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COMPARATIVE STUDY OF THE MECHANICAL PROPERTIES OF IROKO PARTICLE BOARDS PRODUCED WITH TWO DIFFERENT VEGETABLE-BASED BINDERS

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ABSTRACT
The aim of this work was to compare mechanical properties of iroko particle boards produced with two different tannic powders. Two vegetable-based binders were used: African locust bean pod (Parkia Biglobosa (PB)) and bark of India tamarind peel (Piteclobium Dulce (TD)) to bind the particles of Iroko to produce ecological panels without formaldehyde emission. For this study five binder rate 5%; 7.5%; 10%; 12.5% and 15% were used to make particle board of each binder. Hardness, bending, tensile and internal bound tests were performed in order to assess the mechanical properties (MOE, MOR, E, MOT, IB and HB).
The results showed that the mechanical properties increase with binder rate. The mechanical properties of the panels produced from these two different binders met the threshold set by ANSI A208.1 (2009).
Moreover, it was found that, the values of MOE, MOR, E, MOT obtained for African locust bean pod (Parkia Biglobosa) where higher than those found for bark of Piteclobium Dulce On the other side, panels made with bark of Piteclobium Dulce showed higher HB and IB values than those made with African locust bean pod.

1. INTRODUCTION
Owing to the rise in wood consumption, the reserves of native forests started disappearing in a worrying way, woody species have been decreasing, causing the search for new renewable lignocellulosic materials that may efficiently meet the demand.

Considering the fact that the raw materials especially in natural resources sector are limited, the wood-working industry has made several efforts to ensure the sustainability of raw materials. Therefore, for providing wooden raw materials, special attention was paid to wood wastes from wood-working industries and agricultural residues. The particleboard industry is able to use and consume a wide range of wooden and nonwooden lignocellulosic wastes [1]. Alternative raw materials such as agricultural residues and wastes from wood-working play an important role in the particleboard industry.

This environmental pressure supports research regarding new products and a better utilization of the raw material available. Agricultural and wood-working residue has been increasing, especially in the design of particle board using synthetic binders or binders from natural or biological resources.

The synthetic wood binder based on formaldehyde compound has been used for a long time and has been known to have excellent performance, good mechanical and physical properties, and are economically adequate [2–4]. However, these adhesives are carcinogenic to humans, it can cause irritation of the eyes and throat, respiratory disorders, and have a nature as non-renewable and non-biodegradable materials [5–8]

With steadily increasing of environmental and health awareness, natural binders from renewable resources regained attraction as alternative bonding agents. In recent years, few researches have been conducted in Togo on the reduction of the synthetic adhesives in wood-based materials production [9].

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Nenonene et al [9] conducted a study on two vegetable-based binders, African locust bean pod (*Parkia Biglobosa*) and bark of *Piteclobium Dulce* to bind the particles of Kenaf in order to produce ecological panels without formaldehyde emission.

It was new and original way, the total substitution of UF resin with extracts of plant organs of African origin were selected for this study because of their richness in pectic substances or tannins, leads, for levels of incorporation limited to 10% in the MAT of particles of debarked kenaf stem, and under the same heat-pressing conditions (5 min at 180 ° C), to panels whose mechanical strengths are equivalent to those obtained with UF resin, or even superior in some cases. Even more interesting is the combination of bone glue and organ extracts from the plants selected for this study. The synergistic effect of bone glue proteins (gelatin) and pectic substances, and even more of the tannins extracted, allows, for binder contents limited to 10% in the MAT of debarked kenaf stem particles, and the same thermo-pressing conditions, to reach mechanical resistance characteristics in the same range of those described by Guler and Ozen [10] for cotton stalk particle boards in three layers linked by urea resins-formalin incorporated at 6 - 10% for the inner layer.

Based on the results of Nenonene and al [9], this research focused to investigate the effects of extractive substances for bonding performance of two natural binders (African locust bean pod (*Parkia Biglobosa (PB)*) and bark of *Piteclobium Dulce (TD)*) for Iroko particleboard. The objectives of this study were to determine and compare how these two natural resources could affect mechanical properties of Iroko particleboard using different binder rate.

2. MATERIALS AND METHODS

2.1 Panels processing

Iroko (M. Excelesa) dusts was obtained from Lomé (Togo) carpentry wastes, and the pods of the locust bean come from several traditional mustard production units in North Togo (9.2 ° to 10 ° north latitude and 1 ° to 1.5 ° east longitude).

