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Eco-friendly Lignocellulosic Particleboards Bonded with Free-formaldehyde Itaconic Polyamidoamine Epichlorohydrin/soy Protein Adhesive

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HEREIN, we demonstrate a promising route to prepare an eco-friendly particleboards (Pb) bonded with novel itaconic polyamidoamine epichlorohydrin/soy protein adhesive (IA-PEA/SP). The as prepared materials, IA-PEA and (IA-PEA/SP), characterized with ^{1}H-NMR spectroscopy, viscosity, solid content, shear bonding strength, and water resistance. The physico-mechanical tests of IA-PEA/SP bonded- plywood (0.5/5 weight ratio) attained an enhanced dry and wet shear bonding strength of 5.94 ±0.36 MPa and 1.220.02± MPa compared with an alkali-denatured SP adhesive control. The water resistance tests, proved the sustainability of the prepared composite. Moduli of rupture and elasticity of Pb were 7.07 ± 0.12 MPa and of 0.21± 0.005 GPa. A two-fold internal bonding strength (IB) was obtained at IA-PAE/SP adhesive (40%) compared to the control. The water absorption and the thickness swelling improve by ~ 40% and 33%. TGA and Σ Ea calculations showed proper thermal properties. The proposed IA-PAE/SP adhesive paves the way for using green wood adhesives.

Keywords: Eco-friendly, Free-formaldehyde, Particleboards, Physico-mechanical properties, Shear bonding strength, Soy protein, Thermal analysis.

Introduction

Customary formaldehyde-based adhesives such as melamine–formaldehyde (MF), urea–formaldehyde (UF), resorcinol-formaldehyde, and phenol–formaldehyde (PF), are important polymeric resins broadly used for adhesion of board, wood, weave, paper, and construction, especially used as adhesive to wood products, such as plywood, laminated veneer lumber, particleboard, and medium-density fiberboard [1]. The lower cost, superior adhesion property, excellent durability and fast curing of formaldehyde-based adhesives are one of the causes of the extensive use of these resins [2]. However, formaldehyde-based adhesive also have a significant disadvantages about health problem, which is formaldehyde-emission during hot pressing and from the end products [3]. With the increasing concern about the environmental awareness, reduction of formaldehyde-emission from formaldehyde-based adhesives becomes important issue. Recently, many attempts have been done to reduce formaldehyde-emission and enhance the performance of formaldehyde-based adhesive. These attempts mainly focus on modification of formaldehyde-based resins by additives [4-8]. However, the problem of formaldehyde emission has not been primarily overcome by these outlined techniques yet and the adhesive performance cannot meet the environmental and people's prospects. Thus, some requirements for determining acceptable formaldehyde emission levels have been provided. Thus, many manufacturers and researchers pay great attention to study novel environmental-friendly materials in the wood industry [9-10]. Soy protein adhesive has a considerable potential in the wood manufacturing as a type of green, low-cost, abundant, and ecological natural material. Soy-based adhesive have been demonstrated to be one of the formaldehyde-free adhesives, alternative to formaldehyde-based adhesives and has been used for manufacture of interior plywood panels [11-12]. Despite the fact that, SP is a promising raw substance for plywood adhesives, and has been commercially accessible to replace formaldehyde- based adhesives to some extent. The poor water resistance and the

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low wet adhesion strength have limited its use as an alternative to formaldehyde-based adhesives. Therefore, it is necessary to improve the water resistance and adhesion strength of SP to extend its application [13-16].

In order to solve these problems, some techniques could be used to modify the soy adhesive, for example, enzyme modification, cross-linking [17-18]. Whereas synthetic latex is one of the most effective cross-linker [19] hydrolysis, and chemical denaturation [20]. In the past few years, numerous chemical modifications to SP adhesives have been implemented to improve water resistance and wet adhesion strength. Most attempts have focused on unfolding protein chains and display the hydrophobic subunits. The denaturation agents mostly used like sodium bisulfite, urea, and guanidine [21-22]. The cross linking modification is considered as acceptable technique for modifying SP adhesive, cross-linker agents could be mixed with SP before or after applications. Epoxy [23], aldehydes and their derivatives [24] are effective cross-linkers to SP -based adhesive. SP contains many reactive groups, such as -COOH, -OH,-SH, and–NH_2 groups. Each cross-linker has different mechanism for the enhancement of SP adhesive performance for example; epoxy groups are believed to interact with each of the functional groups listed above in SP [25], the curing mechanism of SP adhesive by polyepoxide was suggested by Huang et al [26]. The cross-linking mechanism by aldehydes and their derivatives, like hydroxymethyl phenol, urea-formaldehyde, and the reaction focused on NH_2 in SP.

This work aimed to preparation of eco-friendly lignocellulosic particleboards (LP) of zero-formaldehyde emission, with enhanced adhesion strength and water resistance. The soy protein curing agent, itaconic-polyamidoamine epichlorohydrin (IA-PAE) was prepared and characterized by means of ^{1}H-NMR spectroscopy, solid content and viscosity measurements. The influence of IA-PAE/SP weight ratios on shear bonding strength and water resistance of IA-PAE/SP-bonded plywood composite was studied. The changing effect of IA-PAE/SP weight percentages on the mechanical, physical, and thermal properties of LP was studied to mimic the formaldehyde-based adhesives to produce LP of favored properties such as good mechanical properties, enhanced water resistance and proper thermal stability.

