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EVALUATION OF PHYSICAL AND MECHANICAL PROPERTIES OF PARTICLE BOARD MADE FROM PEA - NUT SHELL AND GUM ARABIC

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ABSTRACT

In this research, efforts have been made to convert peanut shell into the fabrication of particleboards using Gum Arabic as a binder. an average particle size of 2mm. Mix ratios of 2:1, 2.5:1, 3:1, and 3.5:1 of Gum Arabic to peanut shell by weight were produced respectively. Twenty-four Particleboards (200 X 50 X 12mm) were casted and cured for 28 days. Tests on moisture content, water absorption, thickness swelling, modulus of rupture and modulus of elasticity were conducted according to ASTM D 1037-93 procedures. The Results from the tests indicated that the moisture content of the boards with mean values of 7.8% at the time of conducting the test was also below the maximum of 10% specified by ANSI/A208.1-1999 standard. Particleboards produced using Gum-Arabic-peanut shell ratio of 3.5:1 gave the best results in terms of the lowest mean values of water absorption of 43.30%, and thickness swelling 10.72% after four hours of immersion in distilled water. The modulus of rupture and modulus of elasticity, with mean value are 5.52N/mm^2 and 1556.96N/mm^2 respectively, were above 3.0N/mm^2 and 550N/mm^2 as the minimum values specified by ANSI/A208.1-1999 respectively. The particleboards produced met the standard for general-purpose boards except for water absorption and thickness swelling characteristics which were above the maximum of 8% and 3% specified by ANSI/A208.1-1999. Therefore, it can be considered cost effective and suitable for indoor structural applications, offering a cheaper alternative to conventional boards.

KEYWORDS: Peanut Shell; Gum Arabic; Water Absorption; Thickness Swelling; Modulus of Rupture; Modulus of Elasticity.

INTRODUCTION

Large quantities of peanut (groundnut) shell are produced as agricultural waste during processing and pose disposal and environmental problems if not used productively [13]. Researchers have therefore explored using agricultural residues as low-cost, sustainable raw materials for composite panels such as particleboard. Agricultural by-products (including peanut shells) have favorable characteristics abundance, low density and biodegradability that make them attractive alternatives to wood in particleboard manufacture, especially where wood supply is limited or expensive [10]. Recent studies have shown promising physical and mechanical performance for particleboards made from various agro-wastes when appropriate binders and manufacturing parameters are used [6][9]. Gum Arabic (a natural exudate resin) has attracted attention as a bio-binder because it is renewable, non-toxic, and can act as an adhesive for lignocellulosic particles [2]. Several recent investigations have evaluated gum Arabic as a replacement for synthetic resins in particleboard production and reported acceptable bond performance and mechanical properties under specific formulations and processing conditions [4][1]. Using gum Arabic with peanut shell particles therefore offers a route to produce environmentally friendly particleboard while adding value to an abundant waste.

Conventional particleboards typically rely on formaldehyde-based synthetic resins (e.g., urea-formaldehyde), which raise health and environmental concerns and can be expensive. Meanwhile, large volumes of peanut shell waste remain underutilized, often burnt or landfilled [8]. Although prior studies have produced particleboards from peanut shells and other agro-wastes, there is limited, consistent information on how gum Arabic-bonded peanut-shell particleboards perform in key durability tests specifically moisture content, water absorption, thickness swelling, modulus of rupture (MOR) and modulus of elasticity (MOE) [5][3]. These properties determine board suitability for common uses (furniture, interior panels) and are critical for comparing agro-based boards against commercial standards. The lack of standardized, recent data on the combined effect of peanut shell and gum Arabic on these durability indicators creates uncertainty for manufacturers and potential adopters [6][4].

