Arts and Design Studies
ISSN 2224-6061 (Paper) ISSN 2225-059X (Online)
Vol.23, 2014

Utilization of Wood Ash from Rice Husks in Firebricks Production

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Abstract
This paper documents the results of the use of rice husk ash collected from selected parts of Afikpo North Local Government Area of Ebonyi State, Nigeria, as alternative source of silica and calcium oxide in firebricks body. The experiment started with the use of rice husks as alternative to sawdust, which instead of burning off to create pores, produced a very weak brick that crumbled into a heap of clay and ash inside the kiln. In fact, all the formulated samples, yielded the same result, except those with less than 30% rice husks. However, when burnt into ash and mixed with the same material (fireclay) as in the above set of experiments, resulted into a light, dense and hard refractory firebricks at 1250^{o}C, which can be harnessed for use as outer-back up to insulatory bricks in kiln construction. The process involves the extraction of the ash, selection of other materials to be combined with the ash, determination of the quantity of each material and firing at temperature of 1250^{o}C.

INTRODUCTION

Kiln is a box or structure built with bricks in which heat is introduced either by combustion or radiation. It is intended to conserve heat so that wares loaded into it can fire to the required hardness and permanency. Building a kiln entails the use of bricks of various sizes, forms and compositions. And since heat retention is the basic character required of any kiln, bricks are carefully selected to maintain heat at certain temperatures and reduce heat losses at acceptable limit. Therefore, the basic factors that characterize the selection of bricks for kiln construction are insulation and refractoriness. An ideal brick for kiln construction should be able to withstand high temperatures without deformation and at the same time prevent excessive heat losses.

Evidently, not all bricks possess all the qualities required in kiln building, because of their varying nature caused by difference in compositions. For instance, most refractory bricks are dense or hard, but not very insulatory while most insulatory bricks, though refractory, but not hard enough to give the required strength. This is why most insulatory bricks are not load-bearing and are used as back-up for inner lining of kiln chamber, while the refractory hard bricks are incorporated into the design primarily as load-bearers. Thus qualities such as refractoriness, insulation and hardness are seldom found in a given brick of a particular composition. This has made the construction of kilns rather complex.

However, in recent times, due to advancement in technology, modern kilns are now carefully designed to have adequate strength to be able to withstand movements and knocks without being excessively heavy. This has led to the development and use of bricks that are insulatory, refractory, hard, and light enough to make for portability. The development and use of ceramic fibre and diatomaceous bricks is one of the advances that has led to the development of light weight kilns. Though not load-bearing, they are used in conjunction with conventional refractory insulation bricks as back-up insulations.

Therefore, further researches into the development of bricks that will help to reduce the complexities in kiln design and construction, should occupy the ceramist in an advancing technological oriented society with diversified approach to problems. Such experiment is the focus of this paper. It discusses the utilization of wood ash derived from rice husks grown in selected parts of Afikpo North of Ebonyi State, Nigeria, in the formulation of light, dense and hard refractory bricks, that can serve as load-bearer and outer back-up to insulatory bricks.

CLASSIFICATION AND COMPOSITIONS OF BRICKS

Fournier (2000:37) defines brick as “a clay or ceramic unit of building construction, the comnest shape being a rectangle of around 9 x 4 x 2 in/225 x 100 x 50 mm”. However, with the advancement in technology, materials used in bricks production are now varied. According to Fournier, bricks “are now made in an ever widening range of materials from red surface clays to bauxite and chrome ore.

Clays still remain the commonest materials for brick production. This is because clay is among the most available refractory materials on the earth’s surface. Virtually all the clays insulate and resist heat to certain degrees. Primary clay or kaolin ($Al_2O_3.S_iO_2.2H_2O$) is an excellent material for brick making because of its refractory nature. A pure kaolin has a fusion point that ranges from 1500^{o}C to 1800^{o}C (Rhodes, 1973:25, 1968:83). Another refractory clay for brick manufacture is fire clay. Fire clay is a general name for secondary or sedimentary clays usually associated with coal measures or seams (Rhodes, 1968:83, Fournier, 2000:65, Hamer & Homer, 2004:37). Bricks made from fire clays are commonly referred to as firebricks. However, firebrick has become a general name used to denote bricks made of refractory clays (kaolin & fire clays). Fire clays are refractory clays with melting point that ranges from 1300^{o}C to 1750^{o}C (Hamer and Hamar 2004:138, Fournier 2000:65, 126). Fournier addes that "some fire clays are as refractory as china clay and are able to withstand 1700^{o}C without deformation and probably melt around 1800^{o}C".

