

Comparative Analysis of Properties of Particleboards Made from Corn Cobs at Varying Proportions of Clay Soil



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ABSTRACT: Particles of dried corn cobs were employed for manufacture of cement bonded particleboards. Two types of clay soil (red and white) were used as supplement with cement to manufacture cement bonded particleboards. The production of the boards was done at varying proportions of 50/50/0, 50/40/10, 50/30/20, 50/20/30, 50/10/40 and 50/0/50 for (corn/cement/clay) in weight to weight basis while the other considerable production factors like nominal density and curing agent percentage remained constant at 1.30 g/cm³ and 3%. The chemical composition of the soil such as pH, organic carbon, organic matter, total nitrogen, and exchangeable bases were determined. Its impact on physical and mechanical properties such as density, water absorption, thickness swelling, modulus of rupture and modulus of elasticity were also investigated. The results of the analysis of variance shows that all considerable production factors for the cement bonded particleboards were significant at 5% level of probability except clay soil type for density. The results show that cement bonded particleboard made of red clay soil with higher content of exchangeable bases proves better outstanding performance in density, strength and dimensional properties than the white clay soil. Among the cement bonded particleboards made at varying proportions. It was discovered that boards of 50/20/30 (corn/cement/clay) had better strength properties than others. Also, the boards made at the proportions of 50/40/10, 50/10/40 and 50/30/20 (corn/cement/clay) were better dimensionally stabled in moisture exposure but weak in strength. The outcome of this study may serve as a guideline for any manufacturer who intends to use clay soil as supplement for production of particleboards.

KEYWORDS: Cement, particleboard, clay soil, corn cobs, strength, variance

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I. INTRODUCTION

Clay minerals are known to be one of the ancient building materials which are naturally available for infrastructural designs and also play important roles in industrial minerals. Million tons of clay minerals are utilized yearly in various applications like in geology, process industries, agriculture, environmental remediation and construction. The reason for the utilization of certain clay minerals for specific application is attributed to the physical and chemical properties attached to a particular clay mineral which are dependent on its structure and composition (Malu et al., 2018). Some clay contain kaolinites that are white, grayish-white or slightly colored darker and plastic when moistened with water, some contain mainly Montmorillonite while some clays are found to be the intermediate product of disintegration of mica into kaolin (Lopez-Galindo et al., 2007; Nwoye, 2010). Clay as a material displayed some physical properties and technological properties such as binding ability, shrinkage and plasticity (Nwoye, 2003). The chemical composition, grain size, grain

distribution, grain structure and pores also play significant role in applications (Arisa, 1997). It has also been revealed that the characteristic of the clay is been related to increased in rupture and a decrease in porosity (Nwoye, 2008; Bergaya et al., 2006).

Clay is known to be healthy, cheaper, widely available and environmentally friendly. Clays are found and widely distributed in many regions in Nigeria though with different properties which might be attributed to geological differences (Kefas et al., 2007). Previous studies shows that clay soils found in Nigeria contains different grades of kaolin which made it possible for the manufacture of ceramics (white wares, refractories, and porcelain), paper, rubber, paint, plastics, insecticides, adhesives, catalysts, and ink (Manukaji, 2013; Gray et al., 2013; Nweke and Egwu, 2007; Churchman et al., 2006). The suitability and utilization of Nigeria clay cannot be over emphasized because it's come in varieties of heating refractory and insulating materials (Aderiye, 2014).

Over the past decade, wood based ceramic water filters have been successfully produced from the mixture of clay,

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sawdust (woodchips) and water (Folorunso et al., 2014; Oyanedel-Craver and Smith 2008). Many materials have been considered as fillers in production of ceramic composites. It has also been known that addition of lignocellulosic materials like sawdust, rice husk and corn husk can enhance the insulation purposes of ceramic composites (Olusola, 1998). This development was done with the intention of improving the strength properties of the ceramic water filters. It was reported that unreinforced ceramic fails woefully when subjected to around 0.1% tensile strain while the fiber reinforced ceramic (composites) withstand more than 0.5% tensile strain (Callister, 2007). A reinforcing phase can improve the toughness of these materials, while still taking advantage of the matrix's other properties such as wear resistance, hardness, corrosion resistance and temperature resistance (Gad and Annette 2007). It has also been known that toughening of ceramic products could be attributed to either phase-transformation toughening or by fiber synthesis (incorporation) within the ceramic matrix (Osendi and Baudin, 1996; Moya and Osendi, 1983).

