

Development of a Polymeric Composite Jar for the Processing of Ceramic Raw Materials.

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Abstract
This study has looked into the likelihood of substituting porcelain, the chief material used in constructing mill jar with PVC plastic. Experimental design was adopted for this research. The production of the jar was given much attention based on the size proposed by the study. Materials used for the production of the jar were PVC resin, Stearic acid impregnated with calcium carbonate as a filler locally sourced including the equipment used for the melting of the PVC material. The cast pieces were machined to various sizes required for the production of the jar. The cast and machined PVC parts were brought and glued together in stages with the use of ABRO PVC adhesive. The jar underwent series of test grindings running for more than six hours continually in operation. The cast PVC jar was used to mill 2mm grains of feldspartic materials and 2mm grains of quartz materials including 3kg batch of glaze separately at different occasions to achieve fine particle sizes that passed through an 80 mesh seize. The milled glaze was further applied on two bisque wares (a cup and a mug) and were fired to a temperature of about 1250^{0}C. Impact and Tensile test were carried out on the materials in order to ascertain their strength. 9 joule and 11 joule, 5.6KN and 6.8KN respectively was found to be the differences that exist between the strength of cast and industrially made PVC materials. It was noted that jars made of PVC materials are capable of processing ceramic minerals just like jars made of porcelain.
Keywords: Porcelain-jar, PVC Composite-jar, Ceramic, Processing, Raw-Materials.

Introduction

In Nigeria, small scale ceramic industries are yet to satisfy the need of small communities due to inability to have well-equipped studios to turn out sufficient output (Bazunu, and Odokuma, 2008). He attributed such problem to deficiency in procuring enough and assorted materials due to high cost. Sullayman (1991) observed that the techniques of ceramic production adopted by institutions of learning and local communities is the type that is slow and lack dynamism of current technological growth trend to enhanced quantity, self-sufficiency and export potentialities.

The absence of local processing plants for ceramic raw materials in the country Eweka (2009) observed is the cause of insufficiency in output of ceramic wares in the country by institution of learning and local communities which is tacked slow and lack dynamism of current technological growth trends as noted by Sullayman (1991) which would have enhanced quantity, self-sufficiency and export potentialities.

It is obvious that ceramic equipments and processed raw materials are deficient in Nigeria as a result the development of ceramic is lacking to an extend that the ceramist is not able to satisfy the need of his local community. The paucity of raw materials had thrown numerous pottery studios into serious confusion to an extent that they cannot be sustained; resulting to the death of many at inception. Though, some pottery studios manage to stay in production for a few years before they folded up.

It easier for a sculptor to walk into the market or into building equipment store, pick up a brand new working equipment or spare parts, a phenomenon impracticable for a ceramist, this is because most equipment and materials needed are imported and are highly exorbitant. This phenomenon, normally discourage those would-be potters, since only few entrepreneurs of pottery usually succeed.

The determinant factor for success in Ceramic production in Nigeria today is self-sufficiency. Institutions of learning, private workshops and studios have all got to be self-sufficient in most if not all aspects of functions ranging from raw material sourcing to management, production and to marketing if they are to succeed (Datiri, 1998). In the same vein, Cardew (1969) in Ewule (1988) saw pottery craftsmen as people with special abilities to acquire knowledge mastery and competencies in their field of endeavour to enable them be able to tackle various problems as they surface.

The processing of ceramic raw materials in the potting arena is fundamental, this is because it is a process where materials are reduced to minute particle sizes (2mm or less) (Brown, 2011). The resultant effect of reducing these materials into submicron, usually yield appropriate time, energy and cost management efficiency, requisite to fire successful kiln-load of gloss firing; because finely ground materials melt more easily (Henrik and James, 1991).

The need of having a mill in a pottery studio, is paramount to a ceramist, this is because, it gives him/her the confidence to manage materials effectively and efficiently, for no successful pottery studio that mix its own raw materials would be without a ball mill. Yet, some potters lack them for a couple of reasons such as cost and awareness (Carlströme, 1997).

The processing aspect of ceramic raw materials is lacking in most studios in Nigeria and has posed a major challenge faced by potters of old and present, due to the inability to access affordable and locally produced ball mill. Typically, porcelain is the only available conventional material known all over the world used for the construction of jar(s) for processing or grinding ceramic raw materials. These foreign jars usually come into the country in complete component with all accessories attached that makes it a whole (complete miller) processor. Ironically, these processors are hardly found in the market and if at all, are available, they are extremely expensive due to exchange rate.