Even low temperature (fusible or low refractory) clays, that is, those that "will not withstand high temperatures but break down with heat and melt before 1300^{o}C", can be used, particularly when building low temperature kiln (Hamer and Hamer, 2004:63). Rhodes (1968:83) notes that "an ordinary red brick, which is usually fired to about 1000^{o}C, will withstand perhaps 1100^{o}C without melting, bloating or deforming", after all, "early kilns were commonly built of red bricks and these were entirely satisfactory for low-temperature firings".

Therefore, since refractoriness is one of the basic qualities of a kiln, most refractory bricks are made of kaolin and fire clay, in most cases with the addition of grog. Refractoriness refers to the ability of a material to withstand heat without deformation or spoiling. Bricks that deform within the temperature range of 1300^{o}C to 1800^{o}C can be referred to as refractory bricks. The addition of grog provides texture for better control in forming, helps the brick to dry uniformly, reduces shrinkage and the tendency to crack or warp. But, because of the nature of clays, refractory bricks are dense and comparatively heavy in weight. Also, heat is conducted very quickly through them resulting to high heat loss, as a result, they are used where heat retention is not very important, "for example, for the building of chimneys or for the exterior brick-work of oil or gas fired kilns" (Fraser, 1979:4). For the same reasons, Fraser has also noted that they are not recommended for use in the building of electric kilns, as their importation may be very expensive and movement rather difficult.

With the high heat loss associated with refractory bricks shows that bricks that are purely refractory have less insulating property, when compared with those made specially for this purpose. Insulation is another important quality of a kiln that enables it to fire high temperature wares. It is the property of a material that enables it to retain and prevent heat loss within acceptable limit. The production of insulating bricks is "a more recent development that came into use in 1930s (Rhodes, 1968:88). These are soft bricks designed primarily for greater heat retention to acceptable limit. Rhodes groups them into two: those made from clay and those made from the natural material diatomaceous earth or fuller's earth. Clay insulating bricks are made primarily from refractory fire clays and kaolin, formulated in such a way that the finished product is considerably porous. This is achieved either by chemical means or through the addition of insulatory material into the mixture, such as sawdust, wood fragment or cork. Sawdust, for instance, when added as one of the brick's compositions burns off during firing leaving tiny pores, which store air that inhibit the passage of heat through the wall of the brick (kiln). With the pores, heat conduction through the brick takes a considerable time so that heat can be built up inside the kiln chamber, making it possible for the ware to mature at the desired temperature.

Because of the use of refractory fire clays and kaolin, clay insulating bricks can be referred to as refractory insulation bricks. Which means that they are both refractory and insulatory, and are very ideal for hot-face insulation, that is why they are also referred to as hot-face insulating bricks (High temperature insulation – HT1 or K-bricks), Hamer and Hamer 2004:202. Hot-face insulation bricks are those "capable of standing great heat" used for the inner lining of the kiln chamber, where there is direct contact to heat (Fournier, 2000:169). Because of their refractory and insulatory properties in addition to certain degree of hardness, clay insulation bricks can be used to build the entire kiln structure.

Diatomaceous insulation bricks are those made from diatoms, an open-pore silica deposits formed by the shell of a small sea animals (Rhodes, 1969:88 & Hamer and Hamer, 2004:202). Rhodes and Hamer, also affirm that because of their weak structure (light in weight and high porosity), they are commonly used as outer back-up to insulating firebricks and other types of bricks. Diatomaceous bricks are also not as insulatory as those made from clays (Rhodes, 1968:88).

A part from insulating bricks (clay or diatomaceous bricks) there are other natural materials that can be used for insulation purposes in kilns, which have helped to advance the technology of kiln design and construction. Among these are high alumina materials such as silimanite or fused alumina, chromite or magnesite, ceramic fibre, vermiculite, asbestos board or asbestos plaster and aluminum foil (Rhodes, 1968:91, Hamer and Hamer, 2004:202). As noted by Hamer and Hamer, the introduction of ceramic fibre has revolutionalized the subject of insulation in kiln construction. With ceramic fibre, firing cost has been reduced drastically by up to 40% when compared with firebricks, "especially in lower temperatures and where a simple rise to temperature is all that is required".

