EFFECTS OF CHEMICAL TREATMENT AND RESIN CONTENTS ON THE MECHANICAL PROPERTIES OF BREADFRUIT HULL PRODUCED MEDIUM DENSITY PARTICLE BOARDS.

By

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Abstract

Studies were carried out to determine the effect of chemical treatment and resin contents on the mechanical properties of breadfruit hull medium density particle boards. Increase in UFresin loading from 5 to 15% was found to significantly decrease the physical (TS and WA) and equally increase the mechanical (MOR, MOE and UB) properties of the breadfruit hull produced panels. Hence, the physical and mechanical properties of both the treated and untreated fibre panels were found to be statistically significant ($p < 0.05$) as the UF resin loading was increased from 5 to 15%. The physical and mechanical properties of the NaOH treated breadfruit hull panels produced the best values, followed by CH_3COOH treated breadfruit hull panels and the least was the untreated breadfruit hull panels. The physical and mechanical properties of the particleboards were greatly influenced by the chemical treatment and UF – resin loading. The physical and mechanical properties of the treated fibre panels met the minimum physical and mechanical property requirements for type M – 1 particleboards.

Key words: Breadfruit, Particleboards, Physical-mechanical properties.

Introduction

The high rate of demand for forest wood consumption is considered as the main reason for the high rate of deforestation which has a grave impact on the environment as it could accelerate global warming. The growing demand for wood based particleboards have raised serious challenges on the issue regarding the sustained supply of raw-materials to this sector for quite some time [3]. The need to reduce the dependence on wood and forest resources has resulted in a great interest in alternative resources like agricultural residues and wastes for particleboard production.

According to[7] alternative fibres such as agricultural residues and non-wood plant fibres could serve as the balance supply betweendemand for the manufacturing of composite panels such as particle board. Technological development has led to renewed interest in the utilization of industrial and agricultural wastes. It enhances total wastes utilization, redresses cost of production, promotes a cleaner environment and enhances the earnings of farmers.

The agro-based industries generate a significant amount of solid wastes with appreciable potential problems [15]. These wastes include peels from plantain, banana and oranges, bran and husk from rice, straw from cereals and hulls from Africa breadfruit (*Treculia Africana*) and soya bean. Such wastes if not properly handled, could pose disposal problems with consequent effects on the environment and harmonious relationship between the biotic and abiotic component of the ecosystem [15].

Over the years, there have been considerable efforts to develop techniques for recovery and utilization of the biopolymers in the wastes [3]. This became necessary considering the fact that those wastes contain appreciable quantities of dry matter, crude protein, fibre ether extract, high molecular weight cellulose and hemicellulose and could be obtained at a minimum cost. [21] reported that the hulls of bread fruit contain 9.30, 4.38, 2.16, 5.20, 0.41, 0.64, and 0.37g/100g for moisture, crude protein, fat, ash, Mg, Cu and Cr respectively. This indicates that breadfruit hull based on its rich ash and mineral contents could contain oxidants like CuO, CrO_3 and As_2O_3 known to have significant effects in the mechanical properties and water resistance of particleboards [10]. Because the properties of lignocellulosic fibres results from the chemistry of the cell wall the basic properties of the lignocellulosic fibres can be changed by modifying the chemistry of the cell wall polymers. Chemical modification technology has been shown to greatly improve the properties of lignocellulosics [11]. For example, mercerization, esterification, benzoylation and acetylation are chemical treatment technology commonly used to treat wooden and non-wooden fibers to improve the mechanical properties of composites [22]. [18] stated that the dimensional stability of particleboards can be greatly enhanced through chemical treatment of the lignocellulosic fibres.

One of the most important wood based composites is particleboard, which is made from wood or lignocellulose material particles glued with binder (adhesive) under pressure temperature. Factors that influence the mechanical properties of particle boards are adhesive type and loading, wood species, vertical density profile, adhesive cure properties, press time, particle size, surface quality and method mat formation [9,5]. Urea formaldehyde adhesive are commonly used for appearance based panels whereas phenol formaldehyde is more appropriate for outdoor applications because of its resistance to liquid water exposure[8]. However, urea formaldehyde is the most economic and useful adhesive because of its low cost and easy of production [14].

According to [19] the applications of particleboards include production of office dividers, bulletin boards, furniture, cabinets, counter tops and desk tops. Wood based composite performance is mainly related to the properties of adhesive used, its compatibility with fibre and the properties of the fibre itself. In the light of this, studies were carried out to determine the effect of chemical treatments and resin content on the mechanical properties of breadfruit hull produced medium density particleboard.

