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Physical and mechanical properties of cement-bonded particle board produced from *Anogeissus leiocarpus* *(DC.) Guill and Perr* wood species.

[1]Ogunjobi K.M.*, [1]Ajibade M.A, [1]Gakenou O.F and [2]Gbande S.

[1]Department of Forestry and Wildlife Management, Federal University of Agriculture, Abeokuta
[2]Department of Forestry and Technology, Akperan Orshi College of Agriculture Yandev, Benue State

*Corresponding author (Email: Ogunjobikm@funaab.edu.ng)

ABSTRACT

Large quantity of waste is generated in the processing of wood leading to increasing pressure on the forest estate. This study was carried out to determine the suitability of the sawdust of *Anogeissus leiocarpus* species in the production of particle board using Portland cement as adhesive. The mixtures of boards produced were 3:1, 1:1 and 1:3 of sawdust to cement. Twelve boards of 1.5 x 5.0 x 18.0 cm were produced and tested for both physical and mechanical properties. Data obtained were subjected to analysis of variance (ANOVA) and Duncan Multiple Range Test (DMRT) was used to separate the mean differences. Results obtained showed that water absorption rate was highest (135.76 %) in 3:1 mixing ratio and lowest (24.95 %) in 1:3 mixing ratio. Effects of mixing ratio showed that 1:3 was significantly different ($p \leq 0.05$) from 3:1 and 1:1 mixing ratio. Thickness swelling was highest (16.67 %) in boards produced from 3:1 and lowest (10.00 %) in 1:3 mixing ratio. Results of the mechanical properties showed that mean Modulus of Elasticity (MOE) value was highest (343.1 Nmm^{-2}) in boards made from 1:3 mixing ratio and lowest (23.39 Nmm^{-2}) in 3:1 mixing ratio while Modulus of Rupture (MOR) was highest (2.36 Nmm^{-2}) in boards made from 1:3 mixing ratio and lowest (0.20 Nmm^{-2}) in boards made from 3:1 mixing ratio. The study revealed that boards made from mixing ratio of 1:3 have the best potentials for ceiling boards and partitioning panels since it has the highest MOE and MOR with lesser propensity for absorption of water.

Keywords: Cement bonded particle board, *Anogeissus leiocarpus*, water absorption, thickness swelling, Modulus of Elasticity, Modulus of Rupture

INTRODUCTION

Although the Nigerian forest estate is naturally blessed, there is however abuse, over- use and misuse of the resources from the forest which account for its fast degradation. Nigerian forest estates are now bedeviled by an array of forces with overpopulation as the principal factor. The increase in population has undoubtedly led to increase in the felling of wood for furniture, pole production, fuelwood, charcoal production and construction purposes. The lack of genuine and concerted efforts in the protection of the forest has led to indiscriminate logging, overgrazing and over-exploitation of wood resources. Despite the dwindling forest estates, a large quantity of waste is generated during the processing of wood (Ogunjobi *et al.*, 2018).

The current reality is that the demand for wood raw materials is more than the production capacity of the forests. This reduction in the available volume of timber has significant impact on the forest based industries leading to a decline in the contribution of the industries to national and industrial development (Falemara *et al*., 2016). The poor log conversion efficiency of sawmill is partly responsible for the high pressure on the forest resources and the destruction of soil cover. According to Ogunjobi *et al*. (2018), enormous waste is generated during sawmilling activities and this reduces the volume of wood available for utilization and thereby put pressure on the forest estates for supply of materials to cater for the needs of the increasing population. In order to mitigate this development, utilization of sawdust generated during processing of wood in the production of cement bonded particle boards is an attempt at ensuring maximum utilization of the wood products.

Cement bonded particle boards have potentials because of its availability, light weight, high toughness, non-corrosive nature, low density, low cost, good thermal properties, reduced tool wear, less dermal and respiratory irritation, less abrasion to processing equipment and renewability. It can be moulded into any form and shape to meet specific end use. It is asbestos free, does not contain hazardous and volatile substances, and dust from production processing of the board is non- aggressive (Ajayi and Badejo, 2005). It is reputed for higher dimensional stability, higher resistance to insect and fungal attack and higher fire resistance (Dinwoodie and Paxton, 1989), wet and dry rot resistance, freeze-thaw resistance, termite and vermin resistance, excellent workability, exceptional insulation and acoustic performance, low cost and ease of manufacture (Adedeji, 2011).

