EMULATION OF A WHITEBODY FROM SELECTED CERAMIC RAW MATERIALS FROM SOKOTO AND KWARA STATES SUITABLE FOR CASTING TABLEWARES

BY

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D E C L A R A T I O N

I, Zauro Tukur Dikko Muhammad, solemnly declare that the contents of this thesis is the report of my study "Formulation of a whitebody from selected Ceramic Raw Materials from Sokoto and Kwara States suitable for casting tableware". And that I procured and prepared the materials and also produced samples articles as stated in this thesis. Also I took and passed the following courses:

Research Technique

Seminar in Ceramics

Advance Colour and Design

Media Research

Advance Studio Practice.

Sign: mzhitmadan

Date: 25/11/88

C E R T I F I C A T I O N

This thesis entitled "Formulation of a Whitebody from Selected Ceramic Raw Materials from Sokoto and Kwara States Suitable for Casting Tableware" by Zauro, Tukur Dikko Muhammad, 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.

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D E D I C A T I O N

This thesis is dedicated to my grandfather Alhaji Aliyu Dikko Zauro, who had seen the importance of education and enrolled me into the system at a very early age.

This thesis is also dedicated to my late father Mallam Muhammad Iadan and my mother Malama Hauwa Joda Aliyu Dikko.

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A B S T R A C T

Zauro, Tukur Dikko Muhammad, Formulation of a Whitebody from selected Ceramic raw materials from Sokoto and Kwara States suitable for casting Tableware, M.A. Thesis in Industrial Design, Ahmadu Bello University, Zaria, 1988, 12 Tables, 4 Figures, 11 Plates and 32 references.

The problem with which this study is concerned is to identify suitable materials from Sokoto and Kwara States for the formulation of a whitebody. The purposes of the study are:-

1. To identify through experiments the selected ceramic raw materials from Sokoto and Kwara States suitable for casting tableware.

2. To find a good workable body that can be fired to approximately 1 280'c to produce tableware.

3. To make a contribution to knowledge in this area especially to the scanty literature on my topic.

The information supplied by Geologists and local Potters helped the researcher to identify and procure raw materials used in this study. The materials are Rakwamni Kaolin, Wurno secondary clay, Kalambaina

limestone, Mayanci quartz from Sokoto State and feldspar from Okene in Kwara State.

The chemical analysis could not be performed due to lack of equipment, but physical property tests in shrinkage, plasticity, porosity and colour for plastic materials and for the non-plastic materials colour, cleavage and hardness were conducted. After the physical property test some materials were rejected and a triaxial blend method was adapted as the basis for body formulation.

Seven compositions that produced likely results were selected for further tests. Slip casting technique was used as a shaping method to produce samples.

The study, based on the result obtained states the following findings:-

1 • Rakwamni clay can be used as a fine kaolin, Wumo as a ball clay, Mayanci quartz as a source of silica and Kalambaina limestone for whiting all from Sokoto State. Okene feldspar from Kwara State can also be used as a potash feldspar.

2. The amount of water, 250 gm and 4 gm of deflocculants in varied proportions of 2:2 and 1 :3 of sodium carbonate and sodium silicate to every 500 gm of solid ingredients produced a good

workable slips. And the addition of a secondary clay also improved the plasticity in the slips.

3. There was a good balance of the body and the glaze as a result the 1280°c temperature at glost firing was found to be adequate.

4. Ball milling was discovered to be the most effective way to blend ceramic materials.

5. If the casting slip is left undisturbed for days, the casting will be difficult. It will need blunging before casting is done.

6. Gas firing yielded variations of white effect probably as a result of the reduction atmosphere in the kiln during firing.

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DEFINATION OF TERMS

BALL MILL - A machine for grinding rocks and minerals, consisting of horizontal cylinder made from or lined with an abrasion-resistance material (e.g. stone or porcelain) and of some mechanical means of making it to revolve. (Faunier, 1973).

BISQUE OR BISCUIT - The name given to a once fired Ceramic body on which there is no glaze. A biscuit firing usually varies in temperature between 950°c and 1,100°c, but it may be high if vitrification is required. (Medley, 1976).

BLUNGER - A machine for stirring and mixing ceramic materials usually the ingredients of a clay body with water (Faunier, 1975).

BODY - The natural clay of which a pot is formed; materials mixed together for the formation of pottery; or the main part of the pot as distinct from the glaze (Primmer, 1974).

CALCINATION - To disintegrate by heat: The strong heating of a material resulting in a physical or chemical change (Faurnier, 1975)

CASTING - Forming hollow shapes in a mould using a liquid. In the case of pottery, slip is used. (Primmer, 1974).

CERAMIC - (Greek-Keramos). A general word for all pottery and pottery processes. Also used today in connection with industries such as glass and cement. (Primmer, 1974).

PYROMETRIC Cone - It is made from the mixture of ceramic materials formed into triangular elongated pyramids, and designed to melt and blend over or 'squat' at a given temperature. Also called Seger Cone (Faurnier, 1973).

COTTLE - A wall of stiff water proof material used to contain liquid plaster until it hardens. (Primmer, 1974).

DEFLOCCULATE - The addition of electrolytes to slip to reduce the amount of water needed to make it pourable (Kenny, 1974).

ELECTROLYTE - An alkaline substance, usually soda ash or sodium silicate added to a clay slip to deflocculate it. (Kenny, 1974).

"FADI KA MUTU" - Shatter as it falls.

FLUX - A substance which melts and causes other substance to melt inside the kiln. (Kenny, 1974).

FUSIBLE - Fusible materials are those which melt easily or lower the melting point of a mixture such as a glaze. (Faunier, 1973).

FUSION - The melting of different materials into a homogenous liquid mass. (Hammer, 1975).

GLOST FIRING - A Potter's word for Glaze, hence a glost firing, that in which the glaze is fired on the body. (Medley, 1976).

MODEL - A prototype shape modelled in clay or plaster. (Primmer, 1974).

PLASTER MOULD - An assembly of plaster of Paris pieces containing a cavity in which casting are formed. (Geza, 1949).

PLASTER OF PARIS - Semi-hydrated calcium sulphate. It is a white powder prepared from gypsum by driving off the water crytalization. (Hammer, 1975).

PORCELAIN - High temperature ware which is white and translucent. The body is by mixing China clay, China stone and quartz together at definite rates. (Hammer, 1975).

SLIP - A homogenous mixture of ceramic raw materials and water used for casting. (Hammer, 1975).

RHEOLOGY - The science of flow and deformation. These are crucial factors in the behaviour of pottery materials under heat. Also applied to flow characteristics of plastic clay and casting slips. (Faurnier, 1973).

TABLEWARE - A general term for pottery directly concerned with serving of food and drinks. (Faurnier, 1973).

TEMPERATURE - A means of describing heat and is measured in degrees centrigrade (^{o}C) or degree fahrenheit (^{o}F) (Hammer, 1975).

THIXOTROPY - The property of slips to change fluidity by being left undisturbed, the slip at rest becomes more viscous. Also the property of plastic clays to resists initial pressure. (Hammer, 1975).

TRIAXIAL - A diagrammatic method of studying the effect of the various mixtures possible with three materials or colours (Faurnier, 1973).

VITRIFICATION - The point at which ceramic materials reach a "glassy" condition under heat (Cardew, 1973).

VISCOSITY - Resistance to follow offerred by a liquid, due to internal friction. (Faurnier, 1973).

VITREOUS - Glassy or Glasslike. (Ruscoe, 1948)

VITRIFIED - Like glass, fused together. (Cooper, 1972).

C H A P T E R I

1.1 INTRODUCTION:

Although its exact origin is unknown, the art of pottery is known to be one of the oldest crafts. Igwilo (1983), believes that pottery first appeared about 15,000 - 10,000 B.C. with the down of the new stone age. The probable reason why ceramics is considered to be one of the earliest crafts according to Ahuwan (1987), can be found in the wide range of which ceramic products have been utilized from the pre-historic period to the present time.

Slye (1968), also revealed that the origin of pottery is uncertain, however, the beginning perhaps started when men during the neolithic period retired from the nomadic set up and became settled into communities. As man established, he looked around for solutions and just by accident noticed a natural occurance which was plastic and impervious to water. He possible experimented the newly found materials by making a gourd (calabash) shape due to its plasticity when he noted that the material could be hardenned by heat from the sun.

Man's faculties began to widen to the extent that, he discovered later that fire could increase the hardness of his material. On the other hand, Cooper (1972), stated that, man might have smeared clay on the basket to prevent spillage. The basket was said to had been burnt by accident and again man discovered that fire could change the appearance of his material.

Furthermore, according to Ahuwan (Ibid), Nigeria's pottery development towards stoneware started in 1918 when a Briton D. Roberts attempted to make stoneware from local raw materials in Abeokuta with the sole aim of serving the European members of the West African Frontier Force (WAFF). This period actually marked the beginning of tableware production in Nigeria. Na' Allah (1980), confirmed the invitation of another Briton called Michael Cardew by the then Northern Nigerian Government. He was charged to carryout a feasibility study to determine the possibility of establishing a pottery factory for the region in 1950. After serious thought, Abuja (Suleja) was chosen

when it satisfied conditions such as the availability of raw materials, good clay, firewood, water and that Abuja is centrally located. Abuja pottery now called (Dr. Ladi Kwali Pottery, Suleja) glazed products were first displayed in 1953.

It is precisely clear that at the beginning of mordern pottery in Nigeria, production was largely directed at making a stoneware which only Europeans and very few rich men could aford. Through increased interaction with Europeans, the local elites further cultivated sophisticated life styles, hence demand for the new products increased. Nowadays, the demand especially for tableware is evident and accentrated by the fact that hardly is there any average Nigerian home where one cannot find such products like dishes, plates, tea and coffee pots and a host of other ceramic tablewares. It should however be noted that the bulk of these products are imported into the country.

Cardew (1969), observed that Nigeria is blessed with good quality ceramic materials required for setting up a ceramic industry. This assertion is further developed by

Onaji (1985), who opined that ceramic raw materials and fuels are locally available.

1.2 STATEMENT OF THE PROBLEM:

The problem of this study is to formulate a whitebody from selected ceramic raw materials from Sokoto and Kwara States suitable for casting table ware.

1.3 PURPOSES OF THE STUDY:

The purposes of the study are as follows:-

1. To identify through experiments the raw materials suitable for casting tableware and glazes for the body.
2. To find a good workable bodies that can be fired to approximately 1280^{o}c to produce tableware.
3. To make a contribution to knowledge in this area especially to the scanty literature.

1.4 BASIC ASSUMPTIONS:

The study will be based on the following assumptions:-

1. That the raw materials identified will display characteristic of porcelain body.

2. It is assummed that adequate facilities will be available for the analysis of the samples collected.

3. It is assummed that information supplied by the local potters and geological survey will be accurate and helpful in prospecting and locating some of the raw materials.

1.5 LIMITATION:

1. Because of the unpredictable nature of glaze and glaze materials, the findings of this study will not be considered as a finality in the behavioural patterns of glaze and glaze materials.

2. There is lack of adequate facilities in the Department of Industrial Design, Ahmadu Bello University, Zaria, therefore the research will device means of coping with such deficiences.

3. The use of slip casting techniques as a shaping method to produce experimental samples for this study constitute a limitation.

