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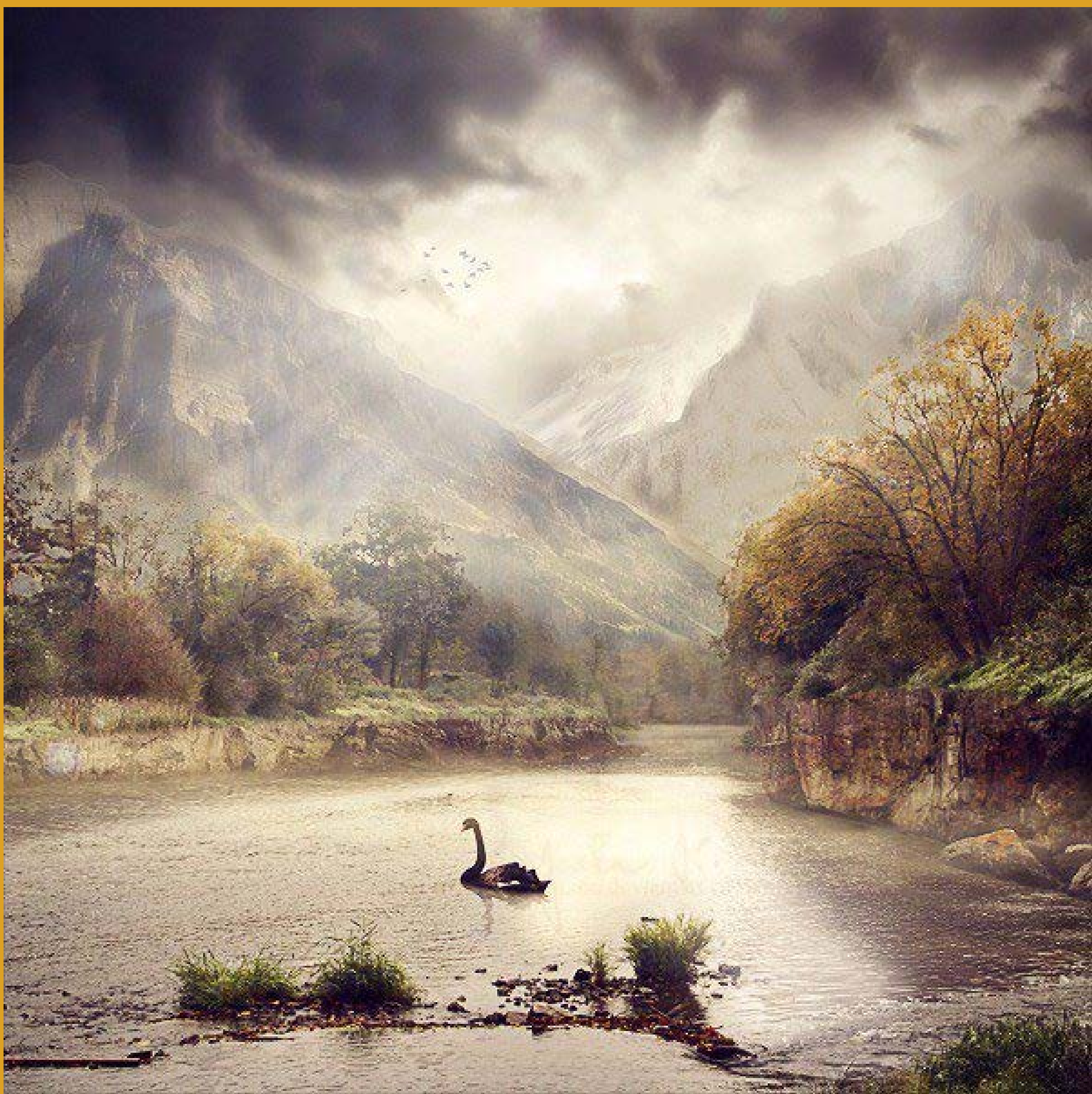

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CAMES

Historique

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Corps du sujet
Les différentes parties du corps du sujet doivent apparaître dans un ordre logique.