Experimental

Materials

A sugar-cane bagasse raw material was a gift from Qena of Pulp and Paper Industry Company (Qena, Egypt). Soybean meal (defatted, extra pure), itaconic acid (methylene succinic acid), and diethylene triamine 98%, were purchased from Loba Chemie. The other chemical were commercial grade.

Synthesis of itaconic-polyamidoamine epichlorohydrin (IA-PAE) curing agent for SP

Firstly, itaconic acid-based polyamidoamine (IA-PADA) molten was obtained as described; (39 g) IA, (31 g) diethylenetriamine (DETA), and (20 g) water was added to 3-necked flask stirred at 170^{o}C for 1.5 h. Secondly, (100 g) water was added to 3-necked flask to dissolve IA-PDAD resin. Finally, 27.8 g epichlorohydrin (ECH) was added to flask, stirred at room temperature for 2 h. Then, the reaction temperature was raised to 70^{o}C and completed by maintaining temperature for another one hour [27].

Characterization of IA-PAE curing agent of soy protein

Determination of the total dry solid content of IA-PAE curing agent

The total dry solid content of IA-PAE curing agent is known as the ratio of weights before and after drying process. The test protocol is placing a known volume of the sample in Petridish in an oven at a temperature of 10°C until a constant mass is obtained.

$$\text{Dry soild content} = W2/W1 \times 100$$

Where; W1 and W2 is the weight of the sample before and aftr drying process.

Determination of the apparent viscosity of IA-PAE curing agent

The apparent viscosity was measured by HBDV-II + PRO viscometer using spindle ≠ 2 at 100 rpm.

^{1}H-NMR spectroscopy of IA-PAE curing agent

The functional groups of IA-PEA curing agent were identified by ^{1}H-NMR spectroscopy using Bruker Avance (III) 400 MHz (Switzerland). D_2O was added to the solution of IA-PAE

IA-PEA/SP adhesive formulation preparation

IA-PEA/SP adhesives preparation method as reported by Gui et al. [28]. In order to obtain the optimum IA-PEA/SP adhesives formulation that

meets the requirements of proper particleboards. IA-PEA/SP adhesives were prepared at different weight ratios of IA-PEA and SP. (X/5) ratios refer to IA-PEA and SP where, X is 0 g (alkali-denatured soy protein as a control), 0.1 g, 0.2 g, 0.3 g, 0.4 g, and 0.5 g IP-PAE : 5 g SP. These components are added to a 50 mL three-neck flask, and then 3 g of H_2O was added to form viscous slurry [29] For comparative analysis, alkali-denatured soy protein adhesive was prepared by adding 40 g SP to100 g H_2O, and 0.3 g NaOH and the slurry was stirred for 30 min [30].

Shear bonding strength (dry & wet bonding strength)

The shearing bonding strength of IA-PEA/SP adhesive was determined as reported by Li et al. [31]. The adhesive is applied to rectangular veneer with dimension of 7.7× 17.8 cm^2 with spread rate 4 mg/ cm^2 dry weight basis on area of (1×17.8 cm^2). Two pieces of the adhesive-coated veneer are lapped together with the parallel and longitudinal grain direction along the axis of the veneer, and then is hot pressed at 140 ^oC, 100 sec, and 1.0 MPa. The two-plywood was cut into 6 samples of bonded area of (1 × 2.54 cm^2) for assessment of shear bonding strength. The shear strength was determined by fracture in tension on an Instron universal testing machine at a crosshead speed of 1mm/min and the load at fracture was measured. In order to determine wet shear bonding strength, the specimens were soaked in water for 24 h, and then dried for 24 h at room temperature.

Water resistance of plywood panels bonded with IA-PAE/SP adhesive (delaminating test)

Water resistance or delamination test of plywood panels bonded with IA-PAE/SP adhesive was characterized as described. IA-PAE/SP (8 mg/ cm^2) adhesive was applied to two sides of veneer [60.9×60.9 cm^2]. The adhesive –coated veneer was stacked between two uncoated veneers with the grain directions of the two adjacent veneers perpendicular to each other. When five-ply was constructed, the stacked veneers were made by cold pressing at 0.69 MPa for 5 min at room temperature. Then, they were hot-pressed at 1.03 MPa for 6 min at 120^oC. The panels were stored at ambient temperature for at least 24 h (Ref 25). Specimens [5.08× 12.7 cm^2] cut from each plywood panel were soaked in water at 24±3^oC for 4 h, and then dried at 49-52^oC for 19 h. This soaking/drying cycle was repeated one and three cycles according to American National Standard [ANSI/HPVA HP-1-2000]. According to standard, a plywood panels meets water resistance requirements for interior applications if 95% of specimens, i.e., 19 out of 20 do not delaminate after the first soaking/ drying cycle and 85% of specimens, i.e., 17 out of 20 specimens do not delaminate after third soaking/ drying cycle [32].