*Anogeissus leiocarpus*is is from the family of *Combretaceae*. *A. leiocarpus* is a tall deciduous tree of up to 30 m in height, typically 15-18 m with light green foliage. The base of the trunk is wider and occasionally striped. It has a dense crown and often drooping branches. The color of the bark is grey and becomes blackish corresponding with the age and is fibrous with thin scales. It has a finely pubescent stems and alternate to sub-opposite, elliptical to oval leaves which are 2-8 cm long and 1.5-3.5 cm wide (Arbonnier, 2004).

The species has a lot of uses in medicine, veterinary medicine, carpentry and construction purposes. In view of the great potentials of the tree, it has become imperative to investigate the sawdust for the production of cement-bonded particle board towards ensuring maximum utilization of wood products. The study, therefore determined the physical and mechanical properties of boards produced from the sawdust of *Anogeissus leiocarpus*.

METHODOLOGY

Collection of Raw Materials

The sawdust of *Anogeissus leiocarpus* was collected from Surulere sawmill, Camp junction, Abeokuta. After collection, it was sieved with a 2 mm wire mesh into fine particles and air dried to reduce the moisture content. The particles were pre-treated with hot water at 100^oC for 30 minutes to remove chemical substances. The particles were dried again to reduce the moisture content to about 12 %. The quantity of cement was measured according to proportion of 25 % wood:75 % cement (3:1), 50 % wood : 50 % cement (1:1) and 75 % wood: 25 % cement (1:3). The measured cement and sawdust was then thoroughly mixed together to prevent formation of cement/particle lumps. Wooden frame of size 1.5 cm x 5.0 cm x 18.0 cm was used.

Particle Board Manufacturing

The experiment was carried out at the Wood Laboratory in the Department of Forestry and Wildlife Management, Federal University of Agriculture, Abeokuta and the properties of the boards were tested at the Forestry Research Institute of Nigeria (FRIN). The variations of mixing ratio used were 25 % wood: 75% cement (3:1), 50 % wood: 50 % cement (1:1) and 75 % wood: 25% cement (1:3). After mixture of cement and wood, the mixture was poured into the frame and pressed for uniform distribution. The process was replicated four times for each ratio giving a total of twelve boards that were produced. The boards that were formed were conditioned for 28 days to allow for proper curing of the cement.

Determination of Physical properties of boards produced from *Anogeissus leiocarpus*

Water Absorption (WA) and Thickness Swelling (TS) tests were conducted based on the procedures in ASTM, 2005. Weights of the boards were measured alongside the thickness (Wo and To). The test boards were submerged in distilled water for 24 hours. Thereafter, they were removed and drained for 10 minutes to remove excess water. Thereafter, the weight and thickness of the boards were measured (Wt and Tt). The percentage water absorption and thickness swelling for each test board were calculated using the formula below:

Water Absorption (WA)

$WA\ (t)= \frac{w(t)-wo}{wo}$x 100 ------------------Eqn. 1

Where WA(t) is the water absorption at time t, W_o is the oven dried weight and W(t) is the weight of specimen at a given immersion time t.

Thickness Swelling (TS)

$TS\ (t)=\frac{r(t)-To}{To}$x100 ---------------------Eqn. 2

Where TS (t) is the thickness swelling at time t, T_o is the initial thickness of boards and T(t) is the thickness at time t.

Determination of Mechanical properties of boards produced from *Anogeissus leiocarpus*

The mechanical properties also known as flexural properties were assessed by testing for Modulus of rupture (MOR) and Modulus of elasticity (MOE). The tests were carried out by placing a flat sample of 1.5 cm x 5.0 cm x 18.0 cm horizontally on a 3-point flexural testing machine. A perpendicular load was applied directly on the sample at the center cutting across the entire width of the board at a constant speed. At the point of break of the specimen, the flexural properties results were collected.

Modulus of rupture (MOR)

$\frac{3PL}{2BD^2}$ -----------------------------Eqn.3

Where P = Load, L = Span, B = Width, D = Depth

Modulus of elasticity (MOE)

$\frac{\boldsymbol{PL}^3}{\boldsymbol{4\Delta BD}^3}$ -----------------------------Eqn.4

P = Load, L = Span, B = width, D = Depth, Δ = the deflection at beam center at proportional limit.