4. Due to the insufficient knowledge about the location of raw materials, the study is therefore limited to the information recieved from respondents.

1.6 DELIMITATION:

In view of the presumed ceramic prospects in Sokoto State, home base of the researcher, the study is delimited to Sokoto State where most of these materials in most probability are available. For the proven quality of feldspar from Okene, the study will extend to Kwara State.

1.7 SIGNIFICANCE OF STUDY:

There is no doubt that people traditionally choose the services of pottery products for daily needs such as cooking, storage as well as for decorative purposes.

In some communities tablewares are mainly used not only for serving of food and drinks but also to decorate apartments as a symbol of wealth. Ahuwan (Ibid), supporting the above assertion states that "the average middle class, at times even lower class home has tea set, stoneware or porcelain. These commodities are common sights during wedding ceremonies. The

newly wed decorate their apartment with variety of ceramic wares call 'Fadi ka mutu'". In view of the high demand of ceramic products, it is hoped that the research into the local raw materials to formulate tableware will contribute to the economic development of the country.

Another motivating factor for the study is the fact that the country is losing millions of naira through the importation of ceramics wares. According to Onaji (1985), Nigerian imported a large consignment of whiteware products worth 13 million naira in 1978. Therefore ten years of continuous importation of ceramic wares is expected to exceed one hundred million naira (₦100m). In a similar opinion Gukas (1985), stressed that most of the tablewares - stoneware or porcelain - seen in our markets are imported. In this regard therefore, it is anticipated that research into the local materials to formulate a whitebody will offer suggestions in making tablewares in the country.

The study for the formulation of a whitebody suitable for casting tableware is important particularly in this period of

government serious campaign to create awareness in people on self-reliance. In addition, it is hoped that the study will enhance to the general public a clear perspective on the importance of industrialization.

Slip casting technique which is considered to be one of the best methods for commercial ceramic production will offer help particularly to the enterpreneurs wishing to set up a small scale pottery industry. It is hoped that this trend will beoon the path to the ceramic technological development. A large proportion of ceramic wares are slip cast - for instance tablewares, sanitary wares, technical porcelain etc.

Finally, the outcome of this study will, hopefully contribute to academic advancement.

C H A P T E R I I

LITERATURE REVIEW

2.1 INTRODUCTION:

This study is for the formulation of a whitebody suitable for casting tableware. The literature review therefore discusses the general historical perspective of whiteware and also contains informations about the principal raw materials for making the whiteware. These are kaolin, feldspar, and quartz. Also reviewed in this chapter are formulation of a whitebody and glazes.

2.2 HISTORICAL PERSPECTIVE OF WHITEWARES:

Long before the infusion of porcelain production into the various cultures, the exact use of white burning clays were not precisely known, but Honey (1963), however believes that the method most of the potters engaged in making of whitebody used was covering the buff bodied ware with slip and white glaze coating. This method was particularly practiced in Turkey and the near East by potters.

The discovery of tin oxide had marked effect on white wares and this culminated in the white beantiful majolica wares. Honey (Ibid) further observed that besides the crude form of porcelain or whitewares produced in Europe, the discovery of Chinese porcelain was a highly remarkable invention in the history of ceramics. Cooper (1972), stated that, a German, John Friedrich Bottger made the first European porcelain in 1709. However, more experiments and tests were conducted to improve on Bottger's formula. Indeed Bottger's discovery became the basis of hard porcelain making in Europe.

Whiteware products are majolica, hard porcelain, white-earthenware, semi-vitreous porcelain and China, Bone China, soft-porcelain and the like. The shaping methods in the making of white ware are throwing, slip casting, jiggering and jollying etc. Historically throwing was the predominant technique of production.

2.3 K A O L I N:

Gukas (1985), defined kaolin as a residual, fine textured white primary clay found in its original site of decomposition. It is relatively free from impurities as such, it can withstand temperature approaching 1750°c. Kaolin apart from making the body white provides plasticity and gives strength to the fired wares. A typical kaolin according to Singer and Singer (1963), would have the following compositions:-

Silica	-	46.51%
Alumina	-	39.53%
Water	-	13.95%

Leach (1973), gave the composition of kaolin as below:-

Silica	-	46.64%
Alumina	-	39.45%
Water	-	13.95%

An analysis of Kankara kaolin (Katsina State) is given in the next page by Hendsman (1974).

Silica	-	44.55%
Alumina	-	31.45%
Iron oxide	-	1.07%
Magnesia	-	0.87%
Lime	-	0.28%
Soda feldspar	-	0.17%
Potash feldspar	-	0.36%
Excess water	-	12.03%
Chemical water	-	9.06%
Titania	-	0.41%
Magnesia	-	0.01%
Sulphur	-	0.05%
Total	=	100.24%

2.4 F E L D S P A R:

Feldspar, number 6 on Moh's scale of mineral hardness is valued for the fluxing role it plays. This it does by forming a liquid during firing. On cooling, this liquid forms a glass which brings the grains of the other constituents (clay and silica) together. Gukas (1985), observed that feldspar can be easily recognized by its colour, hardness, lustre and cleavage.

The three principal feldspars are potash, soda and lime. Singer and Singer

(Ibid), recognized potash feldspar as a valuable material in the formulation of ceramic bodies because it imparts more translucency to the body than soda feldspar and further more, potash feldspar due to its higher vitrification temperature reduces the risk of warpage which is associated with bodies containing soda feldspars. Cardew (Ibid), further reiterates that porcelain makers and also stoneware potters used feldspar to the great extent for body composition and glazes.

2.5 Q U A R T Z:

Singer and Singer (1963), said that quartz is one of the main ingredients used in the making of porcelain, sanitary ware and earthenware. Quartz is number 7 on Moh's scale of mineral hardness and as a source of silica its presence in the body reduces shrinkage, plasticity, improves resistance to warping and also enables glaze to fit into the body. Quartz gives strength to the final fired ware and this, according to Okoruwa (1986), is due to the ability of quartz to combine with other basic oxides of the fluxing components to form a glass which enhances the strength in the ware.

Quartz is hard to grind, therefore, it is usually calcined. Singer and Singer (1986), acknowledged calcination of quartz to 900°c. Quartz in the process of calcination would become soft. This would enhance easy jaw-crushing of the material. Faurnier (1977), said alpha beta quartz transformation begins at 573°c which increases the stability of silica. The use of appropriate amount of fine crystalline silica in the body can stop the craze tendency. Okoruwa (1986), said that, the use of too much quartz should be avoided due to its tendency to causing dunting, lowering of mechanical strength and worsenning of glaze appearance.

2.6 FORMULATION OF WHITEBODY:

In formulating a whitebody, the three principal raw materials involved are feldspar, kaolin and quartz. Feldspar helps the fusion of the body while kaolin provides refractoriness, workability and white effect. Quartz as a glass former assists the body to become hard, strong through firing.

Nelson (1958), contends that empirical experi mentation and testing are the most practical methods to be adapted so as to obtain suitable blend of materials. In a similar view, Okoruwa (Ibid), suggested body formulation through step by step substitution of one material by another until a desired result is obtained. Since whitebodies are essentially composed of the three main constituents - feldspar, kaolin, and quartz, Singer and Singer (Ibid), suggest a triaxial blend involving the three major components. While Okoruwa (Ibid) disclosed that, using materials in the triaxial beginning with 100 parts will provide adequate room for effective experimentation and observation.

Below is a triaxial blend diagram on distribution of porcelain materials as supplied by Gukas (1985).

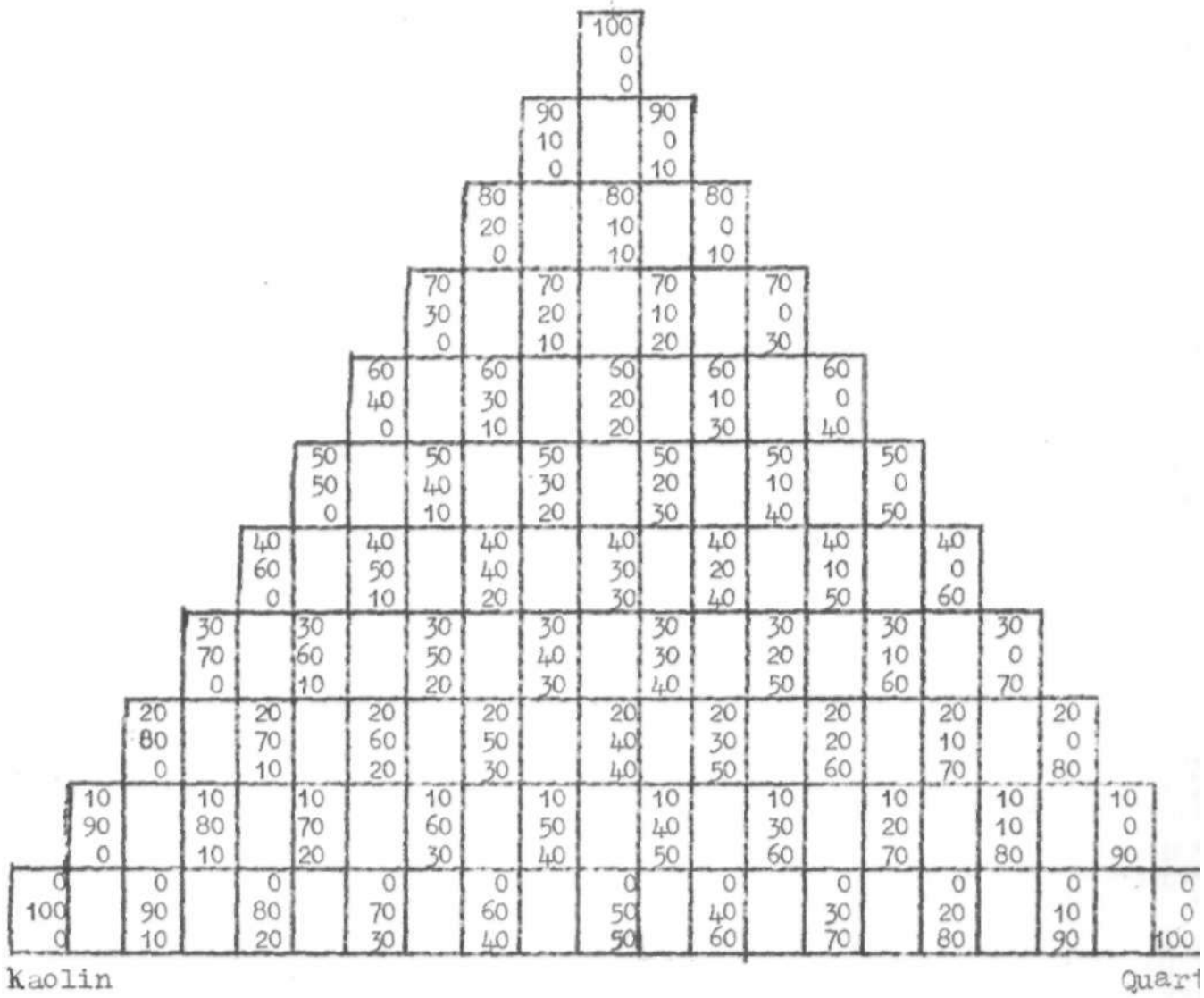


Fig.1: Distribution of porcelain body material in the triaxial blend. Source: Gukas (1985).