Medium density fiberboard (MDF) manufacturing

The lignocellulosic compressed panels were prepared by blending sugar-cane bagasse with 10%, 20%, 30%, and 40% of IA-PAE/ SP adhesive based on dry weight of bagasse comparatively with alkali-denatured soy protein adhesive 40%. The blends were subjected with board formation under hot pressing at pressure 4 MPa and 140^oC for 8 min. The compressed lignocellulosic panels bonded with IA-PAE/SP adhesive was characterized by modulus of rupture (MOR), modulus of elasticity (MOE), and internal bonding strength (IB) were tested according to (ASTM-D 3039). Water absorption and thickness swelling % of the lignocellulosic panels bonded with IA-PAE/ SP adhesive were determined after 24 h immersing in water.

Thermal analysis

Thermal analysis of compressed lignocellulosic panels bonded with IA-PAE/SP adhesive were characterized by thermal gravimetric analysis (TGA) at temperature ranges from 30-800^oC, at heating rate of 10^oC/ min in a nitrogen atmosphere with flow rate of 50 cm^3. Kinetic studies based on weight loss data were obtained by TGA curve analysis. Sefain et al. [30] calculated the thermodynamic parameters of the degradation as follows:

Generally, the chemical reaction rate is given by: $\text{Rate}=-dc/dt= Kc^n$…….(A)

In accordance to thermogravimetric analysis, the concentration, c is expressed by the remaining non-evaporated materials weight at time t for each degradation stage, i.e., w_t-w_∞, where w_t corresponds to the weight of sample at time t and w_∞, its value at the end of the degradation process. The equation (A) can be re-typed as:

$$k= - dw/dt= K (w_t - w_\infty)^n \text{…….(B)}$$

By applying Arrhenius equation, we can obtain:

$$\ln k = \ln(dw/dt)/(w_t-w_\infty)^n = \ln A-\Delta Ea /RT \text{…….(C)}$$

Where; R is the general gas constant, A is Boltzman constant, T is temperature in Kelvin, and Ea is the activation energy.

The reaction rate (-dw/dt) could be calculated as: $- dw/dt = -(w_2 - w_1)/(t_2 - t_1) = \ldots\ldots.(D)$

Where; w_1 and w_2 are the remaining masses of the samples at time t_1 and t_2 respectively.

By plotting the left hand side values of equation (C) i.e. values versus 1/T, using different values of n (order of reaction), should create the best straight line with the most appropriate order of reaction n. The applying of least square method using equation (C) and taking different values of "n" ranging from 0.0 to 3.0 with increments of 0.2, then calculating the correlation coefficient "Rc" and the standard error "Se" for each value of n, points to the appropriate n value that which achieve a highest Rc and minimum Se value. The degradation activation energy of each degradation step could be calculated by multiplying the slope of the line resulting from plotting lnk values against 1/T for the appropriate values of n, by the known value of general gas constant R, 8.314 Joules/deg. mole, the total activation energy Σ Ea could be calculated.

Results and Discussion

The solid content % of (IA-PAE) curing agent was determined to be about 47.29. The apparent viscosity was estimated to be 148 cP.

^{1}H-NMR of IA-PEA curing agent

In order to verify the possible structure of IA-PEA curing agent, ^{1}H-NMR technique was performed. The itaconic polyamidoamine molten (IA-PADA) is formed by the reaction of primary amino group of diethylene triamine and (-C=C-) of itaconic acid Michael addition, then the itaconic polyamidoamine epichlorohydrin resin (IA-PEA) was formed with its distinctive azetidinium rings and N-(3-chloro-2-hydoxypropyl) groups as described in the above schematic diagram (a) that represented in Fig. 1. The structure of IA-PEA curing agent was shown in Fig. 2. Azetidinium rings and N-(3-chloro-2-hydoxypropyl) groups are formed that are responsible for cross linking and condensation reaction between SP and lignocellulosic material components. The signals at 3.39 ppm and 4.66 ppm were attributed to methine proton of N-(3-chloro-2-hydoxypropyl) and methine proton of azetidinium rings. It has thought that both azetidinium rings and N-(3-chloro-2-hydoxypropyl) could effectively react with carboxylic groups, amino, and other nucleophilic groups in SP, in consequence leading to SP cross-linking [33].

