JEAS

JOURNAL OF ENGINEERING
AND
APPLIED SCIENCES

Journal of Engineering and Applied Sciences, Volume 21, Number 1, Dec. 2022, 799 - 812

The effect of sawdust, cow dung, and CaC_2 wastes on properties of refractory bricks

V.E. Ojukwu[1*] and R.O. Ajemba [2]
[1, 2]Department of Chemical Engineering, Faculty of Engineering, Nnamdi Azikiwe University
[*]Corresponding Author's E-mail: ve.ojukwu@unizik.edu.ng

Abstract
The effect of sawdust, cow dung, and CaC_2 waste on fireclay was studied. The X-ray Fluorescence (XRF) analysis of the fireclay showed that it contains about 14.328% and 44.382% of Al_2O_3 and SiO_2, respectively. The result of the scanning electron microscope (SEM) showed that the fireclay contained a mixture of coarse and fine grain particles. The analysis on the fireclay was; fireclay with cow dung only, sawdust only, Cow dung & CaC_2 waste, and sawdust & CaC_2 waste. In each phase, fireclay was combined in the ratio of 100, 90, 80, and 70%, for the additives used. All these properties were studied at 1000^0C and 1200^0C for all the additive combinations. The sample containing 30wt% of Sawdust and CaC_2 waste had the highest apparent porosity of 74% and 74.48% at 1000^0C and 1200^0C, respectively. The lowest apparent porosity was seen in the sample containing 10wt% of cow dung which were 15.29% and 9.06% at 1000^0C and 1200^0C, respectively. In this work, apparent porosity, water absorption, apparent density, and bulk density showed similar graphical trends for all the samples produced. On the other hand, linear shrinkage decreased at constant temperature but increased as the temperature varied from 1000^0C to 1200^0C for all samples produced. Analysis of Variance (ANOVA) carried out on the samples showed that most of the properties evaluated were significant.

Keywords: Refractories, fireclay, additives, biowastes, mechanical properties, firebrick

1. Introduction

Refractories are used in ovens, furnaces, and boilers to achieve heat transfer efficiency whilst minimizing cost. Generally, non-metallic inorganic materials which are both chemically and physically stable over a wide temperature range of 600-1200°C are referred to as refractory materials (Antonovič et al., 2017; Shuaib-Babata et al., 2018). They occur in different forms and can resist heat as high as 1500^0C hence retaining their physical and chemical properties (Antonovič et al., 2017; Chima et al., 2017; Zaidan & Omar, 2018). In Nigeria, there are about seven clay deposits that have proven refractory properties and hence good candidates for refractory brick production (Amkpa et al., 2017b; Oke et al., 2015). Amkpa et al. (2017b) stated that there are possibly clay deposits in all the 36 states of the federation which until now are yet to be studied. This implies that Nigeria could become one of the world's leading producers of refractory materials if the potentials of these clay deposits are exploited. Irrespective of the large clay deposits found in Nigeria, she is yet to meet her refractory needs in both quality and quantity. The major reason for this is that most of the refractories used to wear out after several usages. This is because their chemical and physical properties become weakened over time leading to failures and fractures (Kazemi, 2019). Given this, mixtures of clay with another clay or with additives have been used to further extend the shelf life of the refractory materials by improving properties like thermal shock resistance, cold crushing strength, bulk density, porosity, etc. (Chima et al., 2017). Additives used are mainly biowastes which enable proper management of these wastes and reduce disposal costs (Cultrone et al., 2020). The relationship between mechanical properties and thermal conductivity of an insulating fire brick using petroleum coal dust as an additive was studied by (Rahman et al., 2015). The additive was incorporated in the range of 5wt% to 20wt% and it was discovered that the finer coal dust particles of size less than 20μm performed best in terms of the measured mechanical and thermal properties owing to the fineness of the additives (Rahman et al., 2015). Elsewhere, (Amkpa et al., 2017a) worked on Barkin-

Ladi clay and determined its suitability for refractory application. It was discovered that the clay is refractory having a thermal conductivity of 0.03W/mK, a specific heat capacity of 0.07J/g^{0}C, refractoriness of 1665^{0}C, thermal shock resistance of 24 cycles, and high energy absorption. In the present work, efforts have been made to study the effects of local additives namely; sawdust, cow dung, and calcium carbide (CaC_2) waste on the refractory properties of local clays.

2.0 Material and methods

2.1 Materials sourcing and characterization

The fire clay sample selected for investigation was obtained from Isiagu, Awka South Local Government Area of Anambra State. Definite fire clay of precisely grey to light brown colour was collected. The colour may be due to the high amount of Fe_2O_3 in it. The analysis of fire clay was done in a chemical laboratory using both X-ray Fluorescence and Scanning Electron Microscope (SEM). Consequently, cow dung, sawdust, and calcium carbide (CaC_2) waste were sourced from cow stalls, timber, and panel beating shop all in Awka.

2.2 Materials processing

The clay was obtained in lumps. It was sun-dried to remove its moisture The clay was reduced to smaller sizes mechanically with the aid of a mortar and pestle (crusher) after which they were sieved to the required particle size with the aid of a 600μm sieve. The ratio of the mixture samples for the production is shown below in Table 1.

