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Quality of rattan board with lamination process using tannin-based adhesives

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Abstract. The use of rattan with a diameter of more than 30 mm as rattan laminated board has prospective opportunities in the market. This paper presents research results on the quality of the *Calamus zollingeri* rattan board glued using tannin adhesive from *Acacia mangium* bark extract. Rattan boards were laminated with 3 glue spread (100, 150, and 200 g/m² surface) and 2 pressing temperature (60°C and 100°C). The quality of gluing was analyzed by testing the bonding strength and formaldehyde emission. Results showed that the best quality of rattan laminated board was observed in 150 g/m² surface glue spread and 60°C pressing temperature application. The formaldehyde emission of products was still within safe level comply with JAS 234-2003 standards.

1. Introduction

Rattan is one of the substitutions of furniture made from wood and is demanded by the market [1,2]. In addition, rattan is one of the trade commodities of non-timber forest products with high export value, and rattan furniture producing regions in Indonesia are Sumatra, West Java, East Java, Kalimantan, Sulawesi [3]. Rattan used by craftsmen in production is with a diameter of less than 30 mm, while rattan with a diameter of more than 30 mm is not utilized [1].

Development of gluing technology provides alternative for rattan-based products into composite products such as rattan boards [4]. Commonly used adhesives for composite wood products are synthetic non-renewable resources which produce formaldehyde emission [5]. The effort of using organic adhesives has been developed to reduce these impacts. One source of organic adhesive is bark waste that contains tannin and can be formulated as an adhesive [5,6]. The bark of the Acacia family such as acacia (*Acacia decurrens* Willd.) and mangium (*Acacia mangium* Willd.) contain many phenolic compounds which can be used as substitutes for resorcinol or phenol [6-8].

Tannin adhesives from mangium bark have been used in improving oil palm trunks [5] and laminated composite panels [9,10] quality as well as gluing rattan boards [4]. This research aims to obtain information on the quality of rattan laminated boards using mangium tannin from bark extract. The data can be determined by the appropriate treatment of pressing temperature and glue spread to produce rattan laminated board.

2. Materials and Methods

The materials used for this study were rattan *Calamus zollingeri* Bec. from Palu, Central Sulawesi, tannin-based adhesives, and tannins from bark extract of *Acacia mangium*. The equipment used were rattan split machine, pickling tub, measuring glass, scales, and universal testing machine.



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The tannin adhesive is made from mangium bark extracted with a water : bark ratio of 1:3 (w/w) which is melted down macerated for 3 hours at 80°C as described in [5]. Dried rattan with 10–15% moisture content is used to make a five-layer rattan laminated board sized 1.5 x 7.5 x 90 cm which compressed for 3 hours with a specific pressure of 10 kg/cm², as done by Pari *et al.* [4].

The characteristics of tannin-based adhesives were analyzed by adhesion properties according to SNI 4567 [11] such as acidity, viscosity, specific gravity, solid content, free formaldehyde and gelatinous time. The quality of the rattan laminated board was examined through testing of the dry condition test sample with three replications. The test includes bonding strength and formaldehyde emission referring to the Japan Agricultural Standard (JAS) Glued Laminated Timber JAS 234-2003 [12].

The results of the test sample were analyzed using ANOVA with 2 factors which are pressing temperature and glued spread and their interaction on the bonding properties and formaldehyde emission of laminated rattan board.

3. Results and Discussion

3.1. Characterization of tannin-based adhesives

Visually, the adhesive from mixing tannin extract from mangium bark with formaldehyde (tannin formaldehyde) produces a dark red liquid that is close to the color of phenol formaldehyde. The tannin-based adhesive characteristics of the formulations from mangium bark extract are presented in Table 1.

Table 1. The fisico-chemistry characterization of tannin-based adhesives.

Properties	Tannin formaldehyde	Phenol formaldehyde*
Visual test	Dark red liquid	Red blackish liquid
Acidity (pH)	10.50	10–13
Viscosity (Poise)	12.34	1.3–3.0
Specific gravity	1.02	1.165–1.200
Solid content (%)	8.63	40–45
Free formaldehyde (%)	0.054	< 1
Gelatinous time (minutes)	300	≥ 300

Remarks: * source: SNI 4567 [11]

The results showed that the parameters of viscosity, specific gravity and solid content are different with phenol formaldehyde adhesive commercially (SNI 4567). Specific gravity and solid content lower than the standard indicate that tannin adhesive has a low solid content [5]. The adhesive with high viscosity has shorter pot life and will harden more quickly than low viscosity adhesive, therefore the quality of adhesion is relatively low [13]. However, the pot life of resin tannins as showed in the results of gelatinous times value is still safe because the values > 88 minutes [14]. Tannin-based adhesive with characteristics as mentioned above, has the ability to penetrate pores of lamina material and form a bond with good adhesion [15]. Besides, tannin-based adhesive produced relatively environment-friendly, indicated by the value of free formaldehyde that is lower than the required standard value [5].

