ISSN: 2449 – 0539
BAYERO JOURNAL OF ENGINEERING AND TECHNOLOGY (BJET) VOL.15 NO.2, May, 2020 pp51-63

PARTICLEBOARD PRODUCED FROM MAHOGANY LEAVES AND GUM ARABIC AS BINDER

[1*]Ishaq, S. M., [2]Aboshio, A. and [3]Garba, M. J.

[1,2]Department of Civil Engineering, Bayero University, PMB 3011, Kano - Nigeria
[3]Centre for Satellite Technology Development, Abuja - Nigeria
Corresponding author: safiyanuishaqmuhammad@gmail.com

ABSTRACT

The potential of using mahogany leaves particles for the production of gum Arabic bonded particleboards is reported in this paper. Fresh mahogany leaves, air-dried to a target moisture content of 10% were crushed to 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 crushed mahogany leaves by weight of the mahogany leaves were produced respectively. Twenty four (24) particleboards of sizes 200mm length, 50mm width, and 6mm thick were produced. The boards were cured for 28 days in an acclimatized room, after which tests on moisture content (MC), water absorption (WA) and thickness swelling (TS) were carried out in accordance with the ASTM D1037-93 procedures. Results of the tests indicated that the moisture content of the boards with mean and standard deviation values of 7.95% and 0.24% at the time of conducting the test was below the maximum of 10% specified by ANSI/A208.1-1999 standard. Particleboards produced using gum-Arabic-mahogany leaves ratio of 3.5:1 gave the best results in terms of the lowest mean values of water absorption (29.39%) and thickness swelling (23.8%) after four (4) hours of immersion in distilled water. The particleboards produced met the standard for general-purpose boards except for water absorption (WA) and thickness swelling (TS) characteristics which were above the maximum of 8% and 3% specified by ANSI/A208.1-1999.

Keywords: Particleboard, mahogany leaves, gum Arabic, water absorption, thickness swelling

1. INTRODUCTION

The construction industry is growing globally at a rapid pace as a result of increasing population and standard of living. Consequently, high-performance synthetic materials such as glass fibre and carbon fibre reinforced composites are being developed as an alternative and/or to complement conventional materials for construction applications (Ndazi et al., 2007). Wood and wood-based composite boards have been researched into and manufactured due to their reasonable cost in spite of the low weight to high strength ratio (Ndazi et al., 2007). The growing shortage of wood has also led to the development of suitable alternative materials for construction, to which particleboard is one such material which is being considered as a potential substitute for wood and wood-based board products (Jauberthie et al., 2000). Particleboards are wood-based panel product that are conventionally produced using wood and wood wastes such as shavings, flakes, wafers, chips, sawdust, and strands (Yimsamerjit et al., 2007). Particleboard have found applications in areas like furniture, kitchen cabinets, flooring, wall bracing, ceiling boards, partitioning and cladding (Erakhrumen et al., 2010). 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 (Aisien et al., 2015). Several types of resins such as polyimides, thermo-set epoxies, polyurethane resins, phenol-formaldehyde, isocyanate-based adhesives, epoxy resins and resorcinol formaldehyde are commonly used, although urea-formaldehyde is the cheapest and easiest to use (Aisien et al., 2015). According to Bektas et al. (2005), the beginning of the production of modern particleboards can be traced back to the early 19th century. Aruofor (2000), estimated the use of wood and wood-based panels and boards to be 2.866 million m^3 and 0.121 million m^3 respectively, in the early 1990s. These values are expected to rise to 4.704 million m^3 and 0.688 million m^3, respectively, within the next 20 years (Erukhrumen et al., 2010). The increased demand for wood and wood-based panel products in Nigeria 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 (Erukhrumen et al., 2010). With all these efforts, timber supply is still nowhere close to meeting global demand for wood products resulting in continuous cutting without replacement (Kayode, 2007). Sotande et al., (2012), 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. Trees are planted all around us and these trees shed leaves which reach its peak in the dry season. In most under developed and developing countries, Nigeria inclusive, these leaves have very limited reuse capacity after the target wood has been cut down and they are inappropriately discarded or openly burnt. This improper disposal of leaves has many negative environmental consequences. For instance, burning these leaves leads to an increased level of carbon dioxide in the atmosphere which contributes to global warming. These wastes could also cause blockage of drains which consequently results in flooding. Accumulated wastes from leaves when allowed to decay release offensive odours, thereby contributing to air pollution, and also serve as a breeding ground for mosquitoes and flies which spread several diseases. The reuse of these leaves will offer potential benefits environmentally, socially and economically because they are cheap, abundantly available, resource-oriented when handled appropriately and the environmental problems associated with its disposal are eliminated (Duku et al., 2011). Mahogany leaves are obtained from Mahogany (*Swietenia mahogani*), a tree of the Meliaceae family which can be found in Cameroon, Central African Republic, Chad, Cote d'Ivoire, Equatorial Guinea, Gambia, Ghana, Guinea, Guinea-Bissau, Mali, Niger, Nigeria, Senegal, Sierra Leone, Sudan, Togo, Uganda, Australia, Cuba, India, Indonesia, Puerto Rico, Singapore, South Africa and Vietnam (Orwa et al., 2009). This tropical tree sheds leaves like a temperate tree, with leaves falling in the spring towards the end of the dry season. When the useful parts of these trees have been used, for example, when used for decoration, the leaves (mahogany leaves) served as nothing but contribute to the wastes and littered the whole environment or dumped in the forest when the tree is being used for timber. Orwa et al, (2009) shows that oleoresin, which is used as gum or resin exist in the vessels of the stem of mahogany species. This is an indication that when the leaves are dried, crushed, pressed and used to manufacture particleboard, it may account to the durability of the wood composite and resistance to insect and fungal attack which are some desirable properties in any Particleboard material. Although mahogany has been found to be useful in providing good timber for structural applications, research may not have been carried out to exploit the potential of using mahogany leaves to produce particleboard (Orwa et al., 2009). This research therefore sets out to look into the potential of using mahogany leaves for the production of particleboard and to evaluate the properties of the material.

