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Pulverised Oil Palm Wood (Elaeis Guineensis) in Clay Body and Energy Generation in Ceramic Firing

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Abstract
The use of liquefied gas in firing ceramics is very clean, energy efficient, fast and desirable but costly. Alternative energy is sought for. "Pulverized Oil Palm Wood (POPW) in Clay Body and Energy Generation in Ceramic Firing", was used to determine and utilize wood (oil palm) for firing. This was added to clay body for improving the technique of firing, and reducing the dependency on liquefied gas. The main objective of the study was to determine the effects of POPW in Clay Body and Energy Generation. To guide the study a research question and an hypothesis were developed. The area of coverage was Akwa Ibom State of Nigeria . The method used was Experimental Design. An adopted clay body, and the POPW were analysed before usage. The POPW was added to the clay body (10 – 50%) to test its effects on the dependent variables. The temperatures were collected as data from the experiment. They were analyzed using independent t-test. The findings revealed with gas alone, and POPW augmented with gas, created differences in the energy generated. In conclusion, the research findings revealed alternative energy in ceramic firing encouraging better ceramic production with economic output.
Keywords: Pulverized Oil Palm wood, Energy Generation, wood in clay, Augmentation.

INTRODUCTION

Ceramics is an age-long profession, a cultural craft practice that is constantly evolving, using clay as the principal raw material to manipulate into shapes, sizes and forms ending finally as fired products. It is believed to have started independently in many parts of the world in response to the needs of the local potters (Lious, 1978:1254). According to Igwilo (2006:194 – 205) "ceramic as a word originated from the Greek word 'keramos', meaning subjected to, or hardened by fire".

Ceramics therefore involves all objects made in clay with or without other materials rendered permanent by heat through firing (Umar, 2006). Ceramists like Rhodes (1968:101), Cardew (1971:145), Zakin (1990:18), Grahl (2004:27), Oke, and Nsentip (2007:101) have confirmed that when clay, hydrated aluminium silicates ($Al_2O_3.2SiO_2.2H_2O$), is used to form any object and is fired to vitrification, it cannot return to clay again. Ojie and Esosuakpor (2008:76), suggested that during fusion in ceramics great heat is absorbed by the wares to enable the elements in the clay to vitrify. Podmore (1980:15) posited that the interplay of alumina and silicate structures to produce fusion can only occur during heat interaction. The heat energy that would be utilized in this paper will be from organic matter in claybody.

Renowned ceramics scholars like Rhodes (1968:70), Cardew (1971:145), Zakin (1990:11-38), Speight (1979:183) have pointed with interest to the presence of a lot of organic materials in clay, from plants and animals that exist together in the clay environment. The postulation is that organic matter becomes useful either for fermentation or as a source of fuel during firing (Zakin, 1990:33). Over the years, these sources of fuel (organic material in clay) together with other newly found energy sources have been and will continue to be employed for ceramic firing in different cultures (Clark, 1968:4; Speight, 1979:183). This implies that the search for fuel sources is continuous. The contemporary sources include oil, electricity, gas, kerosene and wood (Rhodes, 1968:98). It is observed that where oil or kerosene is utilised, it is complex, more expensive and more subjected to mechanical failure as there is need to vaporise them so as to reach their respective ignition points for combustion to occur.

Where wood is used, in the traditional method of wood on clay, a lot of space is unnecessarily taken up because of the volume of wood. In a kiln where the volume of the kiln is constant, it becomes desirable not to fill in too much wood so as to allow more space for ceramic wares in the kiln. Rhodes (1968:63) recommended that wood firing however is not as troublesome, difficult or expensive as one may think. However, where energy has to be injected into the kiln from wood, opening and closing the wood chamber for loading the kiln would bring draft of cold air into the system thereby fluctuating the temperature and subjecting the wares to shock. This phenomenon renders the use of wood, though cheap, undesirable for firing ceramics. From the foregoing, there is a necessity to look at the concept of suitability of wood in terms of method of application and ceramic firing.

In this paper, wood, the source of fuel energy is pulverized and actually mixed into an adopted clay body thus the volume occupied by wood in the kiln chamber is greatly reduced and the loading of wood at intervals eliminated. The use of wood for fuel however, would have raised problems about deforestation.