As noted earlier, one disadvantage of using only refractory firebricks in the construction lies in the heaviness of the structure leading to the need for extra support for arches. A part from this, they are also difficult to cut into desired sizes and shapes, but with insulating bricks, the structure can be lightened, the bricks easily cut to the desired sizes and shapes, making kiln construction easier than when refractory firebricks are used. However, the advantages of firebricks (bricks made of clays) over the non-clay bricks are obvious. According to Rhodes (1968:85), they can withstand temperatures beyond that of ceramic kilns, they are relatively cheap and easily available, hard, dense and resistant to wear, abrasion, spalling and do not crumble or disintegrate.

In the foregoing discourse, refractory bricks and insulatory bricks have been mentioned severally. This does not mean that bricks are grouped into the two categories, because a brick can be refractory as well as insulatory. In an attempt to classify bricks, Fraser (1979:2) identified two types; refractory bricks and refractory insulation bricks. He tried to highlight the two basic properties of bricks for kiln construction, showing that a particular brick can possess the two properties. But he failed to take care of those bricks made of clay (fusible clays) that are neither refractory nor insulatory used for building construction and in those parts of the kiln where insulation and heat resistance are not very necessary, such as chimneys, fireboxes etc. It will still be misleading to classify them into the two groups of materials used – clay bricks (fire bricks) and non-clay bricks – because there are extreme cases where clay can be added to the non-clay material(s) to enhance workability and better control of the mixture. For instance Rhodes (1968:90) reveals that it is possible to have a good mixture of "85 parts by weight of vermiculite and 15 parts of ball clay" that can be used to plaster "the outer walls or top of the kiln".

However, a more appropriate way of classifying bricks is the one proposed by Robert Fraser, a well known British Potter. Fraser (2000:37) identifies three main types of brick used by potters that are easily distinguishable. First, is the "open-textured red building bricks" which can as well be used for the outer walls of a kiln where they can provide better insulation than heavy bricks or on those areas of the kiln where heat resistance and proper insulation do not matter. These are low temperature bricks made from low temperature clays (fusiable clays) used wholly for primitive kilns. Second, is the "hard, heavy, close-grained refractory bricks", comprising all grades of firebricks from Low Heat Duty (PCE 15) with working temperatures up to 1400^{o}C to superduty (PCE 33) that resist deformation up to 1550^{o}C. Third, is the "lightweight insulating bricks". These are "superb insulators", light in weight, very porous and expensive when compared with firebricks. Among the less refractory and weaker types are those made from diatomaceous earth, while the more refractory types are made from very pure and iron-free ceramic materials and have an open, sponge-like appearance achieved by physical means (mixing the raw material with sawdust, for instance) or chemical processes", and graded by a K factor (e.g. K26 = 2600^{o}F or 1430^{o}C). The number (26) represents the highest temperature a brick can withstand without deformation, while K is a symbol representing Kelvin, a temperature scale. PCE stands for pyrometric Cone Equivalent, denoting the cone number representing the highest temperature the brick can withstand without deformation (Fraser, 2000:37, 182 & 259).

