PRODUCTION OF KILN FURNITURE USING LOCALLY SOURCED MATERIALS

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Abstract
This study focused on the production of refractory kiln shelves and props in order words call kiln furniture; using local raw materials, sourced from Federal University of Technology Yola (FUTY), Adamawa State and Alkaleri in Gombe State of Nigeria. Some clay and refractory samples were identified, collected, from FUTY Adamawa state and Gombe State. The samples were crushed, pulverised and sieved before production. Three different bodies were compounded for the shelves and a single body for the props. These were used in the production of a number of kiln furniture. The furniture were dried and fired at about 1280°C. The results reveal that, this furniture possess the qualities of a good refractory material like resistance to heat, thermal shock, corrosive liquid, forces of abrasion etc. The results also prove that there lay much potential in the abundant local material left untapped at the expenses of importation of foreign materials. At last production cycle has been made possible.

Introduction
The kiln is one amongst the potter's most important piece of equipment; Cardew (1969) stated that no ceramic manufacturing is completed without being subjected to heat treatment to a very high temperature in a refractory kiln chamber. Firing or heat treatment is a key process in the manufacture of ceramic products, as it controls many important properties of the finished wares. These include mechanical strength, abrasion resistance, dimensional stability, resistance to water & chemical, and heat. Most kilns are intermittent, continuous or rotary in nature. Insulated bricks and kiln furniture or accessories are made of either kaolin, fireclay etc. These are used as base of the kiln & supports to stacks the wares inside the kiln chamber, these bricks and furniture are known as refractory because of their resistance to heat and other factors.

Robert (2011) and Jnevins (2012) advanced that a kiln is a device or furnace similar to an oven that is powered by electricity, wood, fuel, oil or gas. Its purpose is to fire, or bake, pieces of pottery, porcelain and for fusing glass. Kilns produce the high temperatures necessary to finish the items placed in them. General heat work is possible in the kiln by introducing such through the fire box. The flame hits the bagwall and is deflected from the ware to a right direction for proper circulation in the kiln chamber before existing through the chimney.

Thomas (2010) established that clay based ceramics undergo gradual heating to remove structural water; this heating also decompose and burn off organic binder used in forming and to achieve consolidation of the wares. Kiln cannot be without the kiln furniture. When firing ceramic ware it is necessary to support them on rigid bases of some kind and in the case of glazed ware, they must be out of contact with adjacent pieces this is possible with the availability of kiln furniture.

Jnevins (ibid) and Peterson (1995) define kiln furniture as refractory slabs (shelves), posts, and sitters for stacking or supporting ware in the kiln for firing. He also mention that shelves, posts and other accessories for stacking kiln can be improvised from

refractory, broken shelves, old pot as support, these material can constitute a good body. For any body system to be of practical interest, its components must be available in sufficient quality at the right level of cost. Three types of material are usually used: clay, flux, and filler. All these materials must be free from intolerable impurities, and must give an acceptable colour when fired, (Dinsdale 1986).

Nature and Uses of Kiln Furniture

Frank and Janet (1991) are of the view that the materials which shelves are made from determine their life and weight which they will support. Normally a large shelve which spans a wide space and carries a heavy weight of ware needs to be stronger than the small shelve carrying light ware. The materials are also usually high in alumina and silimanite is over 60% alumina; mullite is over 70% alumina and fluxed alumina is over 90% alumina. All these materials are strong and have good thermal shock resistance which is use in fast fire kiln.

Chesti (1986), define refractories as materials that are "hard to fuse" and classified them as materials that can withstand very high temperature, resist the action of corrosive liquids and can also withstand thermal stresses. Refractory materials are used in linings for furnaces, kilns, Incinerators and reactors. They are also used to make crucibles. http://www.pottery.about.com/od/potterykilns/tp/kilnshelf.htm, Bailey and Walker (2012) advanced that kiln shelves made from high refractory material are in different categories:

- Dry-pressed high-alumina shelves: are tougher and last longer than slip-cast high-alumina shelves. Generally speaking, high-alumina shelves are best used in electric kilns and not use for raku, salt, or wood firings. "Dry-Pressing" creates an extremely dense internal structure that in itself gives strength and resists warping.
- Slip-cast high alumina shelves: are of low quality, it yields a weaker, more open inner structure susceptible to deformation under heavy loads and at high temperatures.
- Silicon carbide shelves: is a conductor and strongly recommends they *never* be used in electric kilns. If silicon carbide shelves are used in an electric kiln, the kiln should be disconnected to all power before the shelves are placed or removed.
- Cordiorite shelves: are for use up to cone 10 firing with minimal distortion under proper loading and usage. This enables Cordiorite to withstand a very large number of firing cycles. Cordiorite shelves specifically are developed to withstand the demanding variety of conditions in the Ceramic field. These refractories are suitable for temperatures up to 1300°C and will give long service life with a minimum of bending. It has a proven property of low thermal expansion is an extremely important characteristic of fast firing cycles etc.

Over the past several years, a number of new kiln furniture systems have appeared on the market. At least three of these are lightweight system; a non-stick ceramic body; and a process for producing low thermal mass, high strength kiln furniture. These new systems are increasing energy efficiency, reducing production time and improving the overall manufacturing process for ceramic manufacturers around the world. (Grahl 2001)

The challenges faced from local production of durable kiln furniture which are not comparable to the imported ones, are in the production of the furniture which are made below standard. Most of the kiln furniture produced are not durable, owing to the materials used which are not properly prepared before used. Another issue is lack of requisite technology or equipment to produce such furniture these made them difficult to compete favourably with the imported ones.

Kiln furniture is made of refractory materials that has high melting point. This can maintain its structural properties, high thermal shock resistance, high creep resistance and good mechanical strength at a very high temperature, which are the essential properties for good kiln furniture. Kaolin as a primary clay possesses most of the properties mentioned above. It is important therefore, that kaolin as well with other

materials can be used to produce standard kiln furniture with standard laid down procedures. If this is true then the local materials can be well maximized, to meet the demand in kiln furniture supply. This is because most of these materials are available in large deposit within many states of the federation and Adamawa State inclusive fig 1-3 and Table 1.

It is crucial to note that modern methods of firing require kiln furniture such as shelves, props, spurs, stilts production and are meant for maximum output. Shelve and props are inevitable support or accessories for kiln towards a successful glaze firing. They have numerous uses. Saint-Gobain (2005) advanced some of the under-listed as uses or inevitabilities of kiln furniture:

- Kiln shelves can help a designer or potter take his talent to the next level by motivating to create art forms like never before.
- Kiln furniture because of low mass and high thermal conductivity result in shorter firing cycles helping to save energy, improve productivity and reduce overall firing costs.
- Kiln furniture are used in the production of commercial and manufactured clay bodies including low fire ware, tile stoneware and porcelain.
- Kiln furniture support heavy loads with minimal mass, it is safer and easier to stack/unstack loads. It supports heavy loads without warping.
- It is glaze resistant and it has faster heat transfer (reduced energy consumption). This in the end increases productivity.
- Furniture in the kiln also gives wares stability and creates several compartments to stack wares.

Parago (2006), Walker (2012) and Jnevins (2012) affirms that, there are different factors that determine the life and characteristics of kiln furniture apart from the material of production these are: low density results in lower proportion of heat absorption by furniture, no expansion or shrinkage, extremely rapid or uneven temperature changes are problematic to any refractory, in storage and kiln wash-moisture can cause shelves to crack or even to explode inside the kiln and kiln wash done well also increase the life or the furniture. Kiln wash is a refractory coating– mixture of Kaolin, flint and water; it is painted on one side of the kiln shelves to separate any glaze drips from the shelf. More, for longest shelf life, “3-post” are recommended for use on shelves. A 3-post configuration is the most stable support insuring even shelf weight distribution to eliminate “rocking” during firing. In addition, shelves should be “rotated” on a regular schedule. To properly “rotate” a shelf, it must be flipped and turned so that the kiln posts touch on the same positions but on the opposite side of the shelf. This will fully reverse firing stresses and warpage and lengthen the life of shelf. Most shelves will ultimately bend if heavily loaded and used at high temperatures; where conditions of reduction are experienced the shelf may bend more quickly.