Wood waste and Corncobs are both biomass resources and have the potential to be transformed into valuable biocomposite products for industrial applications. Biocomposites have been defined as generic term for production of panel products made from lignocellulosic materials usually wood, primarily in the form of discrete pieces or particles, as distinguished from fibers, combined with a synthetic resin or other suitable binder and bonded together under heat and pressure in a hot press by a process in which the entire inter particle bond is created by the added binder, and to which other materials have been added during manufacture to improve certain properties (Rocket, 1997). The particleboard from biocomposites is one of the strongest reconstituted panel products that is cheaper, denser and more uniform than the other conventional composites. It is also a substitute to other products when appearance and strength are less important than cost (Danladi and Patrick, 2013).

Therefore if woodfiber reinforced ceramic composites could be cheaply manufactured, then agricultural waste like corn cob could as well be use as friction lining material with clay as alternative binder if investigated. The study is aim at producing particleboards from maize cob incorporated with varying proportion of cement and clay as binders.

II. MATERIALS AND METHODS

A. Materials

Dried corn cobs waste, cement and clays were employed in this study. The dried corn cobs were collected from Bodija Market at Ibadan, Oyo State. The red clay soil was collected from a site located at Forestry Research Institute of Nigeria (FRIN), Ibadan while the white clay soil was collected from a site located at Itu town, Akwa Ibom State. An Elephant Portland Limestone Cement of type CEM II B-L 32.5N manufactured by Lafarge Africa PLC was employed and purchased from a retailer shop at Dugbe area of Ibadan, Oyo State. A reagent of CaCl_3 was used for production of the

particleboard samples. It serves as curing agent and was supplied by FRIN.

1.) Materials preparation

The dried corn cobs were milled into powder using hammer mill machine available at the Department of Forest Products Development and Utilization, FRIN, Ibadan. The derived particle from the corn cobs were thoroughly sieved with wire mesh sieve of size 2.0 mm. This was done to remove the unwanted materials. Similarly, the clay soils were also sieved with wire mesh of size 1.00 mm to get a fine powder and this was done to get uniform homogenous particle size with the cement. Prior to board production, particles of corn cobs were physical pretreated in water of temperature 100°C for an hour through soaking method and this was done to de-polymerize the existing chemical components found in corn cob particle.

2.) Board formation and production

An appropriate quantity of particles derived from corn cobs, clay soils and cement were mixed in six different varying proportions of (50/50/0, 50/40/10, 50/30/20, 50/20/30, 50/10/40 and 50/0/50) for corncob/cement/clay (w/w) basis at a constant nominal density of 1.30 g/cm³. These materials were thoroughly hand mixed for 5 minutes at room temperature of 26 ± 2 °C, with 3% proportion of CaCl_3 added as curing reagent and the mixture was hand fed into a wooden mould of dimensional size 35 cm x 35 cm. The mixed compound was manually pre-pressed into thickness of 2 cm and further pressed into thick layer of 0.6 cm guided with steel stoppers of dimensional size of 0.6 cm. The steel stopper of 6 cm was placed in all the four edges to give uniform thickness under compression force of 1.75 Nmm⁻². The boards were firmly held together under the hydraulic cold presser for 24 hrs to solidify. The boards were de-molded after 24 hours of pressure compression and stacked in the laboratory room to attain balance relative humidity with the environment so as to avoid fractures or cracks. After dehumidification, the boards were air dried in an open space for 7 days to cure. Specific specimen sizes meant for physical and mechanical properties evaluation were cut from the boards in accordance with ASTM D1037 – 99.

B. Property Evaluation

The observed density, water absorption, thickness swelling, modulus of rupture and modulus of elasticity were measured for each test sample.

1.) Mechanical properties

In accordance with ASTM D 1037 – 99, the test samples for mechanical properties were cut into size of 19.6 cm x 5.0 cm (length x width) and subjected to three-point-flex measurement for the determination of modulus of rupture and modulus of elasticity. This test was carried out using Universal Testing Machine (UTM) of model WDW-50 of the speed of movable crosshead being 5 mm/min. Three specimens were tested as replicate for each sample measurements.

2.) Physical properties

In accordance with ASTM D 1037-99, the test samples for physical properties were cut into size of 15.2 x 15.2 cm (length x width). The length, width, thickness and weight of the samples were taken before immersed in cold water at room temperature of 26 ± 2 °C. This was done to determine the behaviour of the board samples to moisture exposure, the weight and thickness of the samples were measured after immersion treatment for 24 hrs. The data collected were used to calculate water absorption and thickness swelling while the volume and weight of the samples before immersion treatment was used to calculate the observed density for each sample.