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DEVELOPMENT OF KENAF'S PARTICLEBOARDS AGGLOMERATED WITH PRODUCED TANNINS BY SOME PLANT ORGANS FROM TOGO

A.Y. Nenonene(1), K. Koba(1), L. Rigal(2), K. Sanda(1)

RÉSUMÉ

Pour satisfaire le double objectif d'atténuation de la raréfaction des bois d'œuvre et de réduction de la pression anthropique sur les formations végétales naturelles, les panneaux de particules apparaissent comme une alternative intéressante. En effet, les panneaux compressés deviennent de plus en plus une méthode de valorisation des déchets de l'industrie du bois, des résidus de culture et de l'agro-industrie d'une part et des plantes saisonnières spécialement cultivées à cet effet d'autre part. Ces panneaux font l'objet d'importation continuellement croissante en Afrique. Le but de cette étude est d'obtenir avec des biomatériaux locaux, des panneaux composites efficients capables d'être une alternative au bois d'œuvre dans l'ameublement et le bâtiment. Deux catégories de matériel végétal ont été utilisées : la tige écorcées d'Hibiscus cannabinus comme matériel fibreux et d'organes tannifères de plantes telles que les cosses de Parkia biglobosa, l'écorce de tige de Pithecellobium dulce et la gaine foliaire de Sorghum caudatum comme matériel liant. Les propriétés mécaniques des panneaux obtenus ont été mesurées suivant les normes européennesEN 310, EN 317 et EN 319. Les résultats obtenus ont variés de 372 à 1 100 MPa pour le module d'élasticité en flexion, de 2 à 5,7 MPa pour le module de rupture et de 0,06 à 0,46 MPa pour la cohésion interne. La plupart des valeursCes panneaux de particules dont les caractéristiques mécaniques sont conformes aux exigences deà la norme américaine ANSI A208.1, 19932009, peuvent être utilisés en intérieur comme plafond décoratif et en ameublement à la suite d'une protection de surface.

Mots clés : panneaux de particules – tannin - module d'élasticité en flexion - cohésion interne

ABSTRACT

To satisfy the double objective to mitigate the rarefaction of the sawlog and to reduce the anthropic pressure on the natural shrubby formations, the particleboards appear to be an alternative. Indeed, the compressed panels become a method of valorization of woody waste from wood industry, crop wastes and agro-industrial residues on the one hand and seasonal plants which can be especially cultivated for this purpose on the other hand. These panels are subject of importation in continuous increase in Africa. The aim of this study is to obtain with local biomaterials, efficient flat composites which can be used as substitute of sawlog in furnishing and building works. Two categories of vegetable material were used: core of Hibiscus cannabinus as fibrous material and tannin based organs as Parkia biglobosa's pod, Pithecellobium dulce's stems bark and Sorghum caudatum's foliar sheat as binding material. Mechanical properties of the panels obtained were measured according to European standards EN 310, EN 317 and EN 319. The results obtained varied from 372 to 1 100 MPa for bending elasticity, from 2 to 5.7 MPa for bending strength and from 0.06 to 0.46 MPa for internal bound strength.Most of the values were in conformity with the American standards ANSI A208.1, 1993. These panels which mechanical properties met ANSI A208.1, 2009 requirements, can be used in interior as decorative ceiling and furnishing with surface protection treatment

Key words: Particleboards – Tannin - bending strength - Internal Bond strength.

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I. INTRODUCTION

The awakening of the conscience on his responsibility in the deterioration of the environment and the framework of life led men to be concerned more and more by rational and durable management of the natural resources and harmful effects of the exposure of human health and environment to toxic chemical substances (Gillah et al., 2000; Mazumder et al., 2005). Moreover, the pressure and the claims of the populations, lead the policies to adopt rigorous measures for the use of technologies of production healthy and respectful for environmental health in the production and development activities.

This modification of the modes of production and consumption affects all the fields of daily comfort as it is the case for building materials in particular those intended for an interior use. Therefore, the particleboards used for the ceilings, the wall linings, furnishing, etc are also subjected to a revolution as for their technology of development. The objectives of this revolution are: to reduce even eliminate the toxic emissions of formaldehyde from the conventional binders such as urea formaldehyde (UF), phenol formaldehyde (PF), melamine urea formaldehyde (MUF), etc., and in addition, to use alternatives vegetable fibers by the valorization of the cultivated or spontaneous annual plants and the agro-industrial residues or crop residues.

To attain these objectives in the field of materials, research is directed more and more to alternatives bio-adhesives which can be proteins (Kumar et al., 2002, Rigal and Maréchal, 2002), polyphenols (Cetin and Ozmen, 2003; Moubarik et al., 2009), fatty acids (Williams and Wool, 2000; Aranguren et al., 2006).