There are different types of whitewares, therefore a look at the composition of various bodies will be of importance to the study.

Rhodes (1973), suggested a mixture of porcelain body composition as:-

Kaolin	-	50%
Feldspar	-	30%
Quartz	-	20%

According to Rhodes (1973), a typical German poreclain body consists of:-

Kaolin	-	54%
Feldspar	-	20%
Flint	-	25%
Whiting	-	1%

In addition Rhodes (1973), suggests the composition of a typical hotel or restaurant Chinaware body, thus:-

Kaolin	-	30%
Ball clay	-	15%
Feldspar	-	18%
Flint	-	35%
Whiting	-	2%

The above composition may be as transparent as porcelain but not as translucent.

Singer and Singer (Ibid), recommended the composition of some whitewares below:-

BONE CHINE:

Bone China	-	50%
China clay	-	25%
Feldspar	-	25%

WHITE EARTHENWARE AND VITREOUS CHINA:

Source: Singer (1963).

Kaolin	-	50%
Quartz	-	40%
Whiting	-	7.5%
Feldspar	-	2.5%

TABLE 2.1:

Vitreous China (Tableware)

Source: Singer and Singer (1963).

Body type	Burning	China clay	Ball clay	Quartz	Feldspar	Whiting
	Cone No					
Hotel China	10-12	37.0	7.5	36	18	1.5
Hotel China	10-11	34.0	7.0	35	22.5	1.5

2.7 PLASTER OF PARIS:

Plaster of Paris is the main material for making moulds in slip casting. It is a gypsum rock calcined to drive off chemically combined water. The rock when heated will reduce to a soft material that can easily be crushed to a fine white powder. The plaster substance mixed with water will crystallize once more to produce a hard white solid. The mixed plaster was poured over the model to make a plaster mould.

2.8 SLIP CASTING:

Singer and Singer (Ibid), said that slip casting is a method of shaping ceramic articles by pouring in the slip into the plaster mould and that slip casting was invented some 150 years ago. They however observed that good behaviour of casting slip are "fluidity, viscosity and time of action".

For the casting operation to be successful, Okoruwa (Ibid), stated the need to "develop a good casting rate, confortable release of the casting from the mould and easy drain of the slip". And Singer and Singer (Ibid), were of the view

that the slip should be left undistrubed for 24 hours. They discovered that thixotropy determines the amount of water to be removed before a good cast is acheived. High thixotropy gives relative plasticity, easy trimming and joining. Ofcource, the slip must be constantly stirred.

Sodium silicate and sodium carbonate known as deflocculants or electrolytes are added into the clay and water mixture with a view to decreasing the amount of water required to produce the desired fluidity. Deflocculants are indespensable in slip casting. Nelson (1978), said one percent or less of either sodium silicate or sodium carbonate added to the dry weight of the clay may reduce the amount of water needed to produce a fluid slip. In another perspective, Norton (1956), agreed with Nelson (1978), by stating the use of one grams of solid compound. Also Uduigwome (1986), disclosed that porcelain industries, Abeokuta used about one gram of deflocculants to every 125 grams of dry ingredient and Okoruwa (1986), used 4 grams of deflocculants to every 500 grams of dry ingredients. Ten

grammes of bentomite can be used to every 500 grams of solid constituents when the slip lacks plasticity. Bentonite acts as a plasticizer. It is better prepared alone because of tendency to high water absorbtion.

The slip will be ball milled for 16 hours after which it is left undisturbed for 24 hours to observe thixotropy and viscosity as noted by Gukas (1985). The slip will be screened through 80 mesh sieve. Russel (1949), as quoted by Okoruwa (1986), revealed that ball milling or grinding improves translucency as well as the dry strength and reduces porosity and particle size of the materials. When no shortcomings are noticed in the actual casting slip, thorough agitation will take place at this point to ease the escape of the air bubbles. Hence, proper stirring of casting slip before operation is necessary.

The casting operation requires careful performance. Ruscoe (Ibid), stated that, after smooth pouring of the slip, it will be left in the plaster mould to absorb water until enough thickness is built against

the mould cavity. Gukas (Ibid), observed 20 minutes for the slip to build in the mould. The surplus slip is poured out. The mould is then drained by slanting it cautiously at an angle.

Singer and Singer (Ibid), emphasized the need for careful pouring of the excess slip because when wrongly handled may create uneven thickness in the ware. The casted object will be taken out from the mould to dry. At leather hard stage, the casted piece is examined prudently and critically to detect any shortcoming. Similar examination is done during drying and after firing of the wares.

2.9 GLAZE FORMULATION:

Glaze, an interesting part of ceramic ware, is very important for this study. The body and glaze must fit well to make a successful piece. Ruscoe (1948), said that glaze formulation can easily be achieved through the "Alumina - silica ratio", and are expressed in the molecular formula form based on the percentage composition or by working recipes. And pointing out a similar view, Okoruwa (1986),

confirmed that "glaze fit, a function of Al_2O_3:SiO_2 ratio is important in all cases".

From the commercial point of view, unglazed pottery ware, cannot compete in the modern market. Certainly pot appearance is of utmost value, that is why Okoruwa (1986), revealed that "body and glaze should be considered as a single system". Rado (1975), seemed to hold the same view when he acknowledged the significance in balancing the glaze and the body.

In his study, Rhodes (1973), stressed the importance of glaze in ceramics by furnishing us with the idea on the upper limit of glaze materials. He maintained that feldspar and quartz should form about 70% while the remaining 30% will be composed from the other materials. The idea of the upper limit is to make the glaze and the body melt at the same point and also to decrease the "expansion of high temperature glazes".

TABLE 2.2:

Upper Limit of glaze material.

Source: Rhodes (1959) p.76.

MATERIALS	PERCENT
Feldspar . . .	50%
Quartz . . .	20%
Clay . . .	0 to 15%
Whiting . . .	0 to 15%
Barium carbonate . . .	0 to 15%
Magnesium carbonate . . .	0 to 15%
Dolomite . . .	0 to 15%
Talc . . .	0 to 15%
Colemanite . . .	0 to 15%
Zinc oxide . . .	0 to 15%

Rhodes (1973), found that about 80% of feldspar and 20% of the other constituents could be of good start for glaze formulation. Singer and Singer (Ibid), noted viscosity as an important phenomenon in ceramics because it controls the success of any glaze firing at varying temperatures.

CHAPTER III

RESEARCH PROCEDURE

3.1 INTRODUCTION:

Sokoto State minerals have not been studied particularly for the production of tableware. The study attempted identifying clays, limestone, quartz in the State that were used in the formulation of whitebody suitable for casting tableware.

The chapter covers the samples for the study, preparation and testing of raw materials. In addition are the body formulation, procedures for casting and also formulation of glaze and application.

A field trip was carried out to the selected areas in Sokoto and Kwara States for the purpose of collecting the sampled materials. The materials were kaolin, ball clay, quartz, limestone from Sokoto State and feldspar in Kwara State.

3.2 S A M P L E S:

The samples for the study comprised kaolin, ballclays, quartz and calcium from Sokoto State and feldspathic stones from Kwara State.

3.3 S A M P L I N G:

In order to identify where raw materials for the study are found, information was gathered from geologists in the field and local potters.

Respondents were asked to supply information on where kaolin, ball clay, quartz and limestone are found in large quantity in Sokoto State and also where feldspar is found in Kwara State. The procedure was guided by the Ndagi (1984), "unstructured interview which encourages respondents to express their feelings freely" thus allowing the researcher to explore a reliable and valid data in form of verbal answers from respondents. Gukas (1985), observed a similar method. The raw materials to be identified were kaolin, ball clay, limestone, feldspar and quartz.

Respondents were divided into two groups and were randomly chosen. The first group of respondents comprised of geologists in the field. It was assummed that being geologists they should have knowledge about the minerals resources of the areas.

The second group of respondents consisted of local potters in Sokoto township. The selection of the group was based on the assumption that through their extensive activities in the production of traditional pottery, they should know where suitable clay is deposited in the area.

Tables were used to enhance clear presentation of the data through visual display of the number of responses from the geologists and local potters. Responses from Geologists and local Potters on the location of clay minerals, limestone and quartz from Sokoto State and feldspar from Kwara State are shown in the next page.

TABLE 3.1:

Frequency distribution on location of a ball clay in some towns and villages of Sokoto State.

Village/ Town	RESPONDENTS		total	%
	POTTERS	GEOLOG-ISTS		
Dange	2	-	2	11.1
Dundaye	2	-	2	11.1
Sokoto	3	2	5	27.8
Wurno	3	6	9	50
No idea	-	-	-	-
TOTAL	10	8	18	100

The analysis of the data in Table 3.1 above shows the arrangement of towns/ villages mentioned by the respondents where ball clay could be found.

Out of the 18 respondents that were asked to locate a deposit of a ball clay in Sokoto area, nine respondents representing 50% mentioned Wurno and five people constituting about 27.8% indicated Sokoto. Two respondents mentioned Dange and Dundaye each representing 11.1% respectively.

In view of the highest number of respondents who identified a deposit of a clay suspected to be of ball clay nature, Wurno which recorded most number of respondents was selected for physical property test. Also selected for the test was Sokoto clay that had been identified by five respondents.

TABLE 3.2:

Frequency distribution on location of kaolin in some towns and villages of Sokoto State.

VILLAGE/ TOWN	RESPONDENTS		TOTAL	%
	POTTERS	GEOLOG-ISTS		
Dange	1	-	1	5.6
Dundaye	1	-	1	5.6
Dakingari	1	2	3	16.7
Kaoje	1	3	4	22.2
Rakwamni	3	3	6	33.2
No idea	3	-	3	16.7
TOTAL	10	8	18	100

Table 3.2 above reveals that six people 33.2% mentioned Rakwamni. Four people representing 22.2% located Kaoje and three people constituting 16.7% for Dakingari. One

respondent about 5.6% from Dange and Dundaye respectively. Also three respondents representing 16.7% had no idea or opinion. Based on the highest number of frequencies, Rakwamni as the area that was mentioned the highest was chosen for sampling of tests.

Apart from the clay minerals that were located by respondents, quartzites, feldspathic minerals and limestone were also identified in some towns and villages in Sokoto and Kwara States. Table 3.3 shows the frequency distribution of respondents on the location of limestone in Sokoto State.

TABLE 3.3:

Frequency distribution on location of limestone in Sokoto State.

VILLAGE/ TOWN	RESPONDENTS		TOTAL	%
	POTTERS	GEOLOG-ISTS		
Dange	2	1	3	16.7
Illela	-	1	1	5.6
Kalambaina	3	6	9	50.0
No idea	5	-	5	27.7
TOTAL	10	8	18	100

Table 3.3 above shows that nine people representing 50% out of the total of 18 respondents mentioned Kalambaina as the area where limestone is deposited. This was followed by Dange with three respondents about 16.7%. One person representing 5.6% indicated Illela and five people about 27.7% were of no idea or view. Kalambaina limestone was selected for the purpose of this study, since it scored the highest number of respondents.

Deposit of quartz mineral in Sokoto State had also been identified by potters and geologists.