This has made it possible for this work to ascertain the likelihood of substituting porcelain, the chief material used in constructing mill jar with a jar made of ceramic and polymeric composite materials. This is to serve as an affordable alternative to the highly expensive imported ones.

Materials and Methods.

Materials Used are:

- Calcium Carbonate.
- polymeric materials composite, (PVC resin and Stearic Acid)
- PVC adhesive,
- Stainless containers.
- Oven
- PVC adhesive
- Battery powered charcoal stove.

Raw Materials Sourcing and Procurement:

This aspect comprised primary collection of materials and the equipment used in the production of polymeric and ceramic jar.

Samples of Ceramic and Polymeric Materials.

Plate 1: *PVC Resin. Calcium Carbonate. Stearic Acid*

Samples of Ceramic and Polymeric Materials Used.

Melting procedures.

Battery Powered Charcoal Stove (BPCS) was procured for melting of the materials. PBCS is a locally made cooking equipment built with a fan inside a box. The box has a round, constructed hollowed and folded pan that leads to the fire chamber where the charcoal was stocked. The fan in the box propelled and produced air with the help of the battery in the box that served as the source of energy to keep the fire in the stove burning. This was found effective for the work because it produced and maintained stable and continuous heat into the oven so long charcoal is stock into it. With this melting of the ceramic and polymeric materials was made easier.

Production Procedures.

Mould Construction for the Jar:

A metal plate and stainless containers were purchased to that effect, and were used for the production.

The metal plate was machined to create grooves to serve as sitting for the mould. The size (circumference) of the containers were measured and the measurements were used to make the grooves such that the containers fitted into the grooved plate without much allowance as shown below in plate 2.

Metal Plate Being Machined. **Testing the Fitting of the Mould.**

Plate 2: *Shaping and Machining the Metal Plate.* *Testing the Container on the Grooved Plat.*

Metal Lock:
A metal pipe was cut and machined to the size of the plastic lid for the jar. The lock was designed to properly protect and preserve materials meant to be milled inside the jar so that no spillage of materials of any kind will be experienced.

Pilot Study.
Trial Test for Melting of Ceramic and Polymeric Materials:
Various polymeric resin (PVC) melting procedures were examined to include the use of steam from boiling water, use of a grill stove or campfire and or an improvised double boiler over a campfire and oven. The melting temperature for PVC materials ranges from 100 degree centigrade, 250 degrees Fahrenheit and 130 ^{0}C to 160 ^{0}C depending on the type (Casino. 2008).

The trial of the above melting procedures were experimented and was noted that ‘oven melting technique’ was the most favourable and was adopted as the melting procedure for this work. This is because PVC is prone to burning if exposed to too much heat and flame therefore, in order to check this problem an oven was purchased together with a battery powered charcoal stove (BPCS) so as to avoid flame, and also to enhance and maintain gradual development of heat in the oven.

The melting point for PVC highlighted above shows that the melting temperature for the type of PVC (granular PVC) procured for the research is 130-160 ^{0}C. With this melting point, the melting of material was made easier and faster.

Four different tests were carried out on different occasions to know precisely the quantity of materials required for the production of the jar. The materials were measured using percentages and subsequently in kilograms.

The break down as follows.

70:20:10 % Ratio of materials.

Materials	*Percentages*	*Weights*
PVC resin	70%	700g
Calcium Carbonate	20%	200g
Stearic Acid	10%	100g
Total	**100%**	**1000g**

Table 1a

75:15:10% Ratio of Materials.

Materials	*Percentages*	*Weights*
PVC resin	75 %	750g
Calcium Carbonate	15 %	150g
Stearic Acid	10 %	100g
Total	**100%**	**1000g**

Table 1b.

80:10:10% Ratio of Materials.

Materials	Percentages	Weights
PVC resin	80%	800g
Calcium Carbonate	10%	150g
Stearic Acid	10%	50g
Total	100%	1000g

Table 1c.

85:5:10% Ratio of materials.

Materials	Percentages	Weights
PVC resin	85%	850g
Calcium Carbonate	5 %	100g
Stearic Acid	10 %	50g
Total	100%	1000g

Table 1d.

Table 1a-d: Percentage Ratio of test analysis of Materials Used for the Production.

The result of the test shows that test number four with the composition 80-5-10 % appeared more feasible than the others, and thus, it was picked for the study.

Test Results.

