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ACETYLATION OF ACACIA MANGI UM WOOD FIBRES AND ITS APPLICATION IN THE MEDIUM DENSITY FIBREBOARD

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ACETYLATION OF *Acacia mangium* WOOD FIBRES AND ITS APPLICATION IN THE MEDIUM DENSITY FIBREBOARD

BY

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Abstract of dissertation submitted to the Senate of Universiti Pertanian Malaysia in fulfilment of the requirements for the degree of Doctor of Philosophy.

ACETYLATION OF *Acacia mangium* WOOD FIBRES AND ITS APPLICATION IN THE MEDIUM DENSITY FIBREBOARD.

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The effective utilisation of low quality wood of *Acacia mangium* Willd. would be for the production of medium density fibreboard (MDF). However, MDF is susceptable to biodegradation and dimensionally unstable when in contact with water, which is also associated with the deterioration of the mechanical and physical properties of the board. Nonetheless, research on wood has shown that it is possible to eliminate the biodegradation and dimensional instability through chemical modification. This study was therefore conducted with the aim of evaluating the acetylation characteristics of *Acacia mangium* wood fibres and the properties and performances of the board produced.

Pilot acetylation was conducted to establish the optimum reaction conditions, which was subsequently used as a guide in the bulk acetylation of the fibres. Boards

were manufactured from both the acetylated and unacetylated fibres and the properties and performances of the boards were evaluated.

The pilot acetylation showed that the best reaction conditions was on wood fibres with 6.5% initial moisture content reacted at 120°C using pyridine as a catalyst. The bulk acetylation was successfully conducted to achieve the targetted weight gain. No problem was encountered in the manufacturing of board of both the unacetylated and acetylated fibres.

The evaluation on the properties and performances of the boards showed that the equilibrium moisture content (EMC) of the board of acetylated fibres (acetylated board) decreased. Dimensional stability of the acetylated boards were enhanced. Both reversible and irreversible thickness swelling reduced. The antiswelling efficiencies (ASE) of the 9.1% WG board ranges from 30.9% to 36.8%; for the 13.9% WG board, 51.6% to 57.6%; and for the 20.4% WG board, 67.1% to 70.1%. The values of both the modulus of elasticity (MOE) and the modulus of rupture (MOR) of the acetylated boards have slightly reduced. However, after aged test, the values of MOE and MOR of the acetylated boards were higher than that of the unacetylated board. The internal bond (IB) strength of the acetylated boards was slightly enhanced. After being boiled, only the IB strength of the unacetylated board reduced significantly. The acetylated boards were considerably resistant to *Pycnoporus sanguineus* fungal attack, but not much to the *Coptotermes curvignathus* termite attack. Comparatively, the 13.9% WG board showed the best performance.

Further studies such as on the resistance of acetylated boards against other species of wood decaying fungi and termites would be necessary to add to the cost effectiveness of this process.

Abstrak dissertasi yang dikemukakan kepada Senat Universiti Pertanian Malaysia sebagai memenuhi syarat keperluan untuk Ijazah Doktor Falsafah.

ASETILASI GENTIAN KAYU *Acacia mangium*
DAN PENGGUNAANNYA DALAM
PAPAN GENTIAN BERKETUMPATAN SEDERHANA.

Oleh

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Penggunaan berkesan bagi kayu berkualiti rendah *Acacia mangium* Willd. adalah melalui penghasilan papan gentian berketumpatan sederhana (MDF). Bagaimana pun MDF adalah rentan terhadap biodegradasi dan berdimensi tidak stabil apabila terkena air, di mana ianya juga mengakibatkan kemerosotan sifat mekanikal dan fizikal papan. Namun demikian, penyelidikan terhadap kayu telah menunjukkan bahawa biodegradasi dan ketidakstabilan dimensi boleh ditingkatkan melalui pengubahsuaian kimia. Oleh yang demikian, kajian ini dilakukan dengan tujuan untuk menilai ciri asetilasi gentian kayu *Acacia mangium* dan sifat-sifat serta prestasi papan yang dihasilkan.