Like glass sheets, all kiln shelves last if stored on their edges. Flat storage makes it more likely that they will break or develop stress cracks. Infinitesimal cracking in the shelf during storage may result in catastrophic failure of the shelf during firing. Kiln shelves are important items that will help maximize the space inside the kiln. They should be stored on their side - standing vertical. This will extending their usable life and prevents damage from improper stacking. This research tries to identify some of the refractory materials within Yola and others outside the University that are available and employed for the production of kiln furniture.

Materials and Method

The population of study chosen for this research is Yola, the Adamawa State capital. This is because Yola is endowed with minerals resources that can effectively serve the purpose of this research; more to that, kiln furniture are in short supply in the Ceramic Section Department of Industrial Design FUTY. The methodology used in this research was the empirical method starting with identification and collection of raw materials; secondary clay and secondary grog, both sourced from FUTY and the primary clay (Kaolin) from Alkaleri, Gombe State.

The three refractory materials were sourced and prepared. These were prepared and blended in three different proportions, the variations is necessary so as to have different mixture or body that can be used and for selectivity. The chemical composition and suitability of the materials had been previously established in a research carried out by Morakinyo et al (2010). The three body compositions/materials proportions before the production are given below:

Recipes and Materials used for the Shelves and Props

The recipes were basically compounded by the researchers but, adopted the percentage ratio of (Ayodele, 2014). In other words his recipe was not used but only substituted his materials for ours.

I. Shelves Recipes:

Sample A

Alkaleri kaolin	70%
Secondary clay from FUTY	15%
Refractory grog	5%

Sample B

Broken shelves grog	55%
Alkaleri Kaolin	25%
Finest grog 80 mesh	15%
Ball clay from FUTY	5%

Sample C

Broken shelves grog	20%
Alkaleri Kaolin	60%
Finest grog 80 mesh	10%
Ball clay from FUTY	10%

II. Props Recipes:

1. 70% kaolin (Alkaleri clay)
2. 15% secondary clay
3. 15% fine sieved refractory grog
4. Diesel oil or used black engine oil for a lubricant
5. Extruding kit. This is made up of a barrel, a ramming upright pipe and a base stand.

Mixture and Production Processes

A concrete floor or a wide strong platform which consist of a level, hard and non-absorbent floor was used for mixing of materials. This prevents variation in the mixtures, moisture content, and the picking up of extraneous material. The raw kaolin and levigated secondary clay were first measured and mixed thoroughly with water into a slip/slurry. After that the grog was also added to the mixture. The mixture was gathered and covered with a polythene sheet. It is left to aged or cure in other word mature between 3 to 7days.

In the production of the shelves the inner part of the frame (See Figure 4) was greased with oil to prevent material sticking, or the inside lined with strips of polythene. (The frame size used was 4cm x 45cm x 30cm). The body was poured and beaten into or rammed hard using the rammer into the shelf metal frame Plate I. The frame was unbolted, and the shelf pulled off. This was repeated severally to get desired numbers of shelves. The Moulded shelves were kept for complete drying Plates I - IV. The drying was kept at a minimum rate so as to avoid higher shrinkage and cracking formation.

The productions of the props were similar with the shelves. The materials were mixed and left to aged. The barrel is mounted on the base stand and the body fed into it. The body was compressed within the barrel pipe by the use of the upright pipe Fig. 5. The rammed pipe is removed from the base stand; leaving the iron hooked to the material in the barrel pipe. The barrel is pushed downward as the extruded prop is exposed; this is taking off and put aside to dry. This process was also repeated to get desired numbers of props Plates IV- VIII.

After production the furniture were left to completely dry before they were packed into the kiln and fired at (1280°C) made ready for used Plates I - VIII. The furniture were fired to this temperature because that is the most highest temperature the kiln can attained, otherwise any beyond that can affect the life of the kiln.

Thickness of Kiln Shelves

The thickness and side of slabs depend on the quality of the raw materials, on the firing temperature and much more the side size of the shelve frame. The higher the temperature, the thicker the slabs need to be to carry load without bending. They slabs after production measured 45 x 30 cm then before drying have a thickness of 3-4 cm.

Simple Observational Test

The shelves were observed after the firing on the following parameters: Abrasion, thermal shock, and resistance to heat.