Plate 3a: *70:20:10 % Ratio of* **.** *Materials Test Result*

Plate 3b: *75:15:10% Ratio of Materials Test Result.*

Plate 3c: *80:10:10% Ratio of Materials Test Result.*

Plate 3d: *85:5:10% Ratio of Materials Test Result.*

Plate 4a-d: *Results of the Test Conducted on the Materials in Order to Determine the Amount to be Used for the Casting of the Jar.*

Jar Production procedures.

The stainless containers used as moulds were fixed right into the grooved metal plate. Afterwards, it was placed inside an oven made of pan (OMP). A batch of weighed polymeric and ceramic materials (PVC resin, stearic acid and calcium carbonate) were mixed and fed in the gap between the moulds, after which the oven was closed.

The battery powered charcoal stove (BPCS) was filled with charcoal, thereafter, the batteries were fixed and some drop of kerosene was sprinkled on the charcoal. The stove was ignited and then it was pushed under the oven when the fire had been set. The battery in the stove powered the mechanism in the BPCS that helped to blow air which kept the charcoal burning. This helped in the gradual development of heat into the oven. This was allowed for a minimum of 35 – 40 or maximum of – 45 minutes depending on the efficiency of the BPCS for the materials to melt. The PBCS was removed after the melting of the materials has been completed and the molten plastic was allowed to cool gradually as shown in plate 5 below.

The OMP was designed such that it had shelves made in steps inside the oven. A cover was also attached to the oven; under it was a vacuum created for positioning the PBCS. The cover was flipped open to drop the materials inside; as well opened to removed the molten Plastic. The PBCS was ignited and placed under the OMP.

Plate 4: OMP with PVC/Ceramic Materials.
Oven Made of Pan Used for the Melting of the Polymeric Materials.

Removing the Jar from the Mould:
The molten plastic (PVC jar) and the covers were brought down from the oven after it has been cooled and the mould were removed as shown in plate 5, 6 and 7

Plate 5 : Chipped Out Cast Jar.

Plate 6: *Cast Cover.*

Machining the Covers, Neck and Corks to Desirable Sizes:
The cast plastic covers and the neck produced were machined to various sizes required for the construction of the jar. These parts were machined to acquire proper shape, exact dimension and surface finishing. Machining as a mechanical process is recommended and is widely practised as one of the manufacturing process worldwide. In line with this the edge of the cast jar (one side) was trimmed with a hacksaw to achieve a smooth surface on the jar.

Plate 7: Cast Neck / Cork for the Jar.

Joining Together Parts of the Jar:
The cast PVC parts were brought and glued together in stages with the use of ABRO PVC adhesive. These parts were joined together starting with the neck to the upper cover (Cap) of the jar, and subsequently to the end cap.

The upper cap and the neck were first glued together, later the upper cover and the neck were joined to the jar. It was afterwards joined to the end cap and finally the fixing of the locks was done. These parts were brought together after the application of adhesive, directly on the area needed to be joined without allowing it dry.

The joining of these parts provided permanent bond as well as made the parts grip together. It helped also in checking leakages of materials while running the mill.

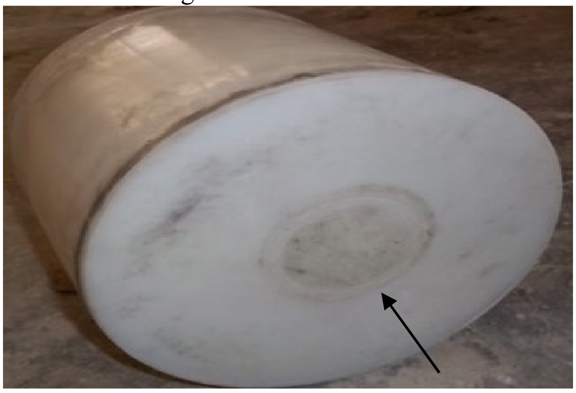

Plate 8: End Caps of the Cast Jars Fixed.

In this stage all parts designed and machined for the jar were assembled by coupling them together. On the whole the Plates below shows the final outlook of the mill jar.

Plate 9: Assembled PVC Jars.
The Final Outlook of the Cast Polymeric Composite Jar.

Proposed Jar Dimensions.

Separate Parts of the Jar.