3.) Soil chemical analysis

Appropriate 2g of each clay soil sample was analyzed using UV visible spectrophotometer (model 210VGP); Flame photometer and Atomic Absorption Spectrophotometer to determine the exchangeable bases, micronutrient, organic carbon, organic matter, total nitrogen, available potassium and the particle size 10 g of each clay soil was used on pH meter to determine the pH values. Five samples were tested as replicate and the data obtained were used for the determination of chemical properties of the soil.

C. Statistical Analysis

The data collected was statistically analyzed using 2 x 6 factorial experiments in completely randomized design using SPSS software of version 22.0. The two factors considered in this study are clay type and mixing proportion. This was done to determine the level of significance among and between the factors at ($P \leq 0.05$). The separations of treatment means was done using Duncan Multiple Range Test (DMRT), descriptive statistic and graphs were used for interpretation of results.

III. RESULTS AND DISCUSSION

A. Chemical Analysis of Clay Soils

As presented in Table 1, the result obtained from the soil analysis test shows that the values for pH, organic carbon, organic matter, total nitrogen were 4.16, 2.23%, 3.38% ; 0.54% and 8.81, 1.26%, 2.17%, 0.342% for red clay soil and white clay soil respectively. Meanwhile, the results derived from the soil test for exchangeable bases include Na, K, Ca and Mg of 1.38, 0.17, 3.7, 12.9 cmol/kg and 1.08, 0.15, 5.4, 8.6 cmol/kg for red clay soil and white clay soils. The outcome of the soil analysis test result agree with previous findings of similar elements found in soil test investigated by (Lopez-Galindo et al., 2007) and the result shows that the clay employed for particleboard production in this study belong to the family of Phyllosilicates that consists of hydrated Alumino-silicates due to the presence of considerable amount of Mg, K, Ca, Na, and Fe.

The presence of these elements in clay sample determines its uses in production of bricks, floors tiles and paper making (Kefas et al., 2007). In the presence of oxygen, it form Alkali metal oxides such as Fe_2O_3 , MgO , Na_2O , K_2O and CaO which contributes to refractory potential of the clays and hence

making it suitable for ceramic products (Malu et al., 2013). It was observed that pH of clays varies; a pH value was moderately acidic for red clay soil while alkali for white clay soil. This observation agrees with previous findings by (Malu et al., 2018) and is attributed to the presence of alkali metal oxides. Clay is a basic material of weakly acidic in nature, the presence of SO_3 gives H_2SO_4 after dissolved in moisture (Nweke and Egwu 2007). The chemical composition of these clay soils shows that red clay has higher percentage of exchangeable bases than the white clay (Table 1). As reported by previous authors, red clay would be suitable for ceramic production, bricks, floor tiles and paper making.

B. Mechanical properties of particleboards made with clays

The mean values for the density, modulus of rupture and modulus of elasticity for each production factor (corn/cement/clay and clay soil type) are presented in Table 2. The values range from 1.0 g/cm^3 to 1.5 g/cm^3 ; 0.00 N/mm^2 to 1.91 N/mm^2 and 0.00 N/mm^2 to 1112.17 N/mm^2 in density observed, modulus of rupture and modulus of elasticity respectively. As illustrated in Figure 1, it was observed that particleboards made from red clay at proportions of 50/0/50 and 50/50/0 (corn/cement/clay) have higher densities than the same proportions for particleboard made from white clay boards. It was also observed that particleboards made from white clay soil at proportions of 50/20/30, 50/10/40, 50/40/10 and 50/30/20 (corn/cement/clay) have higher density values than the values obtained for the particleboards made at the same proportions for red clay soil. It was also observed that the density of the boards' decreases with decrease in clay soil content to cement content. At 50% of clay soil content in the boards, it attained minimum peak point for density but as the clay soil content gradually decrease from 50 to 30%, then the density of the boards began to rise as shown in Figure 1.

The observation trend for density in the figure is similar for both red and white clay made cement bonded particleboards. It was found to attain the highest densities at the proportions of 50/50/0 and 50/0/50 (corn/cement/clay) weight to weight basis.