Tannins which are able to form complexes with other macromolecules can be classified in two groups: hydrolysable tannins which are polymers of gallic acid or ellagic acid and condensed tannins which are polymers of flavonoïdes. In the field of materials, tannins are mainly used to partially substitute (up to 90%) phenol in the phenolic synthetic resins (Lu and Shi, 1995; Hoong et al., 2009) or associated to formaldehyde, or phenolic synthetic resins, or isocyanates resins (Lee and Lan, 2006) to be used as thermohardening matrix in the fibers and particleboards.

The adhesives based on tannin are obtained by various processes of chemical modifications of tannins like hydrolysis and polymerization (Trosa and Pizzi, 2001; Bisanda et al., 2003).

The present work intended to study the binding properties of plant's organs containing tannins on the particles of kenaf stem as alternative vegetable fibers for the manufacture of ecological particleboards with low formaldehyde release.

II. MATERIALS AND METHODS

2.1 Materials

2.1.1 Two categories of vegetable basedmaterial were used:

Fibrous material: It consisted of particles of stem without bark of Kenaf (Hibiscus cannabinus L). The kenaf used in this work was obtained from a culture carried out at the "Station d'Expérimentation Agronomique" of the "Ecole Supérieure d'Agronomie" (ESA) at the "Université de Lomé"(ESA). The kenaf components core characteristics are: crude protein: 1.5%, cellulose: 60%, hemicelluloses: 18%, lignin: 15% (Nenonene, 2009).

Vegetable origin adhesive material: The vegetable origin adhesive materials used in this work were the aqueous extracts of tannin based organs from three plant species:

the pod of the fruit of Parkia biglobosa L., tropical leguminous of the family of Mmimosaceae The pod used in this work was obtained from the northern area of Togo;

the bark of stem of Pithecellobium dulce : a Mimosaceae usually met in tropical areas. This material was harvested on the branches resulting from the pruning of hedge at ESA;

aAnd the foliar sheath of the red sorghum or sorghum of dyer (Sorghum caudatum (Hack.) Stapf Sorghum caudatum, a graminaceous of tropical Africa..

Conventional adhesive material: An urea formaldehyde resin has been used as the standard particleboard adhesives. This resin was provided ready to use, solubilized in water with a dry matter rate of 65%; density: 1.286; pH = 8; viscosity with 25°C: 0.09 Pa.s. It was provided by the Greek company Chimar Hellas SA (reference 106).

Preparation and characterization of the total extracts: The pod of P. biglobosa, the barks of P. dulce and the foliar sheath of S. caudatum dried, were finely crushed with the knife crusher, type RETSCH SM 100 equipped with a sieve of 5 mm mesh. The total phenolic compounds were extracted by maceration of these powders in distilled water during 60 minutes, at temperature 100°C and according to a ratio liquid/solid (mass/mass) of 16. The filtered obtained was freeze-dried. The hydrolysable tannins of the freeze-dried aqueous extracts were determined by the method Folin-Ciocalteu (Makkar et al., 1993) with tannic acid for calibration curve. The optical density was measured by spectrophotometry of absorption UV to 760 Misters.

Preparation of kenaf stem particles: The stems of H. cannabinus collected at maturity stade were barked and stocked under shelter during two weeks for final drying. The stems thus prepared were crushed to coarse particles using a hammer mill of type ELECTRA VS1 equipped with a sieve of 18 mm mesh. The particles obtained were dried 48 hours in oven-dryer at 70 °C before being crushed again in a knife crusher of type RETSCH SM100 equipped with a sieve of 5 mm mesh.

2.2 Methods

2.2.1 Preparation of kenaf particleboards

Preparation of the mixtures of particles of kenaf and urea formaldehyde resin: The particles of barked of stems of kenaf crushed and dried were mixed with resin UF and water with the planetary mixer of type PERRIER 721 during 10 minutes. The resin urea formaldehyde was incorporated in the rate of 10%.

Preparation of the mixtures of particles of kenaf and crude plant organ: The crude plant organs, selected and ground into powder, have been mixed with the particles in proportion of 10% of the total dry matter of the intrants (30 g of extract for 270 g of particles). The mixture was hydrated by water addition up to 27% of water content and was homogenized with the mixer PERRIER 721 during 10 minutes.