Table 1: Percentages of additives and clay in the test samples

Sample	Clay (%)	Cow dung only	Sawdust only	Cow dung and CaC_2 waste		Sawdust and CaC_2 waste	
A	100	0	0	0	0	0	0
B	90	10	10	5	5	5	5
C	80	20	20	10	10	10	10
D	70	30	30	15	15	15	15

2.3 Materials mixing and molding

Based on the research design, the various compositions of clay, sawdust, cow dung, and CaC_2 waste were weighed out and mixed properly. Water was then added to the samples (100%clay, 90%clay, 80%clay, and 70%clay). Due to the addition of water, a sticky mass was formed. With the aid of the mould (solid materials made of wood used to form clay samples into different shapes), the sticky mass was formed into different shapes (cylindrical, rectangular) (Chima et al., 2017). The application of lubricants to the surface of the moulds was done to prevent the test pieces from sticking to the surface (Chima et al., 2017). The first shape is cylindrical with a width of 3.5cm and height of 3.7cm, the second is a rectangular piece with a length of 8cm, width 4cm, and height of 1.5cm, while the third has a long rectangular shape with a length 9.5cm, width 2cm and height 1.5cm

2.4 Drying and firing

The moulded test pieces were then allowed to dry by exposing them to air for some time. After air-drying the test pieces, they were then moved into the oven where they were dried at a temperature of 200^{0}C for two days. They were thereafter moved into a furnace where they were fired at high temperatures (1000^{0}C, 1200^{0}C). There is a temperature gradient in the furnace which enabled the firing of the various clay compositions at various temperatures. The various test pieces were allowed to stay in the furnace for a week after which the furnace was unloaded.

2.5 Measurement of Refractory Properties

a. Apparent Porosity

Apparent porosity is the percentage relationship between the volume of the open space and the total volume of the material as given by (ASTM-C20-00, 2015). The brick was oven-dried at 110ºC to constant weight (D). After which it was transferred to a beaker and boiled with distilled water for 1.5hrs to assist in releasing the trapped air. It was soaked and the saturated weight free of water (W) was obtained. Finally, the specimen was suspended in the water by a rope tied to a spring balance and the suspended weight (S) was obtained when it is completely immersed in water.

$$\boldsymbol{ApparentPorosity = \%P_a = \frac{W-D}{W-S}\, x\, 100} \qquad (1)$$

Where:

D = Constant Weight of the dry Sample

S= Weight of the sample suspended in the water

W= Weight of sample in the air including the moisture in its open pores (saturated weight)

b. Determination of Water Absorption

The fired test pieces obtained after firing were then weighed and the weight recorded as dry weight, M_1(g). Thereafter, the test pieces were soaked in water for one hour, then removed, cleaned, and weighed immediately, and recorded as soaked weight, M_2 (g). The water of adsorption was then calculated.

$$\boldsymbol{Water\ Absorption}\ (\%) = \boldsymbol{100x\frac{M_2-M_3}{M_1}} \qquad (2)$$

Where;

M_2 = soaked weight, M_1= dry weight, M_3= the weight in air

c. Bulk Density (BD) and Apparent Density

The Bulk Density (BD) of a refractory indicates whether the refractory was well fired and thus the degree of densification and it was obtained by dividing the test brick mass by the exterior volume and multiplying with a density of water as recommended by (ASTM-C20-00, 2015).

$$\boldsymbol{Bulk\ Density = \frac{Dry\ weight\ of\ sample\ X\ Density\ of\ water}{saturated\ weight\ in\ air - suspended\ weight\ in\ water}} \qquad (3)$$

$$\boldsymbol{Apparent\ Density = \frac{Dry\ weight\ of\ sample\ X\ Density\ of\ water}{suspended\ weight\ - suspended\ weight\ in\ water}} \qquad (4)$$

d. Linear Shrinkage

This evaluates the linear changes that occur in brick samples when heated. The formula is as given in the work of (Adeosun et al., 2016). This is calculated based on the original length (L_o) before drying and the final length (L_f) after firing to a certain temperature

$$\boldsymbol{Percentage\ Total\ Shrinkage = \frac{L_o - L_f}{L_o}\ x\ 100} \qquad (5)$$

Where; Lo= the green length, L_f = the fired length

3.0 Results and Discussions

3.1 Chemical Analysis of fireclay

The fireclay was analyzed using both XRF and SEM and the result indicated that the clay is a fireclay as it has refractoriness of about 1,460^{0}C as was calculated using Shuen's formula (Iyasara et al., 2016) (Eqn 6). However, this is lower than that recommended by Madugu (2016). Although Elakhame et al. (2016) found that fireclays have an alumina percentage of 39.50%, the fireclay used in the current has some admirable properties especially as the additives were incorporated (Elakhame et al., 2016).

$$\boldsymbol{Refractoriness\ (K) = \frac{360 + Al_2O_3 - RO}{0.228}} \qquad (6)$$

Where RO implies other oxides minus Al_2O_3 and SiO_2

The result of the mineral content of the fireclay was presented in Table 2.