Watch-Tower (2010:18) posited that an area equivalent to 1200 soccer fields (10,800,000)m^2 is logged illegally each day in Amazon forest alone. One needs to see the amount of wood that could be destroyed each day for one use or the other when trees used this way in the entire world is summed up. It is also argued and confirmed that this type of approach contributes to depleting the ozone layer (Mother Earth News, 2010:2-3). This study discourages wasting of wood in this manner. In this work, decayed oil palm wood was utilised as the source for energy extraction. The project became justifiable as the research is poised to putting to use wood waste or already cut down and unwanted non productive oil palm (*Elaeis guineensis*) stems.

Recycling in this manner even seems to point to a way of solving the problem of pollution, which appear to be global and needs practical and realistic approach. By this type of research, industries, business and other ventures could solve their problems synergistically, especially in the ceramic world. In an attempt to solve material problem in ceramics, a ceramist commented, 'potters will search for a clay which first of all has the right reaction to the fire and produces a fired substance of desired properties from internal and external factors, (Rhodes 1968:98)'. These properties may be the energy mode, material melt tendencies, acceptable values, technological suitability involving transformation, conservation, preservation, reservation and safety as was the case of China in 500AD or in the 19th century industrial revolution in Europe (Rhodes 1968:98).As ceramics involve materials and processes with its complex industrial production nature, energy becomes an inevitable need for its survival. Manipulations of these energy sources become challenges (Mogen, 2013:8).

Grahl (2004:27) revealed that ceramic industry problems have been and are still so enormous that it would need a concerted effort to surmount it. Grahl (2004:27), therefore, encouraged industrialists to use human and material resources in meeting our industrial needs. It has been observed that in Akwa Ibom State, and of course Nigeria as a country, there are available human and material resources which could be exploited towards the development of the state (Ukpong, 1987:87). This means that modern researchers should now look inwards for solving their problems.

It would be noted that local ceramic industries in Nigeria had existed before the coming of the Europeans, and they are still competing with current industries for supplying our developmental needs (Igwilo, 2006:196). These industries had their teething problems that affected their development. Nigerian Pottery had flourished even before people like Ladi Kwali, and Adam Joshua Udo Ema created ceramic forms for foreign earnings and placed Nigerian employers of labour on ceramic exportation which brought foreign earnings to Nigeria. Nigeria was favoured in competition in craft export economy with other nations (Cardew, 1971:146). Today, the story is different. Prominent ceramic industries and studios like Manufacturing Ceramic Industry, Kano; Modern Ceramic Industry in Umuahia; Quality Ceramic Industry in Itu, Peace Ceramic Industry in Etinan, and Jacaranda Pottery Industry in Kaduna just to mention but a few, have closed down[Federal Ministry of Industry (FMI),in 2011]. The effects on the populace can be seen in the untold hardship of unemployment. Grahl (2004:28) posited that industries in the world need power to operate successfully. Nigeria needs it now more than ever. Nnaji (2011:4) agreed with Grahl, by observing that Nigeria needs 750,000 mega watts of electricity with which the current government of Nigeria is battling. Even if successful "the electric power in Nigeria is epileptic, therefore unreliable (Udoh, 2006:25)," hence the need to use waste wood (oil palm stem) which can be a recycled source of energy.

It can be argued that Nigerian ceramic ventures have the problem of fuel crisis that needs to be solved. Furthermore, the cost of liquefied gas in Nigeria, a country that is rich in gas, is increasing daily thereby reducing the interest of investors in ceramic production. On the other hand, other sources of energy like nuclear and wind energy seem unrealistic in Nigeria. It appears that this energy crisis like other crises in Nigeria seems un-resolvable. If Nigeria must move along with other developing nations of the world, there must be a way of utilising our untapped energy resources in a cheap, unpolluted and convenient way to solve our problems because this energy crisis has adversely affected manufacturing industries, dampened creativity, increased unemployment and weakened the economy of our nation in no small way. If this situation is allowed unchecked, Nigeria will lose her credibility in creativity, exportation, self-sustenance, and unemployment will rise, thereby reducing many Nigerians to mere beggars.