Materials and Method

Materials collection and pretreatment

Breadfruit hulls were obtained from Eke – Awka market in Anambra State. Urea formaldehyde used as binder was obtained from chemical shops in Onitsha, Anambra state. The hulls of the breadfruit were milled using a laboratory hammer mill and then sifted using standard sieves to obtain particles in the size range of 0.85 – 2.0mm.

Chemical treatment

The milled breadfruit hull particles were treated with 2% NaOH in order to remove the wax, oil traces, cellulose and lignins as described by[13]. The milled breadfruit hulls were soaked in 2% NaOH solution for about 1hr temperature of 50^oC. They were then washed with distilled water several times to obtain a neutral pH for the fibres. The fibres were then oven dried until the moisture content was about 2.7%. The same procedure was equally adopted in the treatment of the breadfruit hulls with 2% acetic acid solution.

Particleboard formation as described by [20].Constant weight of particles was weighed to obtain the target density of $0.75g/cm^3$. The milled treated and untreated breadfruit hulls were respectively mixed thoroughly with (5, 10 and 15%) urea formaldehyde until a uniform lump-free matrix was obtained.

After mixing, the materials were put in a mat-forming box, with dimension of 0.33cm x 0.33m x 0.005m. The mat were then pressed in a laboratory press at 150^oC and 3.5 Mpa for 8minutes, becoming particle boards with a thickness of 10mm and the target density of $0.75g/cm^3$. The boards were then conditioned at 65 ± 5% relative humidity and 20^oC temperature to reach equilibrium moisture content. Three boards were manufactured using untreated fibre hulls while three each were manufactured for the two treatments adopted making a combine total of nine particleboards manufactured for the mechanical testing procedure.

Physical and mechanical characterization

The properties evaluate were the thickness swelling (TS), water absorption (WA), modulus of rupture (MOR), modulus of elasticity (MOE) and internal bond (IB) as specified by [2,6].

Thickness swelling

The thickness swelling was calculated from the difference in specimen thickness before and after soaking in water for 2hr and 24hrs respectively. It was assessed using a digital caliper with a precision of 0.01mm. The percentage of the thickness was calculated using the equation (1).

$$TS(\%) = \frac{T_f - T_i}{T_i} \times \frac{100}{1} \quad \ldots \quad \ldots \quad \ldots \quad (1)$$

Where T_f is the final thickness after soaking for a period of 2hr and 24hr and T_i is the initial thickness.

Water absorption (WA)

The water absorption tests was conducted according to the specified standard. The samples were soaked in water for 2 and 24hrs respectively. The water absorption was calculated thus:

$$WA(\%) = \frac{W_f - W_i}{W_i} \times \frac{100}{1} \quad \ldots \quad \ldots \quad \ldots \quad (2)$$

Where W_f is the final weight after soaking for a period of 2hr and 24hr respectively and W_i is the initial weight.

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Static bending test

Bending specimens of 50mm wide, 270long were cut for each full particleboard. The bending modulus of elasticity (MOE) and modulus of rupture (MOR) were calculated from loaddeflection curves according to the formular;

$$MoR = \frac{3P_bL}{2bh^2} \quad \ldots \quad \ldots \quad \ldots \quad (3)$$

$$MoE = \frac{P_{bp}L^3}{4bh^3Y_p} \quad \ldots \quad \ldots \quad \ldots \quad (4)$$

Where P_b is the maximum load (N), P_{bp} is the load at the proportional limit (N), Y_p is the deflection corresponding to P_{bp}(mm) b is the width of the specimen (mm), h is the thickness of the specimen(mm) and L is the span (mm).

Internal bond strength

The tensile strength perpendicular to the surface was determined using conditioned specimens of 50mm x 50mm from each particleboard. The rupture load (P_s) was determined and internal bond strength was calculated using the following formula:

$$IB = \frac{P_s}{b_l} \quad \ldots \quad \ldots \quad \ldots \quad (5)$$

Where P_s is the rupture load and l is the length of the specimen.

Statistical analysis

The effects of fibre treatments and resin contents on the mechanical properties of the particleboard panels were evaluated by analysis of variance (ANOVA) using SPSS software version 18.0 at 5% level of confidence.

Results and Discussion

Table 1: Mean values of physical and mechanical properties of the particleboard panels at different resin contents and chemical treatments.