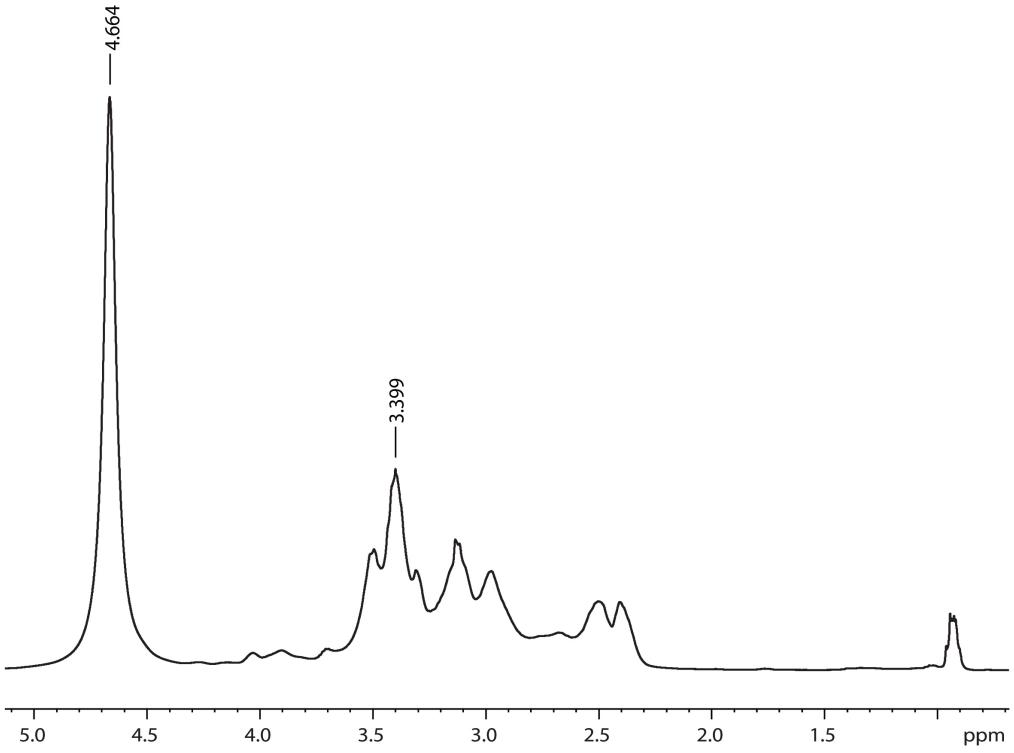

Fig. 1 . ^{1}HNMR spectrum of IA-PEA curing agent.

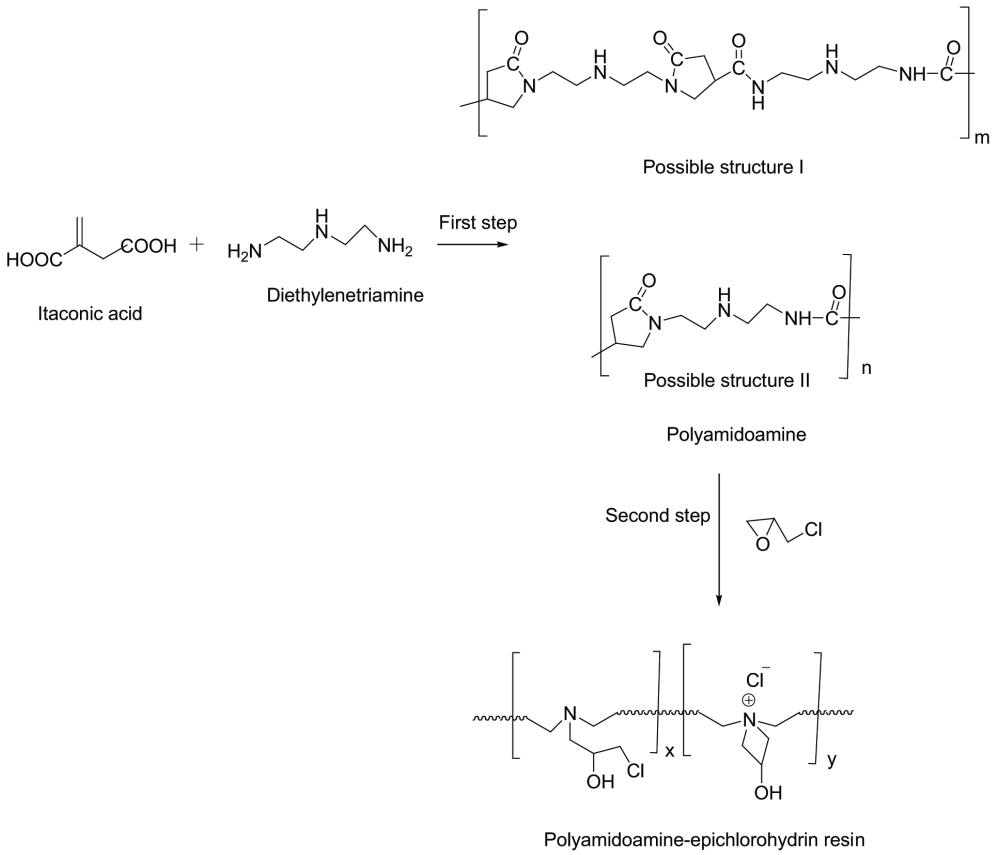

Fig. 2. Scheme of IA-PEA curing agent formation from itaconic acid, diethylene triamine, and epichlorohydrin.

Physico-mechanical measurements of IA-PEA/SP adhesive -bonded plywood composite

In order to understand the influence of changing IA-PEA contents in IA-PEA/SP adhesive formulation performance on the dry, the wet, and water resistance of IA-PEA/SP- bonded plywood composites. A comparative study of control sample, i.e plywood bonded with alkali-denatured soy protein adhesive (A-DSP) was conducted. IA-PAE/ SP weight ratios [0/5, 0.1/5, 0.2/5, 0.3/5, 0.4/5, and 0.5/5] were chosen to be the point of the study. Some interesting results can be seen in Fig. 3, that showed the effect of changing IA-PEA content on dry and wet shear bonding strength of plywood bonded with IA-PEA/SP adhesive, the increasing of IA-PEA content has significant impact on the dry and the wet shear bonding strength. As expected, IA-PEA/SP weight ratio (0.5/5) has considerably higher effect, whereas readings were 5.94 ±0.36 MPa and 1.220.02± MPa compared with control 1.81± 0.31 MPa and 0.490.03± MPa, respectively. Furthermore, the plywood-boned with IA-PAE/ SP adhesive has presented proper water resistance and sustainability that can satisfy water resistance requirements for interior applications as shown in Table 1. However, control sample has shortcoming as expected, and cannot meet the water resistance and sustainability under working conditions. IA-PAE/SP (0.5/5 g) appears to be an efficient and feasible weight ratio for soy-based adhesives curing. These results could be explained that stronger cross linking reaction occurred and generation of more N-(3-chloro-2-hydroxy-propyl) groups and azetidinium rings with more the IA-PEA content that could effectively react with amino, carboxylic acid groups and other nucleophilic groups in SP, thus effectively causes more cross linking to SP [34, 23] represented in Fig. 4., Diagram (b).

