the suitable glaze fit are feldspar, rice husk ash and wood ash. The percentage of each raw material established are 40% feldspar, 20% rice husk ash and 40% wood ash which produced nice and smooth coating and translucent melts, indicating the industrial potentials of these glazes. It was also observed that the correct amount of feldspar and wood ash with equal proportion and less rice husk ash produced an intersting result.

The accomplishment of the suitable glaze fit for the porcelanous throwing wares was as a result of accurate balance of feldspar, rice husk ash and wood ash being the principal ingredients.

4.5 Findings

Based on the studio tests and experiments conducted for the formulation of porcelanous throwing bodies and suitable glaze fit, the following findings were made:

1. Akwanga rice husk ash and wood ash, Kura Falls kaolin, Bayan Dutse ball clay Buhar feldspar and Ningo quartz have good quality for porcelanous products.

2. The glaze composition selected for the porcelanous throwing body fitted very well on the formulated body; even in the absence of purposeful addition of clay except for the combined clay in the raw material in feldspar.

3. The ball milling machine was found to be an effective means for grinding and mixing of porcelain materials. As a result of these operations, the materials were further refined and improved.

4. The gas firing produced variations of colour effects. This was due to the reduction atmosphere which produced light brown, cool white and light blue colours in the kiln.

5. The 1300°C temperature was found to be adequate in yielding dense hard, white, translucent and glassy effects.

CHAPTER V

SUMMARY, CONCLUSION AND RECOMMENDATION

5.1 Introduction

This section covers the summary, conclusion and recommendations based on the findings from the studio tests and experiments.

5.2 Summary

The result of this research revealed that the raw materials procured from Akwanga Local Government Area of Plateau State are of high quality and viable for the production of porcelanous throwing wares and glazes. The results of physical property of Akwanga rice husk ash and wood ash, Kura Falls kaolin, Bayan Dutse ball clay, Buhar feldspar and Ningo quartz indicated high standard and excellent qualities. Buhar feldspar produced a glassy and translucent effect which enabled its use as both main flux in body and glaze for the porcelain productions. The result also showed that the reduction firing produced variations of colours using gas kiln.

5.3 Conclusion

On the basis of the outcome of this research for the formulation of porcelanous throwing bodies and suitable glaze fit, the following conclusions were drawn or established:-

That Akwanga Local Government Area of Plateau State is a potential place for good and viable quality raw materials for the production of porcelain and glazes.

That the ball milling machine was found to be an effective means for grinding and mixing of porcelanous materials. The effects of these operations further improved the refinements of the materials. This is most recommendable for high fired porcelain products.

5.4 General Recommendations

Considering the significance of porcelanous wares in the nation, the researcher wishes to make the following recommendations:-

1. The Federal and State Governments should as a matter of urgency be involved in driving the country towards a better economic campaign for the intensification of resourcing into locally available ceramic materials and place an embargo on the importation of various products such as High-Fired porcelain wares and the raw materials. This will hopefully lead to the full mining of these raw materials for sales.

2. The Fedral and State Governments should consider ceramic graduates in their recently introduced Graduate Loan Scheme. Ceramic Industries being labour intensive will create job opportunities for both skilled and unskilled workers.

5.5 Recommendations For Future Research

The following areas are recommended for future research.

1. There is a need to know the chemical analysis of Akwanga rice husk ash and wood ash, Kura Falls kaolin, Bayan Dutse ball clay, Buhar feldspar and Ningo quartz.

2. There is a great need for feasibility study to determine the possibilities of establishment of High-Fired Ceramic Industry in Akwanga.

3. The future study is required to determine the tensile strength of the bodies formulated in this study for production of high voltage porcelain resistors, porcelain insulators, and porcelain water sinks.

4. The vetrification of porcelanous body and glaze at lower temperature ranges needs to be investigated.

5. The use of clay in porcelanous glaze formulation needs further study.

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APPENDIX I

This appendix shows plate of raw and processed materials used in this study.



Kura Falls kaolin.

Bayan Dutse ball clay.

Buhar feldspar.

Ningo quartz.

Akwanga rice husk ash.

Akwanga wood ash.



Raw and processed materials used for porcelanous throwing bodies.

Kura Falls kaolin,

Bayan Dutse ball clay,

Buhar feldspar,

Ningo quartz.



Raw and processed glaze materials used for glaze fit.

Buhar feldspar.

Akwanga rice husk ash.

Akwanga wood ash.

APPENDIX II



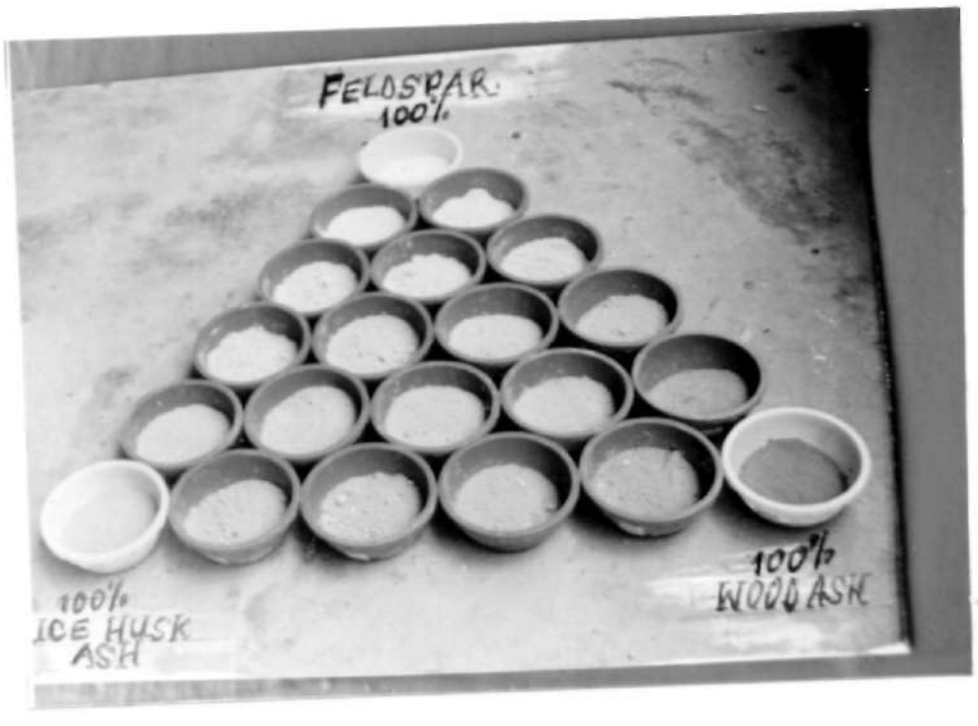
The quadrilateral blend used in this study for porcelanous throwing body.