Treatment	UF-resin (%)	MOE (Mpa)	MOR (Mpa)	IB (Mpa)	WA (%)		TS (%)	
					2hr	24hr	2hr	24hr
Untreated	5	1668[a]	15.17[d]	0.43[a]	86.03[d]	90.22[a]	27.63[d]	31.84[a]
	10	1789[b]	16.05[e]	0.51[b]	76.23[e]	83.07[b]	25.35[e]	28.63[b]
	15	1850[c]	17.84[f]	0.62[c]	72.74[f]	75.63[c]	22.07[f]	25.70[c]
NaOH treated	5	1804[a]	18.15[d]	0.60[a]	67.27[d]	70.09[a]	21.19d	24.23[a]
	10	2050[b]	19.36[e]	0.82[b]	63.30[e]	66.14[b]	18.83[e]	21.64[b]
	15	2247[c]	21.82[f]	0.94[c]	56.22[f]	62.92[c]	16.40[f]	20.75[c]
CH_3COOH treated	5	1745[a]	17.03[d]	0.51[a]	72.48[d]	76.03[a]	24.05[d]	27.05[a]
	10	1983[b]	18.51[e]	0.62[b]	67.61[e]	73.91[b]	21.29[e]	24.80[b]
	15	2055[c]	20.17[f]	0.73[c]	63.19[f]	68.04[c]	19.76[f]	22.11[c]

Means with the same letters for each property treatment method are not significantly different at $P < 0.05$.

Modulus of elasticity (MOE): The modulus of elasticity (MOE) is the slope of the tangent line at the stress point of the proportional limit (Anon, 1993a). MOEis related to the stiffness of a board, and the higher the MOE, the higher the stiffness. Results of Table 1 shows that the chemical treatment methods and increase in resin contents from 5 to 15% significantly increased the MOE from 1668 - 1850Mpa, for the untreated, 1804 – 2247Mpa for the NaOH treated and 1745 – 2055Mpa for the CH_3COOH treated breadfruit hull produced particle board panels. The mean values of the MOEat each chemical treatment methods were statistically significant ($p < 0.05$) as the resin contents were increased in the panels.The highest values of MOEwas obtained from the bread fruit hull fibre panels treated with NaOH followed by the breadfruit hull panels treated with CH_3COOH and the least was untreated breadfruit hull panels. Reduction in lignin, wax, cellulose and hemicellulose contents of the breadfruit hull fibre following treatments with NaOH and CH_3COOH respectively could have been responsible for the improved dimensional stability (MOE) of the produced panels. The results of this study compares favourably with 2142 – 2437Mpa reported by [16]) for NaOH treated bunch of oil palm produced medium density particleboard as the resin (UF) contents increased from 8 to 12%. Except for the untreated breadfruit hull produced particleboard panels at 5% UF resin content, all the other produced panel boards have the mean volumes of MOEexceed the minimum mechanical property requirements (1725Mpa) for type M - 1 particle board according to U.S. standards [4].

Modulus of rupture (MOR): The modulus of rupture (MOR) is the ability of a specimen to withstand a traverse (bending) force perpendicular to its longitudinal axis, [12]. Table 1 shows that increase in resin content from 5 to 15% significantly increased the MORof both the treated and untreated breadfruit hull produced particle boards panels. The highest range of MORmean values of 18.15 – 21.82Mpa was obtained for panels treated with NaOH, followed by 17.03 – 2017Mpa for panels treated with CH_3COOH and the least was 15.17 – 17.84Mpa for the untreated breadfruit hull produced medium density particleboard panels. The observed high values of MORof the treated breadfruit hull particleboard panels compared to the untreated panels could be due to improved interfacial bonding between the fibre and adhesive.

According to [17] chemical treatment of fibres helps in improving the mechanical interlocking and chemical bonding between the resin and fibre, thus produce a composite of superior mechanical properties.[16] reported that the nature of adhesion between the resin and fibre has a great influence on the mechanical properties (MOR, MOE and IR) of natural fibre composites. The findings of this study shows that there was better interfacial bonding between the resin and NaOH treated fibre which resulted to high values of MORas the UF resin content was increased. The results of this especially for the treated breadfruit hull panels was in agreement with 17.75Mpa reported by[13] for NaOH treated bagasse fibre produced panels. The values of MOR obtained for both the treated and untreated breadfruit, hull produced medium density particleboards exceeded the minimum mechanical requirement (11.0Mpa) for type M – 1 particleboard according to U.S. standard [4].

Internal bond strength: The internal bond strength was conducted to determine the interfacial bonding strength between the fibres and the adhesive in the boards.

