

## Ceramic Charcoal Stove in a Mixed Media



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**ABSTRACT:** The acquisition of electric and gas stoves has been a difficult problem for most people in the rural places, hence most of them have resorted to wood for cooking. This has contributed to depletion of our forest and its attendant environmental consequences. This situation has made the researchers to attempt at looking for a way to reduce the amount of wood/charcoal used by designing a charcoal stove. This Ceramic Charcoal Stove was designed and built with locally obtained raw materials; locally composed low-density bricks and fired with a down-draught kiln at 800 degrees Celsius. The study also revealed that, once the charcoal in this stove is ignited, it could boil water at 6-7mins. This is a solution for conservation of charcoal used while cooking because some people are scared of using gas to cook because of its hazardous disadvantages while many others do not have money for refilling the gas cylinder and people who live in the rural area where there is no electric power supply, for electric stove. This solution has been found to have a high efficient heat maintenance property for cooking food and keeping the body warm is a welcomed development. This study is hoped to aid the in furtherance of academic research in this field and other related areas.

### 1. INTRODUCTION

#### 1.1 Background of the study

Many of the world's population living in developing countries lack access to modern energy services for economic and social development. Besides, its existing energy system is unsustainable (K.R Smith, 1993). A large proportion of the households do not have access to grid electricity. Yet, those relying on electricity for cooking experience intermittent power supply. Although liquid petroleum gas burns quite effectively, it is expensive and not viable for a common man. More so, there has been persistent escalating fossil oil prices and fuel crisis which has drawn attention to kerosene and gas for domestic cooking (Olorunsola, 1999). Solar, another potential alternative source of energy, is noticeably location-specific in terms of utilization. Its associated problems are linked to energy storage for use during the period of modest or no sunshine, as well as need for technological artifacts, which are currently scarce in the developing countries (Bolaji, 2005). However, several renewable energy resources including hydroelectricity, solar and biomass are promoted for their high availability and responsiveness to the environment.

In Africa, biomass is a traditional and most reliable fuel source of energy used for cooking by 69% of the population (Sawin, 2013). However, its increased utilization by inefficient technologies has raised fears over the long-term forest degradation with the loss of environmental services (such as, watershed protection and biodiversity (ESMAP, 2011). Biomass burn completely in the most commonly used traditional household sized stoves (WEO, 2006).

Frequent use of stoves developed by improper combustion designs may result into indoor air pollution, impacting negatively on the health of household members, particularly women and children. For instance, Nahar (2016) reported that about two million annual excess deaths of women and children in developing countries are linked to indoor air pollution, precisely due to exposure to carbon monoxide and the volatiles (benzene and formaldehyde) liberated in the form of smoke. Such exposures lead to acute respiratory infections, low birth weights, lung cancer, and chronic obstructive lung diseases and eyes problems. Thus, faster technological development is vital in advancing charcoal stove and its environmental performance.

#### 1.2 Statement of the Problem

Over the years, one of the earliest discoveries of man to sustain its life is fire. Without fire, there would be no warmth and no cooking, and through this course, different inventions of stove have been made to sustain man. But most of these efforts come with various disadvantages especially to the health. Also, a low-class man cannot even afford them hence they make use of the

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metal stove which can easily afford. The use of water to put off the fire, the rusting of the metals, the heat it causes and the dangerous smokes emitting from the rusted iron and the smokes reminds them of spending more to purchase another stove for sustainability.

### 1.3 Objectives of the Study

This study is aimed at developing a mixed media Charcoal burning Stove. The aim of this study will be achieved through the following objectives

- To develop a fast/easy cooking stove: due to the radiation sent through the ceramic materials, this type of stove tends to burn faster, and it is less costly to use.
- To develop a safer mode of cooking and to access the losses due to the nature of the stove.

### 1.4 Justification of the proposed problem

For the previous years, there have been serious studies on the different types of cooking stoves that can be used and it will not at least cause much hazard to its owner. Different types of cooking processes like using firewood, metal frustum stove, gas, electric stove has been manufactured but it still doesn't give the owners what they really require because in one way or the other, the stove comes with different issues. This study concerning stoves has proven not efficient enough to keep cook/properties, health safe from destruction or disaster.

Hence, the result of this study will produce at least a good stove that will guarantee man's safety from accidents and will not pose any health hazard.

This study will equally help people be able to manage and spend less on cooking.

### 1.5 Scope of Study

This study is limited to using clay, sawdust and metal to produce a charcoal stove in a mixed media form. Putting the materials together, and getting them to be a new means of cooking and introducing it to the public.