Table 2: Result of X-ray Fluorescence showing the concentration of various minerals in the Isiagu fire clay sample

Element	Concentration (Wt%)
Na_2O	1.315
MgO	1.273
Al_2O_3	14.328
SiO_2	44.382
P_2O_5	1.115
K_2O	1.938
CaO	0.550
TiO_2	1.004
Fe_2O_3	4.936
TOTAL	100

The result of the SEM micrograph indicated that the clay is a mixture of micro and macroparticles therefore at different wavelengths namely; 536µm, 268µm, and 44.7µm as shown in Figure 1.

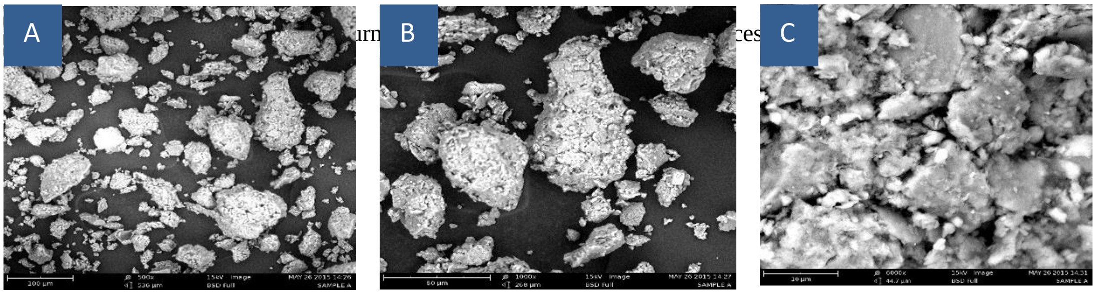

Figure 1: SEM micrograph of Isiagu Clay; A) at 536µm; B) at 268µm; C) at 44.7µm

3.2 Refractory analysis results

a. Apparent porosity

The pore formers, cow dung, and sawdust are known to increase apparent porosity as they were removed when the brick material is fired (Babaso & Sharanagouda, 2017). There was a steady increase in the apparent porosity with additive amount as compared with the control (Fig 2.0) which were 12.95 and 5.33 wt% at 1000^0C and 1200^0C, respectively. The highest apparent porosity (74.48%) was recorded by the sample containing both sawdust and CaC_2 waste at 1000^0C and 1200^0C. This is way off the standard as was given by Chima et al. (2017) which is in the range of 2 to 30%. This may be as a result of the air pockets in the sample as (Keter, 2016) observed. Based on Chima et al. (2017) the reference provided samples containing cow dung only and sawdust only fell within the limit (Chima et al., 2017).

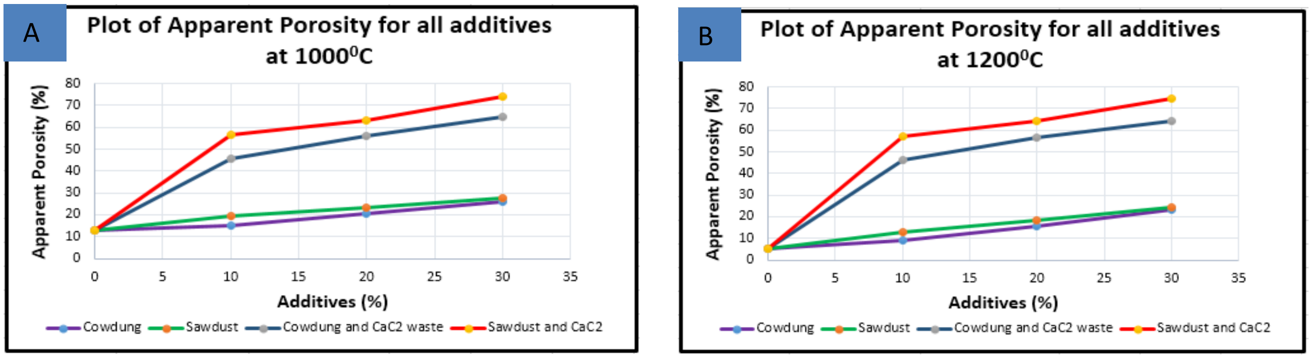

Figure 2: Plot of Apparent Porosity for all samples at A.) 1000^0C and B.) 1200^0C

b. Water absorption

Water absorption in its own right had the same trend as apparent porosity having the highest value of 64.06% for cow dung and CaC_2 waste combination at 1000^0C and lowest value of 2.74% at 1200^0C (Fig 3.0). Just like apparent porosity, water absorption increased steadily with the additive percentage at both temperatures (Ajala & Badarulzaman, 2016). Based on the international standard of 20 to 80%, we can conclude that the water absorption values for all the samples containing cow dung only or sawdust only fell below the limit while the ones containing cow dung & CaC_2 and sawdust & CaC_2 were within the acceptable limit and hence met the requirement for refractory application (Chikwelu et al., 2018).