Preparation of the mixtures of particles of kenaf and plant organ extract: The dry extracts of organs of plant selected were mixed in the form of powder with the particles in proportion of 10% of the total dry matter of the intrants (30 g of extract for 270 g of particles). The mixture was hydrated by water addition up to 27% of water content and was homogenized with the mixer PERRIER 721 during 10 minutes.

2.2.2 Thermopressing of the particleboards

Each type of mixture obtained was introduced manually into a square aluminium mould (27 cm x 27 cm x 5 cm) electrically preheated at 180 °C to form a mattress of particles regular and with quasi-constant thickness (3,7 to 4 cm) and then thermopressed with a CARVER type manual hydraulic thermopress (maximum pressure: 11 tons.m-2). The pressure was manually gradually applied as follows: 5 tons.cm-2 for 60 seconds and then 10 tons.cm-2 for 4 minutes. After cooking, the mould was gradually open during 60 seconds. The plates were unmoulded and weighed after cooling with the ambient air during 30 minutes after release from the mould.

2.2.3 Characterization of the particleboards of kenaf

Mechanical testing of the particleboards: Six specimens of 150 mm x 50 mm and 6 specimens of 50 mm x 50 cm were cut from each particleboard according to the NF-EN 326-1 (1993) standard and conditioned at 20 °C , 65% relative humidity for 14 days before testing.

The 150 x 50 specimens were used for bending testing (modulus of elasticity: MOE and modulus of rupture: MOR) according to NF-EN 310 (1993) standard with a testing machine JFC of the type H5KT equipped with a force cell of 100 KN, the distance between supports of 100 mm, and the speed of moving of ridged of 6 mm.min-1.

The 50 x 50 specimens were used for internal bond strength testing in accordance with NF-EN 319, (1993) standard requirement. The testing machine JFC of the type H5KT equipped with a force cell of 5kN was used.

The Internal Bond (IB) was determined according to standard NF-EN 319 using the testing machine JFC of the type H5KT equipped with a force cell of 5kN and the speed of spacing of the bits was 5 mm.min-1.

Thickness swelling was estimated by the measurement of the increase of the thickness of the panel after 4 hours of total immersion in water.
The data were statically analyzed with STATISTICA software and the Duncan test at p = 0.,05 was used for the average comparison of the different means.

III. RESULTS AND DISCUSSION

Contents of extractable and hydrolysable tannins of the aqueous extracts P. biglobosa, P. dulce and S. caudatum organs

The table 1 gives the summary of the data of the extraction and extract characteristics of the selected tannin based organs which were used to prepare the binders of the particleboards.

Contents of extractable and tannin: The content of aqueous extractable of the selected vegetable organs strongly varies according to the vegetable species. It is 44.5%, 20.2 and 8.3% respectively for the pod of the fruit of P. biglobosa, the stems bark of P. dulce and the foliar sheath of S. caudatum.

For the content of tannin in the aqueous extracts, the three organs of plants studied contain hydrolysable tannins. However, the pod of P. biglobosa and the stems barks of P. dulce are definitely richer in tannin hydrolysable than the foliar sheath of S. caudatum. Indeed, the tannin rates in the extracts are respectively 37.1% (16.4% of the dry matter of the organ) for the pod of P. biglobosa, 37.9% (7.65%) for the stems bark of P. dulce and 21.6% (1.8%) for the foliar sheath of S. caudatum. Some of these organs are known to contain other phenolic components, in particular the apignidin (a 3-deoxyanthocyanidin), which would account for 10 to 20% of dry matter of foliar sheath of S. caudatum (Dykes and Rooney, 2006)

Table 1: Extractable rate and hydrolysable tannins rate of the aqueous extracts of selected organs containing tannin

ORGAN/SPECIES EXTRACTED	EXTRACTABLE RATE (%)	HYDROLYSABLE TANNINS RATE	
		EXTRACTS (%)	*ORGAN (%)*
Parkia biglobosa's pod	*44.5 a*	*37.1 a*	*16.4 a*
Pithecellobium dulce's stems bark	*20.2 b*	*37.9 a*	*7.6 b*
Sorghum caudatum's Foliar sheath	*8.3 c*	*21.6 b*	*1.8 c*

The contents are expressed in percentage of dry matter; the values affected with the same letter are statistically identical (Test of Duncan, p = 5%)

The content of the water extractable tannin of the barks of P..dulce approach the barks of chestnut and walnut for which the, contents, have, respectively from 8 to 10% and from 7 to 11% (Lee and Lan, 2006 ; Muetzel and Becker, 2006).