The shelves were observed in terms of reaction to heat introduce from start to the finish of the firing, none shattered in terms of reaction to the application of heat. Usually shelves bodies shatter or break apart when they can't withstand the thermal shock while undergoing firing in the kiln; this as a result of moist or wrong storage of shelves and etc. Thermal shock is stress caused by temperature changes or stress in a material caused by rapid changes in temperature, often resulting in fractures and crackles (Redmond, 2009).

Secondly, in terms of heat resistance, when the furniture where fired at 1280^0C this did not affect the shelves. That is, none bend nor warped after firing. Thorsen (2008) opines that the sensation of warmth or coldness of a substance on contact is determined by the property known as temperature. Whereas it is easy to compare the relative temperatures of two substances by the sense of touch, it is impossible to evaluate the absolute magnitude of the temperatures by subjective reactions. Adding heat to a substance, however, not only raises its temperature, causing it to impart a more acute sensation of warmth, but also produces alterations in several physical properties, which may be measured with precision. As the temperature varies, a substance expands or contracts, its resistance to changes. The variation in a standard property usually serves as a basis for an accurate numerical temperature scale.

Thirdly, on a simple test of abrasion or reaction to wear the furniture were robbed against each other and also bisques wares were used as medium to determine the scratch resistance. This also was positive, in that the furniture resisted to a large extent. Abrasion is the wearing away, the process of wearing away by friction or scratch. Ceramics bodies are less dense than most metals; as a result, a light ceramic part may be just as strong as a heavier metal part and thus, are also extremely hard, resisting wear and abrasion (Redmond, 2009).

Results and Discussions

Result of Shelves Mixture and Production

The mixtures for both the props and the shelves which constitute the furniture on this research were left to age between 3 to 7 days. During the production some of the mixtures were soft and had to be exposed for the moisture content to evaporate before production. Soundly, to say the production was successful. None of the three mixtures for the shelves and that of the props fail. A satisfying result was obtained. Results from the production proved that the existence of similar elements found in naturally occurred material mixtures contain compounds that are compatible with each other as ceramic refractory materials. This made them behave almost alike.

Result from the studio experiment showed that the refractory materials from Yola and Alkaleri can be used in production of kiln furniture on an industrial scale. These, from physical observation maintain their structural properties, high thermal shock resistance, high creep resistance and good mechanical strength at a very high temperature, which are the essential properties for good kiln furniture. In line with the properties displayed, this can help in meeting the local demand in kiln furniture supply.

The props and shelves were used to stack glaze wares for the first time it was successful. The second firing saw some of them develop faults especially the shelves. This suggests that some improvement in the material composition need be done so as to have better results. This is actually a success because since the existence of the department this is the first time a research of this magnitude is being carried out by a graduating student. Most of the furniture used in the past were purchased from the Ceramic Section, Department of Industrial Design Ahmadu Bello University, Zaria. From this research a data is now available which other researchers both students and staff can utilized in making better stride in future furniture production.

At last production cycle has been made possible by the production of these kiln furniture in the department of industrial design FUTY. From our discoveries Kiln shelves can help and has now make FUTY

designers or potters take their talents to the next level by a motivation to create art forms like never before. Kiln furniture because of low mass and high thermal conductivity result in shorter firing cycles helping to save energy, improve productivity and reduce overall firing costs. Kiln furniture support heavy loads with minimal mass, it is now safer and easier to stack/unstock loads. This in the end increases productivity. Furniture in the kiln also gives wares stability and creates several compartments to stack wares. Today glaze ware can be comfortably stacked without any remorse unlike before.

Utilization of indigenous or local materials can save foreign exchange spent on such product and this in turn generates income. Because dependence on foreign materials also results in a low utilization of available local resources in industrial processes and it militates against the internal development of the indigenous raw materials and indigenous creative skills and technology.

Drawback from Research Experiment

Lack of jaw crusher appears to be a major drawback in working with the bodies. All the materials had to be crushed in a wooden mortar manually. This was very rigorous, energy consuming, time wasting and not having desired grain sizes of both the primary and the secondary grogs. The period was just too short given the scenario of a graduating student who just had few months to carry out this research couple with other courses and level demand.

Summary and Conclusion

It has become obvious going by the series of experiment undertaken, that refractory materials from Yola and Alkaleri can be collected and utilized as sources of materials (refractories) for kiln furniture. These bodies blended very well with natural clay and became an interesting medium in producing ceramics kiln furniture with good qualities. These satisfy the qualities of a good refractory material that has a high melting temperature, resistant to heat, thermal shock, corrosive liquid, forces of abrasion etc. from observation.