The iroko sawdust and the pods of the locust bean once collected were dried with the drier of MEMENT type 100, of the LARASE, at a temperature of 70 °C for three days and ground with a grinder RETSCH SK 100 type equipped with a sieve of 5 mm.

The African locust been pod husks and the India tamarind peel ((Piteclobium dulce) once collected are dried at a temperature of 70 °C for three days and ground with a grinder RETSCH SK 100 type with flails and blades of the LARASE equipped with a sieve of 5 mm for the African locust been and of 0.125 mm for the India tamarind peel. To fabricate the particleboards, the two tannic powders were mixed with the sawdust at 5%; 7.5%; 10%; 12.5% and 15% for ten minutes. The obtained homogeneous mixture was pressed at 160°C with a pressure of 11 bars for 15 minutes. A manual hydraulic press of CARVER type (11 bars as a maximum pressure), with thermoregulated heating plates, equipped with a square steel mold of 30 cm side, was used for the panels formatting. The wood particles mixed with the binder were gravitarily cast into a mold located between two heating plates. The thermal regulation was done by an electric box and the pressure was obtained by an operating lever.

The resulting particleboards were cut into specimens for physical and mechanical tests. Six panels of 300 x 300 mm thickness varying from 7.5 to 10 mm of each rate and granulometry are then manufactured.

2.2 Mechanical tests

a. Mechanical tests

The resulting finished particleboards were cut into specimens for mechanical tests. The samples were of: (a) 150 mm x 100 mm for bending; (b) 150 mm x 20 mm for tensile. The mechanical properties tests were performed according to the standards EN 312-2 2004 and EN 310 [10–12]. The standards NF B51-124:1993 and EN 310:1993 [10,11] were used to calculate, key mechanical properties such as elasticity modulus in bending (MOE), and in traction (E), modulus of rupture in bending (MOR) and in traction (MOT). For the determination of these characteristics it was assumed that the particleboards were homogeneous and isotropic materials since the particles

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were of only one type of wood [13]. Figure 1 show the experimental setup for bending test and Figure 2 the sample dimensions used for tensile tests. The values of MOE, MOR and MOT where giving by the following expressions:

$$MOE = \frac{F.l^3}{4be^3y} \quad or \quad MOE = \frac{(F_{12}-F_1).l^3}{4be^3(y_2-y_1)} \; and \; MOR = \frac{3Fl}{2be^2}$$

In these expressions: l was the distance between the supports, e the thickness of the sample, b the sample width, F the strength at break, $F_1=10\%.F$, $F_2=40\%F$, *y_1 arrow corresponding to F_1 and y_2 the one corresponding to F_2.* $MOT = \frac{F_m}{be}$; *where F_m was the high strength and b and e respectively the width and thickness of the sample.*

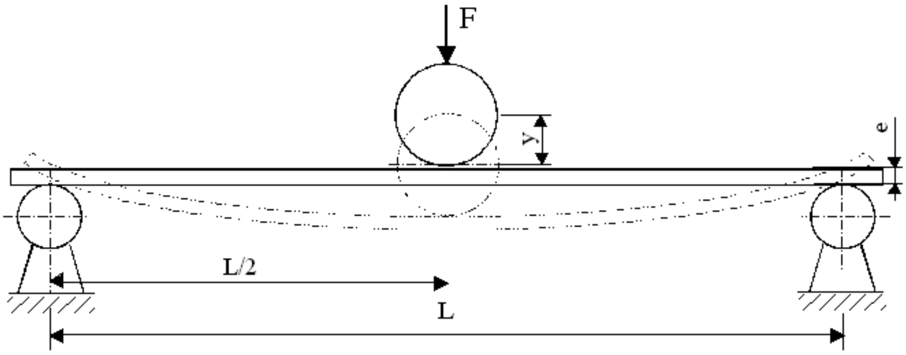

Fig.1: Experimental setup for bending test

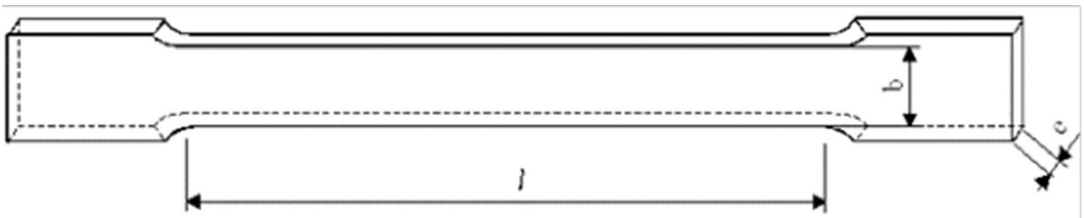

Figure.2: Sample dimensions used for tensile test

b. Hardness Test (HB)and Internal Bond (IB)

The internal bond (IB) and Brinell hardness tests of each panel particles produced were performed according to (EN 312-2, 2004) and NF-EN 319 standards. Ten (10) specimens of dimensions 50 x 50 were subjected to traction perpendicular to the faces. The internal cohesion constraint is calculated according to the formula below.