ISSN: 2449 – 0539

BAYERO JOURNAL OF ENGINEERING AND TECHNOLOGY (BJET) VOL.15 NO.2, May, 2020 pp45-50

2. MATERIALS AND METHODS

2.1 Materials

2.1.1 Mahogany leaves:

Mahogany leaves were obtained from the Faculty of Agriculture model farm in Bayero University Kano, Kano State, Nigeria. The leaves were cleaned and air-dried to remove moisture after which the leaves were crushed to a maximum size of 2mm and sieved through the British Standard sieves with apertures 0.8mm and 2mm (Figure 1). The particles were further air-dried for 48 hours to reduce the moisture content to target moisture of 10%.

2.1.2 Gum Arabic:
The gum-Arabic adhesive used was obtained from Kurmi market, Kano, Nigeria (Figure 2). 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 1333.3g/dm^3.

Figure 1: Milled Mahogany Leaves Particle

Figure 2: Gum Arabic Granules

2.2 Methods

2.2.1 Specific gravity test on mahogany leaves particles and gum arabic:
The specific gravity test was conducted on Mahogany leaves particles and gum Arabic in accordance with BS 8500 (2000) and the test set up is shown in Figure 3.

Figure 3: Specific Gravity Test Setup for Mahogany Leaves Particles

2.2.2 Preparation and production of mahogany leaves particleboard:

The milled and sieved mahogany leaves were transferred into hot water at a constant temperature of 85°C to extract likely inhibitor to binding compounds such as glucose, hemicelluloses, and lignin from the leaves particles as suggested by Sotande et al., (2012). The extracted particles were air-dried to attain approximately 10% moisture content before use. The milled leaves were mixed thoroughly with the gum-arabic adhesive at the ratio described in Table 1 manually to obtain a uniform lump-free matrix (Figure 4). After mixing, the material was placed in a steel mat-forming box with dimensions (Figure 4) 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 (Figure 5).

Table 1: Mix Ratio for the Production of GA/ML Particleboard (By Weight of Mahogany Leaves)

TREATMENT, T (Gum-Arabic-mahogany leaves ratio)	Adhesive Type	(%)	Material type	(%)
T1(2:1)	Gum Arabic	66.7	Mahogany	33.3
T2(2.5:1)		71.4		28.6

T3(3:1)		75	leaves	25
T4(3.5:1)		77.8		22.2


Figure 4: Homogeneous Mixture of Mahogany Leaves Particleboard Materials


Figure 5: Protection of Freshly Prepared Particleboard using Poly Ethane

The boards produced were stabilized in an acclimatized room of temperature (20±2°C) and relative humidity of 65±2% for 28 days as shown in Figure 6 and 7 respectively. The above procedure was repeated for the varying ratio of mahogany leaves particles to the gum Arabic solution presented in Table 1.


