The Potential of Tannin from *Acacia mangium* Willd. Barks As Wood-Adhesive in Indonesia

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Abstract

Plantation forests of fast growing species have been very common in many countries. In Indonesia, through the industrial timber estates programs, nowadays more than 1 million hectares of fast growing species have been planted. *Acacia mangium* is mostly used for the development of timber estates, since it belongs to the most important wood species as raw materials for pulp and paper or medium density fiberboard (MDF) industries in Indonesia. In these industries, synthetic resins (e.g. urea formaldehyde, phenol formaldehyde) are used as adhesives. However, the supply of raw materials for the manufacture of synthetic resins are always in deficit and the prices for those have been escalating. In the industrial processing, the raw material of wood has to be debarked, because the bark decreases the pulp quality. Approximately 10-15% volume of every log is bark. Until now, the most utilization of bark in the factory is for energy production by burning. Better utilization of this product is preferable and on demand in order to reduce the proportion of synthetic resin used in wood-panel products, i.e. MDF and plywood. It is known that tannin extract, produced from tree bark, can be used as wood adhesive for the manufacture of wood based panels. To date, no serious attention has been given yet to use tannin as wood adhesive, especially in Indonesia. Research has been carried out in order to determine the potential of tannin from *Acacia mangium* as wood-adhesive. The key factors for the successful utilization of bark as adhesives are the polyphenol content in the bark and its reactivity to form condensation products.

Key words: Tannin, *Acacia mangium*, bark, medium density fiberboard (MDF), plywood

Acacia mangium and Its Potential

Acacia mangium Willd. is a leguminous tree species in the family Leguminoseae, sub-family Mimosoideae. The genus *Acacia* includes more than 1,000 species of trees and shrubs that occur in Africa, America, Asia, and Australia, with the majority of species found in Australia. *A. mangium* is native to Australia, Papua New Guinea, and Indonesia (Awang and Taylor, 1993).

As one of the fast growing tree species, beside *Paraserianthes falcataria*, *Gmelina arborea*, *Eucaliptus* sp., etc., *A mangium* is mostly used for the development of timber estates in some tropical regions including Indonesia. The species is selected due to its good characteristics; it is very site-adaptable and shows satisfactory growth even on eroded, rocky, thin mineral and deeply weathered, alluvial soils. Its symbiotic relationship with the nitrogen-fixing soil bacteria of the *Rhizobium* genus provides the tree with sufficient nitrogenous compounds to sustain growth. It grows well on *Imperata cylindrica* grasslands, which are usually difficult to reforest due to adverse soil conditions and weed competition. It can also grow on acidic soils with pH as low as 4 (Awang and Taylor, 1993).

According to Indonesian Ministry of Forestry (2001), there are 131 forestry companies that plan to establish 5.8 million ha of industrial timber plantations using above fast growing tree species and other locally grown species. By the end of 2001, however, the realised plantations were only 1.8 million ha (around 30% of the target), since some technical and non-technical problems were faced during the programs.

Of these plantations, about 800,000 ha are *A. mangium* and it was predicted that this kind of plantation will reach 1 million ha by the year 2010. This makes Indonesia as the largest area for *A. mangium* plantation in Asian-Pacific (Natadiwirya, 2002). Data from PT. Musi Hutan Persada, one of timber plantation located in South Sumatra, showed that the area planted with this species has covered approximately 200,000 ha (Arisman, 2002).

Centre for seed technology, Indonesian Ministry of Forestry, reported that increment of *A. mangium* can reach 40 m^3/ha/year or approximately 400 m^3/ha for 10 year rotation. If one million ha plantation is reached by the year 2010, around 40 million m^3 logs per year could be produced, or almost twice of the annual allowable cutting (AAC) from natural forest (Natadiwirya, 2002)

A. mangium itself is a relative newcomer to industrial plantation, with the earliest forestry and forest products studies dating back only about 20 years (Yazaki, *et al*., 1998). Its wood makes attractive furniture and cabinets, moldings, and door and window components since no problem in sawing or peeling (recovery low). Planes well. Sands easily. Drills easily and turns well with low pressure and excellent nailing properties. Due to some changes in wood utilization technology, *A. mangium* has been utilized in the production of tannin, pulp paper, and as a component of composite wood products. Furthermore, in view of the changing picture of available wood resources, composite products in general will become increasingly important in meeting demand for wood products.