CLASSIFICATION AND COMPOSITIONS OF WOOD ASH

'Wood ash' has become a popular term used to describe ashes derived from all vegetable plants (Rogers, 2003:37). It does not only refer to ashes derived from slow growing plants (trees and shrubs) as the name 'wood' suggests, it includes those from fast-growing vegetable plants such as grasses, straws, grain husks (rice husk for instance) and smaller plants such as nettles. Authors such as Rogers (2003), Fournier (2000), Hamer and Hamer (2004), Ali (1999), Leach (1976), Rhodes (1973), Cardew (1969), Tillman (1981) among others, have studied wood ashes, with emphasis on their compositions, classification, preparation and use in the formulation of stoneware glazes. Wood ash is a non-combustible remains of a vegetable matter, that is, the "powdery residue left after the combustion of" a vegetable material commonly used by the potter for the formulation of stoneware glazes (Fournier, 1977:13, 2000:12, Hamer and Hamer, 2004:386). This is because the chemical analyses of wood ash samples indicate the presence of considerable useful elements to the ceramist. Ali (1999) affirms that such analyses conducted by Cooper (1982:136), Cardew (1969:42 & 54) and Leach (1976:162) show that ash contains varying proportions of fluxes and other oxides, such as calcium, silica, phosphorous, magnesium, sodium, potassium and aluminum oxide. As the analyses indicate, apart from the inorganic sulphates (SO_4) carbonates (CO_4) and chlorates (CLO_4) also present in the wood ash, all other constituents are useful to the ceramist in the formulation of glazes, that is why wood ash can be considered as natural glaze, and as such can be used alone in the formulation of glaze. When used with other glaze materials such as clays, it forms an important source of silica and calcium oxide in stoneware glazes. This is because wood ash contains considerable amount of each of the two elements while others appear in negligible quantities, in fact, in some cases in traces.

The analyses also show that the quantity of each of the elements that make up wood ash differs from plant to plant (Fournier, 1977:13, Cooper, 1982:65 & Rogers (2003:27). According to Fournier, Cooper and Rogers such variability depends on (a) the nature or type of soil on which the plant grew, because of difference in soil chemistry from which the plant derived its nutrients. (b) The age and type of plant, because the proportions of the elements of ash derived from fast growing plants such as grasses, straw, grain husks, etc. differ from that of slow growing plants such as trees. Even the parts of the tree – trunk; bark, branches, leaves – very in the proportion of the elements.

As stated earlier, wood ash contains considerable amount of silica and calcium oxide in relation to other elements. That is why the behaviour of wood ash is dependent on the two elements. It is also the high proportion of the two elements that has helped to simplify the classification of wood ash. Silica is a refractory oxide while calcium oxide acts as a flux particularly at high temperatures (stoneware temperatures). Wood ash that contains high proportion of silica in relation to calcium oxide is said to be more refractory than the one which calcium oxide content is higher than that of silica. Based on this, wood ash can be classified into low and high temperature ash or soft and hard ash, adopted by leach (1976:59). This classification takes into consideration the functions of each of the two oxides in a glaze. Rogers (2003:28-30) shares the same view with Leach, but seems to be more precise in using the functions of the two elements in the classification. According to him, ashes can be grouped into two: (a) Basic or alkaline, which refers to those that are high in calcium oxide, derived from tree woods, bushes or shrubs. (b) Acidic; those with high silica content, usually the products of quicker-growing plants such as grasses, cereal crops, certain vegetables and nettles. Grain husks (rice husks for example) are particularly high in silica, "the plant using the strength of the silica crystal as protection for the seed. However, as far as the potter is concerned, these two groupings will help to form an understanding of how any particular ash may be expected to perform", even before the necessary analyses are carried out.

Since the proportion of the elements that make up wood ash differ from plant to plant, it is therefore, necessary that the potter conducts a chemical analysis of the sample(s) he/she has collected for use. In this work, wood ashes used, were derived from rice husks collected from five areas in Afikpo North Local Government Area of Ebonyi State. Table 1 shows their chemical analysis, with the constituent elements expressed in percentage by weight.

	Amasiri Ash	**Akpoha Ash**	**Mgbom Ash**	**Oziza Ash**	**Unwana Ash**
Fe_2O_3	2.02	0.16	1.65	2.46	0.03
MnO	1.09	0.12	0.24	0.55	1.20
Al_2O_3	0.56	0.14	2.36	0.19	0.40
CaO	18.56	23.51	25.76	22.01	20.25
MgO	11.56	17.21	16.53	17.56	13.00
K_2O	5.47	10.02	4.77	4.99	12.63
Na_2O	5.31	8.00	2.99	3.53	11.00
P_2O_5	9.88	5.96	4.02	2.99	8.47
SO_3	4.99	2.63	1.61	3.23	2.20
Cl	3.53	1.21	0.35	2.56	0.81
SiO_2	37.09	31.04	39.72	38.83	30.01

Table 1: Courtesy of Soil Laboratory AIFPU in Ali (1999:35)

As the table indicates, there is evidence that the ashes are refractory because of their high content of silica in relation to calcium oxide, followed by magnesium oxide which is also a high temperature flux.

