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Durability Properties of particleboard made from peanut shell and Gum Arabic as a binder

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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 the peanut shell by weight of the peanut shell were produced respectively. Twenty-four Particleboards (200 X 50 X 12mm) were fabricated 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 5.518N/mm2 and 1556.954N/mm2 respectively, were above 3.0N/mm2 and 550N/mm2 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% respectively, 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

1. Introduction

Particleboards are wood-based panel product that are conventionally produced using wood and wood wastes such as shavings, flakes, wafers, chips, sawdust, and strands [1]. Particle board have found applications in areas like furniture, kitchen cabinets, flooring, wall bracing, ceiling boards, partitioning and cladding [2]. The materials used to bond the particles together are mostly synthetic resins but other additives can be added to improve some properties of the board [3]. Several types of resins such as polyamides, thermo-set epoxies, polyurethane resins, phenol-formaldehyde, isocyanate-based adhesives, epoxy resins, resorcinol formaldehyde, are commonly used, although urea- formaldehyde is the cheapest and easiest to use [3].

Particleboards are one of the primary products used in the building and furniture [4]. These materials are manufactured under pressure, essentially by combining wood particles and/or other lignocelluloses fibrous materials with an adhesive [5]. The extensive use of particleboards can be related to the economic advantage of the low cost of wood raw material, inexpensive agents and simple processing [6]. The demand for these products has increased substantially

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throughout the world, representing 57% of the total consumption of wood-based panels, a percentage that is continuously growing at a rate of 2–5% annually [7].

The increased demand for wood and wood-based panel products has placed significant pressure on current forest resources, which has resulted in over exploitation and unregulated harvesting of trees in both the natural and plantation forest leading to the recent interest in lesser-known timber species [8]. With all these efforts, timber supply is still nowhere close to meeting global demand for wood products resulting in continuous cutting without replacement [9]. Sotande *et al*.,[10], stated that this lack of balance between consumption and sustainable supply will have serious social, economic as well as environmental implication on the populace. This demand has led to the need to find alternative raw materials for the production of boards and panels. This research work will look into the potential of using peanut shell for the production of particleboard through determining the physical and mechanical properties of the material. A manufacturing process of producing particleboard from peanut shells particles may help to reduce the pressure on forest resources and at the same time provide solutions to the problems of shells disposal.

Groundnut, also commonly known as peanut (Arachis hypogaea) , is a tropical legume mainly Grown to produce oil and for human and animal consumption. Peanut is grown in about 120 Countries in the world in a total area of 24.6 million ha, with a world production of 38.2 million Tons (Mt). Asia is the major peanut- producing region in the world. In this region, China and India are the major contributors with 15.7 and 5.6 Mt in 2010, respectively [11]. Africa ranks second in the world peanut production. In this region, Nigeria (2.6 Mt), Senegal (1.2 Mt) and Sudan (0.7 Mt) are the major producing countries [11]. In Africa and Asia peanut is mainly grown by resource-poor farmers. In the Americas, the USA and Argentina are the major producing countries with 1.8 and 0.6 Mt in 2010, respectively. Groundnut shells contain various bioactive and functional components which are beneficial for mankind. Commercially, it is used as a feedstock, food, filler in fertilizer and even in bio-filler carriers. But most of the deserted groundnut shells are burnt or buried resulting in environmental pollution.

2. Materials and Methods

2.1. Peanut shell

Peanut shell was obtained from Tanagar village Gezawa L.G.A , Kano State, Nigeria. The peanut shell were 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 reduce the moisture content 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/dm3.

2.3. Methods

This section presents the methods and steps adopted for the various test.

2.3.1. Specific Gravity test on peanut shell particles

The specific gravity of any material is defined as the ratio of the weight of a given material to the weight of an equal volume of water. This test was conducted on peanut shell particles in accordance with BS 8500 (2000) .

2.3.2. 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 were transferred into hot water at a constant 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 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.

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

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 peanut shell particles to the Gum-Arabic solution presented in Table 1

2.4. 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 as shown in Figure 6 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 length, width, thickness and weight of the samples were measured and recorded. 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 1030C 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 3.3.n (the specific gravity of water was assumed 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).

$$\text{Water absorption } (\%) = \frac{(w_f - w_i)}{w_i} \times 100 \qquad \dots\dots \quad (1.0)$$

Where;
Wf – final weight,
Wi – initial weight.

$$\text{Thickness swelling } (\%) = \frac{(T_f - T_i)}{T_i} \times 100 \qquad \dots\dots \quad (2.0)$$

Where
Ti = initial thickness
Tf = final thickness.

