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Physico–mechanical Properties of Cement-bonded Particleboards Made from Date Palm Fibres (*Phoenix dactylifera*) and Obeche Sawdust (*Triplochyton schleroxylon*)

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Authors' contributions

This work was carried out in collaboration among all authors. Author AMD designed and managed the analysis and literature searches as well as wrote the protocol and draft the manuscript. Author OAS performed the statistical analysis and assisted in presenting results and discussion while author JSA managed the grammar and format. All authors read and approved the final manuscript.

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ABSTRACT

The Despite the array of old-grown date palm with reduced fruit yields in the northern part of Nigeria, the utilization of its biomass has not been fully explored by the wood-based industries in the country. This study was designed to assess the possibilities of using Date palm (*Phoenix dactylifera*) fibres and wood residues of *Triplochyton schleroxylon* for the production of cement-bonded particles. The Date palm straws were pounded in to fibres and mixed with Obeche sawdust in ratio 1:1 by weight. The mixture was dry-mixed thoroughly with cement at 1:2.0, 1:2.5, 1:3.0 and 1:3.5. To enhance the setting of the boards, Calcium chloride ($CaCl_2$) was used as catalyst. The chemical catalyst was dissolved in known volume of water at 3% to the weight of cement, sprinkled on wood-cement composite and mixed into uniform matrix-free-lump for making the boards. The

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boards produced was formed on hydraulic jack press at a pressure of 1.2 KN/m^2 for 24 h. The boards were subjected to physical and mechanical evaluation. The results showed that the stability of the boards increased with increase in the quantity of the cement used. Beyond 1:3.0 wood-cement ratio, the difference was not significant. But, significant in terms of their MOR, MOE and compressive strength. Based on the results obtained from this study, it is evident that cement-bonded particle boards can be produced from the mixture of date palm fibre and wood residues of *Triplochyto scleroxylon* to meet ISO 8335 particularly at 1:3.0 and 1:3.5 wood-cement mixing ratio.

Keywords: Date palm fibre; wood residues; particleboard; dimensional stability; mechanical properties.

1. INTRODUCTION

Cement bonded particleboards were composite product made from wood particles (shavings, chips and sawdust) as reported by Ajayi [1]. The main use of particleboards is in structural application. Cement bonded particleboards consist of certain qualities over panel product such as plywood and fibres board [2]. The common quality of cement bonded particleboards were durability in terms of sound absorption and the resistance to degradation / fungal attack and their perceived performance during natural disaster and tropical storms [3]. These qualities of cement bonded particleboards qualifies it to be a versatile construction material in that it can be used for roofing, ceiling, flooring partitioning, cladding and shutting [2].

Cement bonded particleboards are made from the mixture of Portland cement, chemicals and water, conventionally a glass of water is added to the mixture to accelerate the setting of Portland cement [4]. After blending a three layer mat is formed by two wing formers and one mechanical former. The mats are piled and pressed together with steel plates in batches [5]. Pretreatment is very essential in cement bonded particle board production in that it enhances the ability of bonding wood with cement [6]. The objectives of the paper is to assess the physico-mechanical properties of cement bonded particle board made from Date palm fibres (*Phoenix dactylifera*) and Obeche sawdust (*Triplochyton schleroxylon).*

2. MATERIALS AND METHODS

The materials used for the study were Date palm fiber, Obeche sawdust, Portland cement and chemical additive ($CaCl_2$). Date palm stem were pounded into small particle size (30 mm) and mixed with Obeche sawdust as well as Portland cement. After that the mixture was poured on a mat and compressed under a hydraulic jack pressure for 24 h. After releasing the boards they were put into a black nylon for conditioning for 28-29 days under room temperature (Ajayi, 2000). And data were subjected to statistical analysis using complete randomized design.

2.1 Pre-treatment Methods

The wood material was poured into a big pot and heated up to 85°C in order to remove wood extracts that can hinder binding and setting of cement [7]. The Date palm fibres and sawdust were boiled at 100°C for 2 h after which it was brought down and allowed to stay for about 30 min hot water, drained and exposed to sun-drying for seven days [7].