$IB = \frac{F_m}{S}$; with: S: stressed surface; Fm: maximum breaking force.

3. RESULTS AND DISCUSSIONS

Average MOE values for boards manufactured with *Parkia Biglobosa* (PB) and bark of India tamarind (TD) were plot as a function of binder rate in Figure 3. The MOE values of the two types of binder presented similarly curves. However, particleboards made with Parkia Biglobosa (PB) presented the highest values for all the binder rates. The two curves show that the MOE values increased as a binder rate increased. All the values were higher than the values required by standard ANSI A208.1 (2009) [20] which are from 1725 MPa for medium density of class 1 (M–1).

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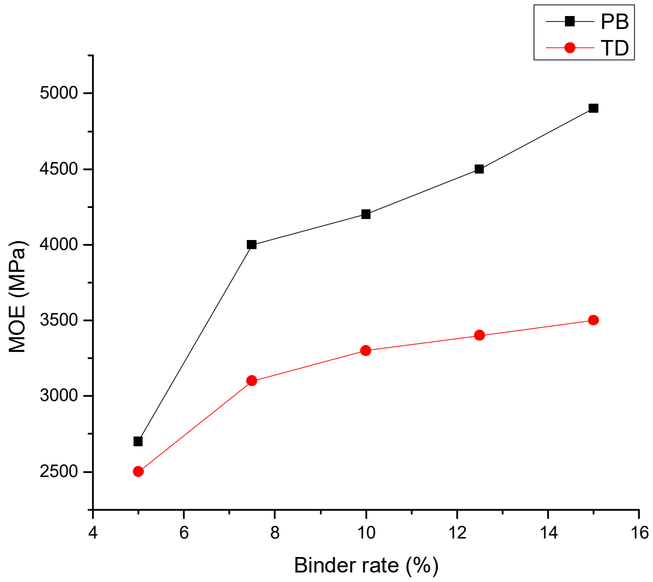

Figure.3: MOE as a function of binder rate

These results are clearly superior to those obtained by [11] (MOE = 125 MPa), and Xu et al [12] (950 to 1,750 MPa) in the case of panels without binder, treated by injection of water vapor, under a pressure of 6 MPa, at a temperature of 190 ° C.

The values measured for modulus of rupture (MOR) showed the same trends as the ones observed for the MOE. MOR increased with increasing binder rates (Figure 4). The minimum values were 18.73 Mpa and 18.85 MPa and the maximum ones were 19,98 Mpa and 21.85 MPa respectively for India Tamarind (TD) and Parkia Biglobosa (PB). The highest values were also obtained for Parkia Biglobosa (PB).

The bending modulus rupture (MOR) complied with the minimum values required by standard ANSI A208.1 (2009) [20] which are from 11 MPa for medium density of class 1 (M–1) and 5 MPa for those of low density of class 2 (LD–2). We note that the flexural rupture stresses (MOR) are in accordance with those obtained by Chow [13] with panels containing red oak sawdust and Villeneuve [14] with panels based on poplar bark, trembling aspen. They noted that the mechanical properties are improved with the increase in the binder content. It is also noted that the modulus of rupture is influenced by the particle size of the particles.

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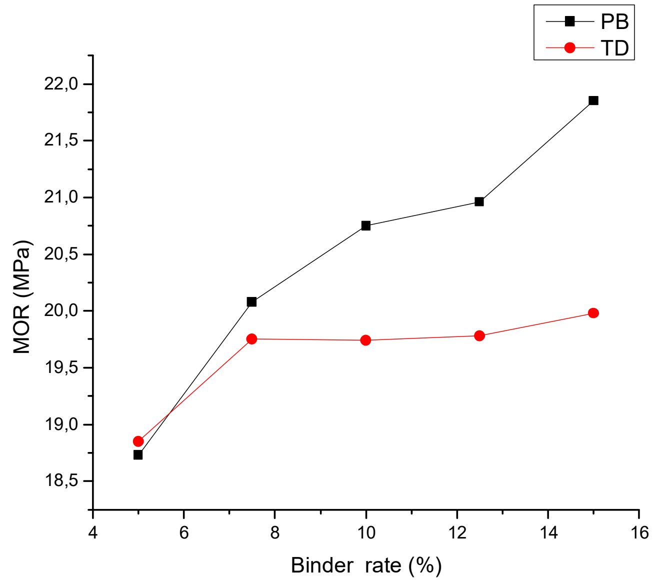

