THE ADHESIVE PROPERTIES OF BARK EXTRACT OF *ACACIA MANGIUM*

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MOHD. NOR MOHD. YUSOFF, CHEW, L. T., ABDUL RAZAK MOHD. ALI & NURULHUDA MOHD. NASIR. 1989. **The adhesive properties of bark extract of *Acacia mangium*.** Laboratory investigations on bark extract of 4-y-old *Acacia mangium* trees showed a high reactivity of the extract towards formaldehyde (Stiasny number about 100). Plywood manufactured using the bark extract showed excellent bonding properties with failing loads twice the minimum failing load for Boiling Resistant type of adhesive, stipulated in the British Standards.

Key words: *Acacia mangium* - bark extract - plywood manufacture

Introduction

Acacia mangium has been planted extensively in Peninsular Malaysia. Hence, large quantities of bark would be made available when the timber is harvested. From this bark, a tannin extract can be produced which can be used as wood adhesive for the manufacture of wood based panels. To date there is no information on this potential from *A. mangium* bark. Nevertheless, barks of other *Acacia* species particularly *A. mearnsii* have been widely investigated (Hillis 1981, Pizzi & Scharfetter 1978) and their tannins have been commercially extracted to produce tannin based wood adhesives (Pizzi & Scharfetter 1981).

In view of the current shortage of supply and the indefinite increase in prices of phenol worldwide, it is desirable to find cheaper sources of phenolics, preferably from renewable resources. This paper evaluates the adhesive properties of bark extract from 4-y-old *A. mangium* thinnings.

Materials and methods

Four-year-old *A. mangium* thinnings were obtained from the Batu Arang Forest Plantations in Peninsular Malaysia. The billets were debarked manually. The bark was collected and chopped into smaller pieces of approximately 1.0 × 1.5 *cm.*

The total extractive content of the bark samples was determined by successive solvent extractions using n-hexane, diethyl ether, acetone and methanol. The bark samples were also extracted with water using the four-stage countercurrent method to yield tannin extract. Experiments were also carried out to study the effects of adding sodium carbonate in the extraction water on the yield and properties of the extract.

Tannin extraction was carried out in a water to bark ratio of 5:1 at a temperature range of 60°*C* to 70°*C* for 4 *h*. The filtered bark extract was evaporated under vacuum in a rotary evaporator at about 60°*C* until a bark extract of 34% solids content was obtained. The bark extract was then analysed for its extraction yield, solids content, pH, Stiasny number (SN), and gelation time.

SN is a measure of the reactivity of the extract towards formaldehyde. Extracts with higher SN have better adhesive properties than extracts with lower SN. The gelation time is the time taken for a two or more part system to form a gel of reproducible, but arbitrary, consistency under standard conditions. It is a simple means of assessing the rate of polymerisation or the efficiency of curing agents.

The adhesives were prepared using the following basic formulation: 100 parts by weight of the adhesive (bark extract at 34% solids content and phenol-formaldehyde at 60% solids content); 12 parts by weight of the coconut shell powder; 12 parts by weight of wheat flour ; two parts by weight of the methanol. Two types of adhesives were formulated as follows: Adhesive A (bark extract : phenol-formaldehyde = 3 : 2, parts by weight); Adhesive B (bark extract : phenol-formaldehyde = 1 : 1, parts by weight).

In the manufacture of plywood three species were used namely mersawa, light red meranti and keruing. Each veneer had a thickness of 0.9 *mm* for the surface and 1.2 *mm* for the core. The moisture content of each veneer was from 7 to 8%. The conditions of plywood manufacture were as follows:

Glue spread : 278 $g\ m^{-2}$

Time of cold pressing : 10 *min*

Temperature of hot pressing : 140°*C*

Time of hot pressing : 5 and 6 *min*

Testing of plywood was done according to the Boiling Resistant (BR) method as stipulated in BS 1203:1963 (Anonymous 1963).

Results and discussion

The successive extractions of the bark using neutral organic solvents (Table 1) showed that *A. mangium* contained 33.5% total extractives whereby the acetone and methanol components represented the highest amount of extractives namely 13.7 and 18.6% respectively. The results show that the bark is rich in phenolics and high polymeric compounds and methanol is a good extractive medium for tannin extraction.

Table 1. Extractive content of *A. mangium* bark

Solvents	Yield of extractives (%)
N-hexane	0.88
Diethyl ether	0.33
Acetone	13.69
Methanol	18.64
Total extractives	33.51

The physical properties of tannin extract are given in Table 2. When the thickness of the bark was < 1 *mm*, the yield of the bark extract was 14.6% and its SN 101. Extracts from bark of thickness > 1 *mm* but of different moisture contents (MC) gave yields ranging from 10.9 to 12.4% and SN ranging from 92 to 98. This is equivalent to a decline of 15.0 to 25.3% and 2.4 to 8.2% in the yield and SN respectively. Hence, it is important to chip the barks to < 1 *mm* to obtain extracts with a higher yield and SN. Table 2 also shows that in the extraction of bark > 1 *mm* thick, a decrease in the MC of the barks gave a corresponding decrease in yield. However, the pH values of all the various extracts remained constant.