This study addresses an important sustainability and materials-engineering gap by evaluating the physical (moisture content, water absorption, thickness swelling) and mechanical (MOR, MOE) properties of particleboard made from peanut shells bonded with gum Arabic. Producing empirical data on these tests will: [1] assess whether gum Arabic can serve as a safe, renewable binder for peanut-shell particleboards; [11] indicate the boards' potential for practical applications (interior use, furniture, non-structural panels) based on durability tests; and [14] contribute to waste-valorization strategies that reduce environmental burden while creating local, value-added products. Recent literature supports the plausibility of good performance for gum Arabic–bonded agro-boards but highlights the need for more targeted studies on peanut shells and the full set of durability tests used here. [8][12]

2.1. Peanut shell

Peanut shell was obtained from Abukur town of Rimi L.G.A, Katsian State, Nigeria. The peanut shell was cleaned and air-dried to remove moisture after which the shell was crushed to a maximum size of 2mm and sieved through the British Standard sieves with apertures of 0.8mm and 2mm. The particles were further air-dried for 48 hours to target moisture of 10%.

2.2. Gum Arabic

The Gum-Arabic adhesive used was obtained from Kurmi market, Kano State, Nigeria. The raw Gum-Arabic granules were cleaned and mixed thoroughly with water to form a homogeneous mixture of a Gum-Arabic solution to a concentration of 1000g/dm^3.

3. METHODS

3.1 Mix Proportion

Table 1 Mix ratio for the production of GA/PS particleboard. (by weight of peanut shell)

MATERIAL	T(2:1)	T(2.5:1)	T(3:1)	T(3.5:)
GUM ARABIC	66.7	71.4	75	77.8
PEANUT SHELL	33.3	28.6	25	22.2

3.2. Specific Gravity test on peanut shell particles

Specific gravity test was conducted on peanut shell particles in accordance with BS 8500 (2000).

3.3. Production of peanut shell particleboards

In order to extract glucose, hemicellulose and lignin from the shell particle as stated by [10]. The milled and sieved peanut shell was transferred into hot water at a temperature of 85°C. The extracted particles were air-dried to attain approximately 10% moisture content before use.

The milled shell was mixed thoroughly with the Gum-Arabic adhesive at the ratio described in Table 1 above manually to obtain a uniform lump-free matrix. After mixing, the material was placed in a steel mat-forming box, with dimensions 200 x 50 x 12mm and manually pre-pressed. The box was then further pressed using 155kg load for 48 hours. The mat-forming box was covered with a polythene sheet prior to board formation to prevent the boards from sticking onto the box.

The boards produced were stabilized in an acclimatized room of temperature (20 ± 2 °C) and relative humidity of 65 ± 2% for 28 days. The above procedure was repeated for the varying ratio of Gum-Arabic to peanut shell particles solution presented in Table 1

3.4. Water Absorption and Thickness Swelling Test

Water absorption and thickness swelling tests were assessed to determine the water absorption characteristics of the particleboards and it is intended to be used to simulate and determine the level of moisture that the board can be subjected to during its service life without deteriorating.

A 30 minutes submersion method was adopted, (ASTM D 1037-93). Twelve number (12) $50mm \times 50mm \times 12mm$ test specimens with all the four edges smoothly and squarely trimmed were used in this test. The test specimens were conditioned as nearly as deemed practical to constant weight and moisture content in a conditioning chamber maintained at a relative humidity 65 ± 2% and temperature of 20 ± 2 °C. The moisture content after conditioning was determined. The samples were submerged completely in distilled water. After 30 minutes of submersion, the samples were suspended to drain for 2 minutes at the end of which the excess surface water removed from the surface and weighed immediately. The thickness values at the edges were also taken from which the thickness swelling of each board was computed using equation 2.0. Each sample was submerged again for an additional 4 hours and the above weighing and measuring procedures repeated at intervals of 30 minutes. Each sample was then oven-dried at 103^0C and weighed after drying. The moisture content was calculated (based on oven-dried weight) from the weights after conditioning using equation 1.0. The amount of water absorbed was calculated and expressed as a percentage by weight based on the weight after conditioning, using equation 3. (The specific gravity of water was taken to be 1.00), (ASTM D 1037-93).

The same test procedure was repeated for the (2:1, 2.5:1, 3:1, and 3.5:1) ratios of Gum-Arabic adhesive: peanut shell sample. Measurements of the thickness was taken at four points midway along each side, 2mm in, from the edge of the specimen. The average was taken for the thickness swelling determination (ASTM D 1037-93).