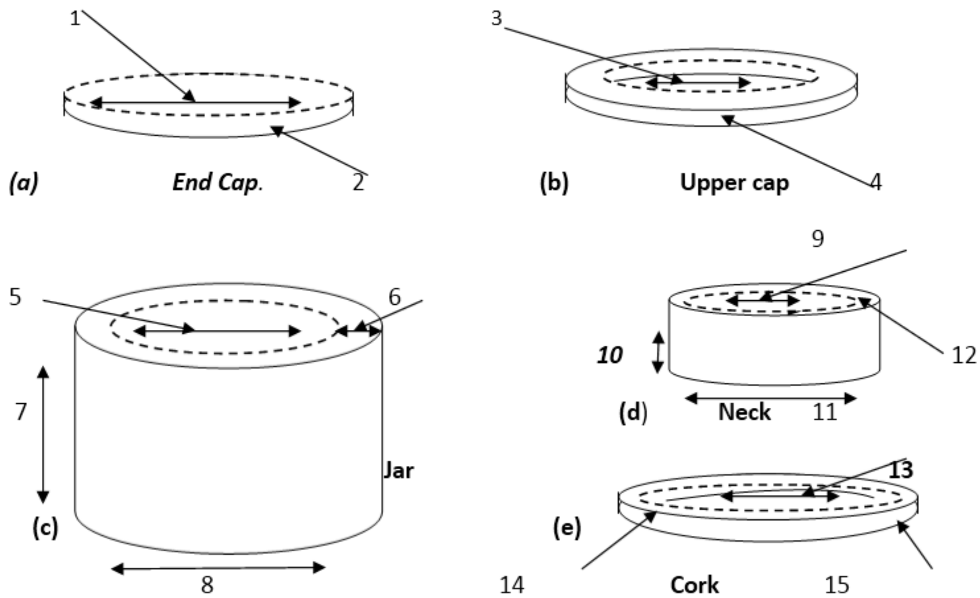

Fig. 1: *Separate Parts and Dimensions of the Cast Jar.*

Table 2: Dimensions of the Cast Jar.

S/No.	Part	Item Considered	Size
1	End cap (cover)	thickness	2cm.
2		diameter	27cm
3	Upper cap (cover)	Opening Diameter.	13cm
4		Thickness	1.5cm
5	Jar	Thickness	2cm.
6		Diameter:-Out-out -In-in	27cm. 23cm.
7		Height	21cm
8		Circumference	84.857cm
9	Neck	Diameter:- Out-out In-in	13cm 10cm
10		Height	11cm
11		Circumference	40.285cm
12		Thickness	1.5cm
13	Cork opening	Diameter	13.5ccm
14		Thickness	2cm
15		Circumference	42.423cm

Drawing of the Cast Jar Indicating the Parts.

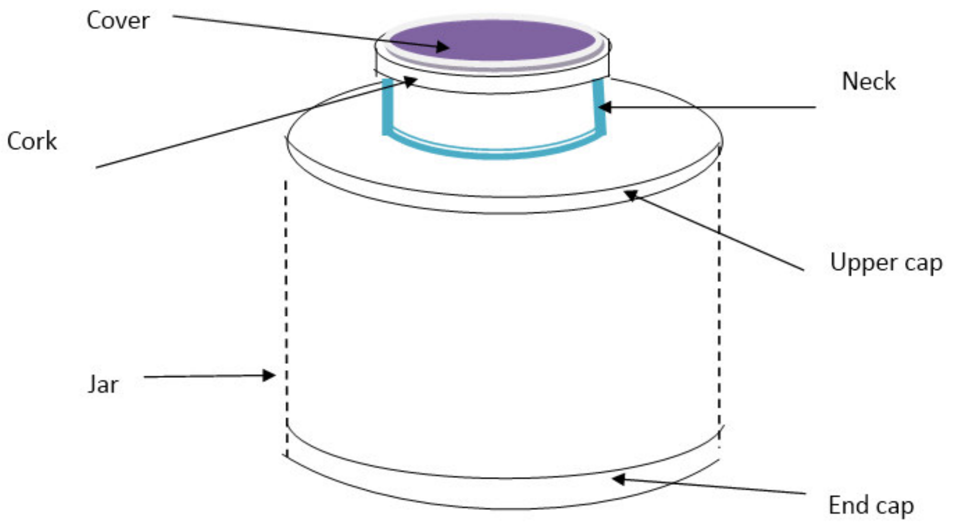

Fig 2: Proposed Outlook of the Cast PVC Jar.

RESULTS AND DISCUSSION.

This study stemmed from the aim of ascertaining the possibility of substituting the conventionally made imported porcelain jar used in the processing of ceramic raw materials, that are highly exorbitant, fragile and are rarely found in the market, for a more affordable, sturdy, and durable PVC jar.