The influence of IA-PAE /SP adhesive weight percentages on mechanical properties of lignocellulosic particleboards

In accordance to the previous results, plywood bonded with IA-PAE /SP in ratio 0.5/5 showed efficient dry and wet adhesion strength, in addition to improved water resistance requirements of interior plywood applications. This ratio is

the start point to complete the development of sustainable lignocellulosic particleboards based on eco-friendly free-formaldehyde IA-PAE/SP adhesive. Lignocellulosic particleboards (LP) were fabricated by blending IA-PAE/SP adhesive with (10%, 20%, 30%, and 40% based on bagasse dry weight) compared with control, alkali-denatured soy protein (A-DSP) with blending weight percentage 40% based on dry weight of sugar-cane bagasse. Fig 5, showed the effect of increasing percentages of IA-PAE/SP adhesive on modulus of rupture (MOR) and modulus of elasticity (MOE) respectively of LP bonded with different weight percentages of IA-PEA/SP adhesive based on dry weight of lignocellulosic raw material. Increasing the percentages of IA-PAE/SP adhesive has positive effect on MOR and MOE, as seen the maximum MOR and MOE were 7.070.12± MPa and 0.210.005± GPa, respectively up to 40% IA-PEA/SP adhesive compared with alkali-denatured adhesive control 3.3350.1± MPa and 0.110.002± GPa, respectively. Furthermore, the maximum internal bonding strength (IB) was 0.630.012± N/mm^2 compared with control 0.2660.01± N/mm^2 as demonstrated in Fig. 6. These results could be reported as, increasing adhesive amounts, generating more N-(3-chloro-2-hydroxy-propyl) groups and azetidinium rings, which are responsible for more cross-linking and polycondensation reactions between adhesive components and lignocellulosic material as demonstrated in Fig. 4, Scheme b.

Physical properties of IA-PAE/SP-bonded lignocellulosic particleboards

Water Absorption and thickness swelling after 24 h

Increasing percentages of IA-PAE/ SP adhesive has drastically impact on water absorption and thickness swelling after 24 h immersing. Minimum water absorption belonged to particleboard manufactured by 40% IA-PAE/ SP adhesive was 48.94 ±1.11% compared with control 77.851.5%± as found in Fig 7. However, thickness swelling was 41.662.77%± and control 60% respectively as found in Fig 7.

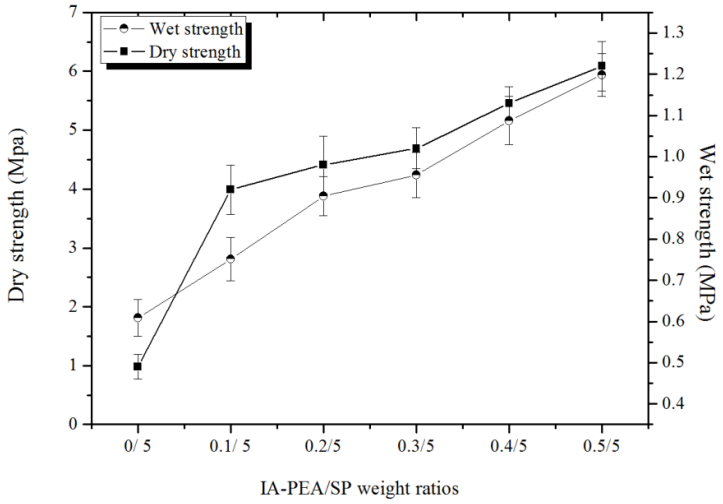

Fig. 3. Dry and wet shear bonding strength of IA-PEA/SP bonded plywood as a function of changing IA-PEA content.

TABLE 1. Water resistance measurements of IA-PEA/SP adhesive –bonded plywoods as a function of changing IA-PEA contents

IA-PEA/SP weight ratios	Delaminating specimens failed in first – cycle soak test	Delaminating specimens failed in third–cycle soak test
0/ 5 (control)	Passed with two specimens delaminate	Passed with four specimens delaminate
0.1/ 5	Passed with one specimens delaminate	Passed with three specimens delaminate
0.2/ 5	Passed without specimens delaminate	Passed with three specimens delaminate
0.3/ 5	Passed without specimens delaminate	Passed with two specimens delaminate
0.4/ 5	Passed without specimens delaminate	Passed with one specimen delaminate
0.5/5	Passed without specimens delaminate	Passed with one specimen delaminate

