

Utilization of Bone Adhesive to Produce Particleboards from Stems of Cotton Plant at the Pressing Temperature of 140°C

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Abstract: Problem statement: To value agricultural residues, a study was carried out to investigate mechanical and physical properties of particleboards produced from stems of cotton (*Gossypium hirsutum* L.) by using bone adhesive. **Approach:** In order to obtain particleboards with minimum physical and mechanical properties as required in the conventional standards for general purpose particleboards, the optimum pressure temperature and the optimum pressure time and density used in this study, were respectively 140°C, 10-15 min and about 0.6-0,671 g cm⁻³. The optimum value of bone adhesive used in particleboards was 10%. The Modulus Of Elasticity (MOE), Modulus Of Rupture (MOR), Traction strain (R_t) and water absorption were determined at the pressure temperature of 140°C. **Results:** The results revealed that the density of particleboards obtained from cotton plant at 140°C have neither notable influence on their mechanical properties, nor evolve in the same way as the constant mechanics of the particleboards. **Conclusion:** The bone adhesive could be used in particleboards production from the chips of cotton instead of the conventional binders which create the environmental problems.

Key words: Bone adhesive, modulus of elasticity, modulus of rupture, rate of adhesive, water absorption, Modulus Of Elasticity (MOE), Modulus Of Rupture (MOR)

INTRODUCTION

The demand for wood and other biomass-based particleboard materials have considerably increased due to the rate of population growth in the world; in fact, the world's population is increasing at the rate of approximately 90 million people per year (Alma *et al.*, 2005, Osarenmwinda and Nwachukwu, 2010). Moreover, the world population currently consumes over 3.5 billion tons of green wood annually, which corresponds to about 0.7 tons per person. It has been thus demonstrated that if the consumption rate of wood fiber and the rate of population growth stay constant, demands for wood fiber will increase by over 60 million tons each year. Therefore, a huge imbalance between supply and demand will be inevitable. This is the predicted supply/demand scenario which we will face in the coming years (to 2010 and beyond) if nothing is done. Consequently, alternative fibers such as agro-fibers and other plant fibers, recycling, more efficient conversion technologies and new products will play an important role in the wood fiber supply/demand map of

the future (Osarenmwinda and Nwachukwu, 2010; Grigoriou *et al.*, 2010).

A number of studies on the utilization of the wastes of agricultural crops in the production of the wood- and plastic-based particleboard materials have been conducted (Alma *et al.*, 2005; Wang and Sun, 2002; Woodhams *et al.*, 2004; Nourbakhsh, 2010); and the outcome of these studies showed that it will be beneficial to use the agro-fiber wastes in the production of particleboard material in terms of the environmental and socio-economic aspects. It has also been found that with the combination of wood chips, it is possible to produce particleboards from the wastes of agricultural crops: kenaf (Grigoriou *et al.*, 2010); cotton (Osarenmwinda and Nwachukwu, 2010); bamboo-based (Okubo *et al.*, 2004) and date palm (Iskanderani, 2009), tea leaves (Kalaycioglu and Nemli, 2006), date palms (Nemli *et al.*, 2001) and peanut shells (Harriette *et al.*, 2006) having physical and mechanical properties required in related standards.

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In West Africa the total amount of cotton stalks is approximately 7400 tons ha⁻¹. In Togo, the total amount of cotton (*Gossypium hirsutum* L.) stalks is approximately 250 000 tons year⁻¹; but this important agricultural waste is usually burned (Nenonene *et al.* 2009). Therefore, the aim of this study is to determine the possibility of using cotton stalks in particleboard production with bone adhesive.

The originality of this study is in the use of bone adhesive for the production of the particle boards. No literature refers to this adhesive in the production of the particle boards.

MATERIALS AND METHODS

To produce particleboards, cotton stalks (*G. hirsutum*) were collected from cotton farm in the localities of the town of Tsevie (Togo, West Africa); the stalks were then chipped by using hammermill. Bone adhesive obtained from the bones of cow was used to manufacture particleboards.

The experimental design for five-layer and adhesive bone-bonded particleboards from carpals is summarized in Table 1. The particleboards prepared were pressed at a maximum pressure of 11bars at 140°C for 20 and 25 min. Three experimental particleboards were produced for each design. Thus the particleboards obtained were conditioned at 20±1°C and 65±5% of relative humidity and the moisture content was about 12%. The particleboards were then edge-trimmed to dimension 300×300 mm.