The contain of hydrolysable tannin of the pod of P. biglobosa are closed to those obtained from the stem back of acacia in Taïwan : 51,6 %, and of pin of China : 46,5 % (Lee et Lan, 2006 ; Muetzel et Becker, 2006)

3.1 Characterization of keénaf particleboards

The characterization of the particleboards obtained with the crude powder and the extracts of the selected plant organs used as binder and with the urea formaldehyde resin are recorded in table 2.

All the particleboards obtained were panels of quite low density (473 to 538) with an average of 489 ± 23 according to the standard ANSI A208.1, 2009 which requires panel density varying from 450 to 490 for low density ones. The nature of the binder did not affect the panel density. This density of the elaborate particleboards is rather close to the value obtained by Sellers et al., (1995) for particleboards manufactured with kenaf core and conventional binders like UF, PF and Polymeric Diphenylmethane Diisocyanate (PMDI) and to thoses obtained by Xu et al. (2013) on kénaf core particle board..

The panels have different mechanical behaviors according to the mechanical and physique parameters measured.

Thus for the bending elasticity (MOE), the values varied from 372 MPa for the panels manufactured with S. caudatum foliar sheath crude powder to 1,104 MPa for the panels based on P. dulce stems bark extract. Statistically, all the particleboards containing crude organs powder and the one made with conventional binder (Urea formaldehyde) got a flexural module of elasticity lower than the standard ANSI A208.1, 2009 requirements (500 MPa). On the other hand, the particleboards prepared with extracts of P. biglobosa pod or P. dulce stems bark showed a MOE higher than that standard requirements. For each organ, the extracts gave particleboard with a very higher MOE compared to that of the crude powder (726 MPa and 402 MPa, 1,104 MPa and 374 MPa and 511 MPa and 372

Table 2: Characteristics of particleboards of kenaf core using crude powders and aqueous extracts of organs containing tannin as binder.

Type of binder	Density	MOE (MPa)	MOR (MPa)	IB (MPa)	TS (%)
Parkia biglobosa's pod powder	*473.93*	*402.54 e*	*3.17 d*	*0.20 c*	*42.57 c*
Pithecellobium dulce's stems bark powder	*492.62*	*374.23 f*	*2.01 e*	*0.10 d*	*39.28 c*
Sorghum caudatum's foliar sheath powder	*490.94*	*371.80 f*	*2.29 e*	*0.06 e*	-
Parkia biglobosa's pod extract	*485.41*	*725.95 b*	*4.98 b*	*0.30 b*	*43.93 c*
Pithecellobium dulce's stems bark extract	*525.65*	*1 104.00 a*	*5.66 a*	*0.45 a*	*42.08 c*
Sorghum caudatum's foliar sheath extract	*498.04*	*511.35 c*	*2.38 e*	*0.11 d*	*64.11 a*
Urea Formaldehyde	*538.08*	*447.92 d*	*4.15 c*	*0.41 a*	*30.38 d*
Standard ANSI 208.1, 19992009 requirements	*450-490550*	*550 500 MPa*	*3 2.8 MPa*	*0,10 MPa*	*EN 317 : 23 %*

The values with the same letter in a column are statistically identical (Test of Duncan, p = 0.05)

MOE: Modulus of bending elasticity; MOR: Bending strength; IB: Internal bond strength; TS: thickness swelling

MPa respectively for P. biglobosa, P. dulce and S. caudatum). Regarding the conventional binder (UF), all the panels containing crude powder had a weaker MOE whereas the panels manufactured with the extracts were more resistant than those of this reference. The extracts of P. dulce stems bark conferred to the particleboards the most effective bending elasticity.

The bending strength (MOR) of the particleboards fluctuated from 2 MPa for the panels made with P. dulce stems bark crude powder to 5.66 MPa for the panels containing the extract of the same organ. Except the crude powder of P. dulce pod and crude powder and extract of S. caudatum foliar sheath whose panels showed weaker values of MOR, all the other binders gave particleboards in conformity with the American standard ANSI 208.1, 2009 minimal required value (2.8 MPa). Only the panels based on extracts of P. dulce stems bark and P. biglobosa pod showed a bending strength higher than that of the control panels whose particles were agglomerated with the urea formaldehyde resin. Excluding the S. caudatum foliar sheath, the extracts of the other species led to particleboards with bending strength definitely more interesting than the crude organs powders.