### 1.6 Limitation of the Problem

A comprehensive study of the ceramic charcoal stove cannot be completely conducted successfully without incurring huge financial implications. Reasons are; for the work to end in success, it must be fired to a desired temperature. Also, it took lots of time and money from the side of the researcher in order to obtain primary and secondary materials.

## 2.0 OVERVIEW

A kitchen stove (according to Oxford University Press. Retrieved 28th March 2012) often called simply a stove or a cooker is a kitchen appliance designed for the purpose of cooking food. Kitchen stove relies on the application of direct heat for the cooking process and many also contain an oven used for baking.

"Cook stoves" (also called cooking stoves or wooden stoves) are heated by burning woods or charcoal, gas stoves are heated by gas, electric stoves by electricity, while ceramic charcoal stoves will be heated by charcoal. A stove with built-in cook top is also called Range.

In the industrialized world, as stoves replaced open fires and braziers as a source of more efficient and reliable heating, models were developed that could also be used for cooking and these came to be known as kitchen stove .

The fuel burning stove is the most basic design of kitchen stove. Nearly half of the people in the world (mainly in the developing world), burns biomass (wood, charcoal, crop residue and dung) and coal in rudimentary cook stoves or open fires to cook their food. More fuel efficient and environmentally sound biomass cook stoves are being developed for use there.

Natural gas and electric stoves are the most common today in western countries. Both are equally effective and safe, and the choice between the two is largely a matter of personal preference and pre-existing utility outlets. If a house has no gas supply, adding one just to be able to run a gas stove is an expensive enterprise.

Modern kitchen stoves often have a stovetop or cook stove (American English) known as hob in British English as well as an Oven. A "drop-in-range" is a combination stove top and oven unit that installs in a kitchen lower cabinet flush with the countertop. Most modern stoves come in a unit built-in extractor hood. Professional chefs often prefer gas stovetops, for they allow them to control the heat more finely and more quickly. Today's major brand offer both gas and electric stoves and many also offer dual-fuel ranges combining a gas stove top and electric oven (Clean Cook top Research –Air research-Feb 2013. Retrieved 14<sup>th</sup> April 2018) Wikipedia Ceramic charcoal stoves are designed and constructed to house heat in charcoal that may originated through the combustion of charcoal. They are usually built with materials of earth origin that are resistant to heat and will behave as insulators impeding heat transfer through the stove wall by conduction. The stove as a facility used in ceramics has undergone immense development and this has been reviewed in the literature related to this study.

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### 2.1 History and Development Of Stove

The history of kitchen stove in Europe began in the 18<sup>th</sup> century. People cooked in open fires fuelled by woods prior to that time, on the ground or on low masonry constructions. Waist-high brick and mortar hearths and the first chimneys appeared in the middle ages, so that cooks no longer had to kneel or sit to attend to the foods on fire. Cooking was effected principally on cauldrons hung above the fire or placed on trivets. The heat control was affected by placing the cauldrons higher or lower above the fire. (Usman Ojonimi 2011, Wikipedia)

Three major disadvantages of open fire that prompted inventors as far back as 16<sup>th</sup> century to device improvements are: it is dangerous; it produces much smoke and has poor thermal efficiency. Attempts were made to enclose the fire to make better use of the heat that is generated and thus reduce the wood consumption. A first step was the fire chamber; the fire was enclosed on three sides by bricks-and-mortar walls and covered by an iron plate (Usman Ojonimi 2011, Wikipedia)

This technique also caused a change in the kitchen ware used for cooking, for it required flat-bottomed pots instead of caldrons. Only in the year 1735 did the first design that completely enclosed the fire appeared; the Castrol/stove of the French architect Francois Cuvillies was a masonry construction with several fire holes covered by perforated iron plates. It is also called stew stove. Near the end of the 18<sup>th</sup> century, the design was refined by hanging the pots in holes through the top iron plate, thus improving heat efficiency even more.

The growth of American coal and iron mining in the 1820s made cast into the wonder materials of the 19<sup>th</sup> century and led to a prolific industry in making stoves for cooking as well as heating. Cast irons could take the repeated temperature swings of hot and cold; and it was an ideal medium for casting into complex prefabricated parts as well as for decorative surface ornaments. Early metal stoves imported in large numbers from Holland and England came in variety of boxy designs, but by the 1840's a number of basic stove types-used for laundry, heating and cooking have been worked out and were being manufactured widely in America (Wikipedia, 2006)

### 2.2 Types of Stoves

#### Gas

Other types of stoves are fuelled by gas and electricity. The first gas stoves were developed already in the 1820s but they were not widely used (James Sharp in Northampton, England, patented a gas stove in 1826 and opened a gas stove factory in 1836). At the World fair in London in 1851, a gas stove was shown but only in 1880s did this technology start to become a commercial success. The main reason for this delay was the slow growth not gas pipe network.

