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Properties of agro-based hybrid particleboards

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Abstract

The development of particleboard from near-zero landfill of agro-wastes material can play a vital role in economic growth of any country. The use of agro-wastes materials serves as a substitute for the conventional wood-based particleboard and provides an alternative material in the development of a low-cost particleboard. Agro-wastes such as rice husks (RH), eggshell (ES), cassava peel (CP) and palm kernel shell (PKS) are abundant within the South-West Geopolitical Zone of Nigeria and are currently underutilized. In this study, the viability of these materials was investigated for the production of particleboard. The planetary ball mill was used to process ES, CP, and PKS to a size range of 150-250 µm while urea formaldehyde was used as a binder. Parameters such as resin content (25 %), hardener content (20 %), pressing time (10 min), press pressure (40 kg/m^2) and press temperature (175 ^oC) were held constant. The hybrid composites board developed was evaluated by physical properties determination (water absorption (WA) and thickness swelling (TS). Also, the mechanical properties such as modulus of rupture (MOR) and modulus of elasticity (MOE) were obtained for each batch of composites developed. From the result, composites designated D (100 % RH) had WA value of 12 % after 2 h of immersion and 85.91 % after 24 h. An optimum density value of 1081.43 kg/m^3 was observed in B while D has the least density value of 830.14 kg/m^3. Thus, composite designated B has a potential for indoor application, especially as furniture component.

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1. Introduction

The annual volume production of particleboards was envisaged to be around 28.4 million m^3 by [1] amounting to about 60-70% of European wood-based panels production [2]. This has led to a growing interest for a substitute material other than wood in the development of a particleboard. The demand for forest resources cause by deforestation is on the increase on yearly basis. Hence, the need for a ready marketable, cost reduction substitute in the development of particleboard. Thus, agro-wastes are potential materials with comparatively unique possibilities in the design of particleboard. Researchers over the years, have explored various types of agro-wastes in the development of particleboard some of which include; rice straw [3], palm branches and vermiculite [4], stone pine [5], almond shell [6], bamboo waste [7], wood and rice husk [8] among others. The choice of these route is informed by the environmental impact the disposal of these agro-wastes imposed on the society. These challenges are savaged by correct utilization of these agro-wastes. To ensure a proper adhesion, synthetic thermosetting resin are common binders used in the development of particleboard. A good example of such are phenol formaldehyde [9] and urea formaldehyde [10-12]. Most board are developed using urea formaldehyde (UF). This is informed by the good curing interface, resistance to microorganisms and to abrasion, excellent thermal properties, colorless qualities, especially the cured resin compared to other resins and shorter pressing time under a lower pressing temperature range UF provides. Thus, enhancing the property of the composite board [13-15].

Incremental research work is considered necessary with a view of establishing an optimal mix ratio of agro-wastes that will produce a better physical and mechanical properties for both interior and exterior application. The thrust of this study is to explore, the viability of using selected agro-wastes as alternative raw material in the development of particleboard, which to the best of our knowledge has not been thoroughly investigated before. The solution to sparce lignocellulosic material will thus be addressed in developing countries especially Nigeria by the alternative use of agro-wastes as potential material in particleboard development.

2. Materials and Method

2.1 **Materials**

Rice husks (RHs) was used in this research were sourced from a rice mill in Omu-Aran, Kwara State. Eggshell (ES) was obtained at Landmark University's Cafeteria while the Cassava peel (CP) and palm kernel shell (PKS) were locally sourced for within the community.

2.2 Methods

The average moisture content of rice husk particles prior to the production of the particleboards was about 5% based on the oven-dry weight of the rice husk particles. The RHs was sieve using ASTM standard sieve and Eggshell (ES) 4kg was initially dried and later milled in a planetary ball mill at 1000 rpm using Si_3N_4 balls of diameter 10 mm for 6 h. The residues were then screened using standard sieves to obtain 2 mm particles. Similar processing route was adopted in the processing of cassava peel (CP) and palm kernel shell (PKS) respectively. Urea formaldehyde (UF) adhesive with a solid content of 63 %, density of 1.27 g/cm^3, viscosity of 60 cp, gelation time of 40 s, and pH of 7 was applied as resin. Ammonium chloride (NH_4Cl) solution (solid content: 20 %) was added to the adhesive as hardener in accordance with [4]. The mat height was reduced and to densify the mats, they were subjected to a cold-press. The mixture was spread evenly on aluminum plate as a mat. The mat then experienced pre-press before transferred to hot hydraulic press at start pressure of 4 MPa and temperature 150 ºC for 5 min. The final stage was cut and trimmed all panels according to British Standard (BS EN). The experiments were repeated in triplicates number of panels to ensure reproducibility.