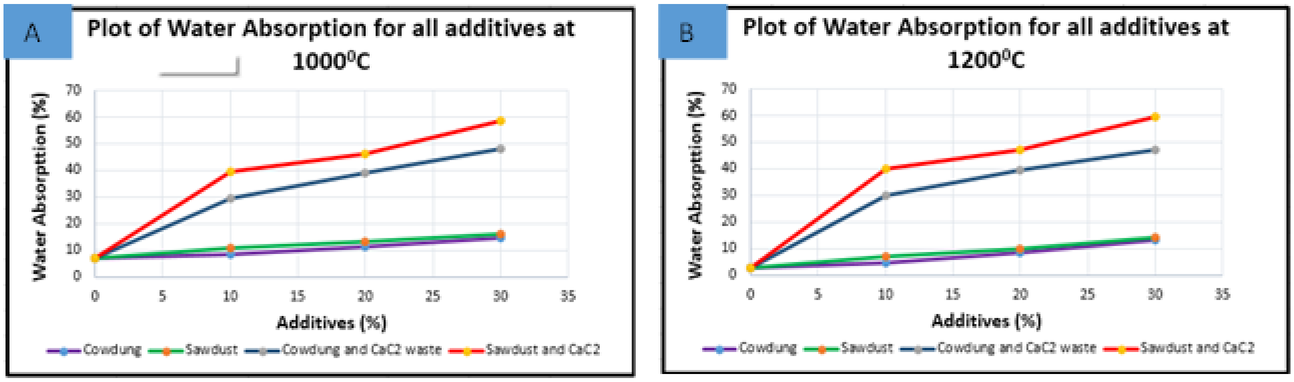

Figure 3: Plot of Water absorption for all samples at A.) 1000^{0}C and B.) 1200^{0}C

c. Apparent Density

The apparent density at both 1000^{0}C and 1200^{0}C increased steadily for sawdust & CaC_2 only and cow dung & CaC_2 only and a slight increase for cow dung only and sawdust only. The internationally accepted standard of 2.3-3.5g/cm^3 was achieved in the samples containing cow dung only and sawdust only at 30% additive percentage while that of sawdust & CaC_2 only and cow dung & CaC_2 only was achieved at 10% additive percentage (Chikwelu et al., 2018).

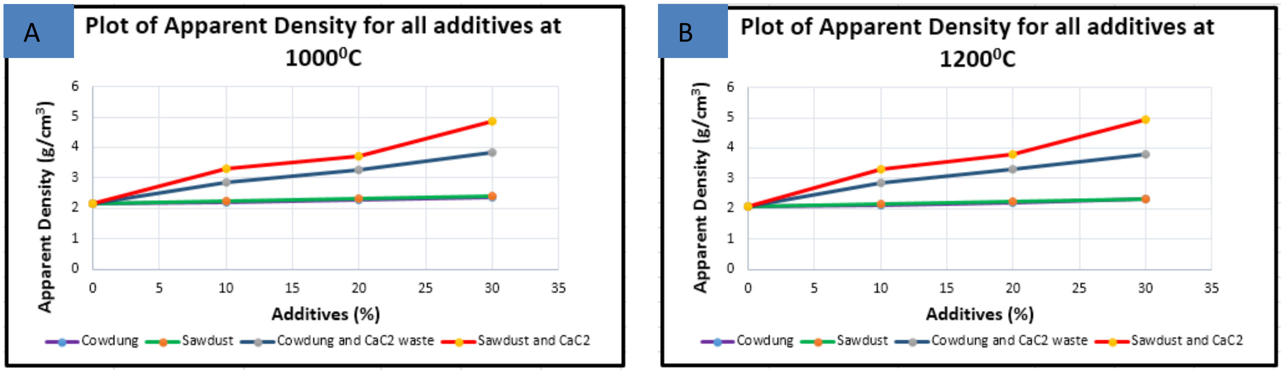

Figure 4: Plot of Apparent Density for all samples at A.) 1000^{0}C and B.) 1200^{0}C

d. Bulk density

Bulk density decrement is following previous works(Chima et al., 2017; Rahman et al., 2015; Velasco et al., 2015) (Velasco et al., 2015). It was seen that the samples containing sawdust & CaC_2 only and cow dung & CaC_2 only fell below the internationally permissible value of 1.7- 2.1 g/cm^3. While the samples containing sawdust and cow dung only at 30% additive met the internationally permissible standard.