In a country where raw materials and other alternative resources of energy are not tapped to the fullest, the nation's modern technologists will be held responsible by future generations for not attempting to solve the problem. In order to solve this problem in ceramic industry the abundantly available clay, as ceramic raw material and the pulverised oil palm wood as one of the energy sources for firing the clay body were utilised in producing ceramic wares. The main question in this study therefore is, will effective use of pulverized oil palm (*Elaeis guineensis*) wood in clay body produce enough heat energy required during ceramic firing?

The aim of this study was to include organic fuel source, Pulverized Oil Palm Wood (POPW), in clay body for energy production experiences and effects during firing.

The objective was to

1. determine the effects of the pulverized oil palm wood in clay body on heat generated and fuel consumption in ceramic firing.

To realize the set objectives, the research sought answers to the following questions:

1. Is there any significant effect of the pulverized oil palm wood in clay body on heat energy generated in ceramic firing?
2. Can the energy generated be useful in Ceramic ventures?

Research Hypothesis

A null hypothesis (0.05 level) was developed to generate the basis for the study that: there is no significant effect of pulverized oil palm wood in clay body on heat generated and fuel consumption in ceramic firing.

In the significance of the Study, it is hoped that the findings of this study would be useful to: the ceramists in industries; for the updating of materials for production, giving information on fuel energy supply and new methods of its operation in firing. The practitioners of ceramics profession would adopt the new suggestion in materials usage, and types of fuel in ceramic industry. The application of the findings such as the firing temperature, and fuel energy would determine economic viability of the products when compared to the traditional clay body product which does not utilise pulverized wood. The results of this study apart from empowering practitioners with new technologies in ceramics would also contribute to the survival of ailing ceramic industries. The findings of the research would promote and increase the aesthetic quality of the ceramic body. The ash contents of the oil palm wood would be used to substitute some fluxes in ceramics. Therefore, the wasted oil palm wood in our farms would complement sources of fuel energy in ceramic firing; this means reducing dependence on crude oil products. It is hoped that the findings should increase the enthusiasm of those who dropped out from ceramic undertaking because of high energy cost of firing and fluxing materials.

As this research is poised to innovating raw materials, the information derived from modern technology is intended to meet national needs and the objectives of the Nigerian Universities Commission (NUC) which include, among other things, to produce high quality graduates with technological capacity to compete favourably in national and international ceramic enterprise. The academic community would also stand to benefit from this work by becoming innovative and developing efficient practical consultancy. In summary, this work will incubate, empower and support entrepreneurship and create employment opportunities for Nigerians. The principal raw materials to be involved and used in the experiment are:

a. The wood adopted was oil palm (*Elaeis guineenis*) in Akwa Ibom State. These palm trees were delimited to the traditionally wild local oil palms with diminishing fruit yielding ability. This was because they are abundant and when their yielding capacity declines they are cut down for replanting new improved species quite unlike formal cultivated plantations which are expensively developed and highly valued. The pulverized oil palm wood was analysed in the Dept. of Soil Science lab. University of Uyo.

Table 1

Element	**Al_2O_3**	**SiO_2**	**FeO**	**Fe2O3**	**Ca**	**K**	**Na**	**Mg**	**Sn**	**Pb**	**Co**	**Cr**	**Mn**	**C**
Quantity	4	15	0.20	0.36	0.01	0.01	0.12	0.05	<0.01	<0.01	<0.01	<0.01	0.20	80.1

Analysis of oil palm wood before experiment (wt %).

b. Clay body: the study was delimited to the adopted clay body (Ebe's recipe) analysed in the Department of Soil Science Laboratory, University of Uyo.

Table 2

Element	**Al_2O_3**	**SiO_2**	**K_2O**	**Na_2O**	**CaO**	**PbO**	**Fe_2O**	**MgO**	**Sn**	**Co**	**B**	**Cr**	**Mn**
Adopted Clay body (ED – I)	20	76	1.01	1.82	0.04	0.05	0.57	<0.01	<0.01	<0.01	<0.01	<0.01	0.22

Analysis of clay body before experiment (wt %).

c. The study was delimited to the objectives of the effects of the pulverized oil palm wood in clay body heat energy production experiences during firing. The effectiveness of the experiments was tested with the result of the fired POPW clay body out come.

In carrying out this research, the following theories: (Le Chateliers Principle; Le Chatelier in 1885; Phlogiston Theory Becher in 1667; Theory of Conservation of Energy, Glasstone (1948:184)) were considered and their applications justified.