PREPARATION OF WOOD ASH FOR BRICK BODY FORMULATION

Ash for brick production does not require the kind of detailed preparation as in the case of that for glaze formulation. All that is needed is to burn the material in order to extract the ash. If present, sort out large aggregates of charcoal and unburnt materials from the ash. After this stage, the ash is ready for use in brick making. This is because those things that will contaminate the glaze when unprepared ash (one that did not pass through thorough washing and sieving) is used are not likely to have negative effect on the brick. Particles of charcoal and unburnt matter will even add to the texture and porosity of the body thereby help to enhance the quality of the brick. Apart from the removal of charcoal and unburnt materials, ash for glaze formulation is also subjected to washing in order to reduce the quantity of the soluble alkalies usually present in the ash. The presence of these alkalies in the brick body is not likely to create much problem, since they are usually present in negligible quantities. Therefore, the formulation of brick body is not as delicate as that of glaze where extreme care is taken to avoid any form of contamination.

Besides, limiting the preparation of ash only to the extraction of charcoal and unburnt materials when necessary also helps to increase the quantity of ash needed for brick making. Usually when ash is washed and sieved the quantity reduces very considerably because of the removal of unwanted materials. Such quantity can be enough for glaze formulation, but may not be sufficient for brick production, because of the brick size and the quantity usually needed to build a kiln. Even the quantity of ash obtained after burning a material cannot be compared with that of the material. Ash analyses conducted by Wolff (1871) as quoted in Rogers (2003) show that about one pound (one 1b) of ash would require the burning of about 91kg (2001b) of dry wood. But for other plants for instance, it was observed that oat straw when burnt rendered about 7.2% of its dry weight as ash, while grass when burnt produces ash of about 5% of its dry weight. With this, one could imagine the quantity of material that will be burnt before a reasonable quantity of ash for mass production of bricks can be obtained, how much more when the ash is sieved.

Another way to increase the bulk of ash needed for brick formulation is to combined ashes derived from plants from different locations provided they belong to the same group. For instance, ashes from fast growing plants usually high in silica content can be combined even if they are not from the same location and are not of the same type of plant. The fact that they belong to the acidic group, as discussed earlier, will make them to exhibit similar characteristics. This is particularly true where the type of plant to be used is not grown in large quantities in any particular area or where plants from different locations are processed centrally to extract the fruits.

In Afikpo, for instance, where this research was conducted, the cultivation of rice is of a subsistent nature, that it was rather difficult to find a large field of rice. Besides, in the area, rice is not processed in the field (i.e. separation of the grains from the husks) but in the rice mill where rice from other locations are processed with the husks heaped together. Therefore, any potter using such heap will be dealing with husks from different locations. But for glaze formulation where large bulk of ash is not usually needed, it is possible to harvest the rice from a particular field, process it locally (manually) to extract the husks. This may also apply to the use of ash from slow growing plants (trees) for brick production. Sawdust can be an important source of ash form slow growing plants. Any potter using it to source ash for his/her work will be dealing with varieties of tree ash since those working in the timber shade do not categorize or heap the sawdust according to tree source and type. Therefore, in brick making, sawdust can constitute a source of bulk ash from slow growing plants of different types and sources, since the belong to the same group (those with high calcium oxide content), while rice husks can be a very good source of bulk ash from fast-growing plants.

The high silica content of rice husks ash, makes it an important source of silica in a brick body, especially for the formulations of refractory bricks. Silica in a body performs three important functions. Hamer and Hamer (2004:324) note that since silica itself is refractory, its addition to a body normally renders the body more refractory. Secondly, "it makes the fired ware harder and more durable". Thirdly, "it alters the amount by which the body contracts in cooling after firing".

OTHER MATERIALS FOR ASH BRICK BODY FORMULATION

Clays used in the formulation of body for other type of bricks can be combined with ash to produce ash brick body. Kaolin and fireclays can be used in combination with ash to form satisfactory ash clay body. Sawdust and grog can be possible additives to improve the quality of the brick. As noted earlier, the refractoriness of kaolin and fireclays makes them ideal materials for the production of refractory bricks.

As a pioneering research, only ash and fireclay were used, with the hope to introduce sawdust, kaolin and grog progressively in subsequent research to see what happens. Fireclay was sourced from Enugu Coal Corporation and processed before used. Being a fairly plastic clay with refractoriness that is up to 1300^oC, as the tables below indicate, it formed workable combinations with ash.