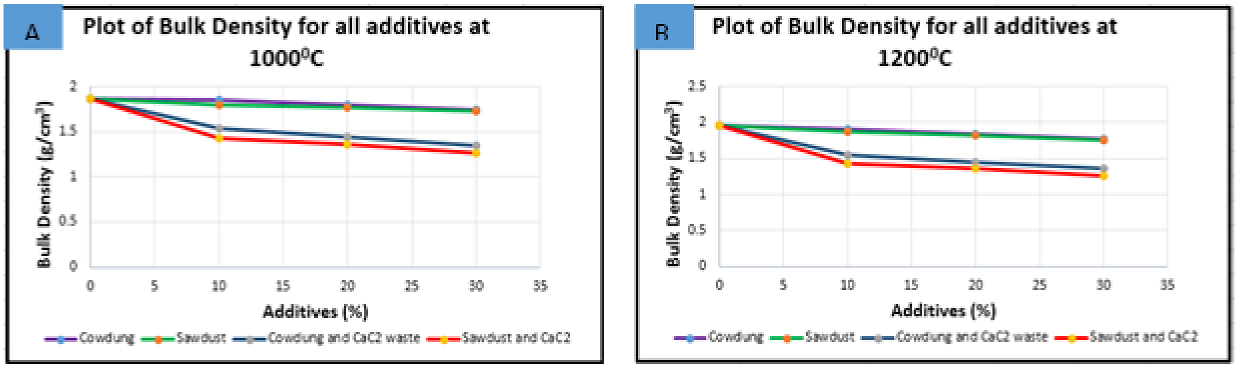

Figure 5: Plot of Bulk Density for all samples at A.) 1000^{0}C and B.) 1200^{0}C

e. Linear shrinkage

The graph in Fig 6.0 shows the variation of the linear shrinkage from 1000^{0}C to 1200^{0}C. The standard permissible limit for linear shrinkage was given by Chima et al, 2017 as 7-10% (Chima et al., 2017). In the present work, the range was met by the samples containing sawdust only as it ranged from 7.4 at 10wt% to 8.76% at 30wt%. Hence, the samples containing sawdust only can be applied in the production of refractory bricks.

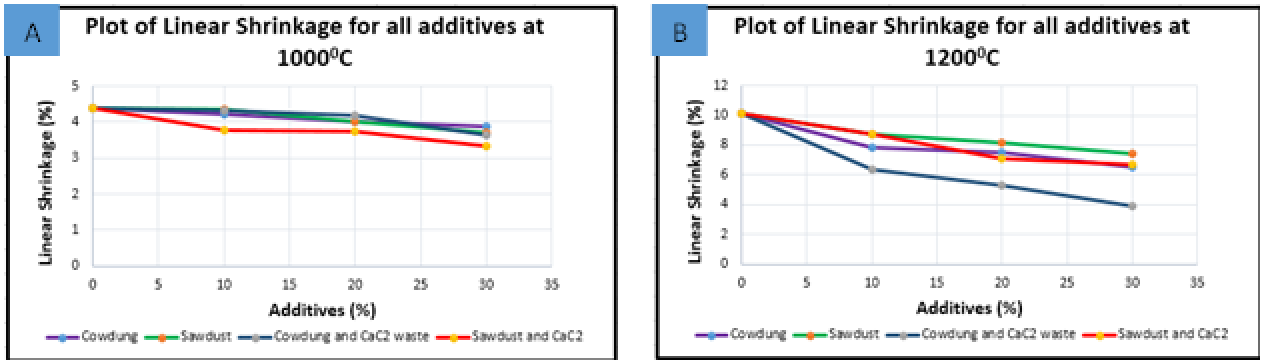

Figure 6: Plot of Linear Shrinkage for all samples at A.) 1000^{0}C and B.) 1200^{0}C

3.3 Analysis of Variance (ANOVA) for the brick samples

The two-way Analysis of Variance (ANOVA) without replication was carried out for all the brick samples using *Excel 2013*. The results of the analysis are given for the additive categories;

A. COW DUNG ONLY

Analysis of Variance was carried out on samples containing cow dung only. The results are as shown in Table 3-7. The analysis of the effect of temperature and cow dung additive using two-way ANOVA without replication was found to be significant (P<0.05) for the properties tested except the linear shrinkage which had a P-value for cow dung additive (>0.05)(Li et al., 2013; Shehu et al., 2018).

Table 3: Apparent Porosity ANOVA

APPARENT POROSITY ANOVA			COW DUNG ONLY		
Source of Variation	*df*	*F*	*P-value*	*F crit*	*Remark*
Temperature	1	24.29455	0.016008	10.12796	**significant**
Cow dung Percentage	3	39.82436	0.00646	9.276628	**significant**
Error	3				
Total	7				

Table 4: Water Absorption ANOVA

WATER ABSORPTION ANOVA			**COW DUNG ONLY**		
Source of Variation	*Df*	*F*	*P-value*	*F crit*	*Remark*
Temperature	1	33.49472	0.010261	10.12796	**significant**
Cow dung Percentage	3	58.13934	0.003714	9.276628	**significant**
Error	3				
Total	7				

Table 5: Apparent Density ANOVA

APPARENT DENSITY ANOVA			**COW DUNG ONLY**		
Source of Variation	*Df*	*F*	*P-value*	*F crit*	*Remark*
Temperature	1	72.08571	0.003431	10.12796	**significant**
Cow dung Percentage	3	131.9714	0.001105	9.276628	**significant**
Error	3				
Total	7				

Table 6: Bulk Density ANOVA

BULK DENSITY ANOVA			**COW DUNG ONLY**		
Source of Variation	*df*	*F*	*P-value*	*F crit*	*Remark*
Temperature	1	22.42373	0.017854	10.12796	**significant**
Cow dung Percentage	3	38.28814	0.006841	9.276628	**significant**
Error	3				
Total	7				