Table 2. Physical properties of bark extract

Sample number	1	2	3	4
Moisture content (%)	36.7	26.7	17.8	30.2
Bark size (mm)	>1	>1	>1	<1
pH	5.0	5.0	5.1	4.5
Solids content (%)	2.3	2.3	2.6	3.7
Extract yield (%)	12.4	11.1	10.9	14.6
Stiasny number	92.3	95.3	98.1	100.5

The properties of tannin extracts of solid contents, 41 ± 1%, obtained by different extraction media are given in Table 3. The addition of sodium carbonate increased the pH values but lowered the extract yields and the SN of the bark extracts. Water gave the highest extractive yield of 21.0% as compared to 13.7 and 18.6% by acetone and methanol respectively. Water is therefore the most suitable solvent in the extraction of bark for tannin production. Table 3 also shows that all the tannin extracts of *A. mangium* gave a SN of > 100, compared to only 70 for tannin extracts of mangrove species (Mohd. Nor & Abdul Razak 1987). This indicates that the *A. mangium* bark is more reactive than the mangrove bark extract.

Table 3. Properties of bark extract obtained by different extraction media

Extraction medium	Water	Water and 0.5% sodium carbonate	Water and 1.0% sodium carbonate
Extract yield (%)	21.0	14.4	18.8
pH	4.5	5.6	6.1
Stiasny number	122.2	113.3	110.3
Solids content (%) (after evaporation)	42.0	40.0	41.5

The gelation time of the tannin extract upon mixing with formaldehyde (based on 37% solution) at various concentrations of 5, 10 and 15% is given in Table 4. Tannin extracts by water had a gelation time of slightly more than 12 *min* when 5% formaldehyde was added. However, upon further addition of up to 15% formaldehyde, the gelation time was reduced to about 8 *min*. Other tannin extracts by water with 5 and 10% sodium carbonate gave gelation times less than 5 *min* upon additions of 5, 10 and 15% formaldehyde.

Table 4. Gelation time of bark extract

Extraction medium	Formaldehyde (%)		
	5	10	15
Water	12 *min* 26 *s*	10 *min* 42 *s*	8 *min* 8 *s*
Water and 0.5% sodium carbonate	5 *min* 0 *s*	3 *min* 53 *s*	3 *min* 42 *s*
Water and 1.0% sodium carbonate	3 *min* 25 *s*	2 *min* 28 *s*	2 *min* 20 *s*

The test results of plywood manufactured using bark extract as adhesive which was formulated into adhesives A and B are given in Table 5. With hot pressing times of 5 and 6 *min*, plywood made with both adhesives A and B passed the knife tests and minimum failing load for BR type of adhesive specified in the British Standards. Adhesive B gave higher numbers for the knife tests and higher failing loads than adhesive A.

Table 5. Properties of plywood manufactured using bark extract and phenol-formaldehyde

		Time of hot pressing			
		5 *min*		6 *min*	
Wood species	Adhesive	Knife tests	Failing load (*kgf*)	Knife tests	Failing load (*kgf*)
Mersawa	A	10	93.8	10	106.7
	B	10	104.7	10	136.4
Light red meranti	A	6	89.5	6	106.0
	B	9	112.0	10	131.6
Keruing	A	7	109.9	9	145.8
	B	10	171.8	10	165.5

Table 5 shows that the plywood made from keruing species gave the highest failing load followed by plywoods made from mersawa and light red meranti species. The failing load values of the plywood from all the three species were double the minimum failing load for BR type of adhesive (45.4 *kgf*). The results indicate that the bark extract from *A. mangium* could be effectively blended with a fortifier to produce an adhesive that would meet the specifications of BR type of adhesive according to British Standards.

Conclusion

In this study of the adhesive properties of the bark extract of *A. mangium*, the bark extract could be used as a bonding agent to partially replace phenol for plywood manufacture. The bark extract was very reactive as indicated by its SN of above 100. The bonding properties of the plywood using bark extract as an adhesive were excellent, evidenced by the failing loads of the plywoods made, exceeding the minimum requirement for BR type of adhesive specified for the British Standards. Hence, bark extract from *A. mangium* has a great potential for adhesive production in commercial exploitation. However, further investigations are necessary to find out the properties of bark extract from trees of different age groups and to test out their applicability on a commercial scale.

References

ANONYMOUS. 1963. BS1203:1963. *British Standard specification for synthetic resin adhesives (phenolic and aminoplastic) for plywood.*

HILLIS, W.E. 1981. Natural polyphenols (tannins) as a basis for adhesives. *Weyerhaeuser Science Symposium Volume 2.* Phenolic resins - chemistry and application. Weyerhaeuser, Washington. 450 pp.

MOHD. NOR, M.Y. & ABDUL RAZAK, M.A. 1987. Utilization of mangrove bark. Pp. 287 - 292 in *Proceedings of the UNESCO Regional Seminar on the Chemistry of Mangrove Plants.* January 12 - 16, 1987. Chulalongkorn University, Bangkok.

PIZZI, A. & SCHARFETTER, H.O. 1978. The chemistry and development of tannin-based adhesives for exterior plywood. *Journal of Applied Polymer Science* 22: 1745-1761.

PIZZI, A. & SCHARFETTER, H.O. 1981. Adhesives and techniques open new possibilities for the wood processing industry. Part 1: Experience with tannin based adhesives. *Holz als Roh- und Wekstoff* 39: 85-89.