Gas stoves became more wildly when the oven was integrated into the base and the size was reduced to better fit in with the rest of the kitchen furniture. By the 1910s, producers started to enamel their gas stoves for easier cleaning. Ignition of the gas was originally by match and this was followed by the more convenient pilot light. The gas stove technology underwent further development until the invention in 1922 of a high-end gas stove called AGA Cooker by Swedish Nobel Prize winner GUSTAF DALEN. This stove is considered to be the most efficient design and is a much sought after kitchen "must have" in certain circles despite the hefty price tag. In the third world countries, domestic gas stove application is hunted by high cost and inadequate supply of gas. ([www.en.wikipedia.org/wiki/stove.2006](http://www.en.wikipedia.org/wiki/stove.2006))

#### Electric Stove

Thomas Ahearn, in 1892, invented a device he probably employed in preparing a meal for an Ottama hotel that year which is "ELECTRIC STOVE". It was one of a kind and was installed in the Windsor Hotel in Monstreal. The electric stove was showcased at Chicago World's fair in 1893, where an electrified model kitchen was shown. Unlike the gas stove, the electrical stove was slow to catch on, partly due to the unfamiliar technology, and the need for cities and towns to be electrified. By the 1930s, the technology had matured and the electrical stove slowly began to replace the gas stove, especially in household kitchen. The electric stove technology has developed in several successive generations resulting in the emergence of resistor heating coils (which heated iron hotplates), glass ceramic cook tops and induction stoves. The spread of electric stove is underdeveloped countries are slow because many towns and villages are not electrified. Also many in the underdeveloped countries are living below the poverty line, so they cannot afford this improved efficient stove. (Canada Science and Technology Museum. Retrieved October, 2011)

### 2.3 Franklin stove

The Franklin stove is a metal-lined fireplace named after Benjamin Franklin, who invented it in 1741. It had a hollow baffle near the rear (to transfer more heat from the fire to a room's air) and relied on an "invented siphon" to draw the fire's hot fumes around the baffle. It was intended to produce more heat and less smoke than an ordinary fireplace, but it achieved few sales until it was improved by David Rittenhouse. It is also known as a "circulating stove" or the "Pennsylvania Fireplace."

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### 2.4 Design and Construction

All stoves operate through the release of heat energy and this must be achieved by the combustion of fuel except electric stove. Rhodes (1977) said that except for the problem of supporting the element there is no great construction difficulty involved in building an electric Appliance.

### 2.5 Methods of Stove Construction

In this type of stove, it has a special way in which it is constructed just like a kiln. It undergoes the same processes bricks for kiln go through for it to be used. Starting from the mixture of clay and sawdust.

There are rules that must be followed to ensure a strong monolithic structure that will function efficiently and be durable. Olsen (2001) says that there are three vital rules in straight wall construction. Curved walls are going to be used in the construction because they are stronger and more durable and stable than straight walls. The curves create a wedging action, which keeps the bricks from falling inward. The only limiting factor on height is the compression of the bottom bricks. Olsen explained that domes can be cast to attain maximum strength.

### 2.6 Heat Retention in Ceramic Stove

Rhodes (1968) said insulating bricks are very important when it comes to housing of heat energy for the heating of wares. He explained that clays are mixed into heavy slip in which air bubbles are induced by chemical means. When the materials is set and dried, it is fired and then cut and shaped into sized bricks. The entrapped air pockets make a light, porous brick with high insulating properties and this he said has excellent heat resistance properties. Steiner et al (2008) also said porous bricks with insulating properties can be produced by the introduction of combustible materials like saw dusts into clay, and when dried and fired, the sawdust burns off leaving air pockets in the fired body that make the brick light and porous. This gives it poor heat conductivity properties and corresponding higher heat retention ability when used in constructing ceramic and electric stoves.

### 2.7 Clay

According to Peterson and Peterson (2003:131) "Clay has been continuously forming for millions of years as alteration products from originally igneous rocks such as granite. Physical and chemical actions of Wind, rain and erosion, and gases cause the continuous decomposition of rocks into clay". They argue that as long as the earth exists, clay is being formed. And chemically, it is a hydrous of aluminum silicate with the formula  $Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$ .

Korankye and Oteng (2008) agreed with chapel (1979) In saying that, Clay is an earthly material substance, composed of a hydrous silicate of alumina which becomes plastic when wet, hard and rock-like when fired. Rhodes (1957) also says that clay is a temperamental material and it is abundant and cheap, easily acquired and prepared. Norton (1956) says clay is made up of tiny crystals, many of them so small that they cannot be seen under the highest power of an ordinary microscope. He further opined that clay is a secondary product in the earth and that it results from decomposition by weathering of older rocks of the feldspar type. Korankye and Oteng (2008) further agreed with Norton (1956), in saying that clay is a product of geologic weathering of the surface of the earth. It is an end product of the weathering of rocks, the principal being feldspar. In handling meaning and scope of ceramics, Korankye and Oteng (2008) said, some ceramic products are useful in construction of bricks, and some clay are designed and composed to withstand very high temperature and these they described as insulating bricks under refractories.