Table 7: Linear Shrinkage ANOVA

LINEAR SHRINKAGE ANOVA			**COW DUNG ONLY**		
Source of Variation	*df*	*F*	*P-value*	*F crit*	*Remark*
Temperature	1	33.27453	0.010356	10.12796	**significant**
Cow dung Percentage	3	1.726773	0.332351	9.276628	**Not significant**
Error	3				
Total	7				

B. SAWDUST ONLY

Analysis of Variance was carried out on samples containing sawdust only. The results are as shown in Table 8-12. The analysis of the effect of temperature and sawdust additive using two-way ANOVA without replication was found to be significant ($P<0.05$) for the properties tested except the linear shrinkage which had a P-value for sawdust additive (>0.05) (Li et al., 2013; Shehu et al., 2018)

Table 8: Apparent Porosity ANOVA

APPARENT POROSITY ANOVA			**SAWDUST ONLY**		
Source of Variation	*df*	*F*	*P-value*	*F crit*	*Remark*
Temperature	1	30.17257	0.011872	10.12796	**significant**
Sawdust Percentage	3	50.36757	0.004584	9.276628	**significant**
Error	3				
Total	7				

Table 9: Water Absorption ANOVA

WATER ABSORPTION ANOVA			**SAWDUST ONLY**		
Source of Variation	*Df*	*F*	*P-value*	*F crit*	*Remark*
Temperature	1	44.20659	0.006934	10.12796	**significant**
Sawdust Percentage	3	75.25756	0.002539	9.276628	**significant**
Error	3				
Total	7				

Table 10: Apparent Density ANOVA

			SAWDUST ONLY		
Source of Variation	*df*	*F*	*P-value*	*F crit*	*Remark*
Temperature	1	67.04651	0.003811	10.12796	**significant**
Sawdust Percentage	3	124.1628	0.001209	9.276628	**significant**
Error	3				
Total	7				

Table 11: Bulk Density ANOVA

BULK DENSITY ANOVA			**SAWDUST ONLY**		
Source of Variation	*df*	*F*	*P-value*	*F crit*	*Remark*
Temperature	1	17.28571	0.025302	10.12796	**significant**
Sawdust Percentage	3	29.2381	0.010108	9.276628	**significant**
Error	3				
Total	7				

Table 12: Linear Shrinkage ANOVA

			SAWDUST ONLY		
Source of Variation	*df*	*F*	*P-value*	*F crit*	*Remark*
Temperature	1	105.6048	0.001965	10.12796	**significant**
Sawdust Percentage	3	2.649703	0.222365	9.276628	**Not significant**
Error	3				
Total	7				

C. COW DUNG AND CAC$_2$ ONLY

Analysis of Variance was carried out on samples containing cow dung & CaC$_2$ only. The results are as shown in Table 13-17. The analysis of the effect of temperature and cow dung & CaC$_2$ additive using two-way ANOVA without replication was found to be significant for properties such as apparent porosity, water absorption, apparent density, and bulk density ($P<0.05$) for the various percentages of additives used. However, the results were not significant ($P>0.05$) for the same set of properties at various temperatures (Li et al., 2013; Shehu et al., 2018). This may be attributed to the high loss of matter as the samples were fired. The result of the linear shrinkage showed that both temperature and additive percentage were not significant. This may also be attributed to the high loss of matter as the samples were fired.

Table 13: Apparent Porosity ANOVA

APPARENT POROSITY ANOVA		**COW DUNG AND CaC2**			
Source of Variation	*df*	*F*	*P-value*	*F crit*	*Remark*
Temperature	1	0.899957	0.41278	10.12796	**Not significant**
Additive percentage	3	156.4839	0.000857	9.276628	**significant**
Error	3				
Total	7				

Table 14: Water Absorption ANOVA

WATER ABSORPTION ANOVA		**COW DUNG AND CaC2**			
Source of Variation	*df*	*F*	*P-value*	*F crit*	*Remark*
Temperature	1	0.907268	0.411111	10.12796	**Not significant**
Additive Percentage	3	284.2538	0.000352	9.276628	**significant**
Error	3				
Total	7				

Table 15: Apparent Density ANOVA

APPARENT DENSITY ANOVA		**COW DUNG AND CaC2**			
Source of Variation	*df*	*F*	*P-value*	*F crit*	*Remark*
Temperature	1	1.058824	0.379187	10.12796	**Not significant**
Percentage Additives	3	616.0588	0.000111	9.276628	**significant**
Error	3				
Total	7				

Table 16: Bulk Density ANOVA

BULK DENSITY ANOVA		**COW DUNG AND CaC2**			
Source of Variation	*df*	*F*	*P-value*	*F crit*	*Remark*
Temperature	1	1.357542	0.328185	10.12796	**Not significant**
Additive Percentage	3	160.2849	0.000827	9.276628	**significant**
Error	3				
Total	7				

Table 17: Linear Shrinkage ANOVA

LINEAR SHRINKAGE ANOVA		**COW DUNG AND CaC2**			
Source of Variation	*df*	*F*	*P-value*	*F crit*	*Remark*
Temperature	1	3.576957	0.154958	10.12796	**Not significant**
Additive Percentage	3	1.494868	0.374557	9.276628	**Not significant**
Error	3				
Total	7				

