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MANGROVE TANNIN AS AN ADHESIVE FOR WOOD-BASED PANELS

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MOHD. NOR MOHD. YUSOFF, CHEW, L.T., ABDUL RAZAK MOHD. ALI & AZIZOL ABDUL KADIR. 1988. Mangrove tannin as an adhesive for wood-based panels. Laboratory investigations on tannin extracted from mangrove bark for the production of adhesive in wood-based panels showed encouraging results. The tannin was found to be reactive and combined well with phenolic resins in the manufacture of plywood and particleboard. Satisfactory bond quality was obtained using a glue mixture comprising 70% mangrove bark extract and 30% phenol formaldehyde in the adhesive formulation of plywood.

Key words : Mangrove tannin - adhesive - plywood - particleboard.

Introduction

At present, urea formaldehyde and phenol formaldehyde resins are the main adhesives used in the wood-based industries. The supply of raw materials for the manufacture of these resins is always in deficit and the prices of synthetic resins have been escalating over the last decade. These have generated interest in the search for renewable materials for wood adhesives manufacture. Plants provide one potential source. Extracts from plants give phenols which are used for synthesis of wood adhesives: a resin results when formaldehyde is added to the polyphenolic substance of the plant extract.

Normally, tannin can be obtained inexpensively by extracting the bark materials with hot water solvent. Research on the use of wattle tannins, and various pine tannins have been done before (Pizzi 1981, Anderson 1977). Wattle tannin has been used industrially for bonding of plywood in South Africa since 1973 and all its exterior grade particleboard is manufactured using tannin-based adhesives (Pizzi 1981).

In Malaysia, mangrove bark extracts have been shown to be reactive towards formaldehyde (Plomley 1966, Abdul Razak *et al.* 1981). The mangrove tannin was also shown to combine well with phenolic resins in the production of plywood (Mohd. Nor *et al.* 1987a & b). In Malaysia, currently mangrove bark is discarded during the manufacture of charcoal. Hence, the large quantities of bark available

could be used for the production of tannin. This paper evaluates the suitability of mangrove bark extract as an adhesive for plywood and particleboard.

Materials and methods

The bark of *Rhizophora mucronata* (mangrove bark) was collected from a charcoal kiln at Klang, Selangor, Malaysia. For preparation of the samples, the bark was first cut into smaller sizes (~ 1 x 2 *mm*) and then sun-dried to about 10-20% moisture content.

The bark samples were extracted with water using the four-stage countercurrent method . In this method, the samples in each tank are taken through four leachings before the spent material was discarded. The conditions were water to bark ratio of 5:1 (about 400*g* oven dried bark and 2 *l* water) and a temperature of 60° to 70° *C* for 4 *h*. The slurry was filtered through cloth. The bark extract was then concentrated to about 40% solids in a rotary vacuum evaporator, and then analyzed for solids content, yield, Stiasny number, gelation time and pot life.

Mersawa (*Anisoptera* spp.) veneers were acquired from a local plywood manufacturer. Three sets of plywood of dimensions 300 x 300 x 4.5 *mm* were manufactured using the adhesive formulations given in Table 1. In addition, another two sets of plywood of dimensions 300 x 300 x 1.5 *mm* were manufactured using the following adhesive formulations: Sample D - 30% phenolic resins and 70% tannin; and Sample E - 35% phenolic resins and 65% tannin. The amount of adhesive applied on the veneers was from 200 to 240 $g\ m^{-2}$. After gluing, the veneers were prepressed at ambient temperature and subjected to a pressure of 0.1 $N\ m^{-2}$ for 10 *min*. The veneers were then subjected to hot pressing at a temperature of 150° *C* and a pressure of 0.12 $N\ m^{-2}$ for 10 *min*.

Table 1. Adhesive formulations for plywood manufacture

	Samples		
	A	B	C
Fortifier (%)	29.3	29.3	
Phenol formaldehyde (%)			15.4
Bark extract (%)	37.6	37.6	41.8
Hardener (%)	33.1		
Wheat flour (%)		16.5	18.3
Wood flour (%)		16.5	6.1
Hexamine (%)			18.3

The plywood samples were cut into test pieces as stipulated in the Malaysian Standards MS 3.22:1974 "Specification for Plywood" for knife test assessments and BS 1203:1963 British Standards "Specification for synthetic resin adhesive for plywood" for the failing load (Anonymous 1965).