Table 2: Chemical Analysis of Enugu Fireclay

	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	MgO	K_2O	Na_2O
Enugu Fireclay	57.32	22.08	5.70	0.33	0.47	0.23	0.66	0.10

Source: Oyeoku (1988) as quoted in Akobundu (1995).

Table 3: Physical Analysis of Enugu Fireclay

	% Drying Shrinkage	% Making Moisture	Green Strength Kgf/cm^2	Plasticity Ratio	Firing Temp.	% Fired Shrinkage	% Total Shrinkage	Fired Strength	% App. Porosity	% Water Absorption
Enugu Fireclay	8.60	20.80	29.70	2.8.1	1300	0.44	9.04	346.70	25.30	11.90

Source: Nigerian Coal Corporation Information Manual as quoted in Ogbu (2005)

Table 2 has shown clearly that Enugu fireclay is high in silica and aluminum oxide (very refractory materials), followed by iron oxide which accounts for its fired colour, while the rest of the oxides are almost in traces. Total shrinkage of 9.04%, plasticity ratio of 2.8.1, approximate porosity that is as low as 25% and with high fired strength of 346.70 at 1300^oC as shown on table 3 are indications that Enugu fireclay can be used alone without any additive.

FORMULATING ASH BRICK BODY

Since only two materials (ash and fireclay) are involved, the trial and error method of line blending was used to formulate the sample bodies. Fournier (1977:133), defines line blending as a method of working out intervals in a series of mixtures involving two different materials. It illustrates the effect of diminishing the quantity of one material and increasing the other and vice versa. Another form of line blending is what Rogers (2003:67) refers to as 'progression method'. In this method, one of the materials is kept constant, while two parts is added to the other material as many times as possible. This is reversed so that the same addition of two parts is made to the other material. Rogers affirms that this method is "particularly useful in gauging the amount of an addition to a previously mixed glaze in order to bring the glaze to a required quality". With the two methods of line blending the following bodies each fired at 1250^{o}C were formulated. This temperature was chosen in order to ensure that the resultant brick will be able to withstand high temperatures above 1200^{o}C within which most of our locally sourced glazes fuse.

Table 4: Line blending (in percentages)

Materials	1	2	3	4	5	6	7	8	9
Rice husks	90	80	70	60	50	40	30	20	10
Fireclay	10	20	30	40	50	60	70	80	90
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

Table 5: Line blending (in percentages)

Materials	1	2	3	4	5	6	7	8	9
Rice husk ash	90	80	70	60	50	40	30	20	10
Fireclay	10	20	30	40	50	60	70	80	90
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

Table 6a: Progression method (in parts by weight)

Materials	1	2	3	4	5	6	7	8	9	10	
Rice husk ash	5	7	9	11	14	16	18	20	22	24	etc
Fireclay	5	5	5	5	5	5	5	5	5	5	

Table 6b: Progression method (in parts by weight)

Materials	1	2	3	4	5	6	7	8	9	10	
Rice husk ash	5	5	5	5	5	5	5	5	5	5	
Fireclay	5	7	9	11	14	16	18	20	22	24	etc

In Table 6a-b, column 1 represents a body of 5 parts rice husk ash and 5 parts fireclay (50/50) arrived at using line blending which was fired and found satisfactory. But in order to arrived at a more satisfactory body the progression method was used. While 5 parts of fireclay was kept constant (as in table 6a) that of rice husk was increased by 2 parts progressively up to 24 parts. This was reversed in table 6b. But to convert the parts to percentages add the parts of ash and fireclay on each column and use the result to divide each of the parts and multiply by 100. For example in column 1, 5 parts of Ash + 5 parts of fireclay = 10. Use 10 to divide the 5 parts of ash and fireclay and multiply by 100 respectively.

i.e. = $^{5}/_{10} \times \frac{100}{1} =$ 50% of ash

also $^{5}/_{10} \times \frac{100}{1} =$ 50% fireclay

Column 2 becomes 5 + 7 = 12

$^{5}/_{12} \times \frac{100}{1} =$ 41.7% of fireclay

and $^{7}/_{12} \times \frac{100}{1} =$ 58.3% of Ash

Column 3 becomes 9 + 5 = 14

$^{9}/_{14} \times \frac{100}{1} =$ 64.3% of ash

and $^{5}/_{14} \times \frac{100}{1} =$ 35.7% of fireclay, etc.