Figure 6: Drying of Mahogany Leaves Particleboards


Figure 7: Conditioning of the Mahogany Leaves Particleboards

2.2.3 Moisture content, water absorption and thickness swelling tests:

Moisture content, water absorption and thickness swelling tests were carried out to determine the water absorption characteristics of the particleboards and to simulate and determine the level of moisture that the board can be subjected to during its service life without deteriorating. The tests were carried out in accordance with ASTM D 1037-93 procedure. The same test procedure was repeated for (2:1, 2.5:1, 3:1, and 3.5:1) mix ratios of gum-Arabic adhesive: Mahogany leaves treatments. Measurements of the thickness were taken at four point's midway along each side, 2mm in, from the edge of the specimen. The average was taken for the determination of thickness swelling.


Figure 8: WA and TS Test Samples


Figure 9: Moisture Content Determination


Figure 10: WA and TS Tests; early Stage

3. RESULTS AND DISCUSSIONS

3.1 Results

3.1.1 Elemental composition of mahogany leaves particles and gum Arabic:

Table 2: Elemental Composition of Mahogany Leaves Particles and Gum Arabic

	Mahogany Leaves	Gum Arabic
Elements	Concentrations in (mg/kg)	Concentrations in (mg/kg)
Cu	0.14	116.55
Ca	321.17	901.84
Mg	15.54	1333.6
Zn	1.58	26.51
Fe	0.98	192.12
Mn	0.07	20.22

As shown in Table 2, the dominant elements present in mahogany leaves particles and gum Arabic as shown by the laboratory result are Calcium, Magnesium, and Zinc. The non-toxic nature of the elements present in the particleboard materials makes the gum arabic-mahogany leaves particleboard to be environmentally friendly; especially when in contact with water since the reaction of such materials with water will not result in the formation of toxic compounds and as such may be used for wide application in packaging. This may also help to eliminate the health hazards resulting from high formaldehyde emission from urea-formaldehyde resin-based particleboards.

3.1.2 Specific gravity of mahogany leaves particles and gum Arabic:

Table 3: Specific Gravity of Particleboard Materials

Sample	Specific Gravity
Mahogany leaves particles	0.81

Gum Arabic	1.93

The specific gravity of mahogany leaves particles (MLP) and gum Arabic (GA) adhesive as shown in Table 3 are 0.81 and 1.93 respectively. The low density of the MLP is a desirable property of any particleboard material. The high specific gravity of GA adhesive in relation to that of the MLP used can explain the reason why the mix ratio of the materials in the production of the boards in Table 1; although showing high quantity for adhesive in the mix, in actual sense the quantity of mahogany leaves particles is higher in the mixes considered.

3.1.3 Effects of moisture content on the density of mahogany leaves particleboards: The effect of moisture content on the density of mahogany leaves particleboards is shown in Figure 11. From the Figure, the density of the boards was found to increase with the increase in moisture content from 1188.29kg/m^3 at 7.64% to 1677.78 kg/m^3 at 8.2% moisture content. This increase may be as a result of the added weight of moisture from the added quantity of gum Arabic used in the mixes that displaced the air in the voids, which may under service condition reduce.

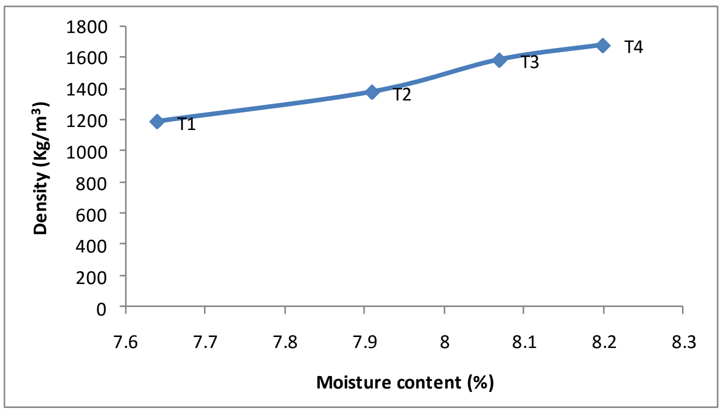

Figure 11: Density against Moisture Content

3.1.4 Effect of material variables on the dimensional stability of the boards:

:

The dimensional stability of the boards was assessed through water absorption and thickness swelling tests. Figure 12 shows the values of water absorption of particleboards produced from mahogany leaves particles using different adhesive-mahogany leaves ratios. The water absorption ranged from 29.39% to 59.85%. The highest water absorption was obtained for particleboards produced using an adhesive-mahogany leaves ratio of 2:1, while the lowest water absorption was obtained for particleboards produced using an adhesive-mahogany leaves ratio of 3.5:1. The relatively high values obtained when the 2:1 ratio was used could be due to the difficulty in compression and the presence of voids in the boards which allowed the boards to take in water (Lee, 1984 and Sotande et al., 2012). And also, gum Arabic has a high affinity for water to the extent that the material has to combine with water for it to function as an adhesive, this property of gum Arabic may also result in the resultant board produced to absorb more water. Generally, the values obtained were similar to those reported by Mendes et al., (2009) and Aisien et al., (2015) for particleboards produced from sugarcane bagasse using urea-formaldehyde as a binder that produced from cassava stalk with urea-formaldehyde respectively. The results obtained from an adhesive-mahogany leaves ratio of 3.5:1 were more resistant to the permeation of water, and hence had the potential to perform better than others in very humid environments or when the boards came into contact with water or moisture. The resistance to the permeation of water observed in the case of the boards which had an adhesive-mahogany leaves ratio of 3.5:1 is an indication of dimensional stability.

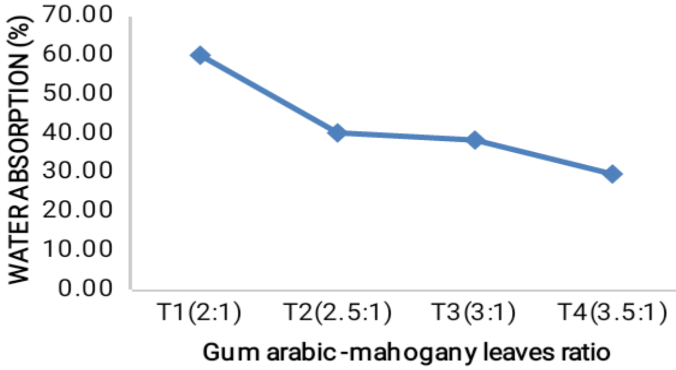

Figure 12: Average Percentage Water Absorption of Particleboard Produced using Different Adhesive-Mahogany Leaves Ratios

Figure 13 shows the values of thickness swelling for particleboards produced from mahogany leaves using different adhesive-mahogany leaves ratios. The mean values of thickness swelling ranged from 23.8% to 29.29%. Copur et al., (2006) and Mendes et al., (2009) reported similar values for thickness swelling for boards produced from hazelnut husk and cassava bagasse, respectively. The highest value of thickness swelling was obtained for particleboards produced using an adhesive-mahogany leaves ratio of 2:1 while the lowest thickness swelling was obtained for particleboards produced using an adhesive-mahogany leaves ratio of 3.5:1. Small values of thickness swelling are indicative of dimensional stability; hence the boards produced using the 3.5:1 ratio would be expected to perform better than the others. It has been reported that the thickness swelling is affected by the presence of void spaces in the boards in the same way as water absorption, as these spaces enhance the absorption of water by the boards which leads to internal swelling (Sotande et al., 2012 and Murakami et al., 1999). Though the results presented are also in agreement with those reported by Murakami et al., (1999) and Adedeji, (2011) who observed that by increasing the adhesive content of the boards, the dimensional stability of the boards can be enhanced. There was no significant improvement in the thickness swelling property of the mahogany leaves particleboards with increase in the gum Arabic content of the mix. The American National Standard Institute ANSI/A208.1-1999 which specifies a maximum thickness swelling of 8% for general-purpose particle boards has rendered all samples from the four treatments falling below the stated standard and as such the samples cannot perform well in very humid environments or when the boards came into contact with water or moisture.