Table 1 shows that the chemical treatment of the breadfruit hull fibres reduced the mechanical properties of the fibre cell wall, thus, making it to be compressed, permitting an improved interface between the resin and fibres. As a result, higher mean IB values of 0.60 – 0.94Mpa was obtained for NaOH treated breadfruit hull panels, followed by 0.51 – 0.73Mpa for CH_3COOH treated breadfruit hull panels and the least was 0.43 - 0.62Mpa for the untreated breadfruit hull panels. The increase in the resin content significantly increased the IB of the produced panels. Hence, the values of IB at each increase in UF resin content were statistically significant ($p < 0.05$). The results indicated that chemical treatment of the natural fibre and a higher amount of resin encouraged stronger interfacial bonding between the fibre and the resin in the boards, thus prolonging the ability of the boards to withstand the pulling force created through the test. The IR values of all the particle boards produced in this study exceeded the minimum mechanical property requirements (0.4Mpa) for type M – 1 particleboard according to U.S. standard [4].

Water absorption (WA): Table 1 shows that increase in the UF resin contents from 5 to 15% significantly decreased the water absorption capacity of the breadfruit hull produced panels. Equally, it was observed that chemical treatments of the breadfruit hull fibres significantly reduced the water absorption capacity of the panels at 2hr and 24hrs respectively. The highest reduction in WA capacity of 56.22% and 62.92% was obtained for NaOH treated breadfruit hull fibre panels, followed by 63.19% and 68.04% for CH_3COOH treated hull fibre produced panels and the least reduction was 72.74% and 75.63% for the untreated panels breadfruit hull produced panels at 2hr and 24hr immersion in water respectively.

The decrease in water absorption capacity of the panels with increase in resin content from 5 to 15% could be attributed to the increase in the chemical components in the resin that is capable of cross-linking with hydroxyl groups of the breadfruit hull fibres hence reducing the hygroscopicity of the boards. The results of this study further indicated that chemical treatment of the breadfruit hull fibres increased the compaction ratio of the panels thus reducing the number of hygroscopic sites for water to bind in the fiber treated panels. The mean WA values of the panels differ significantly at $p < 0.05$ with increase in the UF – resin contents from 5 to 15%. The results in this study compared favourably with 56% and 68% reported by [7] at WA 2hr and WA 24hr when evaluating particle board panels made with peanut husk, with a density of $0.7 g/cm^3$, using 8% urea formaldehyde.

Thickness swelling: The thickness swelling was measured by calculating the difference between the thickness of the specimen before and after soaking in water for 2 and 24 hours respectively. Results of Table 1 shows that the responses of the panels on thickness swelling was very similar to those of water absorption. Table 1 shows that the thickness swelling of the UF bonded boards dropped significantly as UF resin loading rose from 5 to 15%. Chemical treatment of breadfruit hull fibres significantly reduced the thickness welling of the produced panels. For instance, the highest reduction in thickness swelling of 16.40% and 20.75% was obtained for NaOH treated breadfruit hull produced panels, followed by 19.76% and 22.11% for CH_3COOH treated breadfruit hull panels and the least reduction was 22.07% and 25.70% for the untreated breadfruit hull produced panels at 2h and 24hr soaking in water respectively. The results of this study indicated that chemical treatment of the breadfruit hull fibres significantly reduced the thickness swelling of the produced panels. The results of this study indicated that chemical treatment of the breadfruit fibres could have increased the compressibility factor of the fibres, thus preventing much water from seeping in the panels. The chemical treatment of the fibres could further have reduced the number of hygroscopic sites for water to bind in the panels. Tables 1 shows that thickness swelling properties of the panels were significantly affected by chemical treatment and resin loading. The mean values of the thickness swelling of the panels were statistically significant ($p < 0.05$) as the UF resin loading was increased from 5 to 15%. The panels made with NaOH and CH_3COOH treated breadfruit hulls gave thickness swelling values within the accepted value of 25%[4].

Conclusion

The results show that it is possible to produce bread fruit particleboards with improved physical and mechanical properties using chemical treatment methods. The study shows that increase in the UF resin loading from 5 to 15%, significantly increased the MOE, MOR and IR of the produced panels. At the same time physical properties of like WA and TS were significantly reduced with increase in the UF loading from 5 to 15%. The best values of the physical and mechanical properties of the particleboards was obtained with NaOH treated breadfruit hull fibres, followed by CH_3COOH treated breadfruit hull fibres and the least was with the untreated breadfruit hull fibres.