#### 2.7.1 Clay Bodies

The adoption and composition of earth materials to attain a specific property in clay is termed clay body composition. This is done in most cases to adjust a base clay material to respond to particular thermal response, or to attain properties that are lacking in the base materials. Rhodes (1968) concludes in defining clay body as a mixture of clay(s) or clay and other materials or mineral substances which are blended together to achieve a specific ceramic purpose. In this process, Kwakume (2010) said that the researcher composing the body must have adequate knowledge of the materials in the event of disorders. This information was found to be very relevant for this study and it was the bases for the composition of the heat retention bricks for the construction of the stove. It is quite relevant the properties of the base materials be looked at in terms of its physical behavior.

#### 2.7.2 Physical Properties of Clay

Clay, an earth material has properties that aid in identifying it as clay and it has qualities that make it behave in peculiar way confirming it as clay suitable for specific ceramic purposes or not. Every earth material that is said to be clay is identified on the basis of its mineralogical composition. All clay is said to be a product of geological degradation reducing feldspathic rock into an earth material called clay. According to Speight and Toki (1999) this feldspar, alkaline, silica and alumina as its main components, and these are reduced to alumina silicates by glacial activity. After prolonged exposure to the environment, the alumina silicates combine with the humidity of the environment that this new material called clay differs from place due to the differences in the minerals present during the formation.

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Home (1953) however, said that almost all clays apart from kaolin have some level of plasticity, a physical property that allows for modeling and forming with the clay. There are factors that influence the plasticity of all clay. The particle size of the clay according to Rhodes (1968) is a determining factor of the plasticity. Speight and Toka (1999) explained that clays differ in their degree of plasticity. Some are so sticky, they are almost impossible to shape. Rhodes (1977) mentioned color as another physical property of clay that easily affects the clays thermal responses. He said that there are minerals that show their color only when the clay mineral has been exposed to heat. He explained these as metallic oxides that in some cases act as fluxes reducing the maturing temperature of the clay.

The plasticity of clay was found to be of critical importance in this study because it is this property that aids the binding of materials, especially in the case where non-plastic materials are involved. The property of plasticity is of primary importance where and when forming is concerned. Although the plasticity of the base material can be reduced by the introduction of non-plastic materials, proper control measures aid in arriving at an expected end. Almost all the clays available in the pottery villages are comparatively plastic.

### **3. METHODOLOGY**

This Methodology discusses the process of collecting data necessary for the study including the research design, primary and secondary data, population for the study, data collection and materials used in the study are also described. It chronologically dealt with the general procedure is executing the project.

#### **3.1 Research Design**

The qualitative research paradigm was used in this study. In this, the descriptive and experimental methods of research were adopted to collect data for the study. The descriptive research method was used to describe the entire project and the experimental research method was used for the formation of the low density body using Awka/Jos Clay and sawdust, and the designing and construction of the stove. Pre-experimental design was chosen for this project because it employs a single group and although it has a disadvantage of low validity; it is very practical and sets the stage for further research. For the purpose of this study, qualitative research method was adopted because it provided a systematic approach in unfolding the facts to determine the technique for the stove construction.

#### **3.2 Experimental Research**

An attempt was made by the researchers to maintain control over all factors that may affect the results of the experiment. In doing this, the researchers attempt to determine or predict what may occur. Experimental research employs different treatments and established their effects in the study. The outcome leads to clear interpretations of effects and findings. The general procedure is the description of the step by step approach by which the entire project was done.

#### **3.3 Descriptive Research**

Descriptive research on the other hand, describes data and characteristics about the population or phenomenon being studied. The idea of selecting descriptive research method was that, the procedures employed for carrying out the experiment needed to be described chronologically, to produce a very clear and detailed account of all occurrences pertaining to the project. Most quantitative research falls into two areas: studies that describe events and studies aimed at finding out "what is", so observational and survey methods are frequently used to collect descriptive data (Borg and Gall, 1996). Descriptive research involves gathering data that describes events and then organizes tabulates, depicts and describes the data collection.

#### **3.4 Research Population**

According to Fraenkel and Wallen (1996), a population is the group of interest to the researcher, the group to whom the researcher would like to generalize the results of the study. Orndorf and Leedy (2005), also states that qualitative researchers draw their data from many sources-not only from a variety of people, but perhaps also from objects, textual materials, and audio visual and electronic records.