2.5. 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.

Figure 1 Beam deflection unit

The modulus of rupture (MOR) is calculated using equation 3.0

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

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

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

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).
- P1 = load at proportional limit, (N).
- R = modulus of rupture, (kPa).
- y1 = center deflection at proportional limit load, (mm)

3. Result and discussion

3.1. 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.

3.2. 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

3.3. 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

3.4. Variation of water absorption (WA) with time

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% maxima 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.

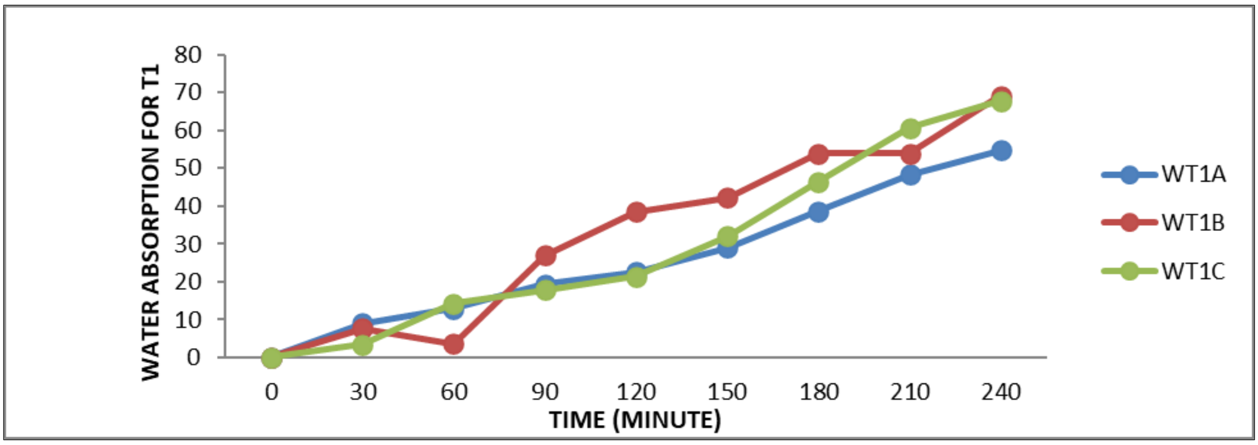

Figure 2 Water absorption variation with time for treatment T1

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.