Some physical properties (density, water absorption) of the particleboards were determined according to TS EN 322 (1999), ASTM-D 1037 (1978) NFEN 326-1 (1994), NFEN 319 (1993) standards respectively.

We also determined several mechanical properties (Modulus Of Elasticity MOE; Modulus Of Rupture MOR; Traction strain R_t) of particleboards on a universal tester (Instron) by the following standards NF EN 310, 1993; NF B51-123 (1987). The average of 10 measurements was reported.

Table 1: Experimental design

Board type	Pressure time (min)	Pressure (MPa)	Density (Kg m ⁻³)	Adhesive (%)	Humidity (%)
A	25		631.063	5.0	
B	25		671.798	7.5	
C	20	1.1	661.764	10.0	20
D	20		667.225	12.5	
E	20		653.944	15.0	

RESULTS

It is interesting to notice that there is no significant difference between all the particleboards made at the pressure times of 20 and 25 min in water absorption rate. All the particleboards had water absorption rate above 200%. The A particleboards give the lowest water absorption rate to all the other particleboards under the same conditions.

The MOR values of the particleboards made from cotton stalks vary from 11.22-20.26 MPa. The modulus of rupture values of all the types of particleboards obtained in this study, were over the minimum modulus of rupture value required in ANSIA 208.1 1999 standard for general purpose particleboards which is 11 MPa (Fig. 1). At the same conditions, the highest modulus of rupture value, 20.26 MPa is obtained at 10% of bone adhesive having a density of 661.764 kg m⁻³, the lowest value of modulus of rupture, 11.22 MPa is obtained at 5% bone adhesive for particleboards having a density of 631.063 kg m⁻³ and at an adequate pressure time of 25 min.

The MOE values of the particleboards (Fig. 2) show that only two of the five types of particleboards obtained respected the ANSI A 208.1 1999 standards according to MOE and MOR values for a rate of bone adhesive of 10 and 12.5%.

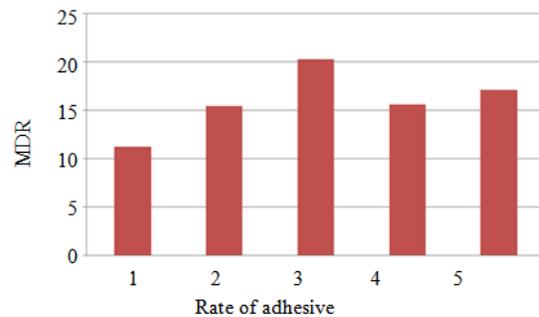


Fig. 1: MOR according to the rate of bone adhesive

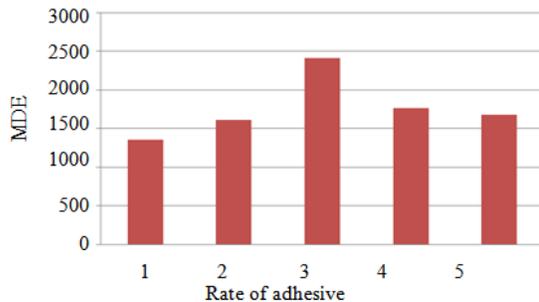


Fig. 2: MOE according to the rate of bone adhesive

Table 2: Results of physical and mechanical of particleboards from cotton stalk

Board type	Adhesive (%)	Density (Kg m ⁻³)	Thickness (mm)	Water absorption (%)		MOE (MPa)	MOR (MPa)	R _r (MPa)
				After 2 h	After 24 h			
A	5.0	631.063	4.65	155.56	211.11	1352.88	11.22	1.22
B	7.5	671.798	4.43	222.22	288.89	1611.85	15.40	1.66
C	10.0	661.764	4.45	200.00	237.50	2412.61	20.26	2.10
D	12.5	667.225	4.32	212.50	262.50	1757.49	15.52	1.78
E	15.0	653.944	4.36	175.00	212.50	1674.09	17.05	3.14