#### **Sample Frame**

Sample frame is also referred to as source list according to Kothari (2007). It is the list of all items of universe (in case of finite universe only). Such a list should be comprehensive, reliable and appropriate. It must also be representative of the population as possible. The sampling frame includes:

Nafuta Clay from Jos

Red clay from Awka, Anambra State

Sawdust

Metal

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### **Sample Size**

This has to do with the number of items to be selected from the population. The sample collected for the study was of optimum size so as to fulfill the efficiency, reliability, flexibility and representativeness. The samples are powdery and therefore their nature makes counting impossible. However, various kilograms of these materials were prepared for this research.

### **Sampling Techniques**

Sample in the context of this study is a portion, piece or segment that is representative of a whole population. Leedy and Orndol (2005) have the view that, the particular entities a researcher selects is what is termed the sample, whereas the process of the selection is the sampling. After identifying the population, purposive sampling was employed to gather the information because Leedy and Orndol (2005) states further that, in purpose sampling, people or other units are chosen, as the name implies, for a particular purpose. The researchers therefore relied on purposive sampling technique to conduct the experiment.

### **3.5 Sources and Types of Data**

The data for this research were both Primary and Secondary Sources.

#### **Primary Data**

The Primary data for this study was clay, sawdust and stainless steel which were gotten from different sources. White clay was gotten from Jos, while Red Clay was gotten from Awka. The Sawdust was also from Awka (UNIZIK CERAMIC STUDIO). The materials (clay and sawdust) were sieved with mesh 200. The outcome of the work was fired to 800°C in a kiln provided by the school for proper documentation of result.

#### **Secondary Data**

Secondary data for this study was the existing literature, and the purpose is for the research to be well grounded with issues relating to the study areas. The secondary data comprised the entire literary materials sought, cited and used from books; articles published and unpublished thesis and others that are related to this study.

### **3.6 Data Collection Procedure**

Having collected the secondary data from documentary sources (books, publications, periodicals, charts, brochures and thesis) and reviewed the related literature, the researchers built a framework of the study and established the techniques applicable to the study and related tools and materials.

The researchers adopted face-to-face unstructured interview to collect data. The researchers also made calls to Enugu State, Ebonyi State and also Abuja to get good information.

#### **Data Plan Analysis**

After getting the needed information, the researcher then proceeded by preparing the clay body to experiment and test the suitability of the various body composition techniques for stove construction. The result was then analyzed to derive the findings and conclusions, and recommendations were finally drawn.

#### **General Procedure in Executing the Work**

- Design and production stages
- Introduction

The method adopted for the construction of the stove is basic. It is made simple to enable a lay person read, understand and follow the procedure in the construction of a similar stove.

This particular stove adopts local earthenware clay and sawdust in a deflocculated system to arrive at a product that is porous, low-density, has considerable heat retention properties, suitable for the construction of stoves that can retain heat to high temperatures.

In designing and constructing the stove, the researchers considered the entire project in stages; the designing stage, the low-density bricks formulation and production, and the metal frame to encase the bricks to form the stove.

### **3.7 Design**

According to David and Stephen (2008) design indeed means to plan, to organize.

They say design is inherent in the full range of art disciplines. Virtually the entire realm of two and three –dimensional human production involves design, whether consciously applied, well executed, or ill considered. Inferring from the explanation above, design necessitates planning to produce or achieve a purpose, and it forms the foundation of every work and provides a summary of a plan serving as a template for a work to be executed.

The design of the ceramic stove was started by making preliminary sketches. One of the sketches was chosen and with the aid of CorelDraw, the stove was designed in three dimensional format.