TABLE 3.4:

Frequency distribution on location of quartz mineral in Sokoto State.

VILLAGE/ TOWN	RESPONDENTS		TOTAL	%
	POTTERS	GEOLO GISTS		
Mayanci	2	4	6	33.3
Yauri	1	3	4	22.3
Zuru	1	1	2	11.1
No idea	6	-	6	33.3
TOTAL	10	8	18	100

Table 3.4 reveals the respondents location of quartz in Sokoto State. Out of the total of 18 respondents, six persons representing 33.3% identified Mayanci as a potential area where quartz can be found. Four persons about 22.3% and two respondents representing 11.1% mentioned Yauri and Zuru respectively. But six people about 33.3% expressed no idea. Mayanci quartz having the highest frequency was selected as a potential source for quartz.

In the case of Okene feldspar, all the eight geologists constituting 100% that were asked to supply information about feldspar deposit in Kwara State mentioned Oguda in Okene. Therefore Oguda feldspar was selected for use in this study.

3.4 PHYSICAL PROPERTY TESTS FOR MATERIALS:

Different physical property tests such as the hardness test, colour and cleavage tests for the non-plastic materials and also plasticity, shrinkage and porosity tests for clays were - conducted. The main purpose of the physical property test was to determine the suitable material among the samples procured for the study, since the chemical analysis could not be performed due to non-availability of facilities.

Tests conducted on the non-plastic materials were achieved as follows:-

HARDNESS:- The physical property test done to identify quartz and feldspar was inaccordance with Dietrich (1980), observation that mineral appearance makes

it easy to be identified and also when a mineral is subjected to a simple test. He further emphasized that, the hardness scale known as Moh's scale of hardness invented by a German mineralogist Friedrich Moh is an effective means for identifying minerals. This theory established in the early 1800's is composed of ten common minerals comprising the softest mineral (Talc) assigned 1 to the hardest mineral (Diamond) assigned 10. Each of the mineral will scratch the mineral of lower hardness as arranged in the table below:-

TABLE 3.6:

Moh's scale of mineral hardness

HARDNESS	MINERAL
1	Talc
2	Gypsum
- - - - - - - - - -	Finger nail
3	Calcite
4	Fluorite
5	Apatite
- - - - - - - - - -	Knife blade and glass
6	Feldspar (orthoclase or microline)

The scale indicated that diamond has the highest number, therefore was considered the hardest mineral and talc has the lowest number as a result, it is the softest mineral. Finger nails have also been considered to be of hardness 2.5. Indeed it supports that finger nails could be used to scratch on talc or gypsum that have hardness one and two respectively. Similarly a mineral of hardness 3.5 would be able to scratch apatite that has a hardness of five.

In order to determine the quartz and feldspar by hardness, a piece of quartz was used to make a mark on the surface of feldspar mineral. Quartz did not show sign of scratch but the mark was clear on the surface of the feldspar mineral

COLOUR:- The colour aspect of the minerals were determined. Quartz appeared milky white but physically containing little iron and very little biotite mica, iron oxide as a flux will contribute to the fusion of the body. Feldspar appeared pink in colour, supposedly potash feldspar.

CLEAVAGE: Quartz and feldspar were each broken to examine the breaking characteristic. Dietrich (1980), stressed that potash feldspar normally display two cleavages. This view was supported by Gukas (1985).

Physical property tests were also conducted on the clay minerals. These included test for water required to make the clay into plastic paste, tactile quality and visual texture of the clay. Others were dry-fired linear shrinkage, porosity as well as the colour of the material before and after firing.

WATER OF PLASTICITY:- To determine the amount of water required to develop optimum plastic qualities.

PROCEDURE:- A clay sample was pulverized to pass through 80 mesh screen and 500 gram weighed into glass slab. Water was added drop by drop from the 500cc graduate filled with water and mixing simultaneously, carried on with a non-absorbent spatula. Amount of water used to develop a modelling consistency

was noted and percentage water of plasticity calculated thus, Kenny (1973).

$$\% \text{ water of plasticity} = \frac{\text{Wt of water used}}{\text{Wt of dry clay}} \times 100$$

Water of plasticity for Rakwamni kaolin:-

Amount of water used = 125gm

$$\therefore \quad \%Wp = \frac{125}{500} \times 100 = 25\%$$

Water of plasticity for Wurno clay:-

Amount of water used = 200gm

$$\therefore \quad \% Wp = \frac{200}{500} \times 100 = 40\%$$

Water of plasticity for Sokoto clay:-

Amount of water used = 200gm

$$\therefore \quad \% Wp = \frac{200}{500} \times 100 = 40\%$$

TEXTURE:- The fired samples were visually inspected and tactile quality also assessed by running ones hands on the surface.

LINEAR SHRINKAGE:- To determine the shrinkage along single line.

WET - DRY:- Three bars each measuring 16 x 2 x 2cm were made from the individual clays. A 10cm line was made on each bar while still in the plastic state. The bars were carefully dried to avoid warping. The 10cm line was again measured in order to determine the new length.

$$\% \text{ Original-dry shrinkage} = \frac{\text{Original length-dry length}}{\text{Original length}} \times 100$$

DRY - FIRED:- The original 10cm line was again measured after the bars were fired to $900^{\circ}c$ and $1280^{\circ}c$ being the biscuit and glost firings respectively. The percentage dry - fired linear shrinkage was calculated thus:-

$$\% \text{ Fired shrinkage} = \frac{\text{original length-fired length}}{\text{Original length}} \times 100$$

RAKWAMNI CLAY:

Wet-dry linear shrinkage of Rakwamni clay:-

Original length = 10cm

Dry length = 9.3cm

% Dry shrinkage = $\frac{10 - 9.3}{10} \times 100$

= 7%

Bisque linear shrinkage:-

Original length = 10cm

Bisque length = 9.2cm

% Bisque shrinkage = $\frac{10 - 9.2}{10} \times 100$

= 8%

Linear shrinkage after 1280°c firing:-

Original length = 10cm

Fired length = 9.1cm

% Fired shrinkage = $\frac{10 - 9.1}{10} \times 100$

= 9%

WURNO CLAY:

Wet - dry linear shrinkage:-

Original length = 10cm

Dry length = 9.2cm

% Dry shrinkage = $\frac{10 - 9.2}{10} \times 100$

= 8%

Bisque linear shrinkage:-

Original length = 10cm

Bisque length = 9.1cm

% Bisque shrinkage = $\frac{10 - 9.1}{10} \times 100$

= 9%

Linear shrinkage after 1280°c firing:-

Original length = 10cm

Fired length = 8.9cm

% Fired shrinkage = $\frac{10 - 8.9}{10} \times 100$

= 11%

SOKOTO CLAY:

Wet-dry liner shrinkage:-

Original length = 10cm

Dry length = 9.1cm

% Dry length = $\frac{10 - 9.1}{10} \times 100$

= 9%

Bisque liner shrinkage:-

Original length = 10cm

Bisque length = 9cm

% Bisque shrinkage = $\frac{10 - 9}{10} \times 100$

= 10%

Linear shrinkage after 1280°c firing:-

Original length = 10cm

Fired length = 8.5cm

% Fired shrinkage = $\frac{10 - 8.5}{10} \times 100$

= 15%

POROSITY:- To determine the liquid absorption of clay samples at bisque and stoneware temperature.

PROCEDURE:- Two cubes were made for each clay. The cubes were fired at 900°c and 1280°c respectively. After each firing the cubes were weighed and soaked in water for 24 hours and weighed again. The percentage porosity was calculated using the formula below:-

Bisque porosity:-

$$\% A = \frac{SW - BW}{BW} \times 100$$

Porosity after 1280°c firing:-

$$\% A = \frac{SW - FW}{FW} \times 100$$

Where A = Absorption

SW = Saturated weight

BW = Bisque weight

FW = Fired weight ($1280^{o}c$)

RAKWAMNI CLAY:

Porosity at bisque:-

Bisque weight = 180gm

Saturated weight = 200gm

$$\% A = \frac{200 - 180}{180} \times 100$$

$$= 11.1\%$$

Porosity after $1280^{o}c$ firing:-

Fired weight = 165gm

Saturated weight = 180gm

$$\therefore \% A = \frac{180 - 165}{165} \times 100$$

$$= 9.1\%$$

WURNO CLAY:

Porosity at bisque:-

Bisque weight = 180gm
Saturated weight = 195gm

$$\therefore \% A = \frac{195 - 180}{180} \times 100$$

$$= 8.3\%$$

Porosity after 1280°c firing:-

Fired weight = 155gm
Saturated weight = 160gm

$$\% A = \frac{160 - 155}{155} \times 100 = 3.2\%$$

SOKOTO CLAY:

Porosity at bisque:-

Bisque weight = 180gm
Saturated weight = 196.5gm

$$\% A = \frac{196.5 - 180}{180} \times 100 = 9.2\%$$

Porosity after 1280°c firing:-

Fired weight = 159gm
Saturated weight = 167gm

$$\% A = \frac{167 - 159}{159} \times 100 = 5\%$$

COLOUR:-

The colour effect on the clay after firing was recorded:-

TABLE 3.7:

Result of physical property test.

TYPE OF TEST	RAKWAMNI	WURNO	SOKOTO
Water of Plasticity	25%	40%	40%
Texture (Visual)	Fine	Fine	Fine
Tactile at Bisque	fairly smooth	Smooth	Smooth
Dry Shrinkage	7%	8%	9%
Bisque Shrinkage	8%	9%	10%
Shrinkage at 1280^{o}c	9%	11%	15%
Bisque Porosity	11.1%	8.3%	9.2%
Porosity at 1280^{o}c	9.1%	3.2%	5.0%
Colour before Firing	White	Grey	Yellowish brown.
Colour after Firing	White	Buff	Darkbrown

From the water of plasticity test, Rakwamni needed 25% while Wurno and Sokoto clays both needed 40% to develop optimum plasticity. Based on the assertion by Kenny (1973), that most plastic clays have percentage water of plasticity between 30% and 45%. From this, it was deduced that both Wurno and Sokoto clays have higher plasticity than Rakwamni clay.

Tactile quality at bisque and glost for Rakwamni was fairly smooth, Sokoto and Wurno were smother after bisque and stoneware firings. The linear shrinkage of Rakwamni clay at wet-dry was 7%, while at bisque was 8% and at 1280^{o}c fired state was 9%. Wurno clay on the other hand recorded 8% wet-dry; 9% at bisque and 11% at stoneware temperature. While Sokoto clay had 9% linear wet-dry, at bisque was 10% and 15% at stoneware. It was then confirmed that the less plastic the clay the less it shrinks.

As for the porosity test, Rakwamni clay had the highest porosity with 11.1% at bisque and 9.1% at stoneware temperature.

Wurno had 8.3% at bisque and 3.2% at stoneware while Sokoto had 9.2% and 5% at bisque and at stoneware, respectively. The high porosity percentage of Rakwamni clay confirmed that, the primary clay absorbs more at the stoneware temperature because it requires a higher temperature to enhance fusion.