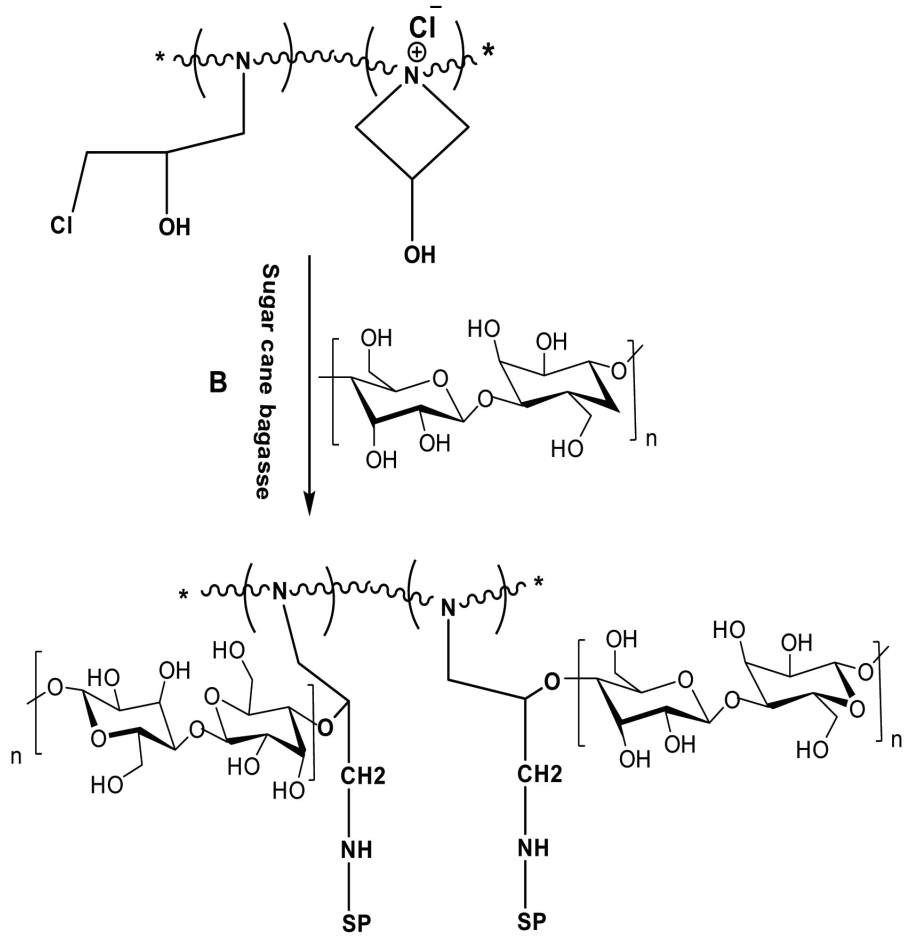

Fig. 4. Scheme b. Suggested cross-linking mechanism of N-(3-chloro-2-hydroxy-propyl) groups and azetidinium rings with SP components and lignocellulosic material.

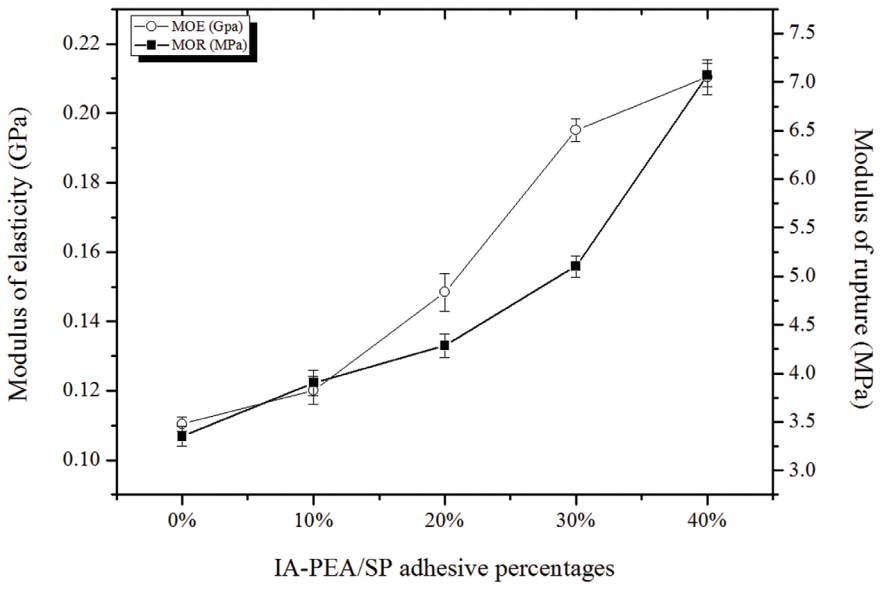

Fig. 5. Modulus of elasticity and modulus of rupture of LP as a function of changing IA-PEA/SP adhesive weight percentages.