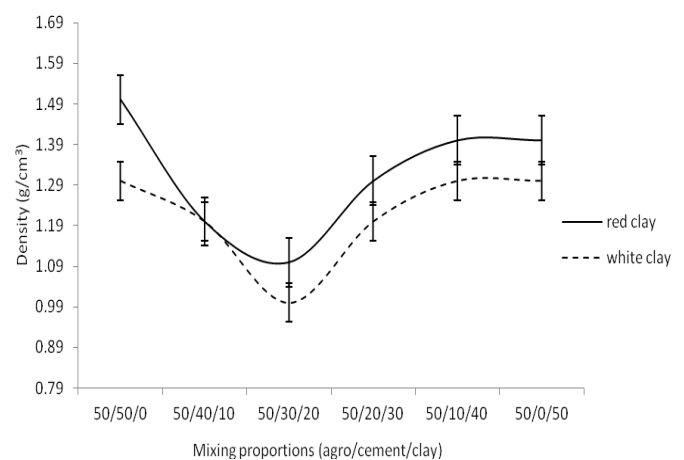


Figure 1: The density of composites made from different clays at various mixing proportions.

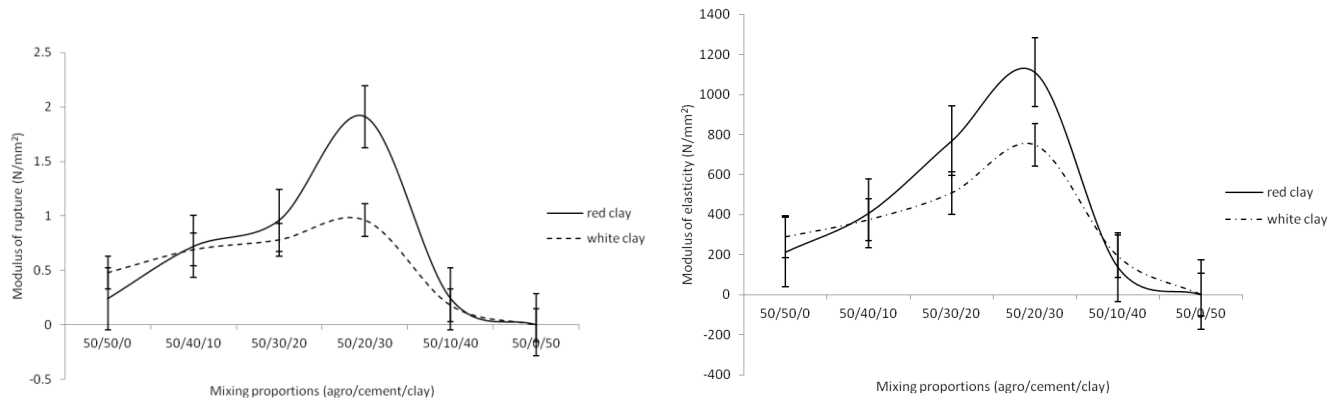


Figure 2: The strength properties of composites made from different clays at various mixing proportions.

However in strength properties, it was observed that the impact of cement content to clay content significantly influence the MOR and MOE. It was discovered that as the proportion of clay content increases from 0%, the MOR and MOE also increases to attain maximum peak values. But as the clay content reached 30%, the MOR and MOE gradually decreases to minimum peak values at 50% as illustrated in Figure 2.

These observations may be attributed to the bulkiness of the materials used; it is well known fact that cement and clay is bulkier than the corn cob particles, the density of each material could affect the outcome of the qualities of the boards while the chemical components found in each material also play a major role in compatibility. The proportion of exchangeable bases found in each clay soil varies; red clay had higher percents of Na, K and Mg than the white clay and this could be attributed to the plasticity characteristic found in red clay. The outcome of the results agrees with the outcome of findings by these authors (Bergaya et al., 2006; Nnuka and Enejor, 2001) that the presence of alkali oxides have been linked to plasticity characteristics of clay which is attributed to the presence of Fe₂O₃, MgO, CaO and Na₂O. It has also been reported that clay materials serves as a major material for manufacture of floor tile due to the dominance of silica and alumina found in it (Bergaya et al., 2006; Nwajugu et al., 2001).

Furthermore, the two dimensional (flaky) particles that

are non clay tends to widen the vitrification range that promotes a stronger texture formed as a result of close-knit structural arrangement (Smoot, 1963). The high silica content value present in clay soil makes it a potential raw material for brick production. Due to this fact, the strength properties witnessed in this study might be attributed to the compaction ratio between the cement/clay and the fibre. Clay has been known to aid dispersion in slips clay with fibre and it's inter granular positions that promote a firmer bond with cement and fibre. As a good material for plasticity, it formed a mullite and glossy bond that also improves strength. This study shows that introduction of clay to the production of particleboards will improve the strength properties of cement bonded particleboards with addition to varying cement content. Meanwhile, it was observed that all the boards made of no cement content fails in stiffness and strength.