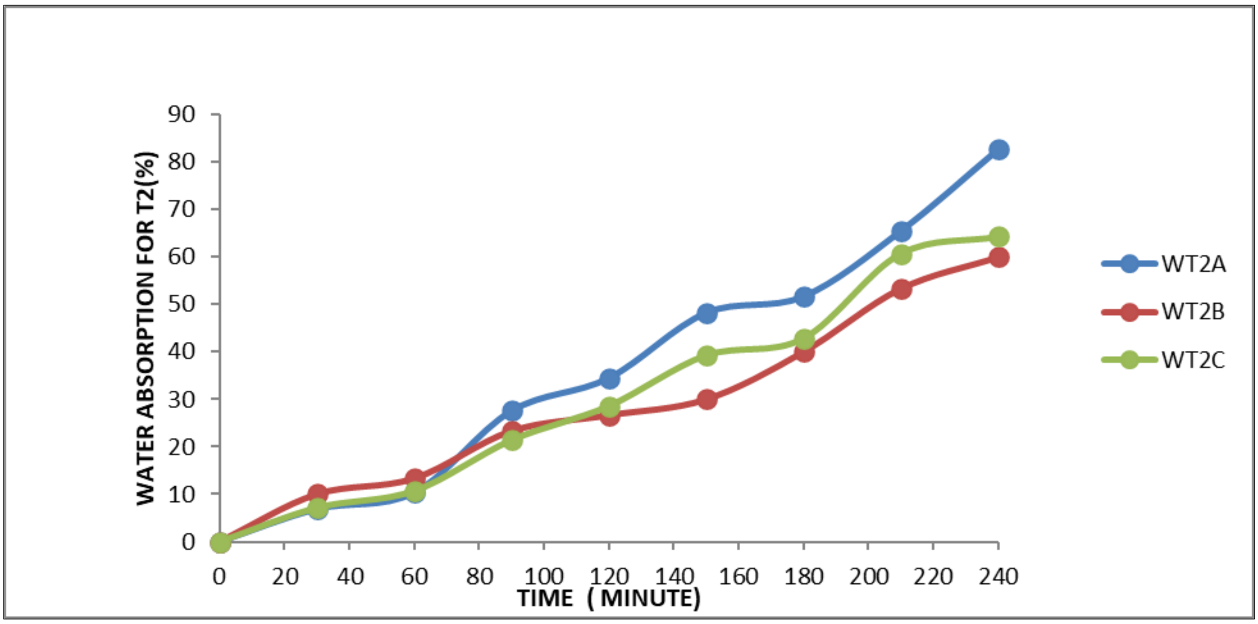

Figure 3 Water absorption variation with time for treatment T2

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.

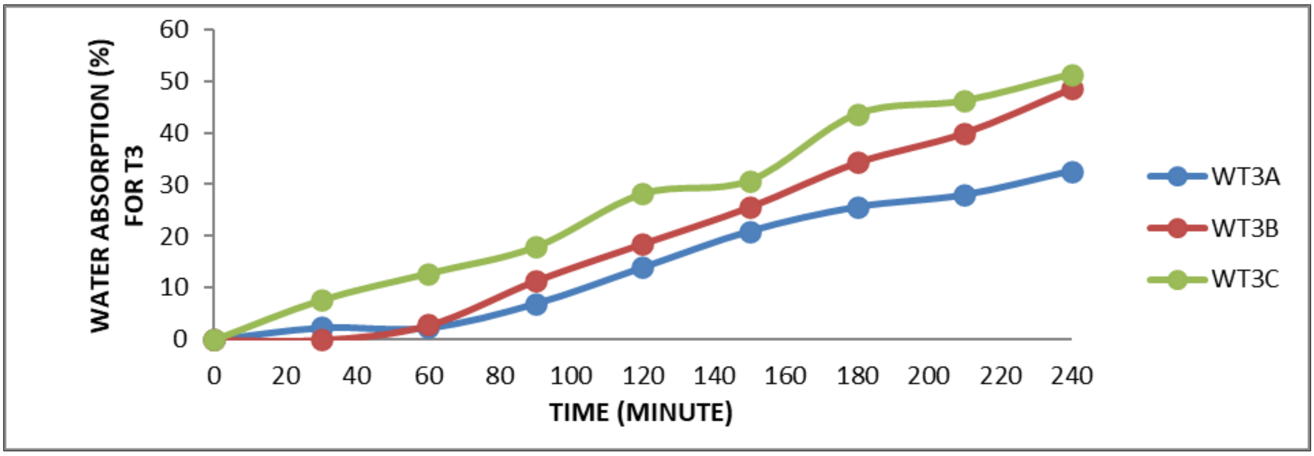

Figure 4 Water absorption variation with time for treatment T3

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.