As regards to colour, clay samples were fired to 1280°c. Rakwamni clay fired white, Wurno buff while Sokoto fired darkbrown. Rakwamni clay turned white, therefore it was considered suitable kaolin for the formulation of a whitebody. Wurno clay was the best with regard to plasticity, texture as well as absorbtion tests conducted. Its shrinkage rate was good and fired buff. Sokoto clay was another good quality plasticclay with the texture. Its wet-fired linear shrinkage was quite satisfactory. This was rejected on the basis of colour. It yielded darkbrown Colour which impaired the whiteness in the bodies.

Mayanci quartz was found suitable after the hardness, colour and firing tests were conducted. Okene feldspar was also selected as appropriate material because it produced white and translucent effect.

3.5 PROCEDURE FOR RAW MATERIAL PREPARATION:

Feldspar:-

i. Washed

ii. Calcined

iii. Jaw crushed

iv. Water ball milled

v. Dried and preserved.

Quartz:-

i. Washed

ii. Calcined

iii. Jaw crushed

iv. Water ball milled

v. Dried and preserved.

Clay:-

i. Soaked

ii. Blunged

iii. Sieved through 80 mesh

iv. Levigated

v. Dried and preserved.

Limestone:-

i. Washed

ii. Jaw crushed

iii. Water ball milled

iv. Dried and preserved.

OKENE FELDSPAR:

The material was soaked in water overnight to remove foreign particles. It was fired to 900°c. The calcined feldspar was then pulverized into smaller particles aim at enhancing sizes that can fit conveniently into the jaw crusher to further reduce to make for easy ball milling. It was milled for 18 hours. The ground material was discharged into containers to settle after which the surface water was removed and the feldspar dried and stored.

MAYANCI - QUARTZ:

It was soaked in water over-night and later washed to remove impurities. Quartz being harder than feldspar, it was subjected to high temperature firing. It was calcined to 1000°c. A hammer was used in breaking the calcined quartz into tiny sizes that could fit well into the jaw crusher. The crushed quartz was ball milled for 24 hours. The ball milled quartz was transfered into a container to settle. Water was drained out carefully after the material had settled. The whole thick mass of ground quartz was removed from the container and broken into pieces to dry. The dry quartz was kept ready for use.

CLAY:

Clay was soaked in a plastic container over-night and stirred for two hours at different times. It was then sieved through 80 mesh to detect unwanted particles like sand, stones etc. After sieving, it was allowed to settle and water on the surface was poured out carefully. The clay slip was dried on plaster bats and stored ready for use.

LIMESTONE:

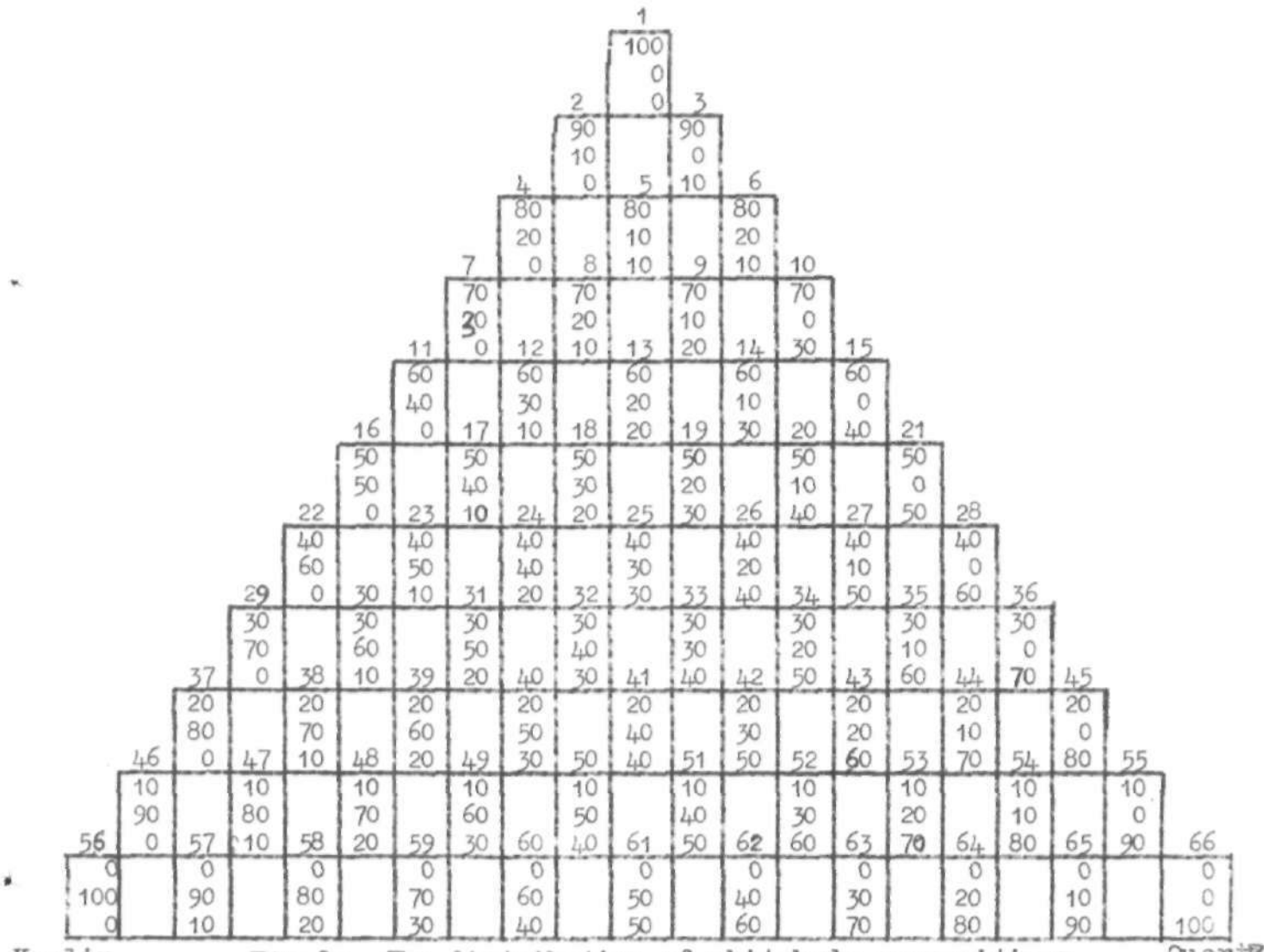
The material was washed thoroughly to remove foreign particles. It was then jaw crushed and ball milled for four hours. The limestone was dried and stored.

3.6 BODY FORMULATION:

From the literature review, it was revealed that formulation of bodies involves the combination of different materials. The materials mainly used are kaolin, feldspar and quartz. Kaolin as one of the major component in the making of whiteware enhances refractoriness, workability as well as colour to the body. Feldspar and quartz being non-plastic materials provide different properties in the body - compositions. Feldspar increases translucency and reduces porosity and lower the fusion point of the body. Quartz helps the body to resist shrinkage and it also improves translucency and body strength. A sixty six member triaxial blend of the main constituent of clay-quartz-feldspar was adapted.

The diagram below illustrates the distribution of the ingredients. In each of the rectangles which have been numbered from 1 - 66, the figure on top represents feldspar and the figure in the middle refers to kaolin while the bottom figure is for quartz. For instance on tile 25, the blend is composed of 40% feldspar, 30% kaolin and 30% quartz.

Feldspar



Kaolin

Quartz

Fig.2: The distribution of whitebody compositions in the triaxial.

From the triaxial test, seven bodies that produced characteristics of porcelain were selected. These were tests Nos. 24, 25, 31, 32, 33, 34 and 41.

TABLE 3.8:

Seven selected body compositions from the triaxial blend.

S/NO.	Test No	COMPOSITIONS		
		Feldspar %	Kaolin %	Quartz %
1	T24	40	40	20
2	T25	40	30	30
3	T31	30	50	20
4	T32	30	40	30
5	T33	30	30	40
6	T34	30	20	50
7	T41	20	40	40

Source: Studio tests (1988)

These compositions formed the basis - for further tests.

Kaolin the only clay material in the composition could not provide adequate

plasticity as a result a secondary clay was introduced into each of the selected body composition in order to improve their plasticity. Wurno clay appeared to be suitable secondary clay because of its buff colour effect and high plasticity. Rhodes (1959), supports the use of secondary clay into body compositions by stating that "the addition of 10% ball clay has a practical improvement" in the body. Hence 10% of Wurno clay was added into each of the body compositions.

After determining the amount of ball clay, the study sought for the proportion of water and deflocculants to be used in the compositions. Kenny (1974), stated that casting slip should contain about 35% to 45% water. Similarly, Uduigwome (1986), confirmed the use of about one gramme of deflocculants to every 125g of dry ingredients and also 40 to 50% of water. The study therefore used 4gm of deflocculants in varied proportions of 2:2 and 1:3 of sodium carbonate and sodium silicate respectively and 50% of water to every 500gm of solid ingredients.

Having decided on the amount of deflocculuants, water and ball clay to use, the slip compositions became as shown on table 3.9 below:

TABLE 3.9:

Slip composition.

MATERIALS	BODIES						
	1	2	3	4	5	6	7
Feldspar	40	35	30	30	30	35	20
Kaolin	35	30	40	45	35	30	35
Quartz	15	25	20	15	25	25	35
Ball clay	10	10	10	10	10	10	10
Water (gm)	250	250	250	250	250	250	250
Defloccul-nts ants	4	4	4	4	4	4	4
Sod.Car; Sod.Sil	2:2	2:2	1.3	1.3	2:2	1.3	2:2

KEY:

Gm	=	gram
Sod.Carb	=	sodium carbonate
Sod.Sil	=	sodium silicate.

3.7 PREPARATION OF CASTING SLIP:

In preparing slip for the study, 500gm of dry ingredient were weighed and also 4gm of deflocculants were weighed out in varied proportions of 2:2 and 1.3 of sodium carbonate and sodium silicate as determined earlier. The deflocculants were dissolved in hot water for effective mixing. In addition 250gm of water was weighed representing 50% of the dry material. The dissolved deflocculants were added in water and stirred after which body ingredients were also added into water. Kaolin and ball clay were added first followed by the feldspar and quartz. The mixture was thoroughly stirred.

The different body compositions prepared were ball milled for 16 hours. The slip was left undisturbed for 24 hours to check the rheology of the slip. The casting suitability was first tested on the plaster bat. The slip drop of each of the body composition was allowed to settle on the bat for two minutes. The droplet that moved easily as declared suitable slip. The slip was strained through 80 mesh

sieve and was poured into the mould to test casting behaviour.

The slip was allowed to build against the mould cavity for fifteen minutes. The surplus slip was poured out and the mould was drained for five minutes. While the cast was allowed to shrink for thirty minutes the waste slip was trimmed off from the mould. The cast piece was removed from the mould to dry. It was neatly cleaned at the leatherhard stage.

3.7.1 POROSITY TEST:

Porosity test is important in determining bodies that have high and low absorption. To find the porosity of the seven body compositions, the study followed the procedure below:-

A bar was made from each of the body compositions by slip casting. The bars were dried and fired to 1280°c. After firing, the pieces were weighed then soaked in water for 24 hours then weighed again. Percent absorption was calculated using the Kenny (Ibid), formula to determine the

porosity of the clay bodies.

3.7.2 SHRINKAGE TEST:

Shrinkage test was carried out to find the linear shrinkage of each of the body compositions.