2.2 Production of composite particleboards

The composite designation and formulations used for the hybrid particleboards are as presented in Table 1. The adhesive used was UF at 30 % v/v as reported by [11,12] predetermined quantities from each formulation was homogeneously hand mixed and dispersed uniformly in a molding frame. A laboratory scale hydraulic press was used on the materials as described by [16]. To ensure evenness of the board thickness, stop bars were utilized. Shortly after the pressing, the composites produced were sheared to 350 × 350 mm^2 and thereafter conditioned for 2 weeks at 27 ºC following the procedure by [16].

Table 1. Formulation by weight percent of constituents' fiber used for the composites design.

Composition code	Wt.% of Rice Husks	Wt.% of egg shell	Wt. % of Cassava peel	Wt. % of Palm Kernel Shell
A	25.0	37.5	37.5	0.0
B	50.0	25.0	25.0	0.0
C	75.0	12.5	12.5	0.0
D	100.0	0.0	0.0	0.0
E	0.0	0.0	50.0	50.0

2.3 Dimensional stability determination

The dimensional stability evaluation was done via the thickness swelling (TS) and water absorption (WA) tests in accordance with [12,17]. Triplicate samples for each formulation in Figure 1 were utilized in the determination of the TS and WA properties; thereafter, the mean value was reported. Sequel to the evaluation, the composites produced were conditioned at temperature at 27 ºC and 65 % relative humidity following the procedure by [16]. The conditioning interphase was monitored by constantly weighting of the samples until no marginal changes in the weights were identified [16]. After 2 h of submersion, the samples were removed from the water and cleaned thoroughly. The composites were then weighed using electronic weighing balance (HX 302T with 0.01 g accuracy) to the nearest 0.01g. The tests procedures were also repeated for 24 h of submersion. The densities of the composites were evaluated following the test procedures stated in [11,18]. The experiments was carried out in triplicate to ensure reproducibility. ASTM D1037-12 was used in determining the water absorption (WA), thickness swelling (TS) and density (d) of the particleboard [19].

3. Results and discussions

Figures 1-4 show the representative variations in the mechanical and physical properties of the particleboard.

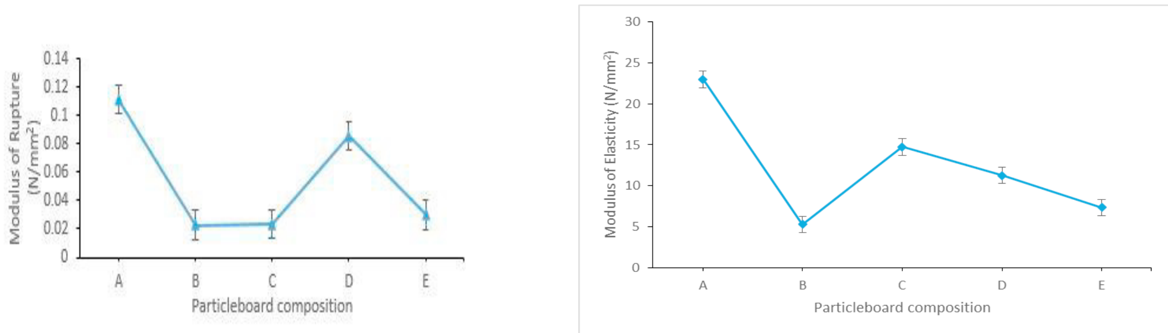

Figure 1. (a) showing variation in modulus of rupture (b) showing variation in modulus of elasticity off different particleboard composition