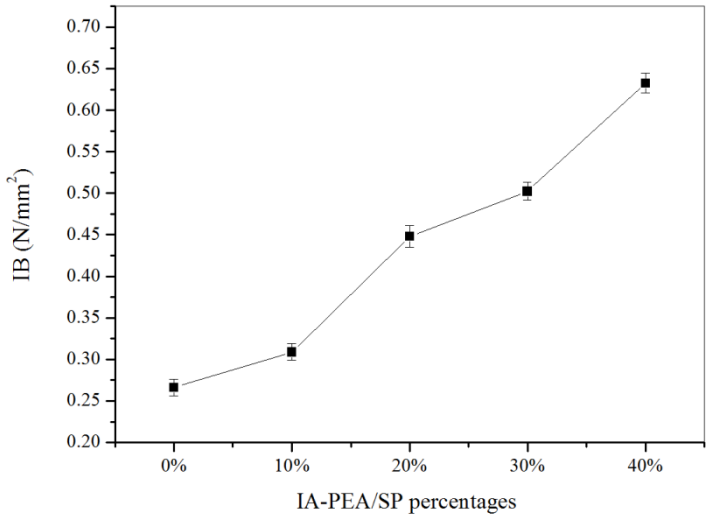

Fig. 6. IB strength of LP as a function of changing IA-PEA/SP adhesive weight percentages.

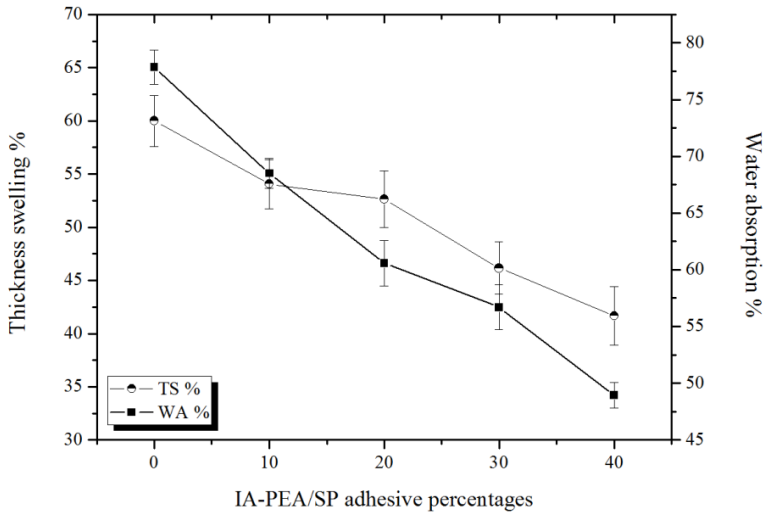

Fig. 7. Water absorption % and thickness swelling % of LP as a function of changing IA-PEA/SP adhesive weight percentages.

Thermal analysis

The thermal patterns of the lignocellulosic panels bonded with different ratios of IA-PAE/SP adhesives were also studied and supported by the calculated thermodynamic parameters of the different degradation stages. TGA pattern of LP was shown in Fig 8. The thermodynamic parameters were tabulated in Table 2. TGA curve of A-DSP-bonded LP showed a weight loss in two distinct stages while, IA-PEA/SP-bonded LP with changing weight percentages showed three distinct degradation stages. The first degradation stage in both type of LP was corresponding to loss of the bounded and absorbed water. In the case of A-DSP-bonded LP, the temperature ranges between 36.16-204.81°C shows about 6.8% weight loss percent and maximum temperature peak 84.24°C. The first degradation temperature was 204.81°C. The second stage of weight loss starts at 204.81°C and continues up to 350.35°C during which there was 63.27% weight loss due to the degradation of SP. However, IA-PAE/SP-bonded PL showed second degradation stage that may be resulted from the degradation of IA-PEA curing agent and the third degradation step may be due to SP.

The first degradation temperature shifted to minor increase value 234.69°C, 242.0°C, 241.0°C and 249.23°C compared with alkali denatured-bonded panel (204.81°C). This could

be explained as a result of presence of IA-PEA cross-linker which may increase thermal stabilities of IA-PEA/SP-bonded LP and continue to 330.86°C, 332.43°C, 330.4°C, and 335.13°C. In order to increase the spotlight on the thermal behavior, comparing the total activation energies as a function of increasing IA-PAE/SP adhesive content compared with alkali-denatured one was conducted. The increasing order of ΣE_a was 147.42 kJmole^{-1} > 153.33 kJmole^{-1} > 163.45 kJmole^{-1} > 175.46 kJmole^{-1} compared with control 127.21 kJmole^{-1} up to 40% > 30% > 20% > 10% of IA-PEA/SP weight percentages. Overall, the increasing of IA-PAE/SP adhesive contents have a little effect on thermal stability of LP.

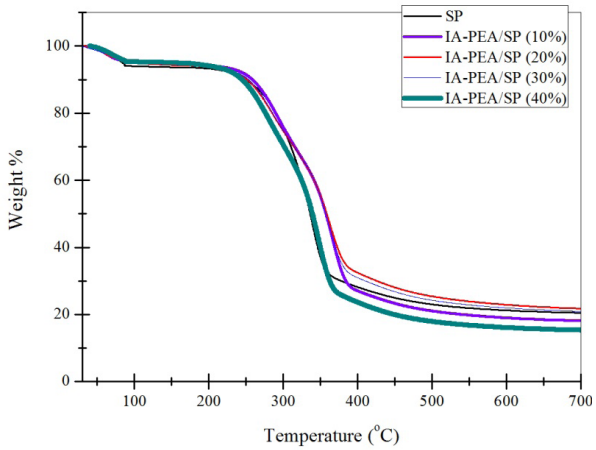

Fig. 8. TGA pattern of LP boards bonded with SP and varying percentages of IA-PEA/SP adhesive.