PROCEDURE:

The bars were casted from each of the body compositions and a sharp 10cm scratch was made on each bar while in the plastic state. The bars were carefully dried and wet-dry shrinkage was determined as soon as the bars dry. The bars were fired to $900^{o}c$ then $1280^{o}c$ after which shrinkage was determined.

The same formula used to calculate the dry and firing linear shrinkage of clay bodies for this study was used to determine the shrinkage of the seven body compositions.

3.8 PLASTER MOULDS:

The use of plaster of Paris is found helpful. It quickly absorbs water from the slip, forming a wall that gives a specific shape. This property makes plasters of Paris

most ideal material for making moulds especially in commercial ceramics. Moulds are indeed indespensable in the reproduction of pottery articles of similar shapes. From the literature review, the correct proportion of plaster to water can best be acheived through experience. However different authorities give varying proportion. Primmer (1974), suggests 1.2kg of plaster to 2 pints (1.23646 litre) of water. While Gukas (1985), employed six mugs full of plaster to four mugs full of water.

For the purpose of this study, plaster was prepared by filling a medium sized plastic bowl with water. The plaster was continuously sprinkled into the water until a mould was formed above the water surface. The plaster was allowed to soak in water for 2 - 5 minutes. The plaster was then mixed gently by agitation of the mixture in order to remove air bubbles. A creamy or thick paste plaster was finally poured over the model to produce the mould.

3.8.1 SINGLE PIECE MOULD (DROP-OUT):

The model was made out of clay and was placed upside-down. A thick cardboard which was sufficiently high and wide was used round the model to serve as a cottle. The base of the cottle was sealed with wet clay well smeared to prevent any spillage of plaster from the slightest openning. A jug full of thick plaster was poured steadily and smoothly on the model by covering it with a thin film of plaster. The model was then completely covered with the rest of the plaster.

After the plaster had set for about 30 minutes the cardboard was removed carefully. The model was taken out from the mould. The mould was cleaned and kept aside for two weeks to dry.



Plate I: Plaster moulds

3.8.2 SLIP CASTING:

The drop-out mould was placed upwards and the prepared slip was stirred thoroughly and poured into the mould slowly and steadily. As the plaster absorbed the slip, more was added in order to top up the mould.



Plate II: Slip casting.

The slip remained in the mould for 15 minutes to form a wall. The surplus slip was removed and the mould was drained in slanting position until all the slip had drained out.



Fig.3: Draining the mould at a slanting position to remove the surplus slip.

The mould was turned upwards and a knife was used to trim the top edge. After 30 minutes, the cast shrank and was then taken out from the mould. When the cast ware hardened, it was cleaned and allowed to dry ready for the bisque firing.

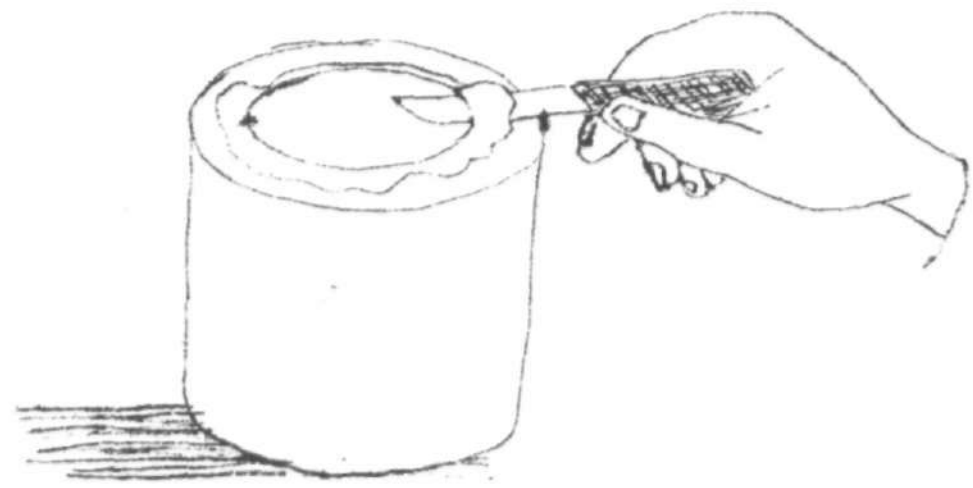


Fig.4: Trimming the mould top edge with a knife.

3.9 GLAZE FORMULATION:

Based on the information from the literature review, glazes are formulated from materials that are insoluble in water. These materials are usually ground to a fine powder and mixed together with the correct proportion of water. Furthermore, glaze can be expressed in percentage composition or in the form of "melecular formula". However the most important aspect is to know the behaviour of the ingredients to be used particularly under heat. In view of the highlight from

the literature review, the percentage of the ingredients and proportion of water was stated from an arbitrary point. Four glaze recipes were tested as stated below:-

TABLE 3.10: Glaze composition.

Materials	Compositions			
	1	2	3	4
Feldspar	50	50	45	40
Quartz	20	20	20	20
Kaolin	10	15	15	20
Limestone	20	15	20	20

Source: Studio test (1988)

The glaze was prepared by mixing the materials already weighed out in grammes with water. Each batch was prepared seperately and ball milled for 4 hours. The slip after ball milled was poured into the plastic bowl. The glaze slip was thoroughly stirred. The bisquit piece was dipped into the glaze slip. The glaze on the base of the pot was wiped off to prevent the piece from sticking to the shelf and then fired.

3.9 FIRING:

Two firings were done to the casted wares. The first firing was the bisque firing of the wares to 900°c. This was to harden and render the wares porous so that the glaze could be applied. After glazing, the bisque wares were fired to 1280°c in the glaze kiln which formed the second firing.

C H A P T E R I V

ANALYSIS OF RESULT, DISCUSSION AND FINDINGS

4.1 INTRODUCTION:

This chapter documents the analysis of the results of tests conducted. These are triaxial blend, shrinkage and porosity tests as well as the casting and firing tests. Also analysed in this chapter are the formulation of glaze and glaze fit tests.

4.1.1 RESULT OF THE TRIAXIAL TEST:

The sixtysix member triaxial blend test involving feldspar, kaolin and quartz produced interesting results. All the tiles were fired to 1280 ^{o}c.

Tile 1 was 100% feldspar, being a flux it fused to a crazed white mass. The results on tiles 2 and 3 indicated the presence of feldspar in greater quantity. Tile 2 yielded a milky white while tile 3 produced a glassy effect with little crazing. Tile 4 and 5 produced milky white with glassy effect.

Tile 6 melted into glass also with little crazing and tile 7 turned out hard and dense producing relative characteristics found in tiles 11, 17 and 18. These compositions gave a brown with little blueish tinge. While tile 9 appeared hard and dense, tile 10 was also vitrified with the same qualities as tile 9.

Tiles 12, 13 and 14 all appeared dense and hard exhibiting milky white. On the other hand tiles 15, 21, 28, 36 and 45 yielded white showing a prominence of quartz. Tiles 19 and 20 turned out white. Tiles 22 and 23 maintained the milky appearance. From tiles 24 - 26 and 31 - 34 most brilliant pearly white was noted. This area yielded the most interesting result. Furthermore tiles 27 and 28 both emitted white but tiny iron specks were clearly noticeable. Kaolin prominence was noted on tiles 29 and 30 while tile 35 just appeared white as quartz was more pronounced.

From tiles 37 - 40 clear creamy white was vividly seen suggesting the probable presence of kaolin. Also from tile 40 - 44 quartz overwhelmed the other materials as such produced a fairly white colour. Tiles 46 - 50 yielded the same effect as found in tiles 37 - 40, consequently the area displayed refractory behaviour. Tile 51 showed a prominence of kaolin and quartz. However, from tiles 51 - 55 there were variations pertaining the effects due to the presence of different proportions of kaolin and quartz with only 10% of feldspar in each of the composition. This range did not show any transparent and shiny appearance - but instead produced grades of whitish effect.

Tile 56 was 100% kaolin as a result it maintained the refractory quality. Tiles from 57 - 65 were white and hard but the fluxing characteristics were missing since the compositions lacked feldspar. Tiles 66 was 100% quartz. It did not fuse but just sintered which could be attributed to its refractory property.

4.1.2 RESULT OF SHRINKAGE AND POROSITY TESTS:

TABLE 4.1:-

Shrinkage and porosity tests.

S/No	Body	Shrinkage % Bisque	Shrinkage $_{o}$ % 1280^{o}c	Absorption$_{o}$ % 1280^{o}c
1	T24	3	13	0.3
2	T25	3	13	0.3
3	T31	2	12	0.3
4	T32	2	12	0.3
5	T33	3	13	0.3
6	T34	2	12	0.3
7	T41	3	13	0.3

Table 4.1 above shows the result of shrinkage and porosity tests. The linear shrinkage test revealed that body 1 (T24) had 3% and 13% shrinkage at the bisque and stoneware temperatures respectively. Body 2 (T25) had 3% shrinkage at bisque stage and also 13% at stoneware. While body 3 (T31) recorded 2% and 12% shrinkage at bisque and 1280^{o}c respectively. Body 4 (T32) and body 5 (T33) gave 2% and 3%

shrinkage at biscuit firing and also 12% and 13% at 1280°c respectively. Body 6 (T34) had only 2% shrinkage at bisque while at glost 12% was recorded. Also body 7 (T41) had 3% and 13% shrinkage at bisque and stoneware temperature respectively.

The most interesting phenomenon in the result was the similar shrinkage rate of 2% each found on body 3, 4 and 6. In addition 12 shrinkage at glost firing was also noticed on each of these bodies. On the other hand body 1, 2, 5 and 7 showed the same shrinkage rate of 3% at bisque and 13% each when fired to 1280°c.

The porosity test also made a remarkable revedation. After the bodies were soaked in water for 24 hours, all the seven bodies tested indicated 0.3% absorbtion each.

4.1.4 RESULT OF CASTING TEST:

Body I:

Materials	% Composition	Weight (gm)
Feldspar	40	200
Kaolin	35	175
Quartz	15	75
Ball clay	10	50
Sodium Carbonate.	.4	2
Sodium Silicate.	.4	2
Water	50	250

The slip after 16 hours ball milling was left undisturbed for 24 hours. The purpose was to check thixotropy, fluidity and viscosity. The slip had settled during the period but was stirred well and sieved through 80 mesh. It was poured into the mould and was allowed to form for 15 minutes. The casting rate was rapid. The surplus slip drained out freely and after 20 minutes the cast shrank. The cast was released easily.

The good casting behaviour indicated the correct choice of the proportion of deflocculants used in the body. While the plastic quality displayed in the composition had revealed the role of a secondary clay. Hence 10% addition of ball clay was adequate. When the body was fired at 1280^{o}c, it matured nicely to a dense body.

Body II:

Materials	% Composition	Weight (gm)
Feldspar	35	175
Kaolin	30	150
Quartz	25	125
Ball clay	10	50
Sodium carbonate.	.4	2
Sodium silicate.	.4	2
Water	50	250

After 24 hours rest, the slip behaved similar to the first composition. It was stirred thoroughly and poured into the mould after the slip was screened through 80 mesh sieve. The casting was quick as a

result the 15 minutes provided for the slip to form was adequate.