2.2 Board Formations

The boards were formed based on specific dimensions of 250 mm × 250 mm × 20 mm. The Date palm fibres was mixed with Obeche sawdust in ratio 1:1 by weight. The mixture was dry-mixed thoroughly with cement at 1:2.0, 1:2.5, 1:3.0 and 1:3.5. To enhance the setting of the boards, Calcium chloride ($CaCl_2$) was used as catalyst. The chemical catalyst was dissolved in known volume of water at 3% to the weight of cement, sprinkled on wood-cement composite and mixed thoroughly into uniform matrix-free-lump. The amount of water used was computed using the formula expressed in equation 1. The composite was transferred into a wooden-frame of 250 mm by 250 mm to form a mat and pre-pressed. The pre-pressed mat was then placed in hydraulic jack press and pressed at a pressure of 1.2 KN/m^2 for 24h. The boards produced was formed on hydraulic jack press at a pressure of 1.2 KN/m2 for 24h.The materials (mixture of Date palm fibres and Obeche sawdust) was blended with Portland cement at a mixing ratio of 1:2.0, 1:2.5, 1:3.0 and 1:3.5. After blending, the mixture was put and spread onto a mat in the boards frame for acquiring required shape, then pre-pressed and moved to the compression site where the boards were subjected to pressure under a hydraulic jack for 24 h.

$$W_t = .60C_t + (0.30 + MC)W \quad (1)$$

Where

Wt = Weight of water (g), C_t = Cement weight (g), *MC* = Moisture date palm fibres and Obeche saw dust (%) and *W* = Dry weight of date palm fibres and Obeche saw dust (g)

2.3 Water Absorption and Thickness Swelling

The boards were selected randomly from various mixing ratios and immersed in water for three consecutive days, and the measurement involved length, thickness as well as weight were taken after 24 h. The boards were replicated three times and the measurements were taken before and after immersion in water. Formulae used to determine percentage water absorption and thickness swelling of the boards are expressed in equations 2 and 3.

$$Water\ absorbtion = \left(\frac{W_2 - W_1}{W_1}\right) x\ 100 \quad (2)$$

$$Thickness\ swelling = \left(\frac{T_2 - T_1}{T_1}\right) x\ 100 \quad (3)$$

Where;

W_1 = initial weight of the board,
W_2 = final weight of the board.
T_1 = initial thickness,
T_2 = final thickness,

2.4 Modulus of Rupture (MOR)

The Modulus of Rupture in this study was obtained through the equation below and the boards used were replicated three times. Meanwhile, the load applied on the boards to rupture was determined from the compression by the crushing machine used.

$$MOR = \frac{3PL}{2bd^2}(N.mm^{-2}) \quad (4)$$

Where;

P = Load or maximum load (N);
L= length of the board (mm);
b= Width of the board (mm);
d= thickness of the board (mm).

2.5 Compression Strength

Mechanical property was determined by subjecting the board samples to compression by means of crushing machine and exerted force or pressure by compressing the boards to the point that it would no longer be compressed and reading was recorded as the compressive strength of the board for the three replicates (Table 2).

2.6 Modulus of Elasticity (MOE)

The MOE of the boards where determined by using equation below;

$$MOE = \frac{\text{Stress}}{\text{Strain}}(Pa) \quad (5)$$

Table 1. Physical properties of the boards in relation to mixing ratio

Wood-cement ratio in weight	Water absorption (%)	Thickness swelling (%)
1:2.0	10.29 + 0.29[a]	17.00 + 2.22[a]
1:2.5	10.22 + 0.25[a]	9.02 + 2.38[b]
1:3.0	6.14 + 027[b]	7.36 + 0.53[c]
1:3.5	5.86 + 0.24[b]	4.01 + 0.54[c]

Values with the same alphabet within same the column are not significantly different at 95% confidence level

Table 2. Mechanical properties of cement bonded particle boards

Mixing ratio	MOR ($N.mm^{-2}$)	MOE (Pa)	Compressive strength ($N.mm^{-2}$)
1:2.0	0.27+0.21[a]	4.18+0.02[a]	6.05+2.52[a]
1:2.5	0.21+0.01[b]	2.50+0.06[b]	5.04+4.00[b]
1:3.0	0.18+0.002[c]	2.18+0.04[c]	4.17+2.65[c]
1:3.5	0.15+0.002[c]	1.99+1.76[d]	3.45+4.51[d]

Values with the same alphabet within same column are not significantly different at 95% confidence level