According to Rhodes (1968:145), Cardew (1971:147), and Zakin (1990:223), the conversion of green ware into ceramic by heat is endothermic while liberation of energy by fuel to generate heat is exothermic. These reactions in the kiln of chosen materials, of a given volume, temperature and pressure in industrial heating, could be expressed in Gas law as: $P_1V_1T_2 = P_2V_2T_1$, where $P_1V_1T_2$, are the initial pressure, volume and the final temperature of the furnace or kiln, while P_2 V_2 T_1 are the final pressure, volume, and initial temperature of the kiln or furnace respectively. Similar conditions could be seen in ceramic firing where the kiln has a volume to be loaded, a pressure to be increased as gas is pumped in to aid combustion, and as ignition is intended to raise the temperature, this formula became useful in the ceramic firing.

Application: for a successful firing, Le Chatelier principle was applied as increasing the temperature of fuel source in any dynamic equilibrium favoured endothermic reaction. The wares in the kiln, countered the change by absorbing the extra heat. On the other hand decreasing the temperature of the system in any dynamic equilibrium favoured exothermic reaction, the system, countered the change by producing more heat to burn more wares.

In applying theory of air supporting combustion, the following illustration is given:
carbon fuel source: methane (CH_4) can be used to combine with oxygen ($2O_2$) to give water ($2H_2O$), carbon iv oxide (CO_2), and Energy (Sharma and Sharma 2005:169-183). In summary of the theory, the enduring aspect was that Air supports combustion.

Using the theory of conservation of energy to apply here, the stored potent chemical energy in wood (*Elaeis guineensis*), was released during combustion, in the form of heat energy which was absorbed by the green wares during firing. This heat-work done was measured by the fallen Orton cones used.

This work was, therefore, anchored on space and matter changeability in the kiln. And according to the report of the US Department of Transportation (DOT) in 2005, matter can become combustible and evolve heat by processing a spontaneous chemical change. Pulverized oil palm wood and clay in this experiment, were among these types of matter.

Using such reasoning in this work meant that the solid clay body was changed to paste, then manipulated during moulding, dried and raised to temperature of vitrification and fusion. It was the wood and gas that were used complementarily for final firing of the work. Air was the common factor while the clay body suffered the operational conditions and changes in state to become ceramic. It is interesting to note that the space occupied by wood logs and green-wares if it were wood- on -clay in the kiln would then become empty when the logs were burnt off.
According to Cardew (1971:148) “empty volume as such ooze out heat from the kiln”. The inclusion of pulverized wood in the body of the green-wares (wood-in-clay), reduces the space which wood logs in the kiln (if used for firing) would have occupied. In this way, more space was provided for storing the green wares in the kiln instead of packing burner pot of kiln with wood logs. This is where internal combustion took over from what would have been external wood application resulting in a wasted external combustion. These principles were followed in this study. To achieve the above procedure, this work developed a clay body (wood-in-clay) which allowed green wares to be designed and fired.

However, in composing clay bodies ,Rhodes (1968:68), Cardew (1971;148) and Zakin (1990;11-38), who have done some work on clay bodies pointed to what percentage of clay and additives that should be used in order to get a satisfactory clay body in ceramic ventures.

In another study Clark (1968:68), Udom (2007:54-61), Ekong (2000:93-98) and Sulton (2011:27) maintained that the incorporation of other materials other than clay would change the face of pottery including energy released and combustion power.

The Additives
The material additive used in this work was oil palm wood stem. Palm tree, according to Ndon (2006:15) is a common name for any flowering plant of the order *Arecales* and of the single family of *Arecaeae*. Ndon continues that there are over 2,000 known palm species economically useful to man. Many of these species are found in the tropical and sub-tropical regions of the world (Moore, 1973:21-41). Nigeria is included; and it has been reported by the Nigerian Institute for Oil Palm Research NIFOR in 2011, that “oil palm: (*Elaeis guineensis*) is African in origin”. The oil palm tree formed a major source of economic sustenance in Nigeria, even Akwa Ibom State, before 1960 till 1970. Therefore its abundance becomes an ensured source of raw material.