Polymeric composite materials (PVC resin, stearic acid and calcium carbonate) was used for the production of the jar. These materials were formulated in batches with the use of graded scale in kilograms. The batches of the materials were further subjected into melting test procedures before the final production of the jar. The essence of the test was to ascertained the right amount of each material required in the formulation so as to serve as guide in the production of the jar.

The cast jar was used in milling of some materials. 3 kilogram batch of glaze was milled to achieve microns that could pass through 80 seize mesh. The milling was successfully achieved in two hours. The milled glaze was further applied on two bisque wares (a cup and a mug) and were fired to a temperature of about 1250^{0}C. The gloss firing was done in order to test the likelihood of plastic chips on the glaze as a result of the grinding effect of the milling media.

The results of the milling exercises of these materials (Quartz, feldspar and the batch of glaze) achieved within some couple of hours.

Plate 10a: 2mm Grains of Un-Milled Quartz.

Plate 10b: 2mm Grains of Un-Milled Feldspartic Materials.

Plate 13: Fine Particle Size of Milled Quartz.

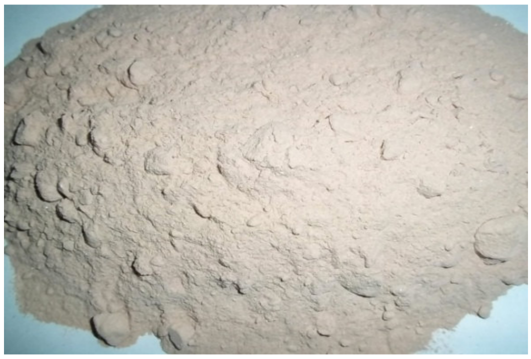

Plate 14: Fine Particle Size of Milled Feldspartic Materials.

Impact and Tensile Test.

Some pieces of PVC plastic both cast and extruded pipe were cut and taken for impact test and tensile test, at the Materials Science Laboratory of the Metallurgical Department, and at the Strength of Materials and Heat Treatment Laboratory both at the Faculty of Engineering, ABU, Zaria. The test was conducted in order to ascertained the impact and elastic resistance properties of these materials at the operational level of the mill during the grinding (milling) process. An impact test is a unit of energy; the international system unit of energy or work, equal to the work done when the application point of one newton force moves one meter in the direction of application (Askeland 1984); while tensile test is the assessment of mechanical properties such as stiffness, yield strength, tensile strength, ductility, toughness, impact resistance, creep resistance, fatigue resistance and others for determining the service life of equipment or an item (Xiao and Leach 2005)

Charpy Impact Testing Machine (CITM) was used in the testing of the PVC materials at the materials science laboratory. The machine is graded according to joule, ranging from joule one to joule 25. Joule 25 is the highest reading of the entire graded joule. The strength of a material is determine through the level of reading of the joule (applied force) at which the material got broken at the release of the flinging arm of the joule. The results of the two different plastics are as indicated in fig. 3a and 3b.

Impact Resistance Analysis of Cast and Industrial PVC Jar Mill.

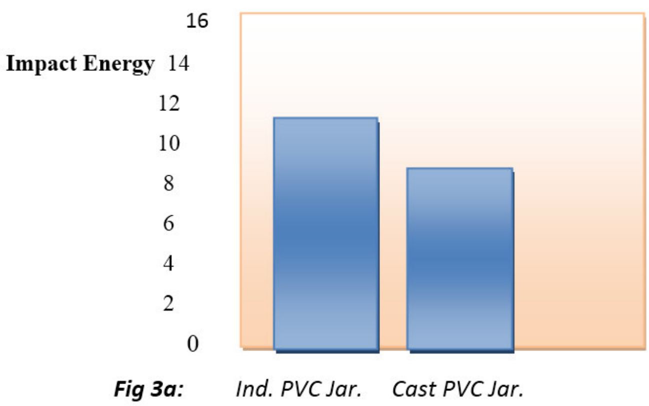

Fig 3a:

Cast and Industrial Pieces of PVC Test Result Conducted at the Materials Science Laboratory of the Metallurgical and Materials Engineering Department, Faculty of Engineering, ABU, Zaria

At the strength of materials and heat treatment laboratory, 500 kilonewton (KN) maximum Capacity Testing Machine was used in testing the materials. The Machine was designed to test a wide spectrum of materials including metals, plastics, rubber, textiles, paper, yarn, wire, adhesives, ceramics, timber, foils, composites and finished components in tension, compression, flexure or shear. The test was carried out in order to determine the flexure capacity of the PVC materials. The result of this test is as expressed in fig. 3b below.