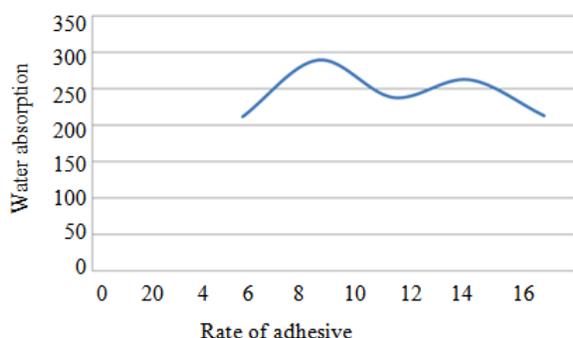


Fig. 3: Water absorption by the particleboards

Furthermore, the mechanical strength MOE MOR described in Table 2 for cotton stalks particleboards made with bone adhesive is determined to be somewhat higher than those of bamboo-based particleboards (Okubo *et al.*, 2004), of kenaf (Kalaycıoglu and Nemli, 2006); wood-waste chips (Yang *et al.*, 2007).

The result obtained shows also that it possible to produce particleboards from cotton stalks with bone adhesive. Bone adhesive can take the place of urea formaldehyde in the production of particleboards without emission of formaldehyde.

Water absorption by the particleboards: In this study the particleboards obtained absorb more than 200% of water after two hours of immersion and more than 288% after 24 h (Fig. 3). These values are over the rate fixed by the standards which is 8%. This behavior of water absorption requires that these particleboards should be used in dry medium and according to the standard EN 312, they are classified in the list of the particleboards P₁ of general use in dry medium.

The behavior of water absorption by these cotton plant particleboards fashioned with bone adhesive requires a later study which will allow carrying out cotton plant particleboards which could respect the water absorption standard.

The traction strain (R_r): The values of R_r obtained in this study, are over the standards value which is 0.3 MPa. These results show that particleboards produced from cotton stalk have a good behavior at the traction.

Results according to the rate of bone adhesive used:

Results of the test of inflection on the particleboards from cotton stalk revealed that, by varying the rate of the bone adhesive used, the obtained particleboards showed the following characteristics:

- The modulus of elasticity MOE varied between 1352.68 and 2412.61 MPa
- The breaking strength MOR varied between 11.22 and 20.2563 MPa

DISCUSSION

The values of MOR obtained are higher than the minimal values prescribed by the American standard ANSI A 208.1 1999. The values of MOE obtained, indicated an increase of the rate of the adhesive up to 10% and then a decrease, presenting the form of a parabola having a top at 10% (Table 2). It is obvious from Table 2, that the values of MOE and MOR obtained, indicate that only the adhesive rate of 10 and 12,5% allow to obtain particleboards respecting the criteria of particleboards of the M1 rank of standard ANSI A 208.1 1999. This same observation was made by Stöckel *et al.* (2010) and Ghalehno *et al.*, (2010). The MOR values evolve in the same way as those of MOE and present a maximum at the same value of the rate of the adhesive. Cotton plants particleboards admit 10% like rate of adhesive allow obtaining the maximum values of MOE and MOR. The evolution of the mechanical properties according to the rate of adhesive is limited to 10%, beyond this value, these properties decreased. When the rate of the adhesive used is lower than 10% the particleboards obtained respect rather the criteria of the rank LD1 where constant mechanics is weaker than of standard ANSI A 208.1 1999 of the M1. In all the cases these panels are utilizable for the heat isolation or the wall lining or more generally in the fields where they do not undergo enough request. This observation was also done by Harriette *et al.* (2006); Ashor and Nourbakhs, (2008); and Iskanderani (2009). The density of cotton plant particleboards obtained at 140°C have neither notable influence on their mechanical properties, nor evolve in the same way as

the constant mechanics of the particleboards. A manufacturer can initiate the production of cotton plant particleboards with bone adhesive without fear and obtain particleboards respecting the international standards at the rate of 10%. Thus, these experimental results showed that the parameters were found to be effective on the physical (thickness swelling) and mechanical (modulus of rupture and internal bond strength) properties.

CONCLUSION

The results indicated that it is possible to produce particleboards from cotton stalk with bone adhesive and to obtain the standards ANSI A 208.1 1999 considering MOE and MOR values. The rate of water absorption by the particleboards produced from cotton stalk by using bone adhesive does not answer the criteria fixed by the standards. Therefore, the particleboards obtained from cotton stalks with bone adhesive must be used in dry condition. In general, mechanical properties (MOE, MOR, R_p) of particleboards produce from cotton stalk respect the minimum criteria fixed by standards ANSI A 208.1 1999 except that of water absorption. The bone adhesive becomes then a potential binding to be used in particleboards production from cotton stalk instead of the conventional binders which create the environmental problems.

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