The interesting thing about the oil palm tree is the economic importance embedded in its existence: from roots, trunks, leaves, the unfertilised inflorescence, oil palm fruit, even the empty fruit bunch. The palm oil, palm kernel oil, the palm kernel cake (PKC), the palm shell, the palm fibres, and even the mill effluent and sludge have their functions. No wonder Ndon (2006:18) posited that all parts of the oil palm tree are useful. While the trunk forms timber, firewood, fencing and construction materials for local bridges, “the old palm trunk is a good breeding ground for rhinoceros beetles which is a delicious traditional dish among the oil palm forest dwellers (Ndon, 2006:19)”. This research is particularly concerned with the energy producing nature of the by-products of the oil palm tree, especially the combustible materials that release heat energy. The palm tree is therefore resourceful.

The oil palm trees are abundant in Akwa Ibom State and can be employed in finding out its efficiency at the best possible stage. There is need to reduce the wood into tiny particles for combining with clay. This additive material can be explored and exploited for firing ceramics.

The research accepted oil palms not below 20 metres for the experiment.

For this study it became advisable to embark on traditional old oil palms in case they were to be cut or damaged for any purpose as paying compensation would not be necessary. And the best method after consultation with Nigerian Institute for oil Palm Research (NIFOR), was to visit across the state. Samples and sites were as follows: Etoi and Nung Udoe roads were very viable in Uyo geographical areas. Eket geographical areas at Esit Eket, Ikot Ataku and Onna, Ikot Abasi Road. In Ikot Ekpene geographical areas collections were made at Ikono, Abak, Essien Udim and Etim Ekpo. The best places to collect specimens were where wide and large proposed building sites were being cleared. There were others waiting to saw planks. It therefore became advantageous to savage the sawn particles otherwise one had to pound the cut stem to dust manually. It was advantageous to collect the dust at site because if taken to timber mill the dust would be adulterated.

The extraction, grinding and milling were done to 100 mesh and could be used to ignite fire if they were raised to their ignition temperature as suggested by D.O.T.in 2010.

In the present experiment, the milling time increased so as to reduce particle size of wood. The time of firing also increased so as to exhaust each wood energy firing at its maximum temperature. This was recorded as results of internal combustion backed up by only air. In the second phase of firing, as soon as this stage was reached, butane gas was employed to finish firing to maturity at cone 6 (1220^{o}C).

The particle size of wood, according to Arnothe and Litvan (1988:1412-1414) was a factor in the clay body homogeneity. This explained why the work of Cardew in 1968 where the big logs of wood gave energy only from external combustion. If the wood were to be made into tiny particles and actually mixed with the clay body, then, there would have been an internal combustion in the green ware. Hence the researcher's axiom, 'wood in clay' and 'not wood on clay'. An experiment carried out by Zakin (1990:7) indicated that percentages of clay for successful clay bodies ratio were as follows:

1. high clay percentage clay bodies = clay 90% and non-clay material 10%
2. medium clay percentage clay bodies = 60% and non- clay material 40%
3. low clay percentage clay bodies = 50% and non- clay- materials 50%

Zakin's pie chart recommended the correct clay body composition for a successful firing. Therefore the percentage of additives to make an effective clay body was guided by Zakin's work.

The Ceramic Firing: There is no ceramic until there is a transformation of green ware by heating. (Zakin 1990:228); Effiom (2000) affirmed that ceramic is green ware made permanent and irreversible by fire; and Cardew (1971:146) maintained that clay ware does not have any commercial value no matter how much craftsmanship is put into its making until it has been fired. Similarly, Andeval (2010:6) submitted that it is the trial by firing that completes the work of potting. This process of generating suitable heat to change clay ware to ceramic is what every ceramist uses to convert clay work to its ultimate end products (Igwilo, 2006:194-205). Therefore, firing is a common problem that potters through the ages have faced (Zakin, 1990:228 – 230). In this experiment, the works were fired between the ranges of 650 and 1240^{o}c.

Cardew's use of wood logs could have posed problems of log haulage, inconsistency of heat when the embers degenerate, kiln atmospheres not being in firm control, burning being subjected to smoky and strenuous conditions that created undesirability and frustration for a modern potter. Harrop (2011:2-4) have advised to conserve and preserve heat for energy efficiency search.