It is crucial that modern methods of firing require kiln furniture such as shelves, props, spurs, stilts production and are meant for maximum output. Shelve and props are inevitable support or accessories for kiln towards a successful glaze firing. The refractory qualities possessed by this material have definitely made possible the production cycle in ceramic production.

It was also established that an undergraduate project under a good supervision can solve or tackled the many problems of Ceramic Section. This conclusion was reached due to the previous attitude on supervision of students' project. Such attitude has made student produce just anything that have no consequence in terms of quality and service delivery or functional expectation of a design piece as Designers.

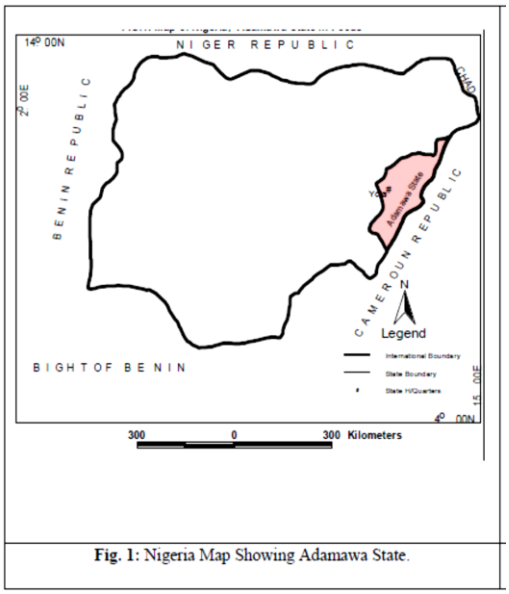

Fig. 1: Nigeria Map Showing Adamawa State.

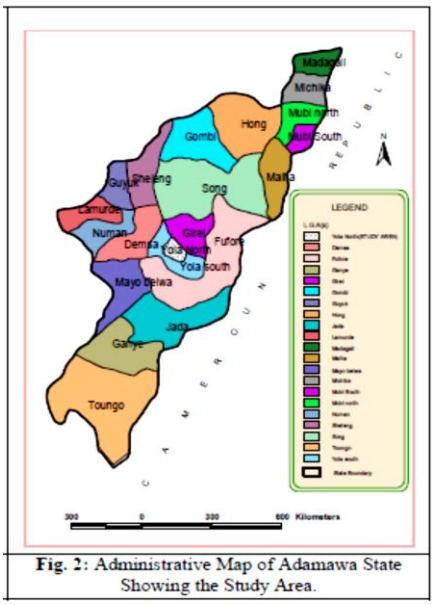

Fig. 2: Administrative Map of Adamawa State Showing the Study Area.

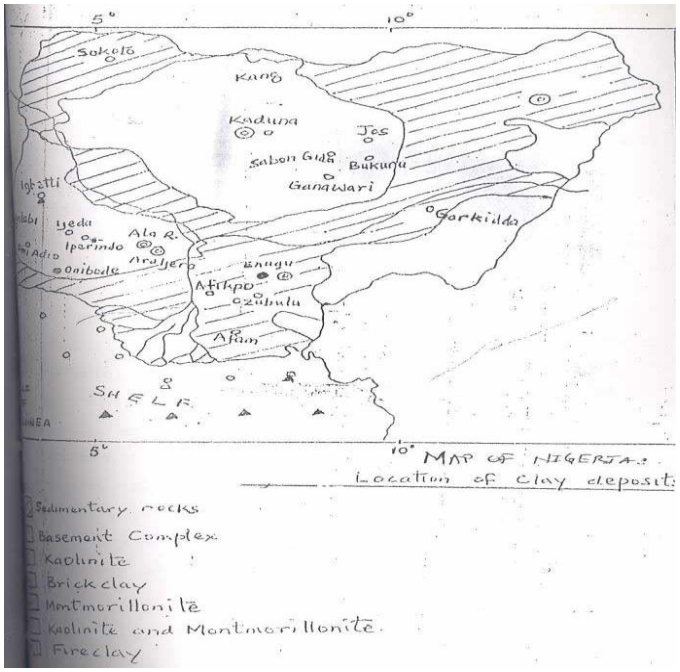

Figure 3: Map of Nigeria indicating locations of clay deposits Source: Saidu (2001)