C. Physical Properties of Particleboards Made from Clays

The mean values of water absorption and thickness swelling obtained after immersed in water treatment for 24 hours ranged from 0.00 to 39.13% and 1.99 to 23.96% respectively (Table 2). The value for water absorption and thickness swelling obtained in this study agrees with previous findings by Chikwelu et al., 2018. The values obtained are within the internationally permissible standard values for water

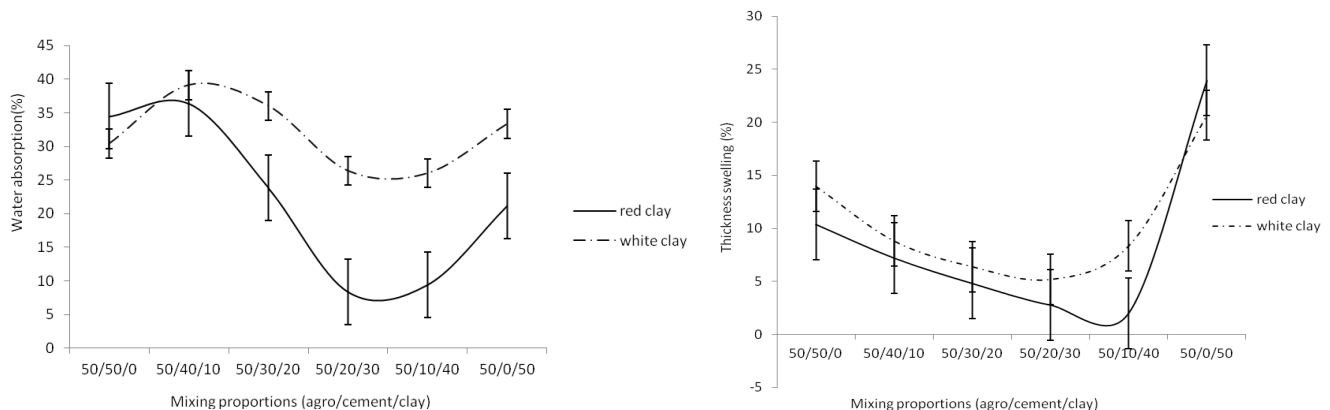


Figure 3: The physical properties of composites made from different clays at various mixing proportions.

Table 1: Chemical analysis of clay soil used for the production of particleboards.

Properties		Exchangeable bases (Cmol/kg)					Micronutrient (Mg/kg)					E.A (Cmol/kg)		CEC		
Sample	pH (H ₂ O)	O.C (%)	O.M (%)	T.N (%)	Avail. P (mg/kg)	Na	K	Ca	Mg	Mn	Fe	Cu	Zn	Al	H	Cmol/kg
Red	4.16	2.23	3.38	0.544	34.6	1.38	0.17	3.7	12.9	34	6.8	3.1	188	NA	NA	NA
white	8.81	1.26	2.17	0.342	70.3	1.08	0.15	5.4	8.6	22	10.3	7	302	NA	NA	NA

NA = not available; O.C = Organic Carbon ; O.M = Organic Matter ; T.N = Total Nitrogen E.A = Exchange Acidic and CEC = Cation Exchange Capacity

absorption and shrinkage of fire clay bricks at 20 – 80% and 7 – 10% (Manukaji 2013; Lawal and Abdullahi, 2010 and Zubeiru 1997). Also, the dimensional properties values obtained for each production variable are presented in Table 1. As illustrated in Figure 3, it was observed that after dimensional test, the particleboards witnessed significant changes. Water absorption values decreases as the clay soil content increases from 0% to 40%. The lowest water absorption value was obtained from particleboard made from red clay soil only and at proportion of 40% while the highest value was at the proportion of 50% for both red and white clays.

Similarly in thickness swelling, it was observed that as the clay content increases, the thickness swelling value decreases. The lowest value for thickness swelling was observed at clay proportions of 30% and 40%, and then gradually increases to the peak point at clay proportion of 50%. It was observed that maximum thickness swelling values was attained at clay proportion of 10% . It was found that as the cement content in the proportion is decreasing to clay content, the water absorption and thickness swelling values decreases. This was observed for particleboards made at varying proportions of 50/20/30 and 50/10/40 [corn/cement/clay]. Meanwhile, the particleboards react differently in thickness swelling. It was observed that particleboards made from white clay soil had lowest thickness swelling value at proportion of 50/40/10 while the particle boards made from red clay soil had its lowest thickness swelling value at 50/20/30. This observation could be from the force mounted on the board’s surface.