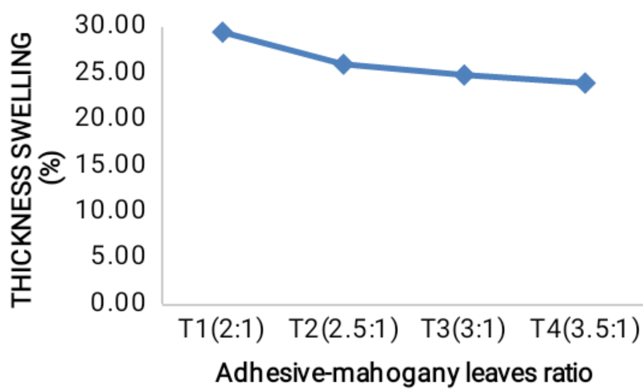

Figure 13: Average Percentage Thickness Swelling of Particleboard Produced using Different Adhesive-Mahogany Leaves Ratios

3.2 Rate of water absorption and thickness swelling for the particleboards

3.2.1 Variation of water absorption (WA) with time:

Figures 14, 15, 16 and 17 show the effects of moisture on the gum arabic-mahogany leaves particleboard with time. From Figure 14, it can be observed that in all the samples from the treatments, T1 failed within the first 30 minutes of immersion in distilled water, 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.

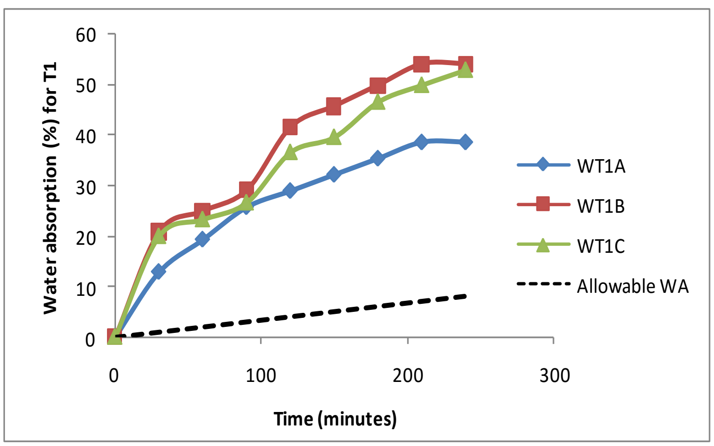

Figure 14: Water Absorption Variation with Time for Treatment T1

From Figure 15, it can be observed that unlike in the first treatment, a little resistance in the rate of WA was observed despite failure of the boards from the same treatment in the first 30 minutes of immersion. 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.

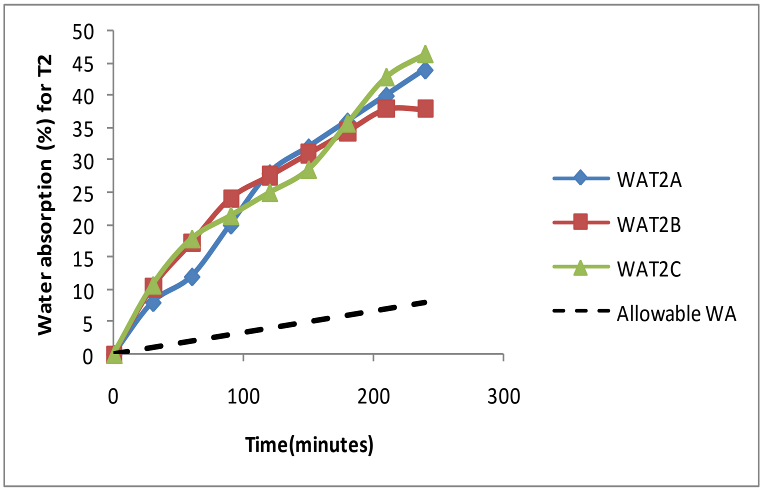

Figure 15: Water Absorption Variation with Time for Treatment T2

From Figure 16, 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, which reduced the number of failure cracks and voids in the board. It also helped to increase inter-particle bond strength in the board. But despite the resistance observed, the boards also failed within the first 30 minutes of immersion in water, which may be due to gum Arabic's high affinity for water because of its unique elemental composition which mostly contains group (I) and (II) elements that have the behaviour of readily reacting with electron gaining elements such as the Oxygen in the water molecule.