3.2. The evaluation of rattan laminated boards

The application of mangium tannin adhesives in rattan laminated boards manufacturing was examined through a bonding strength testing approach. Formaldehyde emission testing was conducted to

determine the levels of formaldehyde from adhesives. Table 2 shows that the treatment of pressing temperature gave significant different results, while the treatment of glue spread and their interactions gave highly significant different results on bonding strength. In addition, both the treatment and the interaction have a highly significant effect on formaldehyde emission.

Table 2. Analysis of variances on bonding strength and formaldehyde emission.

Source of variation	df	F-calculation	
		Bonding strength	Formaldehyde emission
Pressing temperature, A	1	5.62 ^s	705.90 ^{hs}
Glue spread, B	2	308.36 ^{hs}	319.64 ^{hs}
A * B	2	243.53 ^{hs}	107.21 ^{hs}

Remarks: hs = highly significant, s = significant, df = degree of freedom.

The quality of the rattan laminated boards from the test results is presented in Table 3. The highest bonding strength value (45.52 kg/cm²) was obtained in the sample with a glue spread of 150 kg/cm² surface and pressing temperature of 60°C with a formaldehyde emission value of 1.04 mg/L. The bonding strength test value does not meet the requirements of JAS 234-2003 because the value is less than 54 kg/cm², however formaldehyde emission from the sample product meet the requirements of JAS 234-2003 with the category F*–F**. The bonding strength value of the product under study is relatively better compared to the results of the study of [4], which obtained the value of bonding strength from the rattan laminated board (40.36 kg/cm²) using a mangium tannin adhesive of 200 g/cm² surface with pressing temperature 100°C, and formaldehyde emission reached 2.12 mg/L. Furthermore, the results of the study of [4] also showed that the same product using 100 g/cm² surface glue spread and pressing temperature at 60°C resulted in bonding strength and formaldehyde emission of 39.27 kg/cm² and 0.54 mg/L. Based on these results, the use of tannin adhesive glue spread with more adhesive per gluing surface unit (g/m² surface) and a higher pressing temperature, does not necessarily result in better adhesion, but has the opportunity to increase formaldehyde emission.

Table 3. The average value of bonding strength and formaldehyde emission.

Pressing temperature, °C	Glue spread, g/m ² surface	Test parameter	
		Bonding strength, kg/cm ²	Formaldehyde emission, mg/L
		$\bar{X} \pm Sd$	$\bar{X} \pm Sd$
60	100	39.39 ± 0.271	0.54 ± 0.023
	150	45.52 ± 0.542	1.04 ± 0.019
	200	34.71 ± 0.248	1.14 ± 0.143
100	100	38.53 ± 0.259	1.03 ± 0.003
	150	41.47 ± 0.115	2.05 ± 0.059
	200	41.02 ± 0.729	3.21 ± 0.172

Remarks: $\bar{X}$ = mean value; Sd = standard deviation.

This rattan laminated board is also better compared to laminated products made from types of low-density wood originating from plantations, such as sengon (*Falcataria moluccana*), jabon (*Anthocephalus cadamba*), mangium (*Acacia mangium*), sungkai (*Peronema canescens*), and rubberwood (*Hevea brasiliensis*) which use tannin as an adhesive with a glue spread of 140–170 g/cm² surface, with bonding strength of 22.19 kg/cm², 32.36 kg/cm², and 25.56 kg/cm² [9], 35.23 kg/cm², and 32.40 kg/cm² [16]. The bonding strength value of this rattan laminated board is also better than the laminated board made from bamboo andong, mayan, and betung using tannin adhesives from merbau

wood powder extract (21.46–33.52 kg/cm²) [17], and laminated products from a mixture of kecap and sengon wood (18.99 kg/cm²) using isocyanate adhesives (PI Bond) [18].

4. Conclusion

Rattan *Calamus zollingerii* with diameter more than 30 mm could be used as rattan laminated board using tannin of mangium bark extract as adhesive. The highest bonding strength values of rattan laminated board products in this research was observed in glue spread treatment of 150 g/m² surface and a pressing temperature of 60°C, with the formaldehyde emission at 1.04 mg/L this product is categorized as F** according to JAS 234-2003 standards.

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