Water absorption (%) = $\frac{(w_f - w_i)}{w_i}$×100 …… (1.0)

Where;

W_f – final weight,

W_i – initial weight.

Thickness swelling (%) = $\frac{(T_f - T_i)}{T_i}$×100 ……. (2.0)

Where

T_i = initial thickness

T_f = final thickness.

3.5 Determination of Modulus of Elasticity (MOE) and Modulus of Rupture (MOR)

Static bending tests were conducted on specimens after conditioned in an acclimatized room, (20 ± 2 °C) temperature and relative humidity of 65 ± 2% for 28 days. Twelve number $200mm \times 50mm \times 12mm$ samples were produced and tested in accordance with (ASTM D 1037-93). The test was conducted using a universal testing machine assembly (beam deflection unit) shown in Figure 1. The supports were place at exactly 25mm and 175mm marks of the test sample. A knife edged support was used with plates under the specimen at these points. The specimen was loaded each at the centre of the span with the load applied to the finished face at a uniform state through a loading block. The load was applied continuously throughout the test until the sample fail. The load-deflection curve was obtained for all the bending tests. The deflection of the centre of the sample was obtained by measuring the deflection at the bottom of the sample at the centre by means of a dial attached to the base of the testing jig, with the dial plunger in contact with the bottom of the sample at the centre. The load and the deflection at the first failure and at maximum load were noted, respectively. The reading of deflection was taken to the nearest 0.01mm. The mode of the failure, the sequence of failure and the position of the initial failure (whether it occurred in the compression or in tension zone) were also observed and recorded.

(a) Homogeneous mixture of peanut shell particleboard (b) Drying of peanut shell particleboards

Materials

(c) WA and TS test set samples at the beginning of the test (a) Beam deflection unit

Figure 1: Sample preparation.

The modulus of rupture (MOR) is calculated using the equation;

$$MOR = \frac{3PL}{2bd^2} \quad \text{........ (3.0)}$$

The stiffness (apparent modulus of elasticity) for each sample is calculated using equation 4.0

$$E = \frac{P_1 L^3}{4bd^3 y_1} \quad \text{....... (4.0)}$$

Where

- b = width of sample, (mm).
- d = thickness (depth) of sample, (mm).
- E = stiffness (apparent modulus of elasticity), (kPa).
- L = length of span, (mm).
- P = maximum load, (N).
- P_1 = load at proportional limit, (N).
- R = modulus of rupture, (kPa).

- Y_1 = center deflection at proportional limit load, (mm)

4.0 RESULT AND DISCUSSION

4.1. Specific Gravity of peanut shell particles

This test was conducted on peanut shell particles in accordance with BS 8500 (2000). The specific gravity of peanut shell was 0.91. [12] Observe that the specific gravity of Gum Arabic is 1.93.in relation with the specific gravity of peanut shell particle the Gum Arabic has a higher specific gravity than peanut shell particle.

4.2. Rate of water absorption and thickness swelling for the particleboards

The results of water absorption and thickness swelling of peanut shell particleboard at the end of four hours immersion in distilled water are discussed