TABLE 2. Thermal and kinetics parameters of lignocellulosic particleboards as a function of changing IA-PEA/SP weight percentages.

Sample ID	Step	Temp. range °C	Maximum wt. loss temp. °C	Weight loss %	-Rc	Se	"n"	Ea KJ/ mole
0%	1st	36.16-204.81	84.24	6.8	-	-	-	-
	2nd	204.81-350.35	338.75	63.2	0.9432	1.09	3.0	-127.21
								ΣE_a -127.21
10%	1st	39.55-234.69	69.22	4.59	-	-	-	-
	2nd	234.69-291.82	270.0	30.84	-	-	-	-
	3th	291.82-330.86	348.46	43.68	0.9234	0.537	3.0	-147.42
								ΣE_a – 147.42
20%	1st	36.82-242.0	-	4.86	-	-	-	-
	2nd	242.0-314.58	298.34	30.39	0.9517	0.127	0	-51.21
	3rd	314.58-332.43	387.72	49.06	0.9761	0.097	3	-102.12
								ΣE_a -153.33
30%	1st	28.76-241.10	40.55	4.67	-	-	-	-
	2nd	241.10-315.24	278.52	29.72	0.9241	0.0923	0.0	-24.41
	3rd	315.24-330.48	363.60	49.11	0.9252	0.1054	3	-139.04
								ΣE_a -163.45
40%	1st	32.02-249.23	64.87	4.82	-	-	-	-
	2nd	249.23-316.87	287.04	30.82	0.9703	0.153	0.0	-33.22
	3rd	316.87-335.13	366.51	51.07	0.9593	0.696	3	-142.24
								ΣE_a -175.46

Conclusion

In this context, an environmental -friendly LP based on soy protein (SP) cross-linked by itaconic polyamidoamine epichlorohydrin/SP (IA-PEA) was prepared. The as prepared materials, IA-PEA were characterized with ^{1}H-NMR, viscosity, solid content. The IA-PEA/SP composite adhesive was evaluated by shear bonding strength and water resistance (delimitation test) at different IA-PEA curing agent contents. The results of the dry and the wet shear bonding strength showed a maximum values at 5.940.36± MPa and 1.220.02± MP are respectively using 0.5/5 weight ratio of IA-PEA/SP. The delimitation test for the IA-PEA/SP-bonded plywood composite revealed its sustainability after one and three cycles according to the standard methods. The mechanical properties of LP showed the higher MOR (7.070.12± MPa), MOE (0.210.005± GPa) and IB (0.630.012± N/mm^2) up to 40% IA-PEA/SP based on dry weight of bagasse compared with control 3.350.1±MPa, 0.110.002± GPa, and 0.2260.01± N/mm^2 respectively. The water absorption and the thickness swelling of LP were increased by ~ 40% and 33%, respectively. The increasing of IA-PAE/SP adhesive content has little effect on thermal stability of LP. Finally, we can conclude from these results that the claimed IA-PAE /SP could be used as an alternative wood adhesive to formaldehyde- based adhesives.

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الواح لجنوسيليلوزية صديقة للبيئة مترابطة بالمادة اللاصقة الايتاكونيك بولى اميدو امين ابيكلوروهيدرين وبروتين الفول الصويا الخالية من الفورمالين

هنا نعرض طريقة واعدة لتحضير الواح لجنوسيليلوزية صديقة للبيئة مترابطة بالمادة اللاصقة الايتاكونيك بولى اميدو امين ابيكلوروهيدرين وبروتين الفول الصويا (IA-PAE/SP) الخالية من الفورمالين. المواد التى تم تحضيرها، الايتاكونيك البولى اميدو امين والمادة اللاصقة الايتاكونيك البولى اميدو امين- بروتين فول الصويا تم توصيفها من خلال تقنية الرنين النووى المغناطيسى للهيدروجين بروتن وتم تقييم اللزوجة ونسبة المحتوى الصلب وقوة القص للترابط ومقاومة الماء. حقق الفحص الفيزيائى-الميكانيكى للخشب الرقائقى المترابط بالمادة اللاصقة الايتاكونيك بولى اميدو امين ابيكلوروهيدرين وبروتين فول الصويا تحسناً فى قوة القص الجافة والرطبة للترابط لتعطى 5.94±0.36 MPa و 1.22± 0.02MPa على التوالى مقارنة بالكنترول (alkali-denatured SP adhesive) عند النسبة 0.5/5 weight ratio .

اختبار الالواح اللجنوسيليلوزية لمقاومة الماء اثبتت استدامة هذا الكبوزيت. تم الحصول على اقصى معامل تمزق ومرونة الالواح هي 7.07±0.12 ميجا باسكال و0.02 ±0.21 جيجا باسكال وعلى قوة ترابط الالياف الداخلية (IB) عند تركيز للمادة اللاصقة 40% (IA-PAE / SP) مقارنةً بالكنترول. نسبة التشرب وامتصاص الماء وانتفاخ السمك يتحسن بنسبة ~ 40 ٪ و 33 ٪ على التوالى. اظهرت حسابات (TGA) وطاقة التنشيط أن المادة اللاصقة IA-PAE / SP اعطت الواح لجنوسيليلوزية ذات خواص حرارية جيدة. المادة اللاصقة المقترحة تمهد الطريق لاستخدام المواد اللاصقة الخشبية الخضراء.