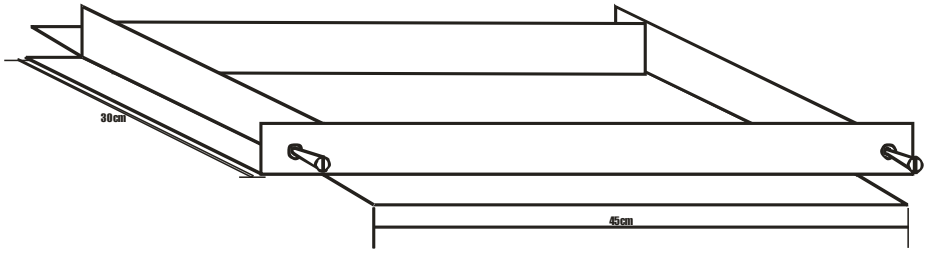

Figure 4: Shelve Mould

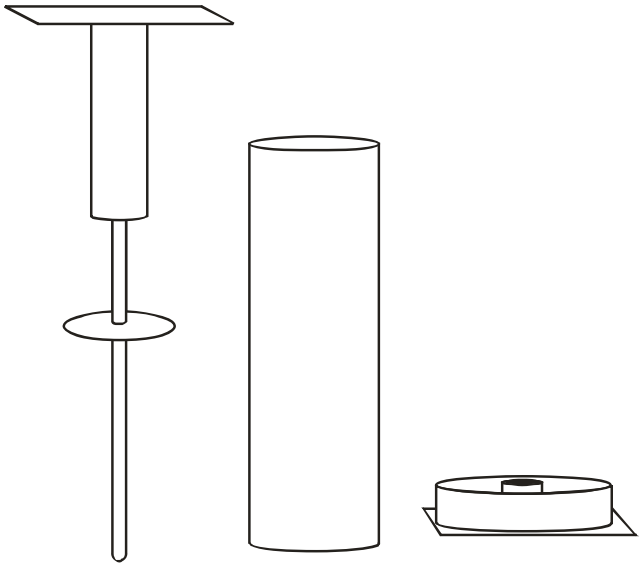

Figure 5: Prop Hand Extruder



Plate 1: Moulding the Shelves



Plate II: Unbolting Moulded shelf



Plate III: Pulling off the frame from a Moulded shelf



Plate IV: Drying of Moulded shelves



Plate V: Props frame ready for moulding



Plate VI: Compression of body into the prop's mould



Plate VII: Removal of moulded prop from mould



Plate VIII: Samples of moulded props

Table 2: Mineral Deposits in Adamawa State.

S/No	Minerals	Location (LGA)	Major Industrial Uses
1	Clay	Mubi, Garkida, Numan, Girei, Ganye, Gombi	Ceramics, Chalk burnt bricks etc.
2	Limestone, Clay	Numan, Guyuk & Lamurde	Cement, ceramics, Lime fluke stone, filter
3	Gypsum	Numan, Guyuk & Lamurde	Cement processing, ceiling board etc.
4	Bentonite	Guyuk	Drilling mud in oil Industry, fertilizer,
5	Trona	Song	Glass, soap & chemicals industries caustic soda, water treatment pulp paper
6	Graphite	Fofure, Toungo, Ngurore	Manufacture of pencils
7	Feldspar	Maiha, Gerei	Ceramic industry, ornamentals
8	Magnesite	Gombi	Electrical installation
9	Barite	Ganye	Drilling of mud, manufacture of white
10	Cassiterite	Toungo	Tin and metallic coating
11	Coal	Numan	Source of energy
12	Uranium	Michika	Nuclear energy fuel, sources of Radium in
13	Mn, Pb, Zn,Cu, N03	Jimeta	Roofing sheets, Fertilizer, ceramic glazes

Note: Radioactive Potassic Feldspar, found is both the sedimentary and basement areas throughout the State.

Sources: Opeloye and Dio (1999); Ladi (2000); Federal Ministry of Solid Minerals Development (1999); Uyanga, (2000); Idama (2000) and Gambo, (2002).

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