D. SAWDUST AND CAC$_2$ ONLY

Analysis of Variance was carried out on samples containing Sawdust & CaC$_2$ only. The results are as shown in Table 16-20. The analysis of the effect of temperature and Sawdust & CaC$_2$ additive using two-way ANOVA without replication was found to be significant ($P<0.05$) for properties such as apparent porosity, water absorption, apparent density, and bulk density for the various percentages of additives used. However, the results were not significant ($P>0.05$) for the same set of properties at various temperatures (Li et al., 2013; Shehu et al., 2018). This may be attributed to the high loss of matter as the samples were fired. The result of the linear shrinkage showed that while the temperature is significant additive percentage was not significant. This may also be attributed to the high loss of matter as the samples were fired.

Table 18: Apparent Porosity ANOVA

APPARENT POROSITY ANOVA		**SAWDUST & CAC$_2$**			
Source of Variation	*df*	*F*	*P-value*	*F crit*	*Remark*
Temperature	1	0.440156	0.554475	10.12796	**Not significant**
Additive Percentage	3	190.7879	0.000638	9.276628	**significant**
Error	3				
Total	7				

Table 19: Water Absorption ANOVA

		SAWDUST & CAC$_2$			
Source of Variation	*df*	*F*	*P-value*	*F crit*	*Remark*
Temperature	1	0.145871	0.727961	10.12796	**Not significant**
Additive Percentage	3	349.1949	0.000259	9.276628	**significant**
Error	3				
Total	7				

Table 20: Apparent Density ANOVA

		SAWDUST & CAC$_2$			
Source of Variation	*df*	*F*	*P-value*	*F crit*	*Remark*
Temperature	1	0.384615	0.579065	10.12796	**Not significant**
Additive Percentage	3	813.6769	7.3E-05	9.276628	**significant**
Error	3				
Total	7				

Table 21: Bulk Density ANOVA

BULK DENSITY ANOVA		**SAWDUST & CAC_2**			
Source of Variation	*df*	*F*	*P-value*	*F crit*	*Remark*
Temperature	1	1	0.391002	10.12796	**Not significant**
Additive Percentage	3	208.1667	0.00056	9.276628	**significant**
Error	3				
Total	7				

Table 22: Linear Shrinkage ANOVA

		SAWDUST & CAC_2			
Source of Variation	*df*	*F*	*P-value*	*F crit*	*Remark*
Temperature	1	51.37499	0.005594	10.12796	**Significant**
Additive Percentage	3	2.732023	0.215525	9.276628	**Not significant**
Error	3				
Total	7				

4.0. Conclusion

The effect of cow dung and sawdust together with CaC_2 additives on the refractory properties of clay was studied. Also, all the samples were subjected to an ANOVA test using Excel 2013. The conclusions drawn from this work is as follows;

i. In this study, CaC_2 waste was combined with pore formers (Cow dung and CaC_2) which produced more pores compared with other additives previously used.
ii. The highest apparent porosity (74.48%) was recorded by the sample containing sawdust and CaC_2 waste only at 1000°C and 1200°C.
iii. Water absorption in its own right had the same trend as apparent porosity having the highest value of 64.06% for cow dung and CaC_2 waste combination at 1000°C and lowest value of 2.74% at 1200°C.
iv. The apparent density at both 1000°C and 1200°C increased steadily for sawdust & CaC2 only and cow dung & CaC_2 only and a slight increase for cow dung only and sawdust only. This is due to the difference in the pore amount between the former and the latter. Bulk density and linear shrinkage both followed the internationally acclaimed standard.
v. The samples containing cow dung only and sawdust only had P-values (<0.05) indicating that temperature and additive percentages were significant for all properties measured. This was the reason moderate pores were produced on the surface of the samples making them good for refractory application.
vi. However, the linear shrinkage indicated that cow dung percentage was not significant ($P>0.05$) compared with temperature. This is so because linear shrinkage increased with temperature.
vii. Samples containing cow dung and CaC_2 only and sawdust and CaC_2 only, showed that only additive percentage was significant for properties measured. This was responsible for the many pores formed on the surface of the samples which makes them adequate for insulation application.

5.0 Recommendation

From this work it is clear that CaC_2 waste can't be used as an additive for refractory brick production since it gave porosity far above the internationally acclaimed standard. Other biowastes such as melon shell, groundnut shell and palm kernel shell can also be studied to investigate their effect on fireclays.

Acknowledgements

The authors wish to acknowledge the assistance and contribution of the staff of the Department of Chemical Engineering and those of Projects Development Institute (PRODA) Enugu towards the success of the work.

Reference

Adeosun, S., Akpan, E., Gbenebor, O., Taiwo, O., & Eke, I. 2016. Refractory behaviors of magnetite–kaolin bricks. *JOM*, *68*(11), 2824-2831.

Ajala, A. J., & Badarulzaman, N. A. 2016. Performance Assessment of Physico-Mechanical Properties of Aloji Fireclay Brick. *International Journal of Integrated Engineering, 8*(2).