Figure.4: MOR as a function of binder rate

Figure 5 showed the variation of the Young's modulus E as a function of binder rate for the two types of panels. The longitudinal Young's modulus (E) of the panels increases with binder rate and reached a maximum of: 3150 and 2600 MPa at 15% respectively for PB and TD panels elaborated in the same way with Iroko raw sawdust;
E (MPa)

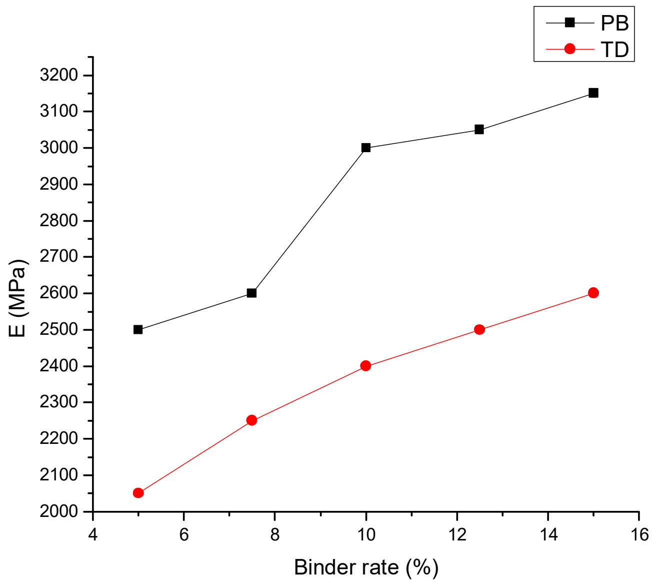

Figure.5: E as a function of binder rate

The values of the longitudinal elastic modulus (E) are lower compared to those of the flexural elastic modulus (MOE) showing that panels are more suitable for the ceiling than the posts.

Figure 6 shows the results obtained for modulus of rupture in tension (MOT). MOT increases with binder rate. The ANSI A208.1 standard, (2009) fixed the threshold of the modulus of rupture at 11 MPa.

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The panels made with PB were more resistant than those made with TD.

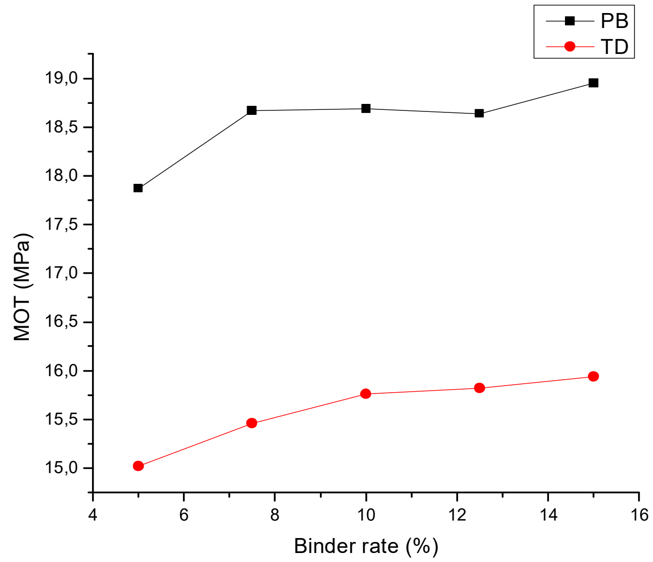

Figure.6: MOT as a function of binder rate

Sawdust panels made from PB powder have better tensile modulus than those made from TD powder from the bark of Indian tamarind. These resistance values obtained comply with the minimum values (11 Mpa) prescribed by standard ANSI A208.1., (2009).

Tests have shown the Young's modulus of elasticity E and the tensile stress MOT were conform to those obtained by [13] with panels containing red oak sawdust and [14] with panels with poplar bark base, trembling aspen. They noted that the mechanical properties were improved with the increase in the binder content.