The slip was drained well and the cast was taken out freely. The plastic quality of the composition showed that the ball clay introduced in the body was sufficient. Furthermore, the percentage and types of deflocculants used enhanced fluidity. On firing the product to 1280°c, it vitrified nicely yielding transparent and smooth effects. There was no warpage or any form of distortion.

Body III:

Materials	%Composition	Weight (gm)
Feldspar	30	150
Kaolin	40	200
Quartz	20	100
Ball clay	10	50
Sodium carbonate	.2	1
Sodium silicate	.6	3
Water	50	250

There was settling tendency in the slip after it was left undisturbed for 24 hours. It was stirred and sieved. The slip casted well in 15 minutes. The drainage was effective and plastic property was noticed in the slip. The proportion of deflocculants used and the amount of ballclay in the composition appeared to have been justified since there was a rapid formation of shape as well as the comfortable release of the casted object.

The body when fired to 1280^{o}c vitrified well thus yielding smooth, transparent and translucent appearance. A portion of casted cup was chipped deliberately and fired to 1280^{o}c. The idea was to examine its resistance in that form. Consequently, it did not show any sign of warpage. The products made from the composition produced a healthy sound when struck, a test of vitrification.

Body IV:

Materials	% Composition	Weight (gm)
Feldspar	30	150
Kaolin	45	225
Quartz	15	75
Ball clay	10	50
Sodium carbonate	.2	1
Sodium silicate	.6	3
Water	50	250

The composition had the tendency to settle after 24 hours rest. When it was stirred, sieved and cast, it yielded a good cast in 15 minutes. The drainage of the slip was satisfactory and the cast was confortably released from the mould. On firing the body to 1280^{o}c, it gave good, transparent and smooth effect. The ware rung when struck suggestive of partial glassification.

Body V:

Materials	%Composition	Weight (gm)
Feldspar	30	150
Kaolin	35	175
Quartz	25	125
Ball clay	10	50
Sodium carbonate	.4	2
Sodium silicate	.4	2
Water	50	250

There was no settling of the slip when it was left undisturbed, it was however agitated and screened through 80 mesh sieve. There was enough plasticity in the composition. Rapid casting was recorded and the excess slip drained out smoothly after 15 minutes. When it shrank the cast released easily from the mould.

The good drainage and early release of the cast coupled with the plasticity experienced in the slip confirmed the correct choice of deflocculants and the

amount of ball clay in the body composition. The body fused at 1280°c becoming transparent and translucent.

Body VI:

Materials	% Composition	Weight (gm)
Feldspar	35	175
Kaolin	30	150
Quartz	25	125
Ball clay	10	50
Sodium carbonate	.2	1
Sodium silicate	.6	3
Water	50	250

The slip settled after 24 hours rest. It was however stirred thoroughly and sieved. It casted within 15 minutes and there was also a good drainage as well as early released from the mould. Therefore the plasticity and the amount of deflocculants in the composition were considered sufficient. The ware was fired

to 1280°c. It produced glassy and transparent effect. The body was resonant when struck

Body VII:

Materials	% Composition	Weight (gm)
Feldspar	20	100
Kaolin	35	175
Quartz	35	175
Ball clay	10	50
Sodium carbonate	.4	2
Sodium silicate	.4	2
Water	50	250

The settling behaviour was noted in the slip. However, it was stirred thoroughly and strained. There was a good flow of the slip as well as drainage. The slip formed clearly within 15 minutes and the casted piece was removed easily. The plasticity in the composition was adequate. When fired at 1280°c the body produced transparent and smooth effect,

4.1.5 RESULT OF THE GLAZE TEST:

RECIPE I:

Materials	% Composition	Weight (gm)
Feldspar	50	250
Quartz	20	100
Kaolin	10	50
Limestone	20	100

The batch was ball milled for 4 hours, sieved through 80 mesh and applied on the pot then fired to 1280°c in the gas kiln. The result showed a good melt with white and transparent, smooth appearance. There was no running behaviour and other forms of defects. The glassy effect was probably due to the presence of flux in the composition. Consequently, the proportion of feldspar and limestone which were the main and auxillary fluxes respectively seemed to have been appropriate.

RECIPE II:

Materials	% Composition	Weight (gm)
Feldspar	50	250
Quartz	20	100
Kaolin	15	75
Limestone	15	75

The glaze batch was ball milled for 4 hours. It was stirred thoroughly after settling. The glaze slip was sieved and the biscuit ware was dipped. The glaze at the foot was wiped off and then fired to 1280°c. It fused with nice melt that produced white, smooth and transparent surface. Hence the choice of the material appeared to have been accurate, since there was no shortcomings such as crazing, crawling, running, dunting or chipping.

RECIPE III:

MATERIALS	% COMPOSITION	WEIGHT (GM)
Feldspar	45	225
Quartz	20	100
Kaolin	15	75
Limestone	20	100

The composition was ball milled for 4 hours. The glaze slip was stirred thoroughly and strained through 80 mesh sieve. The bisque ware dipped into the glaze and when fired to 1280^{0}c, it vitrified and produced a glassy, smooth and transparent coat. Indeed this composition displayed more glassy effect than the other glaze batches. Since there was no fault in the glaze, it could be deduced that the choice of materials was adequate.

RECIPE IV:

Material	% Composition	Weight (gm)
Feldspar	40	200
Quartz	20	100
Kaolin	20	100
Limestone	20	100

The glaze slip was sieved after 4 hours ball milling. It was agitated thoroughly and applied on the bisque ware. The glaze at the foot was cleaned neatly and then fired to 1280^{0}c in the gas kiln. The glaze matured with a good melt. It yielded transparent, smooth and glassy appearance. The ware that was coated thinly exhibited translucent effect with this glaze composition. The

correct proportion of the material appeared to have been accomplished because no fault was really observed in the glaze behaviour.

4.2 DISCUSSIONS:

Based on the analysis and observation during the formulation of a whitebody suitable for casting table ware, about four of the materials used for this study namely Kaolin, quartz, ball clay and limestone were procured from Sokoto state. Feldspar being the only material obtained from Kwara State.

From the outcome of the physical property test (table 3.1) it was observed that the shrinkage of kaolin of 1280°c was less than secondary clay shrinkage but as for porosity the kaolin absorbed more than the secondary clay. For instance kaolin had the stoneware firing shrinkage of 9% and also 9.1% absorbtion while Wurno secondary clay had recorded 11% shrinkage at stoneware and 3.3% absorbtion at 1280°c. This result therefore formed the basis to speculate that the more plastic the clay the less absorbtion and the less plastic the material, the more its absorbancy. Similarly the plastic quality also determined the degree of shrinkage of clay materials. For example, Rakwamni

kaolin which had a low plasticity recorded 9% shrinkage at stoneware and Wurno secondary clay of good plastic quality showed 11% shrinkage at 1280°c.

The sixty-six member triaxial blend of feldspar, kaolin and quartz produced effects that provided an adequate range within which to select suitable bodies.

The use of two parts of sodium carbonate to two parts of sodium silicate and one part of sodium carbonate to three of sodium silicate seemed to have been worked well. There was no fault in casting and drainage. Therefore the varied proportion of deflocculants in each body composition was suitable.

The tests conducted also revealed that, the 10% addition of Wurno secondary clay improved the plastic property of the slip. The introduction of the clay (Wurno) did not impair much the whiteness of the bodies as usually caused by impurities found in secondary clays.

The result for shrinkage and porosity test on table 4.1 was also of interest. Bodies of the same shrinkage rate of 2% each produced equal shrinkage of 12% each at stoneware temperature as well as equal water absorbtion of 0.3%. Also in a similar case, compositions that gave 3% shrinkage each at bisque state displayed 13% shrinkage each when fired to 1280^{o}c. The water absorbtion of each of the bodies was 0.3% each. This result showed that all the seven bodies had the same water absorbtion degree.

It was also observed that the correct amount of water contributed to the effectiveness of the casting slip. The composition with accurate proportion of water would cast rapidly. Thus confirming that the use of 250gm of water to 500gm of solid ingredients for the study was appropriate.

Porcelain characteristics were noted in the portion where kaolin and feldspar dominated quartz, while the area where feldspar and quartz dominate kaolin, the characteristic of porcelain was not clear due to insufficient amount of kaolin.

An area where kaolin and quartz were more pronounced than feldspar appeared refractory, therefore required more feldspar to help in the fusion of such compositions.

The translucent effect in the bodies was perhaps consequent to 16 hours ball milling, the type of feldspar and quartz used in the formulation. Bodies that were thinly cast also displayed translucent behaviour.

The result of the glaze tests were also observed. The glaze recipes produced nice and smooth coatings and translucent melts indicating the industrial potentials of these glazes. The consolidant of the good glaze behaviour was a result of balance of the ingredients.

4.3 F I N D I N G S:

Based on the studio tests and experiments conducted for the formulation of whitebody suitable for casting tableware, the following findings were made:-

1. Rakwamni kaolin, Mayanci quartz, Wurno clay and Kalambaina limestone were found to be of high quality even in the absence of the chemical analysis. Therefore, it could be said that Sokoto State has potential for good quality raw materials for the production of ceramic wares.

2. Okene feldspar from Kwara State was also found to be of good quality. This finding is in the line with those of Pedro (1987), and Umar (1988).

3. The glaze compositions appeared to have fitted well on the formulated bodies.

4. The correct proportion of sodium carbonate and sodium silicate improved the performance of the casting slip.

5. The addition of 10% Wurno clay to the casting slip made a significant improvement to the plasticity.

6. Ball milling was found to be an effective way for the mixing of ceramic materials.

7. It was observed that, the mould became ineffective with continuous use because of water absorption.

8. The 1280°c temperature was found to be adequate to yield dense, hard, glassy, and translucent effects.

9. The gas firing produced variations of colour effects due to the reduction atmosphere in the kiln. Wares that were placed near the burners exhibited clearer appearance than those placed far away from the burners and at the top part of the kiln. Rhodes (1959) enlightened that "white glazes fired in oxidation will have slightly creamy or warm colour while those in reduction will tend to be cool white or blue white".

CHAPTER V

SUMMARY, CONCLUSION AND RECOMMENDATION:

5.1 INTRODUCTION:

This chapter covers the summary, conclusion and recommendation based on the findings from the studio tests and experiments conducted.

5.2 SUMMARY:

The result of this research revealed that, the raw materials procured are suitable for the formulation of white wares.

The outcome of physical property tests conducted to identify the raw materials in the absence of chemical analysis for Rakwamni kaolin, Wurno secondary clay, Mayanci quartz and Kalambaina limestone had indicated some encouraging results that describe their state of purity and high quality. The Chene feldspar had also shown interesting result. It produced a glassy and translucent effect as such it could be used as a main flux in ceramic productions.

An area of feldspar prominence in the triaxial appeared hard and dense. And where kaolin and feldspar dominated, hard and dense bodies were also produced showing some characteristics of porcelain. The portion of kaolin prominence gave whitish effect but the sign of fusion was missing.

The result also revealed that, reduction firing produced variation of white but oxidized firing yielded clearer effects in whitewares.

5.3 CONCLUSION:

Based on the outcome of the study for the formulation of whitebody suitable for casting tableware, the following conclusions were drawn.