The likelihood of allowing heat energy to waste away as suggested by Oke and Udom (2007:56) in traditional open burnt firing, and Cardew (1971:148) in log firing, need a closer look so as to conserve energy. This is the reason for introducing some combustible substance to encourage internal combustion in firing. In this work, the temperature would maximise at 1220^{o}C. Clark (1968:8) mentioned the use of grass and leaves by primitive tribes in the third world but interestingly enough, Clark continued that the western potters did not lose anything by trying this method. In this paper it is argued that the 'primitive tribe' would improve with this basic principle.

This study shows the optimism that benefits can accrue from integrating oil palm wood particles into firing. It is a fact that wood particles as Okongwu (1988:1409 – 1414) mentioned have effects of lessening breaking strength to some extent in the ceramic composition, but the sizes of the wood, the proportion of wood/clay, the maximum temperature, the type of wood can also create desirable effects in ceramic products. It is interesting that an earlier experience of using cow dung by the researcher would have been encouraged but for knowing exactly which grass and element contents the cow ate. Thus, if the pulverized oil palm, *elaeis guineenis*, of known elements, which is abundant is introduced into clay body, it can raise the heat to a traceable source. Gas can then be complemented which would reduce the cost of the firing. Other effects could also be beneficial.

The ways of realising the quantity of heat supplied to the wares in the kiln was using Orton Cone and a thermocople.

The data collected from observations and recording of the temperature were analysed as shown in table 3.

Mean and Standard Deviation statistical tools were employed to answer research questions. This allowed the average of the result of each of the experiments to be known easily. Independent t-test was adopted to test the research hypotheses because of the two sets of data: the POPW and the POPW/GAS results.

Research Procedures

The ball-milled POPW was added to the controlled clay body in the ratio (0:100), (20:80), (30:70), (40:60), (50:50) batches. At least 50 dice were made to have enough representation of the batches.

Design and Production

The size of the dice needed for the experiment was (12 x 4 x 1.5) cm^3. Each piece was produced by pressing method in metal mould. Similar method of production was applied to the entire specimens which were kept for one week to air dry for firing. In drying out it was necessary to keep them flat between moderate load of paper to ensure flattened surface.

Loading and Firing: Enough quantity, fifty, of each batch was loaded for each firing. The pyrometric Orton cone levels, 022 to 6, for firing maturity reliability, were laid together with the specimens in the kiln. Digital pyrometer was also used to confirm the temperature. At the end of exhaustible combustion temperature of each specimen, the group temperature was recorded and the firing stopped. These were based on 650^{o}C, 700^{o}C, 800^{o}C, 900^{o}C and 1050 while the limit for liquefied gas was 1220^{o}C maximum temperature. Having recorded the data that would help test for different effects as required in the objectives, the researcher shut off the kiln and allowed it to cool to room temperature before unloading finally. This was for kiln safety.

B. Adopted clay body: Ebe's Recipe of 2008: 30% Kaolin, 30% fire clay, 20% ball clay, 10% feldspar, 5% quartz, 3% talc 2% bentonite (100% in all).

These tested specimens actually established the elements present before the experiment as any newly formed element or compound during the experiment might show some new effects.

The Firing: Experiments were conducted in stages 1, 2 and 3.

Stage 1 was made up of the control specimen of 100% Ebe's clay body(adopted clay body) and 0% POPW fired traditionally with gas to cone 6 (1230^{o}C).

Stage 2 was made up of the determined percentage composition of Ebe's clay body and POPW specimens fired with air only to exhaustible energy level in temperature.

Stage 3 was made up of the stage 2 augmented with gas to cone 6 (1230^{o}C).

The ultimate aim of the ceramic experiments depended on firing so as to meet the ideal conditions for testing other variables. Observations were made and recorded in Table 3.

After the experiments were conducted, data were obtained and the analysis done, using mean and standard deviation for research questions and t-test for the hypothesis as shown in the following tables:

Presentation of Result

Tables, linear and bar graphs are used to present the results.