References

1. Anon (1993a). Woodbased panels – Determination of modulus of elasticity in bending and bending strength. BS EN 310. British Standard Institute pp. 81 – 84.
2. ASTM-D (2000). America society for testing and materials, standard test methods for properties of wood based fibres and particle panel materials, Philadelphia. pp. 81 – 86.
3. Colak S., Colakog G., Aydim I. and Kalaycog H. (2007). Effects of steaming process and some properties of eucalyptus particleboard bonded with Uf and muf adhesives. Buld. Environ. 42(1): 304 – 309.
4. CPA (1999). American National Standard particleboard ANSI 1208 Composite Panel Associaton, Gaithersbong, MD, pp. 11 – 16.
5. Cuk N., Kunakar M. and Medred S. (2011). Properties of particleboards made by using an adhesive with added liquefied wood. Material and Technology 45(3): 241-245.
6. EN 323 (2000). Wood-based panels: Determination of density, Europeancommittee for standardization, EN, Central Secretariat; pp 36 – 39.
7. Guler G. and Buybksari U. (2011). Effect of production parameters on the physical and mechanical properties of particleboards made from peanut (*Arohishypogaea L.*) hull. Bioresources., 6(4): 5027 – 5036.
8. Guru M., Tekeli S. and Billci, (2006). Manufacturing of urea-formaldehyde – based composite particleboards from almond shell. Mater Des., 27: 1148 – 1151.
9. Hassan E. B., Kim W. and Wan H. (2009). Phenol-formaldehyde type resins made from phenol – liquefied wood for the bonding of particleboard. J. Appl. Polym. Sci., 112(3): 1436 – 1443.
10. Huang C. and Cooper P. A. (2000). Cemented – bonded particleboards using CCA – Treated wood removed from service forest production. J., 50: 49 – 55.
11. Jadhav S. A., Suchithra P. S., Narute S. J. and Pane A. I. (2015). Polymeric particleboards: A sustainable substitute to wooden boards. Mor J. Chem 3(4): 723 – 729.
12. Jani S. M. and Izran K. (2013). Mechanical and physical properties of urea-formaldehyde bonded Kenof core particleboards. J. Trop. Agric and Fed Sci. 41(2): 341 – 347.

13. Magzoub R., Tahir O. P., Nasroon T. H. and Kantner W. (2015). Comparative evaluation of mechanical and physical properties of particleboard made from bagasse fibres and improved by using different methods. Cellulose Chem. Technol., 49 (5 – 6): 537 – 542.
14. Nemli G., Kirci H and Tewzi A. (2003). Influence of impregnating wood particles with mimosa bark extract on some properties of particle boards. Ind. Crops and Prod., 20: 339 - 344.
15. Nwabueze T. U. and Otunna O. (2006). Effect of supplement of breadfruit (*Treculiaafricae*) hulls with organic wastes on growth characteristics of *Saccharomyces Cerevisiae*. African Journal of Biotechnology, 5(16): 1494 – 1498.
16. Norul – Izani M. A., Paidah M. T., Nor M. Y. and Anwar U. M. K. (2013). Properties of medium-density fibre board made from treated empty fruit bunch of oil palm. Journal of Tropical forest science, 25 (2): 175 – 183.
17. Ray D. and Sarkar B. K. (2001). Characterization of alkali-treated jute fibres for physical and mechanical properties. Journal of Applied Polymer Science, 80: 1013 – 1020.
18. Sawpan M. A., Pickering K. L. and Fernyhough A. (2011). Improvement of mechanical performance of industrial hemp fibre reinforced polylactidebiocomposites. Composites Part A – Applied Science and Manufacturing, 42(3), 310 – 319.
19. Sellers T. (2010). Growing markets for engineers products spus research. Wood Technol., 127 (3): 40 – 43.
20. Trischler J. and Sandberg D. (2014). Monocotyledons in particleboard production adhesives, Addictive's and surface modification of reed canary grass. Bioresources, 9(3): 3117-3938.
21. NwabuezeT. U. and Nnabueze J. C. (2001). Growth, nutrient utilization and biomass production of *SacchorolysesCerevisiare* from Citrus waste. J. Agric. Biotech. Environ., 3: 32 – 37.
22. Xiaoping L. I., Zhangkang W. U. and Gunatia U. U. (2014). Influence of the mechanical properties of tobacco stalk fiber cell wall on particleboard panels. Advances in material science and applications, 3(1): 1- 5.