APPENDIX III



Plate of the porcelanous throwing body on the wheel.

APPENDIX IV



Triaxial blend used in this study for glaze fit.

APPENDIX V



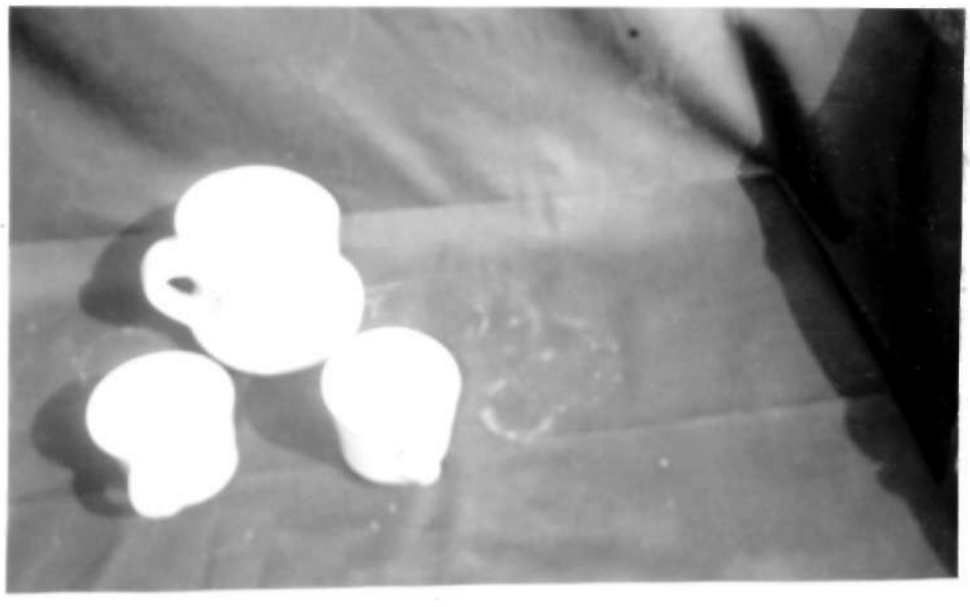
Plate of the fired experimental samples for the study.



Lided bowls



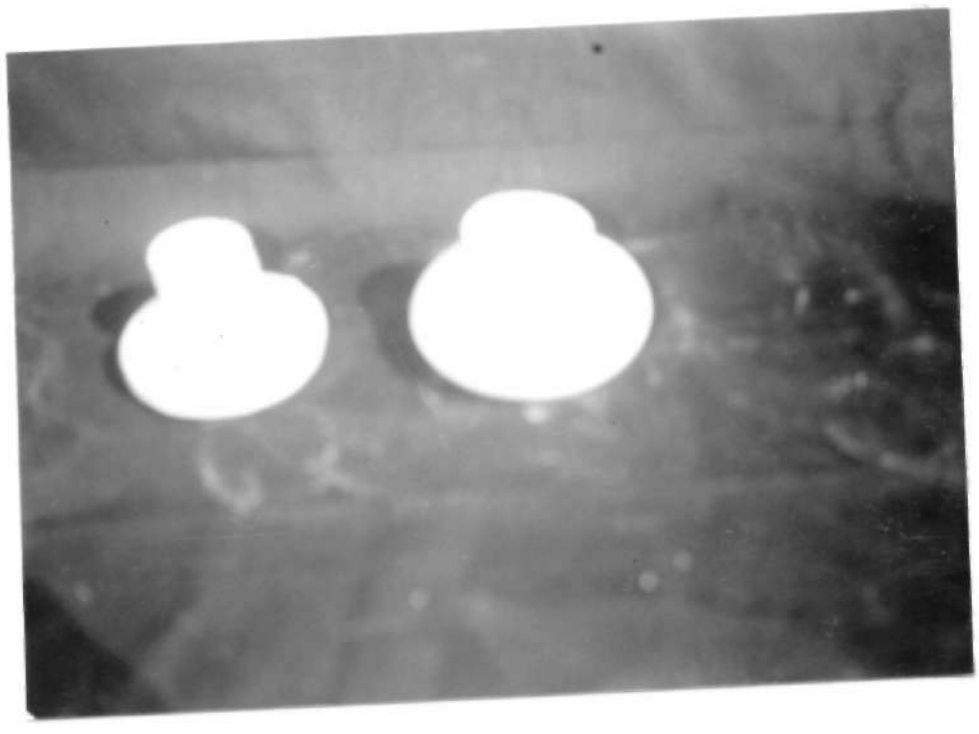
Opened bowls



Jug and cups



Mortars and pestles



Flower vessels