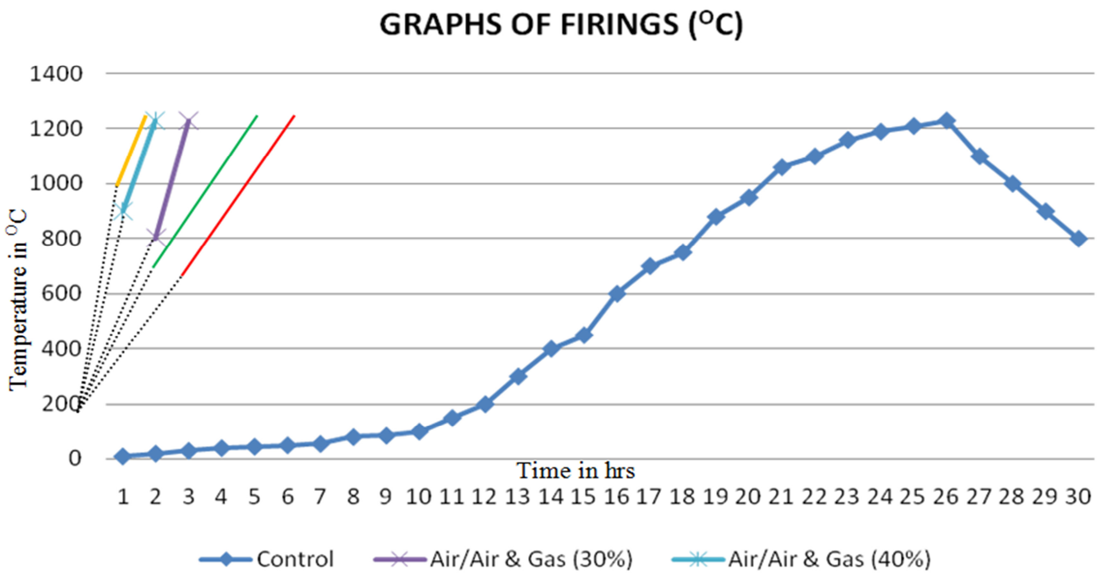
The research question sought to find out if there were any significant effects of pulverized oil palm POPW in clay body on heat generated in ceramic firing?

Table 3: The effects of pulverised oil palm wood (POPW) in clay body on heat and fuel consumption in ceramic firing are recorded from the observations as:

Specimen	Clay Body in %		Firing with air only in °C				Firing with Air and Gas to Cone 6				firing with gas only to Δ6
	Ebe's clay body	POPW	Start	Stop	Firing (hr)	Rate of firing °C/hr	Start	Stop	Firing time (Hrs)	Rate of firing °C/hr	1230°C
Control	100	0	Rm. T	-	-	-	-	-	-	-	1230°C @ 47°/hr for 26 hrs
1	90	10	"	650 Δ019	4	162	650	1240 Δ6	6	85	
2	80	20	"	700 Δ018	4	175	700	1230 Δ6	5	106	
3	70	30	"	800 Δ014	3	267	800	1220 Δ6	4	105	
4	60	40	"	900 Δ012	2	450	900	1230 Δ6	3	110	
5	50	50	"	1050 Δ04	1	110	1050	1215 Δ6	1¾	94	
Calculated mean:		x	=	820		:	1228.00				
Standard deviation:		std	=	160.468		:	10.368				

NOTE: Each reading was the average of three observations. Cone sample Rm, T. = Room Temperature

Entries in Table 4.1 showed the greater mean of 1228.00 for maximum temperature when POPW clay body was fired with air and gas, and a lower mean of 820.00 for maximum temperature when POPW clay body was fired with air only. The standard deviations of 160.468 and 10.368 show the variability of each score from the mean.



The result means that the maximum temperature obtained from both firing methods is greater with air and liquefied gas than with air only. This result is further demonstrated in Figure 2. The graphic presentation revealed that the estimated marginal means for firing with liquefied gas and air, and air only, are increasing across level, but greater at the former than the latter.

Figure 1: Graph of firings in (^{O}C)