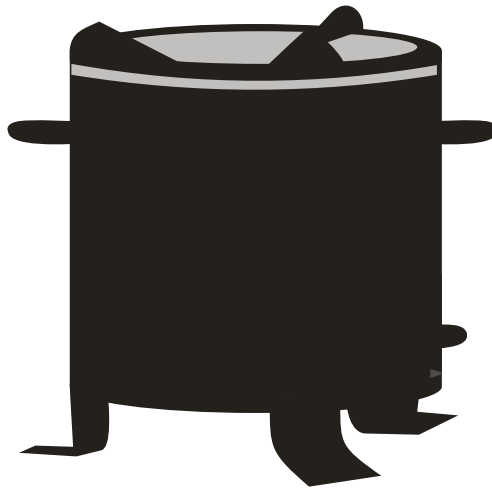


Plate 1: Stove shape

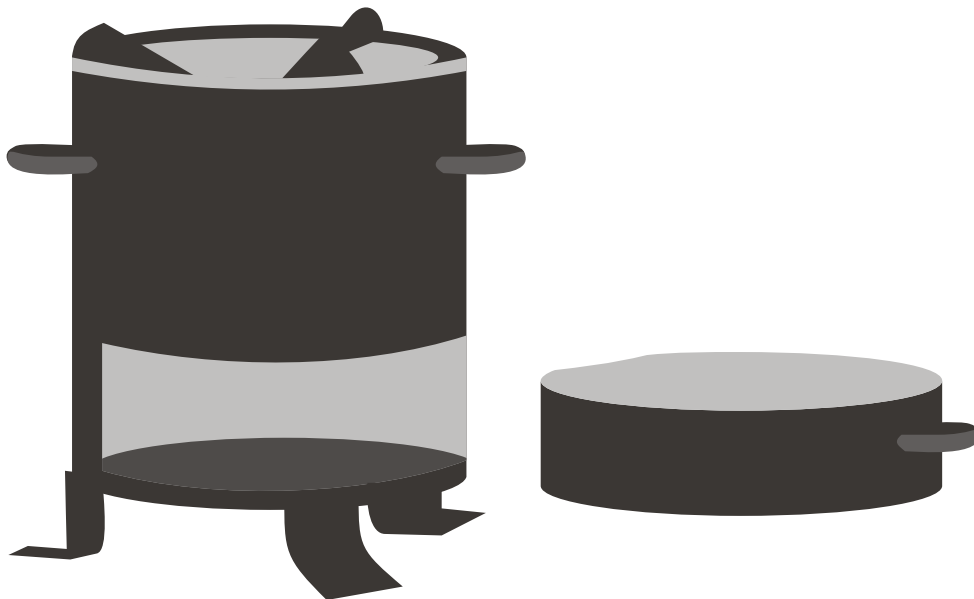


Plate 2: Stove and ash tray

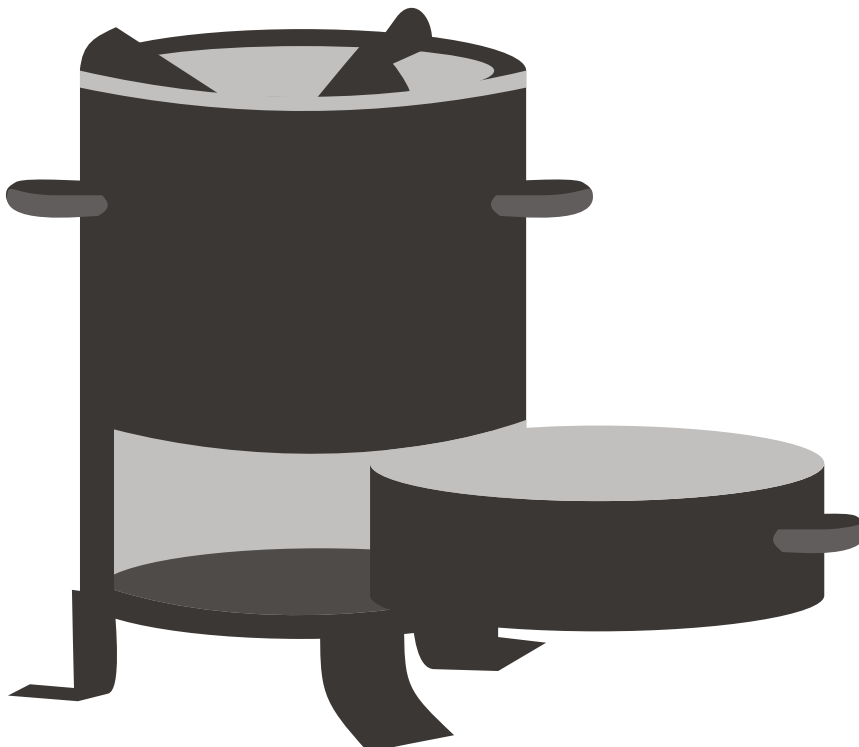


Plate 3: Ash tray being inserted in stove

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### Concept of Design

Simple arrangement of forms of design elements is very necessary for designing and production of any artwork. It is deemed expedient to eliminate unnecessary and complicated design that causes a lot of problems and tends to mar the progress of the processes of making a unique piece of work.

### 4.0 TOOLS, EQUIPMENT AND MATERIALS

In this study, materials, tools and equipments used have been described. These are any hand or machine-operated devices employed in engineering the production of the work.

Commonly used tools for this project include weighing scale, wooden workers bench. Equipments /Machines used are; Sieve, hammer, and Down-draught kiln, Potter's Wheel

- Sawdust

This material was mixed with Nafuta(JOS) and Awka Clay on different proportions to experiment for the production of low-density bricks. It was the main component of the clay body used for the production of low-density bricks for construction of stove.