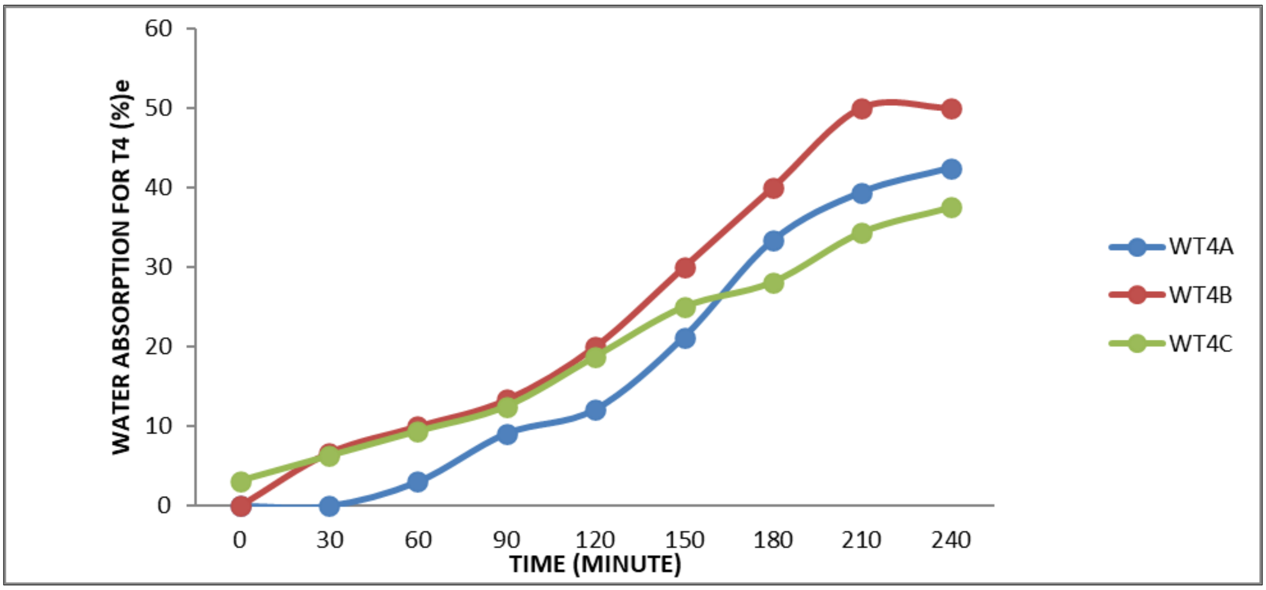

Figure 5 Water absorption variation with time for treatment T4

3.5. Variation of thickness swelling (TS) with time

Figures 6, 7, 8 and 9 shows the rate at which peanut shell particleboards increases in thickness as it was soaked in water. From the figures although an improvement was recorded as the quantity of the Gum Arabic was increased, the swelling in the thickness of the boards was still above the 3% maxima specified by ANSI/A208.1-1999 [13]

From figure 6, it can be observed that the TS values increase with increase in soaking time. In the 90 minutes of soaking, the all the samples from the fist treatment failed. after that the high values observed may be as a result of presence of many voids in the board which allow the particleboard to easily absorb water and hence cause internal swelling. The values of TS continue to increase at rapid pace throughout the test duration.

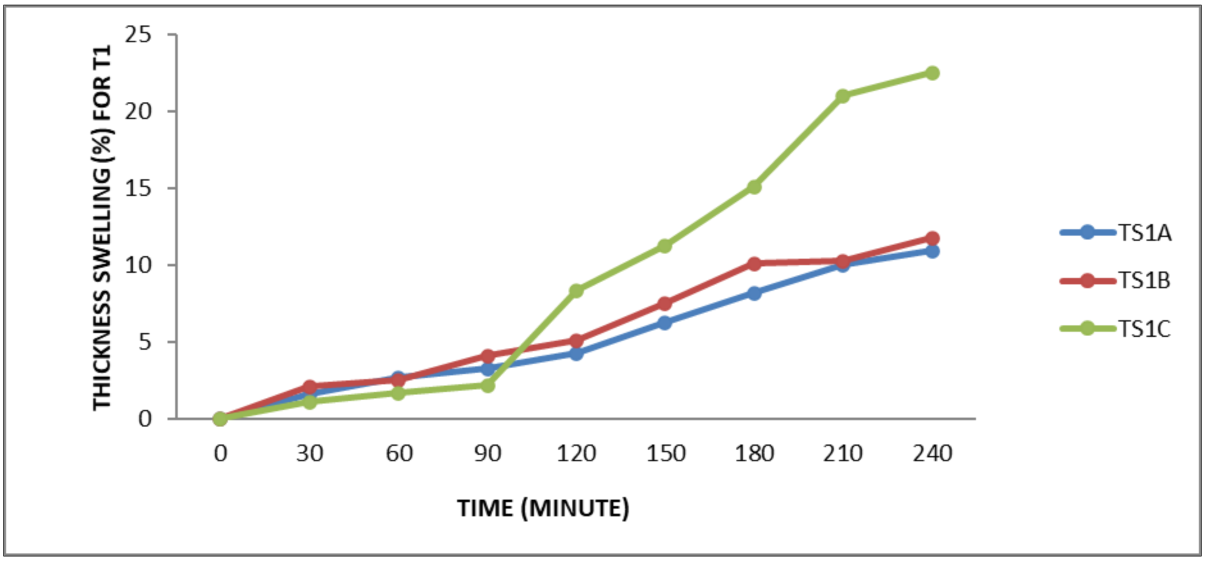

Figure 6 Variation of thickness swelling with time for treatment T1

In figure 7, although the samples failed, more resistance to swelling of thickness of the boards can be observed. This resistance may be as a result of more quantity of binder added in the mix which helped to reduce the number of voids and cracks in the board that may enhance water intake. It can also be observed that the thickness swelling rate was slow for the first 2hour of immersion in water.