Amkpa, J. A., Ajala, J., & Badarulzaman, N. A. 2017a. Thermal Conductivity of Barkin-ladi Fireclay Brick as Refractory Lining. *IOSR Journal of Mechanical and Civil Engineering, 14*(2), 1-5.

Amkpa, J. A., Badarulzaman, N. A., & Aramjat, A. B. 2017b. Influence of sintering temperatures on physico-mechanical properties and microstructure of refractory fireclay bricks. *International Journal of Engineering and Technology*, *8*(6), 2588-2593.

Antonovič, V., Szczerba, J., Keriene, J., Stonys, R., & Boris, R. 2017. Refractory Materials for Biofuel Boilers. *Frontiers in Bioenergy and Biofuels*, 443.

ASTM-C20-00. 2015. *Standard test method for apparent porosity, water absorption, specific gravity and bulk density*.

Babaso, P. N., & Sharanagouda, H. 2017. Rice husk and its applications: Review. *International journal of current microbiology and applied sciences, 6*(10), 1144-1156.

Chikwelu, G., Onuegbu, T., Ezeofor, C., & Akpomie, K. 2018. Characterization of Mbaukwu Clay from Awka-South, Anambra State, Nigeria for Industrial Purposes. *The Pacific Journal of Science and Technology, 19*(1), 251-256.

Chima, O., Nwoye, C., & Nnuka, E. 2017. Enhancement of refractory properties of blended clay with groundnut shell and rice husk additives. *American Journal of Engineering Research (AJER), 6*(6), 218-226.

Cultrone, G., Aurrekoetxea, I., Casado, C., & Arizzi, A. 2020. Sawdust recycling in the production of lightweight bricks: How the amount of additive and the firing temperature influence the physical properties of the bricks. *Construction and Building Materials, 235*, 117436.

Elakhame, Z., Bello, S., Agunsoye, J., Patric, I., & Otitoju, O. 2016. Characterization of Ujogba Clay Deposits in Edo State, Nigeria for Refractory Applications. *Kathmandu University Journal of Science, Engineering and Technology, 12*(2), 71-82.

Iyasara, A. C., Stan, E. C., Geoffrey, O., Joseph, M., Patrick, N. N., & Benjamin, N. 2016. Influence of grog size on the performance of NSU clay-based dense refractory bricks. *American Journal of Materials Science and Engineering, 4*(1), 7-12.

Kazemi, N. 2019. Reasons for crack propagation and strength loss in refractory castables based on changes in their chemical compositions and micromorphologies with heating: special focus on the large blocks. *Journal of Asian Ceramic Societies, 7*(2), 109-126.

Keter, C. K. 2016. *Development and testing of composite refractory bricks (a case study of selected Kenyan clays).* Egerton University.

Li, J., Peng, J., Guo, S., & Zhang, L. 2013. Application of response surface methodology (RMS) for optimization of sintering process for the preparation of magnesia partially stabilized zirconia (Mg-PSZ) using natural baddeleyite as starting material. . *Ceramics International, 39*, 197-202. doi: http://dx.doi.org/10.1016/j.ceramint.2012.06.009.

Madugu, C. H. 2016. *Production of Insulating Refractory Bricka from Kankara Kaolin using Acha (Digitaria Exilis) Husk as Alternative Pore-former*. Glass Technology Section. Department of Industrial Design. Ahmadu Bello University, Zaria, Nigeria.

Oke, S. R., Talabi, H. K., Olorunniwo, O. E., Atanda, P. O., & Aramide, F. O. 2015. Production and Characterization of Clay Bonded Carbon Refractory from Ifon Clay and Spent Graphite Electrode. *International Journal of Metallurgical Engineering, 4*(2), 33-39. doi: 10.5923/j.ijmee.20150402.02, on 28 January, 2020

Rahman, M. H., Islam, M. T., Minhaj, T. I., Azad, M., Hasan, M. M., & Haque, A. M. R. 2015. Study of thermal conductivity and mechanical property of insulating firebrick produced by local clay and petroleum coal dust as raw materials. *Procedia Engineering, 105*, 121-128.

Shehu, M. S., Lamido, S. I., & Nyam, T. 2018. Utilization of response surface methodology for the optimization of refractory bricks production. *International Journal of Engineering Development and Research., 6*(4), 301-307.

Shuaib-Babata, Y., Yaru, S., Abdulkareem, S., Busari, Y., Ambali, I., Ajao, K., & Mohammed, G. 2018. Characterization of Baruten Local Government Area of Kwara State (Nigeria) fireclays as suitable refractory materials. *Nigerian Journal of Technology*, *37*(2), 374-386.

Velasco, P. M., Ortiz, M. P. M., Giró, M. A. M., Melia, D. M., & Rehbein, J. H. 2015. Development of sustainable fired clay bricks by adding kindling from vine shoot: Study of thermal and mechanical properties. *Applied Clay Science, 107*, 156-164.

Zaidan, S. A., & Omar, M. H. 2018. The effects of bauxite, metakaolin, and porosity on the thermal properties of prepared Iraqi clays refractory mortars. *Applied Physics A, 124*(5), 1-8.