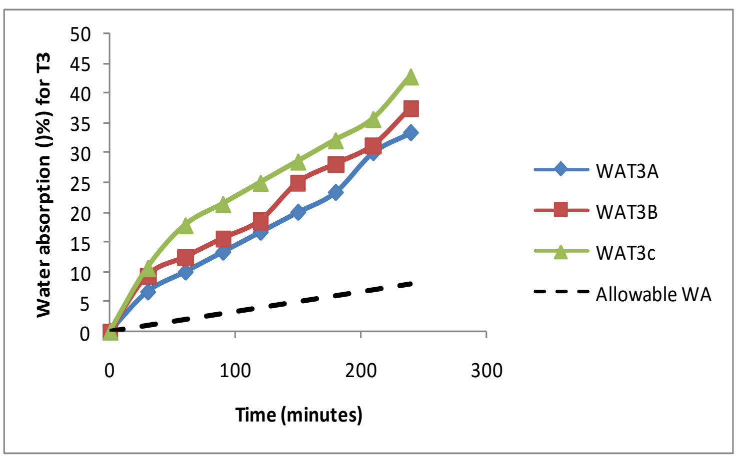

Figure 16: Water Absorption Variation with Time for Treatment T3

In Figure 17, the samples although exceeded the first 30 minutes before failing (with 6.45%, 6.45% and 6.67% water absorption) due to the excess amount of gum arabic used, the samples also failed within 60 minutes of immersion in distilled water.

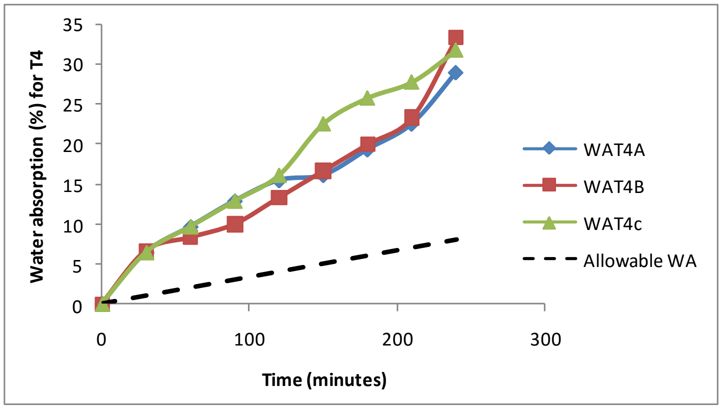

Figure 17: Water Absorption Variation with Time for Treatment T4

3.2.2 Variation of thickness swelling (TS) with time:

Figures 18, 19, 20 and 21 show the rate at which mahogany leaves 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. From figure 18, it can be observed that the TS values increase with increase in soaking time. In the first 30 minutes of soaking, all the samples from the fist treatment failed. 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.

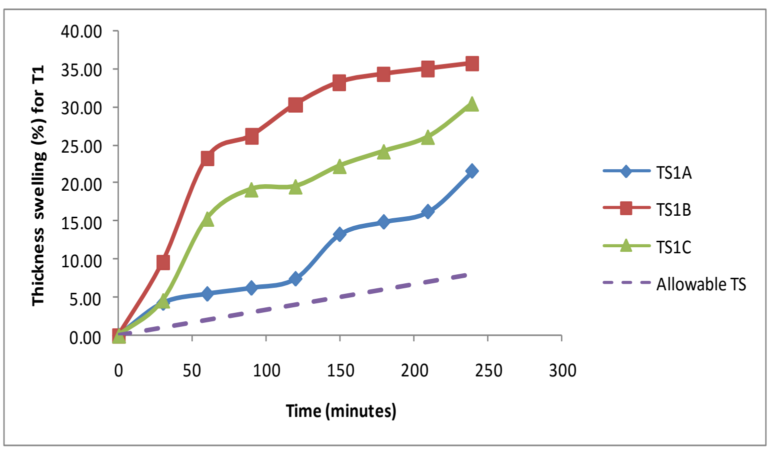

Figure 18**:** Variation of Thickness Swelling with Time for Treatment T1

In Figure 19, although the samples failed, more resistance to swelling of thickness of the boards can be observed compared to the first treatment, T1. 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 after the first 1hour of immersion in water. This may be that the material is reaching saturation beyond 1hour of soaking.