DATA ANALYSIS

The data collected were subjected to Analysis of Variance (ANOVA) to test for significant difference among the parameters evaluated while mean separation was carried out using the Duncan's Multiple Range Test (DMRT).

RESULTS

Physical properties

Table 1 shows the mean values of water absorption (WA) and thickness swelling (TS) of the cement-bonded boards soaked in water for 24 hours. According to the result obtained, water absorption (WA) rate was highest (135.76 %) in boards made from 3:1 mixing ratio of sawdust to cement (75 % sawdust : 25 % cement) and lowest (24.95 %) in boards made from 1:3 mixing ratio of sawdust to cement (25 % sawdust: 75 % cement). There was no significant difference in water absorption of boards made from 1:1 and 3:1 mixing ratio but significantly different ($p \leq 0.05$) from boards made from 1:3 mixing ratio after 24 hours of immersion. Result also revealed that boards produced from 3:1 (75 % sawdust: 25 % cement) had the highest (16.67 %) thickness swelling (TS) while the lowest (10.00 %) was recorded for boards produced from 1:3 (25 % sawdust: 75% cement) mixing ratio.

Mechanical properties

The results in Table 2 showed that mean MOE was highest (343.12 Nmm^{-2}) in boards made from 1:3 mixing ratio and lowest (23.39 Nmm^{-2}) in boards made from 3:1 sawdust / cement mixing ratio. It was observed that mean value for MOR was highest (2.36 Nmm^{-2}) in boards made from 1:3 sawdust /cement mixing ratio and lowest (0.20 Nmm^{-2}) in boards made from 3:1 sawdust / cement mixing ratio. There was also no significant difference between boards produced from 3:1 and 1:1 sawdust / cement mixing ratios but 1:3 was significantly different ($p \leq 0.05$) from others.

Table 1: Mean values of Water absorption and thickness swelling from boards produced from *Anogeissus leiocarpus* sawdust

Mixing ratios	Water absorption (%)	Thickness swelling (%)
3:1	135.76 ± 20.49^{b}	16.67 ± 11.54^{a}
1:1	118.07 ± 19.55^{b}	11.67 ± 6.38^{a}
1:3	24.95 ± 1.98^{a}	10.00 ± 3.85^{a}

Means in columns with the same superscript denotes no significant difference (P ≤ ? > 0.05)

Table 2: Mean values of Modulus of Elasticity and Modulus of Rupture from boards produced from *Anogeissus leiocarpus* sawdust

Mixing ratios	**Modulus of Elasticity (Nmm^{-2})**	**Modulus of Rupture (Nmm^{-2})**
3:1	23.39 ± 1.90^{a}	0.20 ± 0.02^{a}
1:1	76.99 ± 27.84^{a}	0.63 ± 0.19^{a}
1:3	343.12 ± 149.97^{b}	2.36 ± 0.65^{b}

Means in columns with different superscript denotes significant difference ($P \leq 0.05$)

DISCUSSION

In this study, the mean values of water absorption (WA) ranged from (24.95 % - 135.76 %) which are comparably higher than (8.52 % - 44.07 %) reported by Sotannde *et al.* (2012) for *Afzelia africana* wood residues, (12.77 % – 17.85 %) for selected wood sawdust residues (Egbewole (2017), (23.1 % – 61.8 %) reported by Erakhrumen *et al.* (2008) for *Pinus caribaea* sawdust-coir mixture. It is also higher than 17.81 % – 22.37 % and 18.77 % - 22.99 % reported for *Gmelina arborea* and *Leuceana leucocephala* respectively observed by Ajayi *et al.* (2008) and (24.66 %–46.37 %) by Badejo *et al.* (2011) for eight hardwood species at different levels of percentage chemical additive content in board. Similarly, the mean values of thickness swelling obtained in this study ranged from 10.00 % – 16.77 % which is higher than 0.97 % – 3.41 %, 8.24 %-14.07 %, 2.9 % - 12.3 %, 1.13 % - 4.22 % for *Gmelina arborea;* and 1.58 % - 4.79 % for *Leucaena leucocephala*, and 0.98 % – 3.62 % reported by Sotannde *et al.* (2012), Egbewole (2017), Erakhrumen *et al.* (2008), Ajayi *et al.* (2008) and Badejo *et al.* (2011) respectively. The higher values for WA and TS observed in this study may be due to the lack of pre-treatment of wood samples with chemical additives. The chemical additives are hygroscopic in nature (Shukla *et al.*, 1981) and act as catalyst in the setting process of the cement binder to achieve formation of stronger boards with little or no void spaces to accommodate water (Ajayi, 2003). This is in agreement with the findings of Badejo *et al.* (2011), Ajayi *et al.* (2008), Sotannde *et al.* (2012) that chemical additives play some inhibitory role on the % WA and board produced with chemical additives had significant lower % WA than boards produced without chemical additives.