One layer particleboards of density 720 $kg\,m^{-1}$ and dimensions 300 x 300 x 16 *mm* were produced at 170° *C* with pressing times of 10 and 12 *min.* The wood finish was obtained from a local particleboard factory and comprised particles meant for the core layer of the three-layer board (thickness about 0.4 *mm*). The moisture content of the board was about 9%. The amount of formaldehyde used for cross linking the extract was 15% based on dry extract. In addition, the influence of formaldehyde content (5 and 10%) in mangrove tannin on the properties of particleboards was also investigated. For comparison, particleboards were also prepared using adhesive from mimosa tannin. Methods of testing for particleboard were in accordance with BS 5669: 1979 (Anonymous 1979).

Results and discussion

Properties of bark extracts

The mangrove bark extract had the following properties: pH 4.1; solids content 2.6%; yield 17.7%; and Stiasny number 64.6. The high Stiasny number of the bark extract makes it a potential material for the manufacture of tannin-formaldehyde adhesive for plywood and particleboard. The gelation time of the extract at about 40% solids content was short (100-140 *s*). Similarly the pot life of the extract at pH 8 (about 30% solids content) was very short (< 1 *h*) (Table 2). However, the pot life increased when the pH value was lowered from 6 to 4.

Table 2. Viscosity (cps) of mangrove bark extract (30%) at different pH values (Estimation of pot life)

Time (h)	0	1	2	6	12	40
pH 4	60	100	280	400	500	640
pH 6	40	4540	5360	-	6840	6960
pH 8	135	——	——	solid	——	——

not available

Tannin-Formaldehyde adhesive for plywood manufacture

For the BR (Boil-Resistant) type of adhesive the minimum failing load is 45.4 *kgf* and the value for the knife test is 5. Hence, all the samples for the dry-test and boil-resistant test exceeded the requirements for the BR type of adhesive (Table 3). Those plywood samples using a glue mix which contained a fortifier had more than twice the minimum failing load value minimum for the BR type of adhesive.

In the experiments where the amounts of phenolic resin used were 30 and 35% and that of bark extract accordingly between 70 and 65% respectively, all the values met the specification for BR-plywood (Table 3). The results indicate that

up to 70% mangrove tannin could be used in the glue mix containing phenol formaldehyde without affecting the minimum bonding strength for BR-plywood.

Table 3. Dry and boil-resistant tests of plywood bonded with a mixture of mangrove tannin and phenol formaldehyde

Sample	Dry		Boil Resistant	
	Knife test	Failing load (*kgf*)	Knife test	Failing load (*kgf*)
A	10	150	7	109
B	10	148	7	107
C	10	145	6	79
D	10	107	6	83
E	9	99	7	65

Tannin extract or the production of particleboard

Particleboards made with mimosa tannin had a higher strength than those made with mangrove tannin (Table 4). In the trial to determine the influence of formaldehyde content in mangrove tannin, the amount of formaldehyde was reduced from 10 to 5%. The results indicate that decreasing the formaldehyde content to 5% improved the physical properties (Table 5). Even at this low level of formaldehyde content no great deterioration of the other mechanical properties or thickness swelling of the board were observed.

Table 4. Properties of one-layer particleboards at 15% resin content

Bark Extract	Board Properties		Mechanical Properties			Thickness Swelling (%)	
			Bending Strength ($kg\ cm^{-2}$)	Internal Bond Strength ($N\ mm^{-2}$)			
	Thickness (*mm*)	Density ($g\ cm^{-3}$)		Dry	Wet	2 *h*	48 *h*
Mangrove	19	0.90	145	0.21	-	9.1	23.0
	19	0.90	165	0.22	-	8.3	20.4
Mimosa	19	0.95	261	0.47	0.23	6.3	14.9
	19	0.95	305	0.83	0.34	6.2	16.7

Table 5. Influence of formaldehyde content in mangrove tannin on the properties of particleboard

Formaldehyde Content (%)	Board Properties		Mechanical Properties		Thickness Swelling (%)	
	Thickness (mm)	Density ($g\ cm^{-3}$)	Bending Strength ($N\ mm^{-2}$)	Internal Bond Strength ($N\ mm^{-2}$)	2 h	48 h
5	19.0	0.94	153	0.25	9.4	20.1
10	19.0	0.90	122	0.16	7.6	18.2

Conclusions

The yield of tannin extract by water extraction from mangrove bark was 17.7% making it an excellent raw material. The mangrove bark extract showed high reactivity towards formaldehyde, with a Stiasny number of 64.6 and a short gelation time (40% solids content) of 100-140 *s*. In this preliminary investigation, in the presence of a fortifier having high methylol content, the mangrove bark extract could be used up to 70% in the adhesive formulations of plywood. Mangrove bark extract could also be used as a binder in particle board production. However, before commercial trials could be initiated, further investigations are needed in order to optimize the conditions during manufacture of plywood and particleboard.

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