3. RESULTS AND DISCUSSION

3.1 Physical Properties

Water absorption and swelling thickness of the boards in relation to various mixing ratio were presented in Table 1. The results showed that variations in wood – cement mixing ratio had a significant effect ($p < 0.05$) on the water absorption of the boards. The rate of water absorption decreased with increase in cement content of the boards. Boards produced with 1:2.0. Wood – Cement mixture had the highest average water absorption of 10.29% which was not significantly different from 10.22% obtained when 1:2.5 ratio was used, but differed significantly from 6.14% and 5.86% obtained from the mixing ratios of 1:3.0 and 1:3.5, respectively which signified that low cement ratio might lead to higher water absorption and thereby resulting to poor strength and density. This is in line with the observation of many researchers [8,9] and the use of chemical additives played a vital role in inhibiting the higher percentage water absorption of the boards.

3.2 Thickness Swelling

This also varied significantly with wood – cement ratio. The boards produced with 1:2.0 wood-cement ratios had the highest thickness swelling by average value of 17.95%. The trend was the same when 1:2.5 wood- cement ratio was used, while the least average thickness swelling of 4.01% was obtained when wood- cement ratios increased to 1:3.5 .This is in line with Oyagde [10]; Halingan [11] reported that there are relationship between modulus of rupture and the board thickness. Therefore, cement bonded particle board with low cement ratio should be avoided because it possessed high thickness swelling and can easily be broken down meanwhile wood-cement ratio of 1:3.5 was recorded with the least thickness swelling which implies that cement bonded particle board thickness swelling has strong relationship with cement proportion in the mixture, therefore, more cement should be used in making cement bonded particleboards.

3.3 Mechanical properties

The results of mechanical properties of the boards in relation to the mixing ratio were presented in Table 2. The study reveals that compressive strength, modulus of rupture (MOR) and Modulus of elasticity (MOE) have significant influence on cement bonded particleboards.

a) Modulus of Rupture (MOR)

The result of the modulus of rupture showed that variation in wood-cement mixing ratio had significant influence on the MOR of the boards ($p<0.05$). The boards produced with wood cement ratio of 1:2.0 had the highest MOR of 0.27 $N.mm^{-2}$ and followed by 0.21 $N.mm^{-2}$ obtained when 1:2.5 was used and the lower values ranged from 0.15 to 0.18 $N.mm^{-2}$ were obtained from mixing ratio of 1:3.0 and 1:3.5 respectively. Several authors reported an inverse relationship between the wood-cement ratio and MOR [6,12]. However, MOR decreases with an increase in wood-cement ratio because higher quantity of wood in the board enhanced flexural properties of the board that is consistent with this study.

b) Modulus of Elasticity (M.O.E)

The results of modulus of elasticity showed that variation in wood produced with wood-cement ratio of 1:2.0 had the highest MOE of 4.18 Pa (Table 2). Meanwhile, average MOE ranged from 2.18 to 2.50 Pa obtained in 1:3.0 and 1:2.5 wood -cement ratio respectively. However, the least MOE of 1.99 Pa was obtained when 1:3.5 wood-cement ratios was used. This signifies that increased in cement content contributes positively to the strength of the boards, thereby resulting enhancing the modulus of elasticity in the boards [13]. However, density of the boards made from wheat straw coconut chips and bamboo chips significantly influenced the particleboards strength properties [14].

3.4 Compressive Strength

The results presented in Table 2 showed that variation in wood – cement ratio had significant effect ($p<0.05$) on the compressive strength of the boards. The compressive strength decreased with increase in cement content of the boards. Higher compression value was obtained in 1:2.0 ratio by 6.05 $N.mm^{-2}$ while, lower value of 3.45 $N.mm^{-2}$ was found in 1:3.5 wood-cement ratio respectively. The results of this study is consistent with what was reported by Benyar and Mindness [15], that wood fibers are generally not used to improve the compression of wood-cement bonded composite through a small improvement in strength may sometimes resulted from their use.

4. CONCLUSION

Date palm fibres and Obeche sawdust can be used in manufacturing cement bonded particleboards at higher cement ratio for quality products as the revealed in this study wood-cement ratio of 1:3.0 and 1: 3.5 produced strong boards that might be used for ceilings or floor purposes in that physical and mechanical properties of the boards were tested and confirmed that outlined mixing ratio can be used for such application. Meanwhile, as the cement ratio increase, the mechanical properties of the boards also increased but lowered the physical properties of the boards.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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