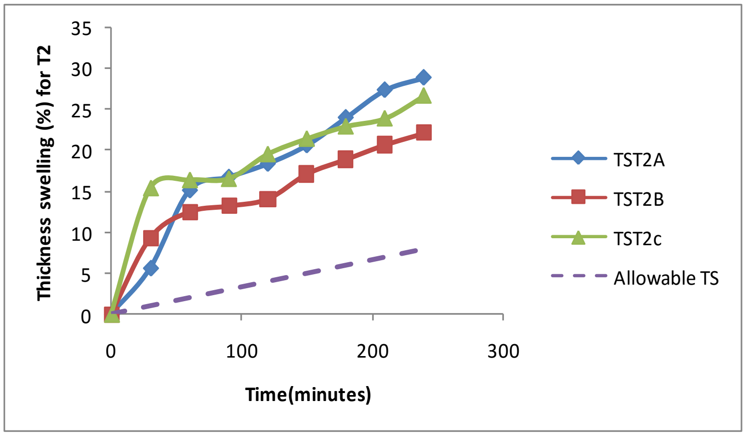

Figure 19: Variation of Thickness Swelling with Time for Treatment T2

From Figure 20, 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. All the samples from the treatment T3 also failed after 30 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.

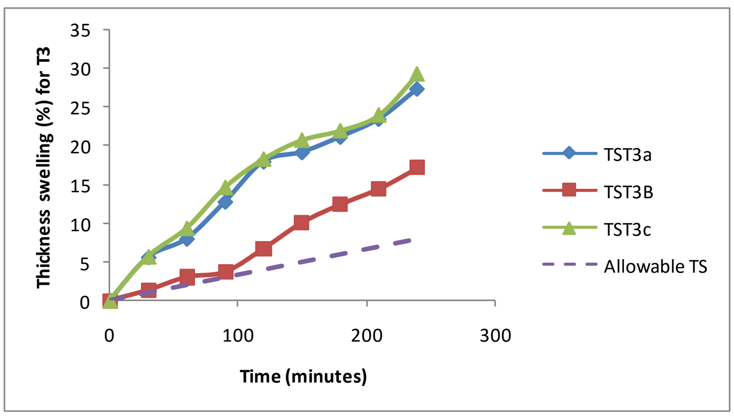

Figure 20: Variation of Thickness Swelling with Time for Treatment T3

In Figure 21, 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 30 minutes of immersion in distilled water.

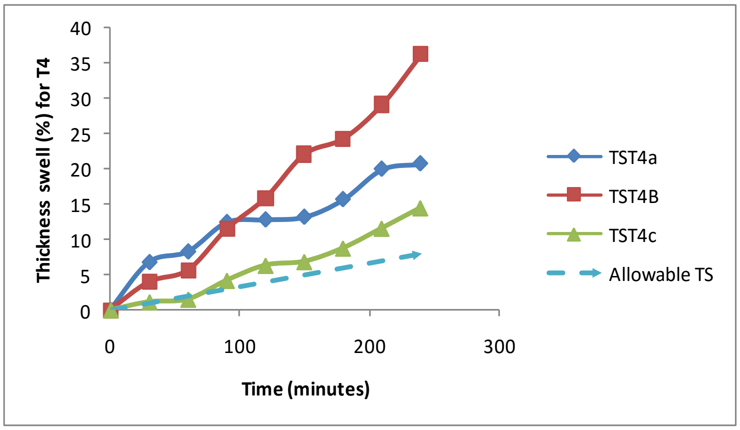

Figure 21: Variation of Thickness Swelling with Time for Treatment T4

4. CONCLUSIONS

The potential of using mahogany leaves particles and gum-Arabic as a binder to produce particleboards was investigated, and the following conclusions were drawn:

1. Dominant elemental composition present in Mahogany Leaves particles and gum Arabic are; Cu (0.14mg/kg:116.55mg/kg), Ca (321.17mg/kg: 901.84mg/kg), Mg (15.54mg/kg: 1333.60mg/kg), Zn (1.58mg/kg:26.51mg/kg), Fe (0.98mg/kg: 192.12mg/kg) and Mn (0.07mg/kg: 20.22mg/kg) respectively.

2. Particleboards produced using gum Arabic adhesive-mahogany leaves ratio of 3.5:1 are more dimensionally stable with average water absorption and thickness swelling of 29.39% and 23.80% compared with the other samples with values 59.85% and 29.29%, 0.12% and 25.93% and 37.90% and 24.61%, respectively.