With this the parts were converted into percentages as shown in table 7a and b below:

Table 7a: Progression method (in percentages)

Materials	1	2	3	4	5	6	7	8	9	10
Rice husk ash	50	58.3	64.3	68.7	73.7	76.2	78.3	80	81.5	82.8
Fireclay	50	41.7	35.7	31.3	26.3	23.8	21.7	20	18.5	17.2

Table 7b: Progression method (in percentages)

Materials	1	2	3	4	5	6	7	8	9	10
Rice husk ash	50	41.7	35.7	31.3	26.3	23.8	21.7	20	18.5	17.2
Fireclay	50	58.3	64.3	68.7	73.7	76.2	78.3	80	81.5	82.8

ANALYSIS OF RESULTS

It was the initial desire of the researcher to experiment with the use of unburnt rice husks to produce insulating bricks, with the hope that rice husks would react in the same way sawdust does when used for this purpose. With the dusty nature of rice husks, one would assume it will be an important alternative to sawdust for the production of insulating bricks. With this in view, the researcher decided to use it in combination with fireclay, but met one of his greatest disappointments. Instead of burning-off to create pores, it produced a very weak brick that crumbled and formed a heap of clay and ash inside the kiln. However, those with less than 30% rice husks survived but yielded a very heavy brick that can be said to be predominantly fireclay.

The explanation of the above phenomena may be attempted with reference to the sintering process. Sintering is an important process in the early stages of firing. Fraser (1998:43) defines it as 'a process whereby heat converts a powder into a cohesive mass without developing a glassy phase". According to Fraser, "what in fact happens is that the corners and contact surfaces of the particles soften, thus causing the particles to stick to each other". Since this reaction occurs when rice husk ash is used, it means that this reaction is hindered when unburnt rice husks is used. And since those bodies that had below 30% unburnt rice husks fired to a very heavy brick shows that the reaction increases with high proportion of unburnt husks in relation to fireclay. Therefore, it is possible that sintering was hindered by the reactions that occurred during the burning of the husks. A more concrete and acceptable reason(s) can only be made after thorough research on how rice husks reacts in clay when subjected to heat.

Virtually all the samples formulated with rice husk ash and clay (as contained in table 5 – 6) sintered, though with varying weight and lightness. The results can be grouped into two – results from those with high ash content (above 50%) and those from low ash content (below 50%). Samples with high clay and low ash content produced bricks that were relatively heavy, while those with high ash and low clay content yielded bricks that were relatively light. Which means that the more the quantity of clay in relation to ash, the heavier the brick, and the more the ash content the lighter the brick. Furthermore, the results show that those with ash content below 30% yielded very heavy bricks predominated by clay, while those with clay content below 30% gave highly fragile bricks with low fired strength. However, a balance between the two extremes gave the following satisfactory results as contained in table 5.

Sample 3:

Rice husk ash 70
Fireclay 30

Sample 4:

Rice husk ash 60
Fireclay 40

Sample 5:

Rice husk ash 50
Fireclay 50

Sample 6:

Rice husk ash 40
Fireclay 60

Sample 7:

Rice husk ash 30
Fireclay 70

Samples 1, 2, 3 and 4 in table 6a-b also yielded similar results.

The above samples produced results that could be harnessed for use in kiln construction. The best results among them are those from sample 3, 4 and 5. While sample 6 and 7 gave dense heavy hard bricks, sample 3, 4 & 5 produced creamy bricks that were not only dense and hard but also lighter in weight. They can give satisfactory result when used as outer-back up to insulating firebricks.

CONCLUSION

This paper has highlighted the usefulness of vegetable ash as alternative source of silica in a ceramic body, particularly those derived from fast-growing plants. Rice husk ash, for instance can be useful, in the formulation of brick body when combined with fire clay in certain proportions. Its addition to fireclay, within the percentage range of 50-70 can prove very satisfactory in the production of refractory bricks. Such bricks can be harnessed for use in ceramic kiln construction, particularly as outer back-up to insulating firebricks.

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