For the Internal bond strength (IB), contrary to the particleboards manufactured with the powder of crude S. caudatum foliar sheath, all the other panels met the normative value which is 0.1 MPa (ANSI 208.1, 2009). However, the internal bond strength of the panels manufactured with the crude organ powder was definitely lower than that of the panels based on extract. Indeed, except for the extracts of S. caudatum foliar sheath which gave panels of average IB of 0.11 MPa, the other extracts led to panels of relatively high IB (0.3 and 0.45 MPa respectively for P. biglobosa pod and P. dulce stems bark). The extracts of P. dulce stems bark gave particleboards with internal bond strength equivalent to that of the control panels based on UF (0.41 MPa).

As for the thickness swelling of the particleboards, none of the binders (powder of the crude organs, aqueous extracts of the organs and UF) did improve resistance of the panels to water. Indeed, the panels were all very sensible to moisture with a swelling going from 30.4% for the panels containing UF (most water resistant ones) to a total disintegration for the panels containing powder of S. caudatum foliar sheath. The particleboards based on products with vegetable origin were completely more sensitive to water than those manufactured with urea formaldehyde. The extracts of the plant organs did not have any improving effect on the sensitivity of the panels to water (TS: 39% to 44%).

The worse mechanical performance of the particleboards containing S. caudatum organs can be explained by the fact that the extractable and tannin contents of the foliar sheath were the lowest (8.3% and 1.8% of the organ dry mater respectively). Moreover, one of the main phenolic products in sorghum extractable is apigenidin (Bellemare, 1998) which has more colouring properties than adhesive ones. The panels obtained with plant crude organ's powder showed flexural characteristics closed to that of kénaf core and phenol formaldehyde resin's particleboard of the same density manufactured by Xu et al. (2013) (MOE: 364 MPa and MOR: 2.33 MPa). Except for the panels containing the powder of P. biglobos's organ, the IB of the crude organ's panels is definitely weaker than the one of the same density made by Xu et al. (2013). The particleboards manufactured with the extracts of the plants organs have mechanical characteristics (MOE: 511 – 1104 MPa; MOR: 2.38 - 5.66 MPa; IB: 0.1-0.45 MPa) closed to those of 550 in density made by Xu et al. (2013) containing particles of kénaf core binding with polymeric methylene diphenyl diisocyanate (MOE: 843 MPa, MOR: 5.97 MPa and IB: 0.4 MPa). In addition all our panels showed mechanical properties weaker than those of kenaf medium density particleboards obtained by Kamal et al. (2009) and by Juliana and Paridah (2009) using urea formaldehyde resin.

The P. biglobosa pod and the P. dulce stems bark extracts conducted to panels whose mechanical characteristics largely satisfy the requirements of standard ANSI 208.1, 2009. This behavior, which expresses a greater stiffness of the panels, could reveal the specific role played by tannins introducing of the covalent bonds between the components of the lignocellulosic particles, in particular with lignin and hemicelluloses. However, although having similar tannins contents, the extract of P. biglobosa (37.1% of tannins) led to worse results than the extract of P. dulce (37.9% of tannins). This difference could be related to the difference in nature between the tannins contained in these two extracts: the phenolic compounds of P. biglobosa appear more condensed with other molecules, since a part of them is released during the extraction only beyond a temperature of 100 °C per hydrolysis (Nenonene, 2009). These tannins, more condensed, although hydrolysable, would be less favorable to the development of covalent bonds during the thermo-pressing.

Except for their thickness swelling which is very high, the panels that we obtained had mechanical behaviors generally comparable to those of the panels manufactured by several researchers with the core of kenaf and a variety of binders

(Sellers et al., 1995, Webber et al., 2000; Kalaycıoglu and Nemli, 2006, Kamal et al., 2009; Juliana et al., 2009, Xu et al. 2013).

CONCLUSION

All the extracts of the selected plant organs present binding properties which make it possible to consider their implementation in the protocol of development of particleboards of stems freed of bark of H. Cannabinus (kenaf) of low density that we chose. Except for the thickness swelling rate, all the obtained panels have satisfactory mechanical characteristics in comparison with the standard, although the mechanism of the particles adhesion is probably different according to the extracts origins. In the case of the extracts rich in tannins, the dominating mechanism would be closed to a resinification with development of covalent bonds between the phenolic components of tannins and the components of kenaf fibers, increasing in particular the bending elasticity of the panels.

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