- Clay

Is the most abundant and the cheapest to acquire but has a negative quality which makes its transportation from one place to another very difficult, clay is bulky. It is a hydrate silicate of alumina and the natural residue of feldspar from which all pottery wares are produced. Clay according to study, came about as a result of disintegration of feldspar rock by certain chemical and physical factors which include water, pressure, temperature, wind, among others, into a very microscopic particles.

Clay is an earthy material, soft when wet, and hard when fired. It contains the chemical formula  $Al_2O_3$ ,  $SiO_2$ ,  $2H_2O$ . Clay is one of the most important materials this project, Red and white clay were used.

Table 1:

- Red clay result analysis

Analysis	Content
SiO <sub>2</sub>	62.43
Al <sub>2</sub> O <sub>3</sub>	31.98
Fe <sub>2</sub> O <sub>3</sub>	1.27
K <sub>2</sub> O	0.28
Na <sub>2</sub> O	0.35
CaO	1.17
MgO	0.26
TiO <sub>2</sub>	0.21
MnO	0.31
ZnO	0.02
Raw Color	Red
Fired Color	Cantaloupe

Table 2:

- Nafuta(JOS) Clay result analysis

Analysis	Content
SiO <sub>2</sub>	62.29
Al <sub>2</sub> O <sub>3</sub>	25.40
PO <sub>2</sub> O <sub>3</sub>	1.27
K <sub>2</sub> O	0.48
Na <sub>2</sub> O	0.046
CaO	-
MgO	0.032
TiO <sub>2</sub>	0.83
Raw Color	white
Fired Color	white
Loss of Ignition	8.99



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Plate 17: Stove in a green ware stage

### 4.1 Objectives One and Two

The first objective was to study the methods and processes in composing low-density bricks from local earthenware clay while the second objective was meant to compose low-density bricks from Jos clay.

- Composing Low-density Bricks

The researchers therefore considered the creation of multitude of air cells in the bricks for the stove as necessary physical properties required for the retention of heat in the stove. To arrive at a suitable body composition for the manufacture of low-density bricks for the constructor of the stove, several experiments were carried out to arrive at the suitable composition for the clay body. The materials that were used for the experiments were Awka clay, Jos clay, sawdust and water. In this, it was expected that, the clay would form the main body component in the composition, the sawdust the second component which was a combustible material will eventually burnt off during firing to create the multitude of air required for retention of heat. The weighing scales was used to weigh the materials and were all fired at the same time in the same kiln to the same temperature.

#### Experiment One: Awka Clay

Table 3.0 Quantity of materials for experimental brick one

Materials	Quantity
Awka Clay	1000 grams
Sawdust	200 grams
Water	300 grams

The composition was mixed and kneaded together to get it in a ball position. It was rolled into coils, joined up with the use of slip so it won't separate. It was left to dry and was fired at 800 degrees Celsius.

#### Experiment two: Awka Clay

Table 3.1 Quantity of materials for experimental brick Two

Materials	Quantity
Awka Clay	1000 grams
Sawdust	300 grams
Water	300 grams

The composition was mixed and kneaded together to get it in a ball position. It was rolled into coils, joined up with the use of slip so it won't separate. It was left to dry and was fired at 800 degrees Celsius.

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### Experiment three: Awka Clay

**Table 3.3 Quantity of materials for experimental brick Three**

Materials	Quantity
Awka Clay	1000 grams
Sawdust	500 grams
Water	300 grams

The composition was mixed and kneaded together to get it in a ball position. It was thrown on the potter's wheel because it has lost much plasticity and couldn't be rolled up again. It was left to dry and was fired at 800 degrees Celsius.

### Experiment four: Jos Clay

**Table 3.3 Quantity of materials for experimental brick four**

Materials	Quantity
Jos Clay	1000 grams
Sawdust	500 grams
Water	300 grams

The composition was mixed and kneaded together to get it in a ball position. It was thrown on the potter's wheel because it has lost much plasticity and couldn't be rolled up again. It was left to dry and was fired at 800 degrees Celsius.

### Objective Three

The third objective was to use the composed mixture of clay and sawdust for the construction of a Ceramic Charcoal Stove. To be able to achieve that, a metal frame was fabricated to encase the stove.

- Fabrication of the frame for the stove

To ensure that the correct measurement is used, the researchers did all measuring and cutting of materials to design specification. The materials used were a stainless sheet.

After cutting the materials to the specific sizes, the researchers employed the services of an electric arc welder to weld the cut pieces together. The grinding machine was used for neatening up the welded joints to finish.