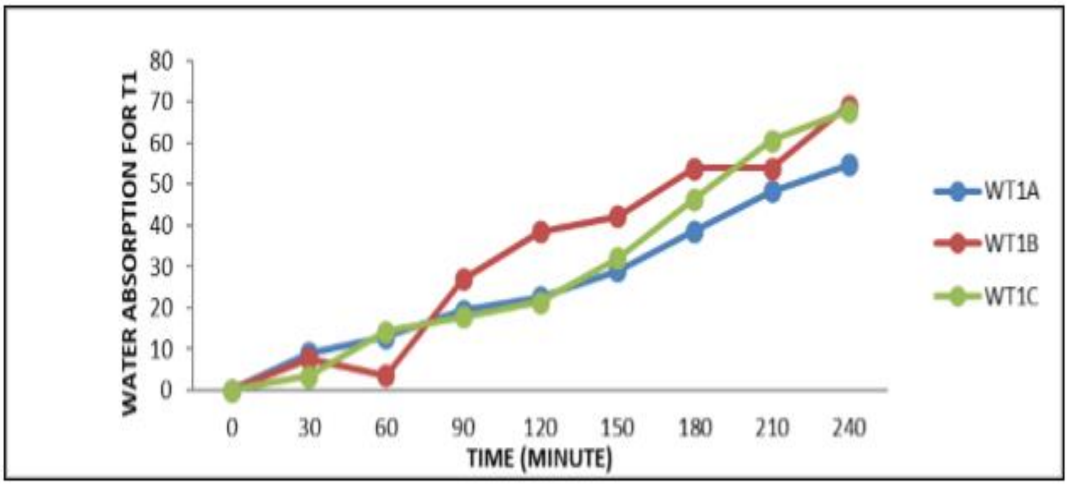

Figure 2 Water absorption variation with time for treatment T1.

Figure 2, 3, 4 and 5 shows the effects of moisture on the Gum Arabic-peanut shell particleboard with time. From the Figure 2, it can be observed that the samples T1B and T1C failed within the 60 minutes of immersion in distilled water while T1A failed within the first 30 minute, as evident from having WA values above the 8% maximum specified by ANSI/A208.1-1999. The values continue to increase throughout the time of soaking. The rapid increase may be as a result of low amount of binder used in the mix and the presence of voids in the boards.

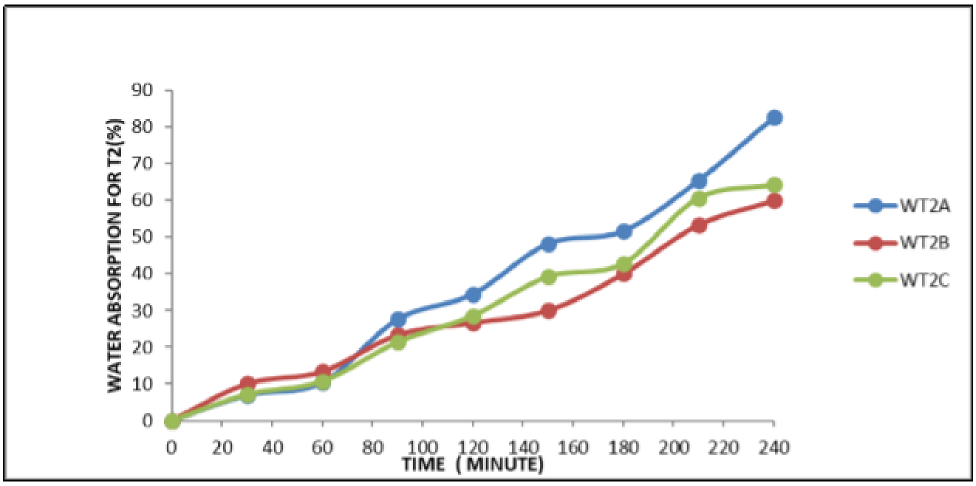

Figure 3 Water absorption variation with time for treatment T2.

From Figure 3, it can be observed that for the second treatment like for the first one, a little resistance in the rate of WA was observed in T2A and T2C for the first 30 minute of immersion in water while for T2B there would be a failure for the first 30 minute. The samples failure may be due to the lack of sufficient binder in the mix which resulted in formation of voids which in turn caused difficulty in compression and thereby allow the board to take in water.

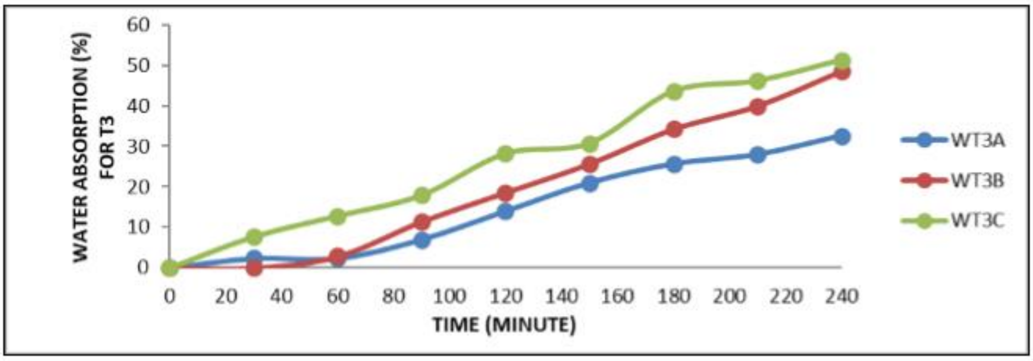

Figure 4 Water absorption variation with time for treatment T3.