Resistance to penetration was carried out at four points of three test pieces of dimension 50 x 50 mm from the two types of panels produced with rough Iroko sawdust.

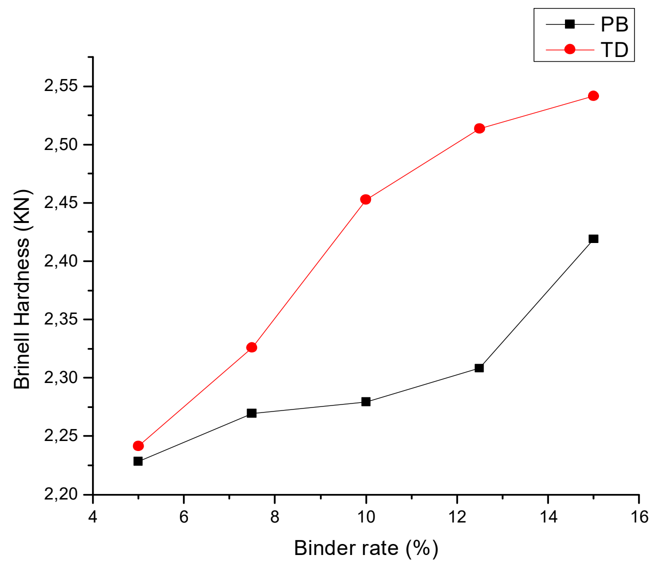

Figure.7: Brinell Hardness (HB) as a function of binder rate

Figure 7 shows the results of the Brinell harnesses of the panels using different binder rate.

These values are greater than the 2.225 KN threshold set by the ANSI A208.1., (2009) except for panels made with 5% binder rate. The HB values increased with the binder rate These results, were conforms to those obtained by Chow (1978) [13]with panels containing red oak sawdust and Villeneuve, (2004) [14] with panels based on poplar bark trembling aspen. They noted that hardness is improved with increasing content of binder.

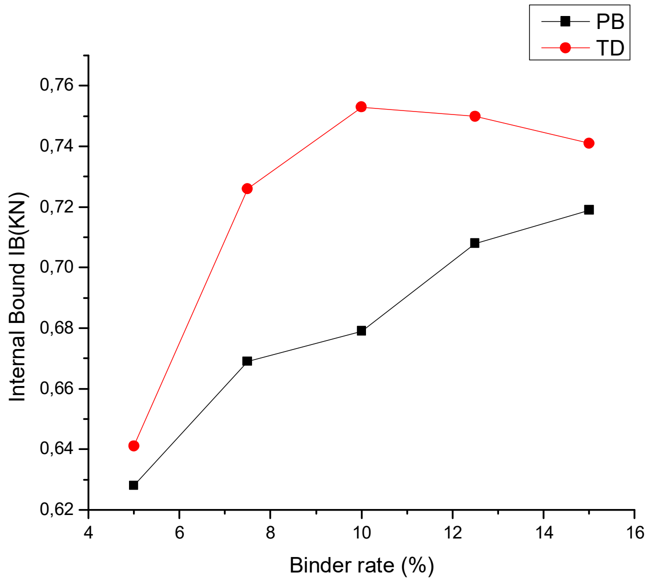

Figure.8: Internal bound (IB) as a function of binder rate

The internal bound of the iroko sawdust particle boards (Figure 8) increases slightly with the binder rate. TD panels were more resistant than those made with PB bark. These results comply with the requirements provided by ANSI A208.1., (2009). They confirm those of Konaï and al [15] who characterized the tannin of anchor as an adhesive resin; Drovou and al [16] with the kapok panels with the PB binder and [9] who also used tannic pod powder from PB as an adhesive for the manufacture of kenaf panels.

4. CONCLUSION

The mechanical properties in flexion and tensile (MOE, MOR, E and MOT), internal bound (IB) and Brinell hardness (HB) of Iroko particle boards made with Parkia Biglobosa (PB) and India Tamarin TD) binders, using different binder rates were in agreements with the requirements of the ANSI A208 standard. .1., (2009). The panels were medium density (MD 1).

The mechanical properties were improved with the increase in the binder content. The best mechanical properties in flexion and tensile (MOE, MOR, E and MOT), were obtained with Parkia Biglobosa (PB) binder.

On the other hand, the particle panels obtained from TD binder showed highest internal bound (IB) and hardness compare to those made with PB.

The values of mechanical properties in bending were higher than those in traction showing that these panels are better to use as a ceiling particleboard

5. ACKNOWLEDGEMENTS

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