Rakwamni kaolin, Wurno secondary clay, Nayanci quartz from Sokoto State and Okene feldspar from Kwara State are good quality ceramic raw materials that could be used in the formulation of tableware. Limestone from Sokoto State can also be a good source of whiting for bodies and glazes.

The 250gm of water used to every 500gm of solid ingredients worked well. Ball milling and sieving of the slip before casting improved the casting behaviour.

The total amount of deflocculants in varied proportion to every 500gm of solid materials were appropriate and the 10% addition of Wurno clay had greatly improved the plasticity in the slip.

The plaster of Paris was found to be an indispensable material for mould making because it absorbs moisture quickly from the slip, forming a wall that gives a specific shape.

5.4 RECOMMENDATION:

Considering the significance of ceramics in nation building, the researcher wishes to make the following recommendations:-

1. Federal Government should as a matter of urgency support Universities and Polytechnics offering ceramic courses financially. This will

encourage them to prospect and tests ceramic raw materials which will hopely lead to the technological development of the country.

2. The Federal Government should also support ceramic organisations such as Ceramic Association of Nigeria and providing members with research grants. By so doing a blue print on raw materials will be produced which will form the basis of ceramic development.

3. The Federal Government should also consider ceramic graduates in its recently introduced graduate loan scheme. Ceramic Industries being labour intensive will create job opportunities for skilled and unskilled workers if established.

4. The Federal Government should purchase modern equipments for the analysis of raw materials. It will help the researchers to analyse and document various materials.

5. The Department of Industrial Design should provide more space and equipments to aid students in research.

6. Research institutions should explore effective ways to develop local materials in ceramic production which will reduce foreign dependency.

RECOMMENDATION FOR FUTURE RESEARCH:

The following areas are cocommended for future research:-

1. There is need for further research into local materials to produce deflocculants to be used in casting slips.

2. If equipments were available, there is need to know the chemical analysis of Rakwamni kaolin, Wurno clay, Mayanci quartz and Okene feldspar.

3. A further study is required to determine the tensile strength of the bodies formulated in this study.

4. Also further research is required into the use of copper sulphate, cobalt sulphate which might aid in whiteness.

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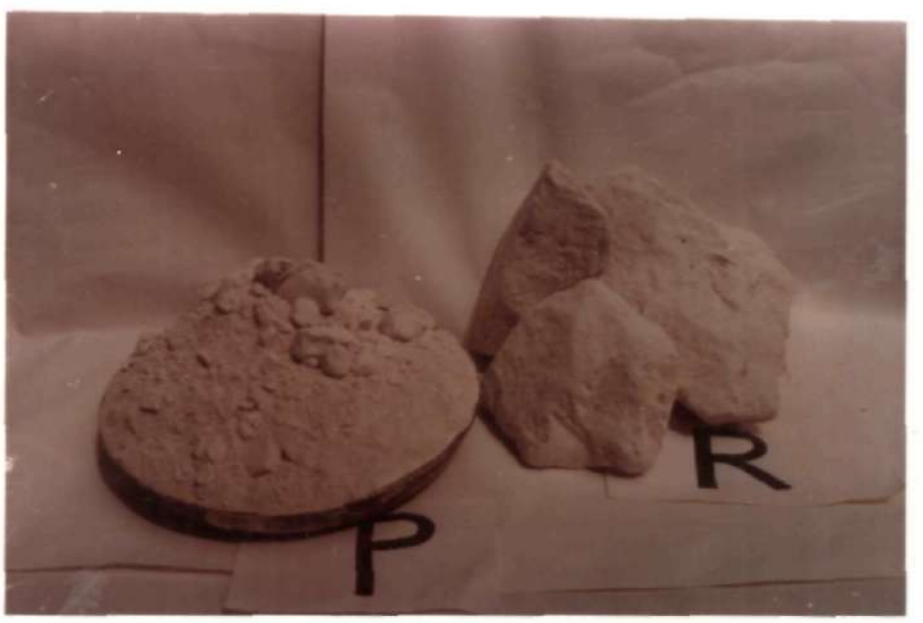
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APPENDIX I

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



Rakwamni kaolin



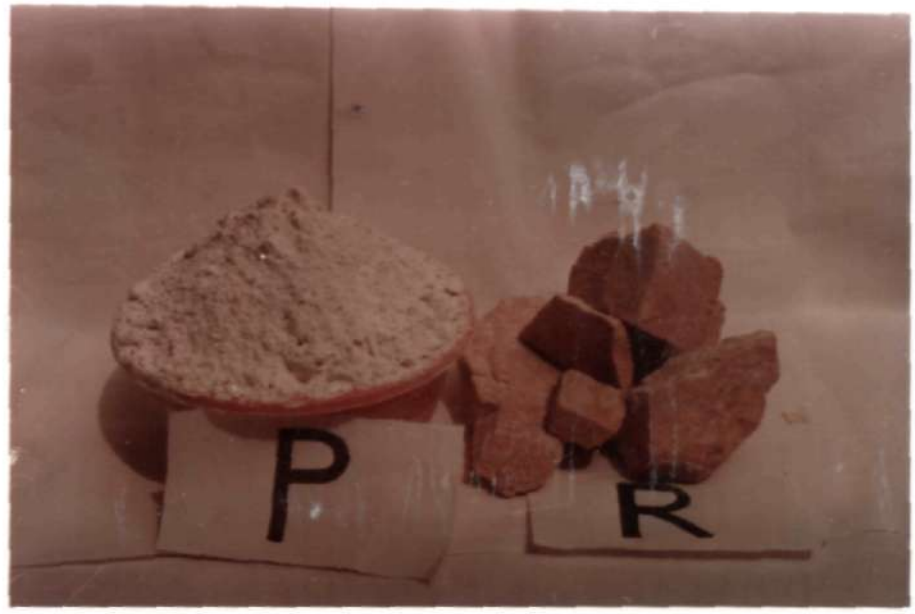
Wurno clay



Kalambaina limestone



Mayanci quartz



Okene feldspar.

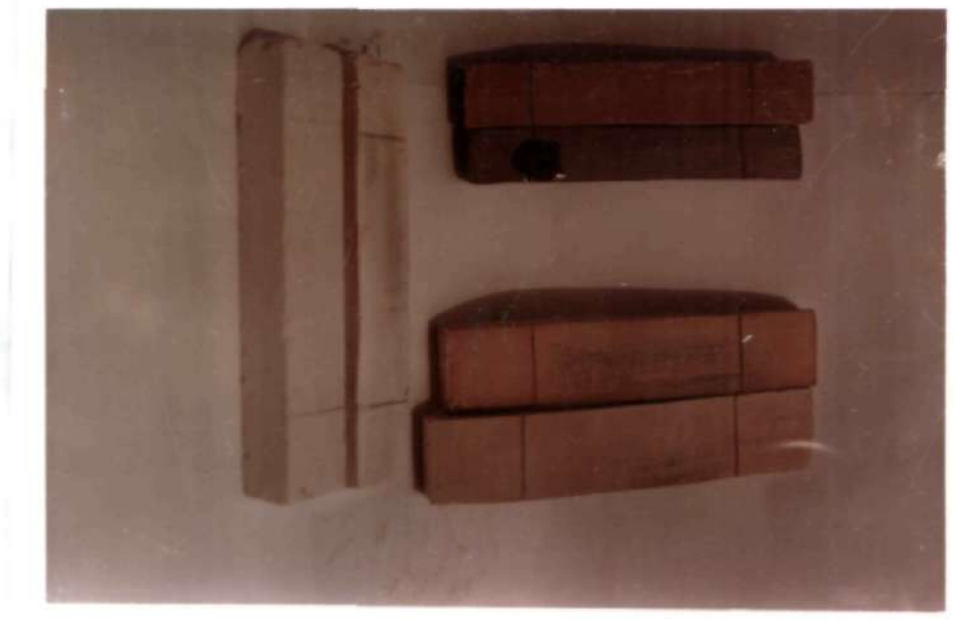
KEY:

R = Raw

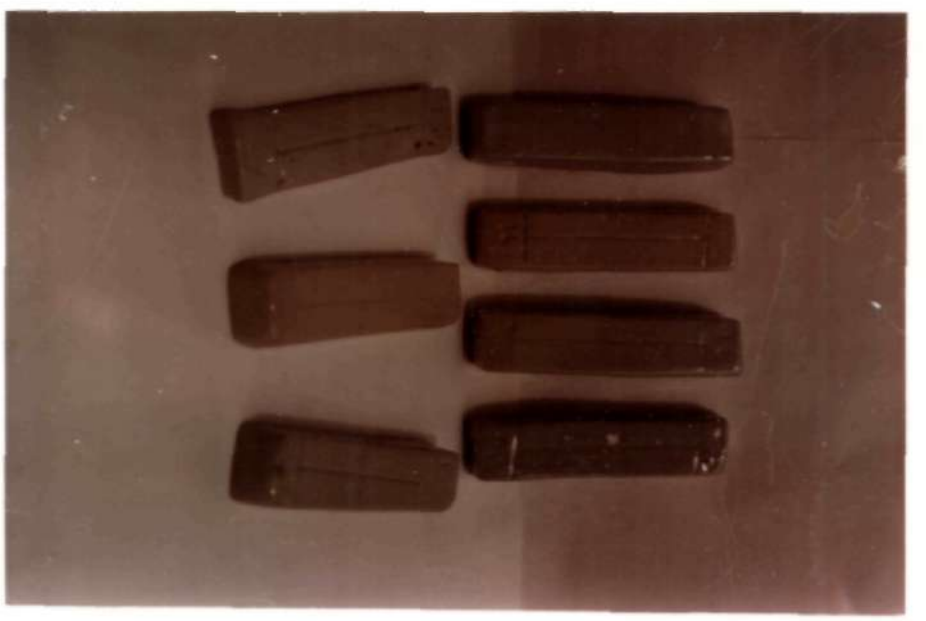
P = Processed.

APPENDIX II

This appendix indicates the plates of the shrinkage test bars of the clay samples and porcelain bodies.



Shrinkage test bars of the clay samples.



Shrinkage test bars of porcelain bodies.

APPENDIX III

This appendix indicates the plate of the triaxial blend used in this study.



APPENDIX IV

This appendix indicates the plate of the fired experimental samples for the study.



APPENDIX V

Mineral exploration in Nigeria relevance to ceramic production.

Mineral	Location
Kaolin	Plateau, Bauchi, Oyo and Sokoto States.
Feldspar	Oyo, Kwara and Borno States.
Quartz	Kwara and Borno States.
Diatomite	Borno and Oyo States.
Rock salt	Anambara and Imo States.
Phosphate	Benue State.
Barytes	Plateau and Gongola State
Flourite	Gongola State.

Mineral	Location
Alluvial gold	Oyo, Niger, Kwara, Kaduna, Sokoto and Bendel States.
Primary gold	Oyo, Kwara and Sokoto States.
Primary tin	Plateau State.
Alluvial Tin	Borono, Oyo, Plateau, Kano, Kaduna, Bauchi States.
Magnesium oxide	Gongola State.
Lead/Zinc/ Silver/Salt.	Anambara State.
Dolomite	F. T. C.
Marble	Plateau, Cross River and Ogun States.

SOURCE:

Nigerian Mining Corporation: Time for patronage, Sunday Triumph, Septermber, 20th 1987, page 10.