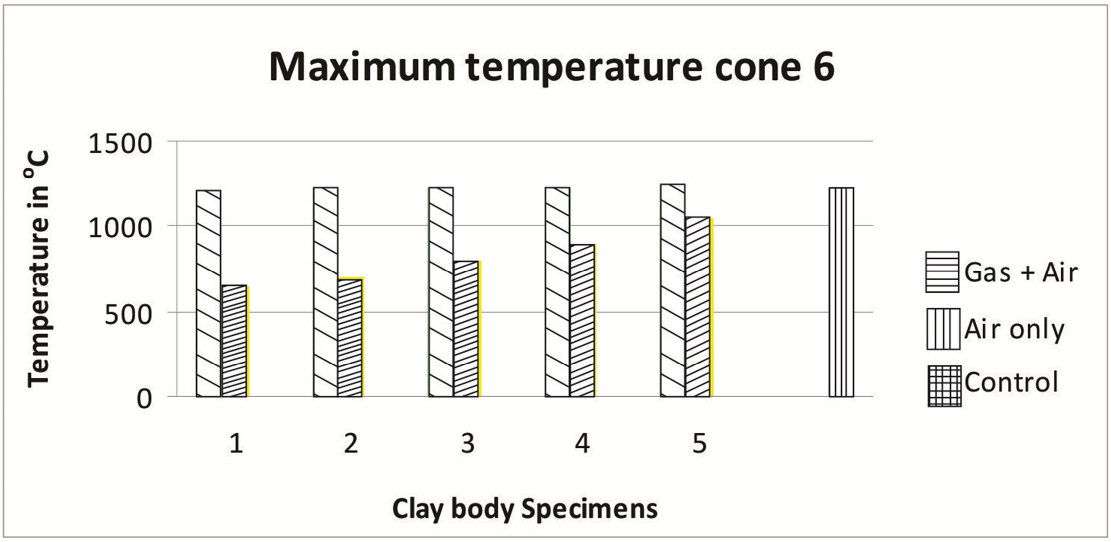


Figure 2: Maximum temperature cone 6 of Ebe's clay body and POPW compositions 1 to 5 in ceramic firing

4. Augmenting POPW with gas increases firing efficiency; it can be found out from this analysis that low firing of the POPW clay body does not require gas augmentation.
5. High firing of POPW clay body requires less amount of gas than firing with gas only.

The application of Le Chatelier's principle shows that, with the pressure increment and the constant volume of the kiln, the temperature increased to the advantage of the firing. The effects of absorption of heat energy by the wares were noted as the wood gave out the heating effects and according to Cardew (1971) in his firing number 100, energy was lost by radiation from the wood to the surroundings. This was because the firing was wood on green-wares; but in this experiment of POPW in clay, where the wood is actually mixed homogeneously inside clay, internal combustion conserved heat from radiating. Another finding is that oxygen of the air aided combustion which according to La Voisier (1777) supports combustion. This was derived from the atmosphere, meaning that external factor (air) is an advantage material in heat generating. It should be noted that the primary source of energy that raised the temperature was the 80% organic matter as seen in the POPW analysis.

The experiment also showed that the more the percentage of POPW in the specimen, the less liquefied petroleum gas was required. There were interestingly some alumina and silica contents in the POPW, confirming that these two components are actually clay constituents; and therefore, can become an integral part that enhances the composition as modifiers (Zakin, 1990:3 – 11). The findings further showed that, apart from significant effects in energy provision, POPW in ceramic firing is another source of ceramic secondary fluxes that could be explored and exploited in the ceramic industry.

In returning to the research hypothesis, there is no significant effect of pulverized oil palm wood (POPW) in clay body on heat generated and fuel consumption in ceramic firings.

In this work the temperature was measured, and since the temperature is related to energy of a system (Glasstone, 1966), it thus justified in relating the heat to the heat energy obtained by burning the POPW in wood and confirming the heat-work-done with Orton cone.

Table 4 Summary of t-test analysis for effects of POPW in clay body on heat generated in ceramic firing

Variable	Firing	N	Mean	Std deviation	df	t-test	t-crit
Temperature	With Air only	5	820.00	160.446	8	-5.674*	2.309
	With Air and liquefied gas	5	1228.00	10.368			

** Significant at 0.05 level of significance*

Table 4 showed that the calculated value of -5.674 was greater than the critical t-value of 2.309 at .05 level of significant with 8 degrees of freedom. The result is significant; therefore, the hypothesis that there is no significant effect of POPW in body heat generated and fuel consumption in ceramic firing is rejected. The result means that POPW in clay body affects fuel consumption in terms of temperature observed.

Conclusion

In conclusion, finding a way of solving energy problem by utilizing the neglected raw materials like the Pulverized Oil Palm Wood (POPW) of felled oil palm trees in ceramic firing in Nigeria especially the outcome of combination of POPW in clay body, combination of firing with the POPW in air and augmenting with gas, there is a better future for ceramic industry and energy utilization in Nigeria.

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