### Features of the Stove

- The stove consists of a combustion chamber (inner retort) constructed using a 2.0mm thick stainless steel material.
- The combustion chamber is designed to receive solid biomass fuel (charcoal) and enhance complete combustion of combustible gas released during charcoal burning process.
- The combustion chamber is imbedded in a cylinder (outer retort) form.
- The combustion chamber and outer retort are designed in a way that a 30mm gap is left in between to provide a free movement of air and enhance resistance to heat transfer to the inner wall of the outer retort. This minimizes heat loss given the low thermal conductivity.
- A tray ash was arranged for under the stove so as not to allow ashes to litter on the floor when cooking is ongoing.

## 4.2 Presentation and Discussion of Results

This section discusses and presents the results of the use of Awka and Jos Clay mixed with sawdust as locally obtainable raw materials for the composition of low-density bricks, for use as heat retention bricks for the construction of a charcoal stove. It also discussed and evaluates the suitability of the locally composed stove and the product it gives out. The data for this chapter were gathered through the observation of the entire project and tests conducted to confirm the suitability or otherwise of some of the cooking derived from the project. And this has been described below.

### Findings on Materials Used

The low density brick

In all, three equipments were conducted. Experiment three was the only composition that satisfied the requirements of the project because experiment two was found to be less porous. Experiment three was made from a composition of Jos Clay and Sawdust/Awka Clay and Sawdust. In this, it was observed that the plasticity of Awka Clay was essential for the binding of the two materials forming the body.

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Compositions made from Jos Clay were unable to hold the materials together and kneaded to a ball. This was contrary to the aged clay of Awka.

The drying of the stove mould (bricks) was very slow compared to the rate at which bricks made from raw Awka Clay dried. On the contrary, the clay sawdust body took a longer time to dry most probably due to the water retention properties of sawdust.

It was observed that, after firing the stoves, they became light in weight compared to the green ware. The identity of the fired stove was reduced. The high porosity in the stoves produced was evidence of the presence of entrapped multitude of air pockets, which makes light porous an effective heat burner.

How did the researchers get the stove to this point?

First, the materials which were used are clay, sawdust, water, potter's wheel and Kiln.

Then secondly, proportions are keys at this stage. Accepted source used on this is a proportion of 50/50 ratio by volume of clay to sawdust. The main factor when determining the proportion of clay and sawdust is the plasticity of the clay during the working and the strength of the stove after firing. Because, sawdust will reduce both plasticity and strength of the clay.

After the clay and sawdust has been mixed, water was added and mixed in small amounts until the clay mixture blends and becomes workable.

Once the clay is workable, it was wedged to further mix the clay and remove bubbles inside of the clay. This was a bit difficult with less plastic clays and at higher sawdust proportions.

After the mixture, the store was thrown using the potter's wheel.

After the clay was cut off from the wheel, it was perforated with a round iron at the base so as to give room for ash removal. Thereafter the stove covered with a waterproof material allowing it to dry slowly.

Once the stove was completely dry, it was ready for firing. A gas firing downdraught kiln was used to fire it to 800 degrees Celsius. The kiln was left to cool off after a day before it was opened. A metal sheet was formed and welded to cover the outer body.

### 4.3 Discussion on the General Findings

The entire process of cooking/boiling water with the stove took about 30mins. This involves the use of charcoal inside the stove and another boiling of water, after the removal of the smoldering charcoal. During this period, the charcoal which was already lit turned the refractory piece. The charcoal also were reddish, pot was kept on top of the stove with water of about 250ml volume inside of it to boil. At exactly six minutes, the boiling point of the water reached. The water in the pot was poured out and another pot with water inside it was put on the stove, this was after the charcoal has been poured out from the stove,. It took about 24mins for the water to start boiling slowly.



Plate 6: Boiling of water with the stove

Picture of where the water was boiling after the charcoal has been ignited

The entire process of boiling water with the stove took about 30 mins. The first boiling involves the use of charcoal, a little Kerosene and a match were used to lit the charcoal inside the stove and a pot containing water of about 2590ml volume was placed on the stove. At exactly six minutes, the water started boiling and the pot was brought down. Another pot containing the same quality of water was immediately placed on the stove after the charcoal has been poured from the stove.

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Plate 7: The Stove



Stove showing Ash tray

### CONCLUSION

Through the study, the researchers have shown that the ceramic charcoal stove present interesting energy performance and safety. Switching to the ceramics charcoal stove is beneficial in many ways. The reduction of pressure on the forests, the risks and hazard involved in going to fetch firewoods by women and children and the improvement of the household economy. It is desirable that the authorities in charge of energy and environment issues popularize the ceramic charcoal stove and encourage their production and purchase.

This study could not measure the emissions from cookstoves. The next stages of research will address this aspect.

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