3. Particleboards produced can be classified as high-density boards (H) for having all density values above 800kg/m^3.

4. An environmentally friendly particleboard that satisfies ANSI/A208.1-1999 standard can be produced using mahogany leaves particles and gum Arabic as binder to suitably serve in various indoor applications.

REFERENCES

Adedeji, Y. M. D. (2011): Sustainable housing in developing nations: The use of agro-waste composite panels for walls. *Built Human Environment* Rev.;4:36-47

ANSI A208.1-1999: American National Standard Institute Table A. Washington DC: ANSI;1999. pp.7

ASTM D1037-93: Standard methods for evaluating properties of wood-based fiber and particle panel materials. Philadelphia, PA: American Society for Testing and Material; 1995

Aisien, F. A., Amenaghawon, A. N. and Bienose, K. C. (2015): Particleboards produced from cassava stalks: Evaluation of physical and mechanical properties. *South Africa Journal of Science*, Vol 3(1), pp.4

Aruofor, R. O. (2000): Review and improvement of data related to wood products in Nigeria: An output of the EC-FAO Partnership Program (1998-2001)

Bektas, I., Guler, C., Kalaycioğlu, H., Mengeloglu, F. and Nacar, M. (2005): The manufacture of particleboards using sunflower stalks (Helianthus annuus l.) and poplar wood (Populus alba L.). *Composite Materials*, vol. 39, No.5, pp.467-473

Duku, M. H., Gu, S. and Hagan, E. B. (2011): A comprehensive review of biomass resources and biofuels potential in Ghana. Renew Sustainable Energy Rev. 2011:15(1):404-415

Erakhrumen, A. A., Areghan, S. E., Ogunleye, M. B., Larinde, S. L. and Odeyale, O. O. (2010): Selected physico-mechanical properties of cement-bonded particleboard made from pine (*Pinuscaribaea M.*) sawdust-coir (Cocos Nucifera L.) mixture. *Scientific Research Essays*, vol. 3, No. 5; pp.197-203

Jauberthie, R., Rendell, F., Tamba, S. and Cisse, I. (2000): Origin of the pozzolanic effect of rice husks. *Construction and Building Materials*, vol.14, pp.419-423

Kayode, J. (2007): Conservation implication of timber supply pattern in Ekiti State, Nigeria. *Res J Forestry*, vol.1,No. 2, pp.86-90

Lee, A. W. C. (1984): Physical and mechanical properties of cement-bonded southern pine excelsior board. *Forest Products J.*;34(4):30-34

Mendes, R. F., Mendes, L. M., Júnior, J. B. G., Santos, R. C. D. and Bufalino, L. (2009): The adhesive effect on the properties of particleboards made from sugarcane bagasse generated in the distiller. *Revista de Ciências Agrárias*. 32(2):209-218

Murakami, K., Ueda, M., Matsuda, H., Zhang, M., Kawasaki, T. and Kawai, S. (1999): Manufacture and properties of three-layered particleboards with oriented face strands of veneers. Effects of face strand/core article ratios, Resin types and resin contents on the board properties. *Journal of Japan Wood Res Soc.* Vol. 45, No. 5, pp.395-402

Ndazi, B. S., Karlsson, S., Tesha, J. V. and Nyahumwa, C. W. (2007): Chemical and physical modifications of rice husks for use as composite panels. Composites Part A: *Journal of Applied Science and Manufacturing*, vol. 38, pp.925-935

Orwa, C., Mutua, A., Kindt, R., Jamnadass, R. and Anthony, S. (2009): Agroforestry Database: A tree reference and selection guide version 4.0. Availablefrom:(http://www.worldagroforestry.org/sites/treedbs/treedatabases.asp),retrieved 2010.

Sotannde, O. A., Oluwadare, A. O., Ogedoh, O. and Adeogun, P. F. (2012): Evaluation of cement-bonded particleboard produced from Afzelia Africana wood residues. *Journal of Engineering Science Technology*, vol. 6, No. 7, pp.732-743

Yimsamerjit, P., Surin, P. and Wong-on, J. (2007): Mechanical and physical properties of green particleboard produced from corncob and starch binder composite. In: Proceedings of the PSU-UNS. International Conference on Engineering and Environment–ICEE-2007; 2007 May 10-11; Phuket, Thailand, pp.4-6