In the industrial processing, the raw material of wood has to be debarked, because the bark decreases the quality. Approximately 10-15% volume of every log is bark. Until now, the most utilization of bark in the factory is for energy production by burning. Bark is the material formed by a tree to the outside of the vascular cambium. The vascular cambium forms wood (xylem) to the inside and inner bark (phloem) to the outside. Chemical compositions of bark consist of cellulose, polyoses, lignin, polyphenol, suberin and extractives (Fengel and Wegener, 1983). The term of polyphenols refers to a large number of related compounds deriving mainly from flavonoid derivates. Tannin extracted from tree bark and other natural resources, such as certain seeds, are such potential substitute for phenolics. Barks generally contain higher amounts of polyphenolics compared to wood; the most important being polyphenolic tannins (Coppens *et al*., 1980). There have been some materials used commercially such as polyflavonoids polymers from Western hemlock (*Tsuga heterophylla* (Raf.) Sarg), tannin from the bark of the black wattle or mimosa tree (*Acacia mearnsii* De Wild.), and wax from the bark of Douglas fir (*Pseudotsuga menziesii* (Mirb.) Franco) (Laver, 1991).

Following Dalton's pioneering work on wattle tannin (*A. mearnsii*) in the 1950's, the basic principles for the use of wattle tannin in wood adhesives were established by Plomley (1966). Wattle tannin adhesives were commercialised in Australia for plywood production at this time, and this application was followed in 1968 by use in particleboard production. In view of the large potential market for tannin and the extensive present and future plantings of *A. mangium*, an opportunity may exist for a major industry to be developed if the bark extracts from this species can be shown to be suitable.

Wood Adhesives from Tannin *A. mangiu*m barks

The term tannins cover various vegetable substances having a tanning effect. Requirements for tanning effects are the existence of several phenolic hydroxyl-groups and the tendency to build surfeited solutions. Tannin extracts are not pure polyflavonoids. They are often accompanied by non-tannins compounds like simple Mono- or Biflavonoids (phenolic non-tannins), carbohydrate and hydrocolloidal gums.

Tannin based glue systems, based on natural tannins extracted from bark, have been used very successfully for many years but have not gained widespread use due to limitations on availability. These glues are usually prepared by chemically reinforcing a "tanning extract" in order to overcome the deleterious effect of the non-polyphenolis ingredients (the non-tannins), which are an essential component of such tanning extracts in their normal application for leather tannage, and then reacting this reinforced "tannin" with a source of formaldehyde at point of use to prepare a short pot life, rapid curing tannin formaldehyde glue system (Long, 1991). In particular, condensed tannins from tree barks are used for adhesives after reaction with formaldehyde, as additives for drilling mud, as complexing agent for metal ions, and as polyols in the reaction with diiscoyanates for adhesive and urethane foams (Laver, 1991). Yusoff, *et al*. (1988) recorded that extracts from plant give phenols which are used for synthesis of wood adhesives: a resin is resulted when formaldehyde is added to the polyphenolic substance of the plant extract.

As a glimpse, a great deal of progress has been made on adhesive applications of condensed tannins derived from tree barks, particularly in South Africa where wattle (mimosa) adhesives are important commercial products and are even exported to other countries (Laks, 1991). Nowdays, two German companies are using quebracho tannin and wattle tannin for the production of particleboards and medium density fiberboards (MDF) (Roffael, *et al*., 2000) and many German companies become interested in using tannins as a binder for production of boards with low emission values.

In general, the hot water extraction method (dilute solution) is used in the manufacture of tannin for adhesives because such methods are the cheapest. However, some of the extractable fractions affect adhesive properties.

The tannin content of the bark extract was measured by reaction of the extract with formaldehyde in acid medium according to the Stiasny method (Wissing 1955 cit. in Prasetya and Roffael, 1991). Stiasny number (SN) of tannin corresponds to the reactivity of tannin to formaldehyde. SN value is as an indicator of the amount reactive compounds contained in the extracts Extract with higher SN has better adhesive properties than extract with lower SN..