Mean water absorption moisture content properties of the boards decreased with increase in mixing ratio. This was so because of the ability of wood to absorb water. Board samples of mixing ratio 1:3 absorbed lesser water because of the presence of the binder (cement) which covered up the pore holes that must have been created by the porosity of wood. This agrees with Falemara *et al* (2014) on strength and dimensional stability properties of cement bonded boards produced from groundnut shell and corroborates similar findings of Ajayi (2006); Ergun and Halil (2009); Tagelsir, *et al* (2011); Amiandamhen and Izekor, (2013); Owoyemi and Ogunrinde (2013). According to Fuwape, *et al* (2007), the dimensional stability of cement bonded composite is a function of the quality of cement binder ratio, higher cement binder, low thickness swelling and vice versa. It is deduced that when the board is exposed to wet conditions, the compression stress is released, which causes the board's spring back, structural deformation, breakdown of bonds, fragility of boards and reduction in board's stability (Ajayi 1993; Hiziroglu *et. al.* 1993).

The mean values of MOE ranged from (23.39 – 343.12 Nmm^{-2}) which is lower than (43.69.61 – 7817.02 Nmm^{-2}), (4171 – 13063 Nmm^{-2}), (319.68 –1339.20 Nmm^{-2}), (2200 – 4010 Nmm^{-2}) reported by Egbewole (2017), Erakhrumen *et al.* (2008), 0) and Badejo *et al.* (2011) respectively. Also, the mean values of MOR ranged from (0.20 – 2.36 Nmm^{-2}) which is lower than (5.38 – 15.45 Nmm^{-2}), (28.1 – 80.3 Nmm^{-2}), (8.74 - 16.54 Nmm^{-2} for *Gmelina arborea*; and 5.94 - 10.79 Nmm^{-2} for *Leucaena leucocephala*), (4.56 – 11.52 Nmm^{-2}), (3.28 – 10.46 Nmm^{-2}) but higher than (0.49 – 0.60 Nmm^{-2}), reported by Sotannde *et al.* (2012), Erakhrumen *et al.* (2008), Ajayi *et al.* (2008), Badejo *et al.* (2011) and Egbewole (2017) respectively. Difference in the values observed may be due to varying densities at which boards were produced and level of curing reagents used which was not determined in this study. The mechanical properties increased with increase in mixing ratio because of the strength properties derived from the curing and setting of the cement which was highest in boards with mixing ratio of 1:3, making the ability to resist shock increase as the mixing ratio of the boards increased. This result conforms to similar findings by Omole and Adetogun, (2010); Badejo *et al*., (2011), Ajayi and Aina, (2012) that mixing ratio have influence on the mechanical properties of boards. The increase in mixing ratio caused the increase in MOR and MOE of the boards. Therefore, it is possible to produce the strongest experimental board at the highest levels of mixing ratio (1:3). However, heavier, stronger and stiffer boards could be manufactured by progressively increasing the mixing ratio (Ajayi 2000; Badejo 1999; Fuwape 1995).

CONCLUSION

The study showed that *A. leiocarpus* was suitable for the production of cement bonded particle boards which could be used as ceiling board as well as in partitioning panels. The boards produced had favourable prospects in terms of both physical and mechanical properties. The mixing ratio had effects on the properties of the board. The mixing ratio 1:3 recorded the least water absorption and thickness swelling with highest values in both MOE and MOR. Therefore, the boards made from mixing ratio of 1:3 have the best potentials since it has the highest MOE and MOR with reduced propensity for the absorption of water. The sawdusts which constitute physical nuisance and environmental hazards can therefore be utilized as value addition to *A. leiocarpus* wood products.

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