Tensile Test Analysis of Cast and Industrial PVC Jar Mill.

Breaking Load Tensile Strength.

Fig 4.6b:

Cast and Industrial Pieces of PVC Test Result Conducted at the Materials and Heat Treatment Laboratory, Mechanical Engineering Department, Faculty of Engineering, ABU, Zaria.

The results in fig.3a and 3b above indicated that the instrument used in the testing of the specimens were able to break the pieces of the cast and industrially made PVC jars at 9 joule, 11 joule and at 5.6KN and 6.8KN respectively.

By this result therefore, there is an indication that no amount of force or impact exerted by the tumbling of milling media in the jar would cause the jar to break. It is also an affirmation that PVC pipes are good materials for use as a container for mills used in the processing of ceramic materials.

Conclusion

The problem of this study is to develop a composite PVC jar for grinding, instead of the conventional porcelain jar for the processing of ceramic raw materials. The design and construction of the jar was given much attention based on the size proposed by the study. Materials used for the production of the jar were locally sourced including the equipment used for the melting of the PVC material impregnated with calcium carbonate as a filler.

The jar underwent series of test grindings. 2mm grains of 2kg of feldspartic materials and 2mm grains of 2kg of quartz materials, including 3kg batch of glaze was milled separately at different occasions to achieve fine particle sizes that passed through an 80 mesh seize.

The expensive and fragile 'imported' conventional porcelain jar which are rarely found in Nigerian markets; used for processing ceramic raw materials, could be replaced by a jar made up of PVC material.

A functional and durable jar can be made from a matrix of composite materials involving PVC and conventional ceramic powders, provided that appropriate batch formulation is adopted.

REFERENCES

Askeland, D.R (1984): The Science and Engineering of Materials. 2nd ed. Chapman and Hall. http://www.elsevier.com/wps/find/journaldescription.cws_home/405943?generat=true Accessed 15 August, 2012.

Bazunu, H.U.M. and Odokuma, E.(2008): Designing and Production of a Wheel Trough Using Thixotropic Polyester for Locally Fabricated Throwing Wheels. Ashakwu Journal of Ceramics. Vol.5. Pp 24- 30.

Carlströme, E. (2009) Novel Ceramic Processing Methods Using Responsive Polymers: Engineering Materials: Trans Tech Publications, Aedermannsdorf, 2nd edition, pp 27-34.www.wiley.com/college/**callister**/0471135763/.../solutions.pdf Accessed Nov. 16, 2011.

Casino, V. (2008): Melting Temperature of PVC.http://en.wikipedia.org/wiki/Polyvinyl_chloride. Accessed 7 January, 2012.

Datiri, Y.C. (1998): Design, Fabrication and Operation of a Model Diesel Oil Burner.(An Additional Option to Ceramic Firing Techniques). Unpublished Post-graduate. Thesis submitted to the Department of Industrial Design, Faculty of Environmental Design, ABU. Zaria. P1.

Eweka, K.J. (2009): Fabrication of Waste Engine Oil Burner: Trends and Challenges in Nigerian Pottery Industry. Ashakwu: Journal of Ceramics, Vol:6.Pp. 48-56.

Ewule, J. (1988): Development of a Model Gas Kiln for Ceramic Production from Local Resources:

Unpublished Post-graduate Thesis Submitted to the Department of Industrial Design, Faculty of Environmental Design, ABU. Zaria.

Henrik, N. and James, D. (1991): Glazes for the Self-Reliant Potter: Digitalfire Ceramics Technical Articles Deutsches Publication, Germany. Pp 55-59.www.gate-international.org/documents/.../pdfs/g16foe.pdf Accessed October, 2011.

Rhinehart, H. And Wiston (2008): Introduction To Research Methodology. Third Edition. Africana-FEP Publishers Limited. Ibadan, Nigeria. Pp 39-40 www.scribd.com/.../Lect-1-Meaning-and-Charateristics Accessed 15 June 2012

Sullayman, U.A. (1991): The Utilization of Local Raw Materials for the Production of Marble Wares Using the Jigger-jolly Techniques: Unpublished Post-graduate Thesis Submitted to the Department of Industrial Design, Faculty of Environmental Design, ABU. Zaria. P3.

Xiao, X. and Leach, M. (2005) Intermediate and High Strain Rate Tensile Testing of Plastic Materials, in: Proceedings of the Society of Experimental Mechanics (SEM) Annual meeting.

http://www.sciencedirect.com/science/article/pii Accessed 24 July. 2012.