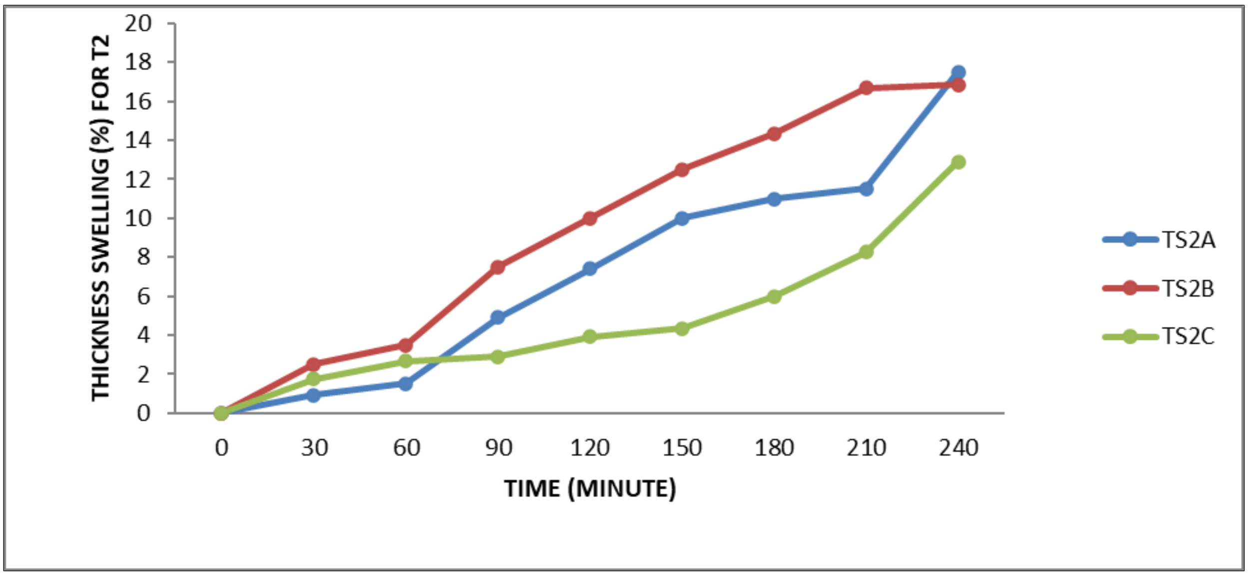

Figure 7 Variation of thickness swelling with time for treatment T2

From figure 8, more resistance to permeation of water into the boards that may cause internal swelling was observed. This was due to the high quantity of Gum Arabic used in the mix. some of the samples from the treatment T3 also failed after 90 minutes of immersion in distilled water, as evident of swelling above 3% specified by ANSI/A208 for general used boards. The high affinity for water by Gum Arabic may be the reason for such failure.

In figure 9, remarkable improvement was observed in terms of the thickness swelling of the boards. This improvement may be attributed to the amount of binder that was sufficient enough to prevent water intake and also due to the high degree of compaction during the production of the boards. But the high affinity for water by Gum Arabic adhesive made it easy for water to penetrate the boards and weakens the bond between the particles. Hence increase the thickness swelling of the particleboards. But the samples failed after the first 90 minutes of immersion in distilled water.