Boards at proportions of 50/20/30 and 50/40/10 (corn/cement/clay) was well compacted than the others. The other proportions might have witnessed springback after released from the pressure and this allows movement of moisture within the internal structure of the boards to give contraction and expansion. The behaviour of the particleboards to moisture treatment implies that the porosity nature of clay

reduces. This might be attributed to the additional binding force provided by the cement, it helps to encapsulate and protect the corn cobs particles from absorbing moisture being hydroscopic in nature. The arrangement of the particles within the binding force of cement and clay also play a major role for restriction of moisture uptake in particleboards. The corn cobs were closely knit to formed fibre to fibre interactions which tend to hold moisture molecules within the composite complex. This arrangement may be similar to other lignocellulosic materials like sawdust, rice husk and corn husk. This could also be advantage for composite in terms of insulating the ceramic composite (Olusola, 1998).

Statistically, the results for analysis of variance shows that the main factors (clay type and mixing proportions) and the two factors interaction (clay type x mixing proportions) considered for investigation were significantly different in all the properties assessed except for density in Clay type. This was illustrated using alphabetical letters (a) to (f) alongside with the mean values obtained in Table 2. The mean values of the same alphabet letter are not significant while the mean values of different alphabet letters are significantly different at 5% level of probability.

As presented in Table 2, the values obtained for particleboard made from red clay soil were higher than the values for particleboard made from white clay soil for both physical and mechanical properties. This is represented with (a) and this implies that particleboards made from red clay soil had better mechanical properties and lesser water absorption rate than particleboard made from white clay soil. There are significant differences among the varying proportions for all the properties. This is also presented in Table with the letters that range from (a) to (f). The value denoted (a) is significantly different to (b) and others. This implies that value with (a) is better than the others in terms of properties. The cement bonded particleboards made from the proportions of 50/20/30

Table 2: The mean values for mechanical and physical properties of particleboards.

Production factors	Levels	Mechanical properties			Physical properties	
		Density (g/cm ³)	Modulus of rupture (N/mm ²)	Modulus of elasticity (N/mm ²)	Water absorption (%)	Thickness swelling (%)
Clay type	Red	1.20 ^a	0.68 ^a	374.09 ^a	19.30 ^a	10.809 ^a
	White	1.20 ^a	0.56 ^b	367.45 ^b	35.21 ^a	9.252 ^b
Mixing proportion	50/50/0	1.40 ^a	0.36 ^d	200.89 ^d	32.46 ^e	12.17 ^e
	50/40/10	1.20 ^d	0.84 ^b	638.64 ^b	37.75 ^f	6.00 ^c
	50/30/20	1.20 ^d	0.72 ^c	290.60 ^c	29.91 ^d	10.58 ^d
	50/20/30	1.10 ^e	1.44 ^a	930.42 ^a	18.18 ^b	3.96 ^a
	50/10/40	1.20 ^c	0.36 ^d	164.07 ^e	18.00 ^a	5.17 ^b
	50/0/50	1.30 ^b	0.00 ^e	0.00 ^f	27.24 ^c	22.31 ^f

Mean values within the same group column with different letters represents significance at P ≤ 0.05 to each other.

(corn/cement/clay) having denoted (a) can be regarded as best outstanding proportion for particleboard with better physical and mechanical properties.

IV. CONCLUSION

Nigeria is a country that is blessed with numerous natural resources and one of it is the clay. Clay has being in existence for decades as raw material for building. It is readily available and less costly. An introduction of clay soil as supplement in bio-composite technology will be added advantage to wood panel products industry. The outcome of this study therefore concluded as follows;

1. This study has been able to prove that particleboard can be produced using cement and clay as potential binders.
2. It has also being noted that addition of clay into the composition of particleboards improves both the physical and strength properties.
3. Among the particleboards made at varying proportions, the board with proportions of 50/20/30 (corn/cement/clay) had better strength values than the others
4. Also, the boards made at the proportions of 50/40/10, 50/10/40 and 50/30/20 (corn/cement/clay) were better dimensionally stabled in moisture but weak in strength.
5. It was further revealed that particleboard made from red clay soil was better than the white clay soil in both physical and mechanical properties. This implies that red clay soil can be used as supplement in production of cement bonded particleboard meant for low load bearing capacity structure like ceiling.

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