From Figure 4, it can be observed that there is more resistance to permeation of water into the particleboard microstructure due to the high quantity of Gum Arabic binder used in the mix, unlike the first and the second treatment it can be observed that sample A failed within 120 minutes of immersion in distilled water while sample B failed within 90 minute and sample c failed within 60-minute immersion in distilled water. But despite the resistance observed, the boards also failed within 4hr of immersion in water.

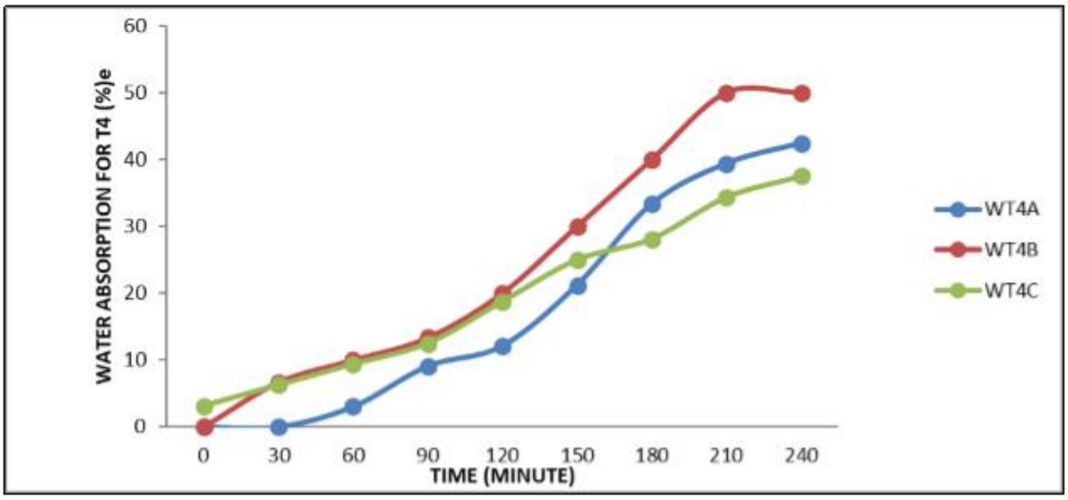

Figure 5 Water absorption variation with time for treatment T4.

In Figure 5, the samples although exceeded the first 90 minutes before failing, due to the excess amount of Gum Arabic used, the samples also failed within 4hr of immersion in distilled water.

4.3. Modulus of elasticity (MOE) and Modulus of rupture (MOR)

The results of modulus of elasticity and modulus of rupture for the peanut shell particleboards are shown in Table 2.

Table 2 Mean Modulus of rupture (MOR) and modulus of elasticity. (MOE)

Treatments (T)	MOR(N/mm2)	MOE(N/mm2)
T1	4.800	1323.18
T2	5.240	1116.70
T3	6.020	1798.10
T4	6.010	1989.80

5. CONCLUSION AND RECOMMENDATIONS

The following conclusions can be drawn

- The particleboard produces by the weight of Gum-Arabic to peanut shell particle satisfy the ANSI/A208.1-1999 Standard on the moisture content of the general-purpose boards.
- The particleboards produced can be classified as high-density boards (H) for having density values above 800kg/m^3.
- Particleboards produced using Gum Arabic adhesive-peanut shell ratio of 3.5:1 are more

dimensionally stable with average water absorption and thickness swelling of 43.30% and 10.72% compared with the other samples which have a high values of water absorption and thickness swelling.

RECOMMENDATION

Particleboards Produced from Peanut Shell and Gum Arabic As A Binder May Not Be Suitable
for use in exposed structures because of high absorption water rate.

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