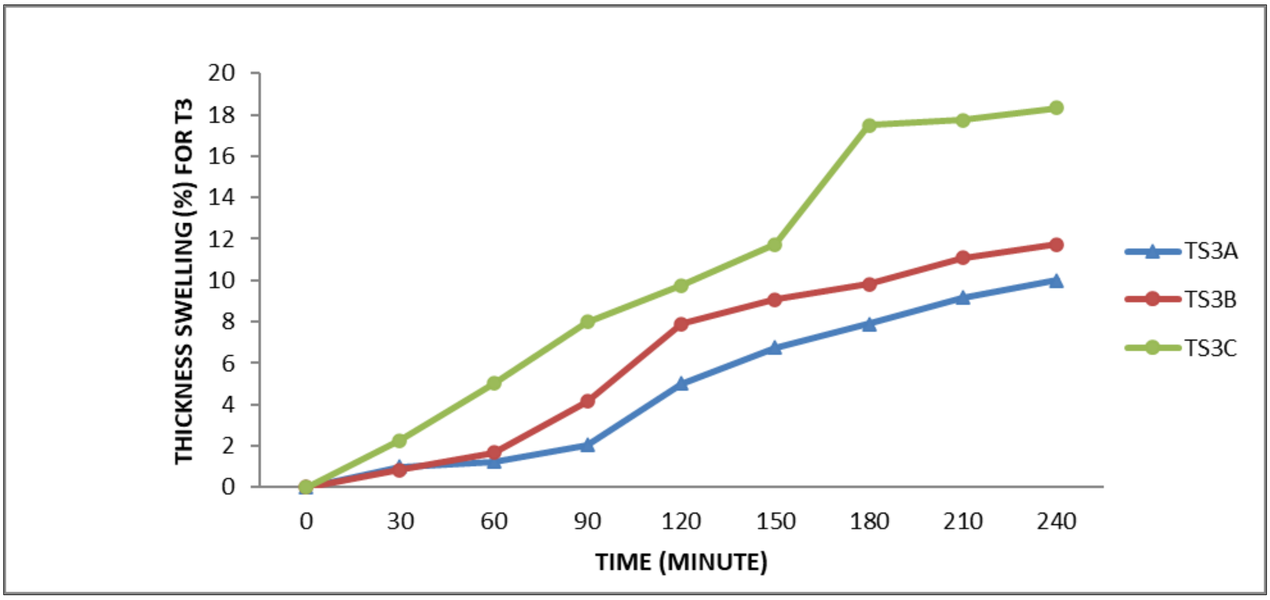

Figure 8 Variation of thickness swelling with time for treatment T3

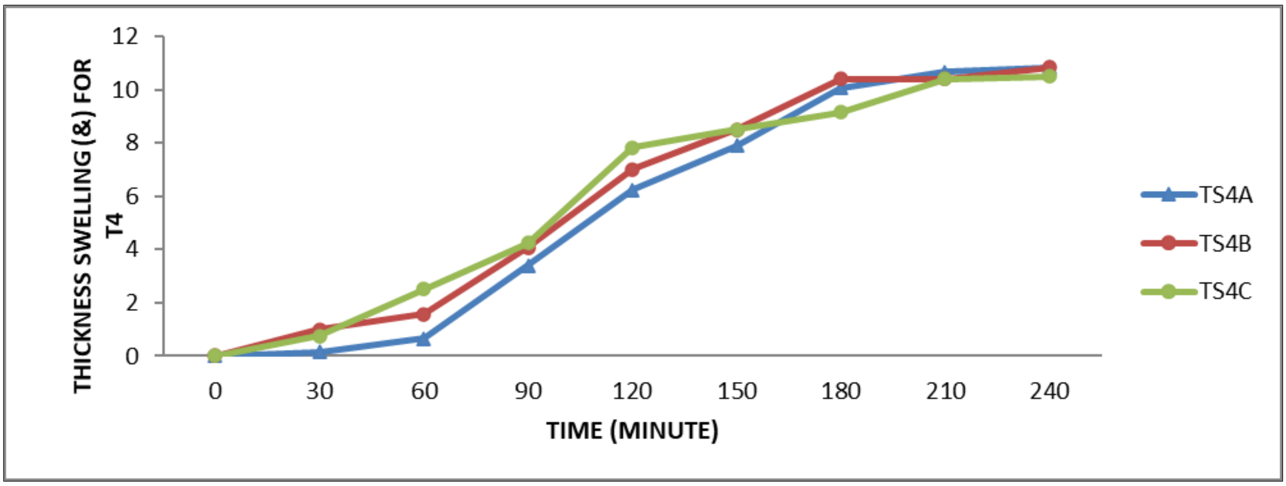

Figure 9 Variation of thickness swelling with time for treatment T4

4. 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/m3.
- 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 absorbtion and thickness swelling.
- Particleboards produced from peanut shell and Gum Arabic as a binder may not be suitable for use in exposed structures because of high absorption of water.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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