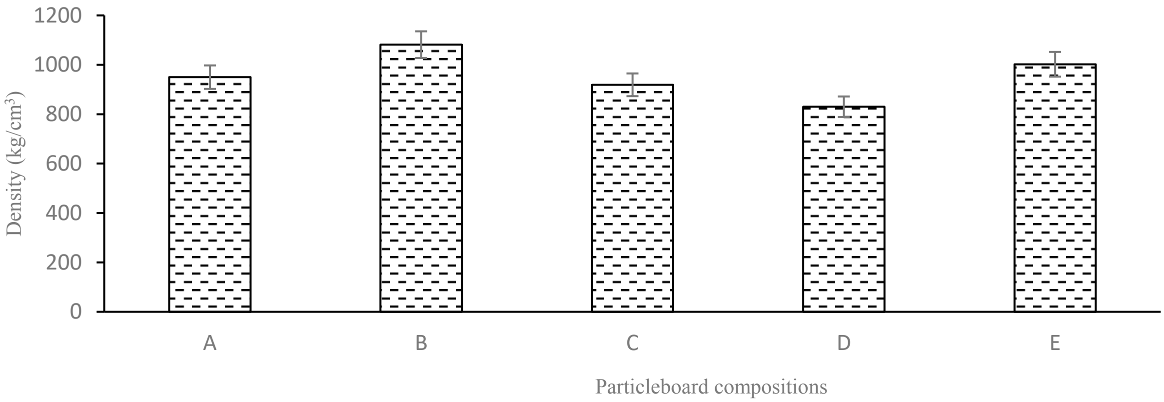

Figure 2. Variation in density value of particleboard composites

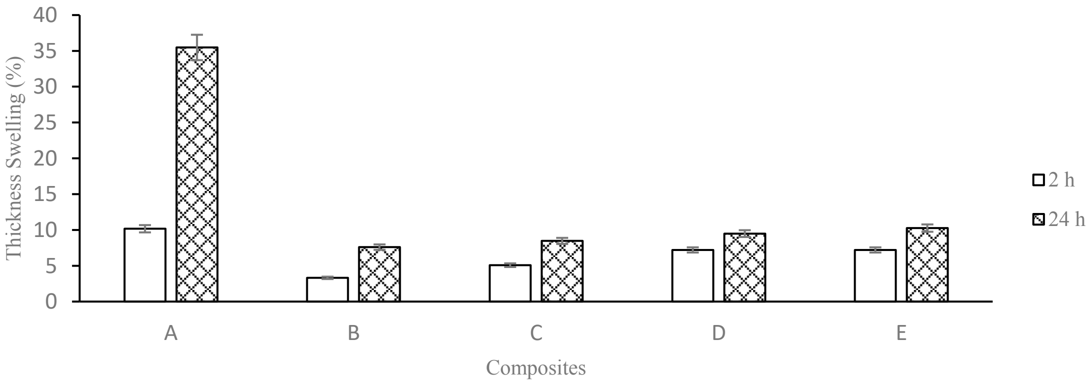

Figure 3. Variation in thickness swelling of particleboard composites

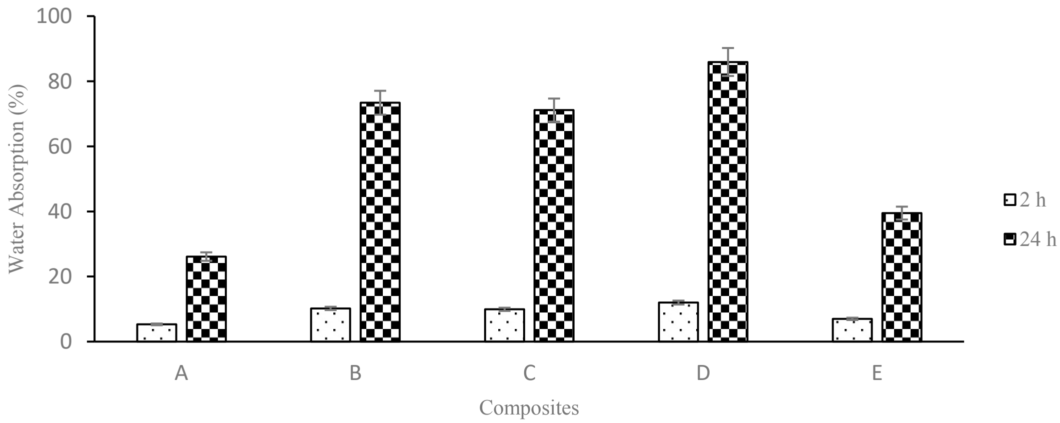

Figure 4. Variation in water absorption of particleboard composites

From Figures 1-2, the lower gap filling properties between the interphase created by the matrix of RH and EGS particles is likely to have accounted for lower MOE and MOR value in composites designated B,A and C. Sample D has the maximum WA value, it is apparent that RH is a lignocellulosic material having a high affinity for water. As presented in Fig.3, sample D had a density value of 830.14 kg/m^3 being the lowest. The lower bulk density possessed by the RH might have accounted for this trend, being an homogeneous phase consisting of RH as the primary phase The mix ratio gives a better density value when compared with coconut husk with values ranging from 896 kg/m^3 to 989.8 kg/m^3 [20]. According to ANSI 208 standard, particleboard with designation A-E are classified as medium densities particleboard [21]. After 2 h of immersion, the TS was observed to be within the interval 3-11%, while the corresponding WA values were 5-13%. The pore sites are likely to be co-shared by the molecules/ atom in ES and CP around the RH matrix, hence, creating a higher affinity for water absorption sequence. However, after 24 h of immersion, the WA (Fig.4) increased significantly to 26-86% while the TS values were 7-36%. This similar trend was previously reported by authors [7].

Conclusions

This study explores the viability of using different agro-based materials in the design of an hybrid particleboards with application as indoor as furniture component. Based on the results obtained, composite B had the optimum yield of density and composite A the optimum thickness swelling. An increase in the volume percent of RH led to about 13.8% improvement in the density value of the hybrid composite. In general, based on ANSI standard, the composites board can be classified as medium densities particleboard.

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