In comparison to commersialised tannin, wattle and quebracho tannin (Table 1), *A. mangium* tannin from several locations in Indonesia contains relatively high extract content and SN and shows promising results.

Table 1. Extract content and SN of *Acacia mangium* from several location in Indonesia

Species	Extract content or yield (%)	SN (%)
Acacia mangium bark (East Kalimantan)[a]	21.98	n.d
Acacia mangium bark[b]	30.26	n.d
Acacia mangium bark (South Sumatera)[c]	35.13	n.d
Acacia mangium bark (Darmaga-West Java)[d]	29.76	80.03
Acacia mangium bark (BIOTROP-West Java)[e]	18.38	90.87
Acacia mangium bark (Parung Panjang-West Java)[f]	22.29	90.94
Wattle or mimosa bark (*Acacia mearnsii*)[g&h]	35	86.1
Quebracho wood (*Schinopsis* sp.)[g&h]	21	104.1

[a] Achmadi and Darmawan, 1991
[b] Pari, *et al*., 1992
[c] Fahmi, Ar., 1988.
[d] Prasetya, *et al*., 1998.
[e] Syarif, A., 2001
[f] Karlinasari, L., 2001
[g] Long, 1991
[h] Roffael, et al., 2000
n.d. = no data

The content and composition of extractives vary not only among wood species; they also depend on the age of the tree, geographical site and the climatic factor. Averaged throughout the species, the foliage tannin concentration increased significantly as the site quality decreased. The increase in tannin concentration was approximately proportional to decrease in site quality (Tiarks, *et al*., 1989).

Many environmental factors could influence the amount of tannin in plants, including nutrient status, light intensity, water deficit and temperature. The base status of the soil, meaning the availability of nutrients such as magnesium and calcium, determined the yield of polyphenols. Sites on soils with a low pH were expected to have higher polyphenol concentrations in the leaves. Later, deficiencies of nitrogen and phosphorus were found to be more important in controlling polyphenol production, whereas a calcium deficiency seemed to decrease the polyphenol content (Tiarks, *et al*., 1989).

Karlinasari (2001) reported that *A. mangium* tannin reinforced by synthetic resins such as Urea Formaldehyde (UF) and Phenol Formadehyde (PF) into Medium Density Fiberboard increased strength properties (modulus of rupture, modulus of elasticity) and formaldehyde release. In addition, the dimensional stability (thickness swelling) or water resistance, exiting tannin in UF-resin systems lead to decrease thickness swelling (TS) while in PF-resyn systems lead to increase TS. The bondability (internal bond) seemed to decrease as a high amount of tannin was used in UF and PF-resyn systems. Due to the problem with internal bond (IB) and TS; therefore further research on bondability and dimensional stability are needed

The application of tannin in plywood manufactures in Indonesia has been carried out by several reasearchers such as Prasetya, *et al*. (1998), and Achmadi and Aryeti (1993). According to Prasetya *et al*. (1998), composition of tannin formaldehyde was better to be applied for plywood in grade interior than that of eksterior in terms of shear strength. Meanwhile Achmadi and Aryeti (1993) reported that mechanical properties or shear strength of plywood glued with tannin PF mixture could not reach Indonesian standard.

Tannins, being phenolic in nature, undergo the same well-known reactions of phenols with formaldehyde either base-or acid catalysed (PIZZI, 1980). Formaldehyde reacts with tannins to produce polymers through methylene bridge linkages to reactive positions of the flavonoid molecules, mainly the A-ring. However, because of their size and shape, the tannin molecules become immobile at a low level of condensation with formaldehyde, so that the available reactive sites are too far apart for further methylene bridge formation. The results are incomplete polymerization that leads to the weakness and brittleness that are characteristics of many tannin formaldehyde adhesives (PIZZI, 1980; 1998). The presence of synthetic resin will considerably improve the strength of the cross-linked adhesive network.

Conclusion

Tannin from *A. mangium* has great potential for use as adhesives in wood industry. Research has shown that incorporating tannins with phenol formaldehyde and other crosslinking agents produced good-quality adhesive for the manufacture of wood composites such as MDF and plywood. *A. mangium* tannin needs to be more explored with the available methods and technology to get satisfy result.

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