Asetilasi panduan telah dilakukan untuk mewujudkan keadaan tindakbalas yang optimum, yang boleh digunakan

sebagai panduan dalam asetilasi pukal gentian. Papan-papan telah disediakan dari kedua-dua gentian, iaitu yang telah diasetilkan dan yang tidak diasetilkan. Sifat- sifat serta prestasi papan telah dikaji.

Asetilasi panduan menunjukkan bahawa tindak balas yang terbaik adalah dengan menggunakan gentian kayu yang mengandungi kelembapan awal 6.5% untuk ditindakbalaskan pada 120°C dengan menggunakan pyridina sebagai mangkin. Asetilasi pukal telah berjaya dilakukan untuk mencapai perolehan berat sasaran. Pembuatan papan daripada gentian yang telah diasetilkan dan yang tidak diasetilkan dapat disediakan dengan mudah.

Penilaian terhadap sifat-sifat dan prestasi papan menunjukkan bahawa kandungan kelembapan seimbang (EMC) untuk papan yang disediakan daripada gentian yang telah diasetilkan (papan diasetilkan) telah berkurangan. Kestabilan dimensi bagi papan-papan diasetilkan bertambah baik. Kedua-dua pengembangan tebal yang berbalik dan tidak berbalik berkurangan. Keberkesanan anti pengembangan bagi papan dengan perolehan berat 9.1% berjulat dari 30.9% ke 36.8%; bagi papan dengan perolehan berat 13.9%, 51.6% ke 57.6%; dan bagi papan dengan perolehan berat 20.4%, 67.1% ke 70.1%. Nilai kedua-dua modulus kenyalan dan modulus patahan bagi papan-papan diasetilkan berkurangan sedikit. Setelah melalui ujian penuaan, nilai modulus kenyalan dan modulus patahan bagi papan diasetilkan adalah lebih tinggi berbanding dengan papan tidak diasetilkan. Kekuatan ikatan dalaman bagi papan diasetilkan telah bertambah baik. Setelah direbus, hanya kekuatan ikatan dalaman bagi papan tidak diasetilkan berkurangan dengan bermakna. Papan-papan diasetilkan boleh dianggap sebagai tahan terhadap serangan kulat *Pycnoporus sanguineus*, tetapi kurang tahan terhadap serangan anai-anai *Coptotermes curvignathus.* Secara bandingan, papan dengan perolehan berat 13.9% telah menunjukkan prestrasi yang terbaik.

Kajian-kajian lanjut seperti kerintangan papan diasetilkan terhadap spesis kulat pereput kayu dan anai-anai yang lain perlu dilakukan bagi menambah keberkesanan kos proses ini.

CHAPTER I

INTRODUCTION

The successful introduction of *Acacia mangium* into Sabah, Malaysia from Australia in 1966, promotes this species to a major fast-growing tree in forest plantation programmes in Asia and the Pacific. Currently, over 150,000 hectares of *Acacia mangium* have been planted worldwide, and the area covered is expanding rapidly (Kamis and Taylor,1993).

However, early indication showed that due to its inherent characteristics as a fast growing tree, which produced wood of inferior quality has led to some problems in solid wood utilization. It has been envisaged that effective utilization of this species may therefore lies in the production of composite wood products, particularly the Medium Density Fibreboard (MDF).

MDF was first commercially manufactured in the United States in 1960s (Maloney,1991). In 1977, MDF was manufactured in Western Europe. Since its introduction, MDF has gained a fast reputation as a panel product because of its properties of being high in internal bond strength, good screwholding power, good machinability, and uniformity in structure. These properties are similar to those of solid wood. Compared with particleboard, MDF shows exceptional surface and form stability (Suchsland, 1973). These properties also make MDF suitable for furniture manufacturing.

MDF by definition is a composite material which consists of dry wood fibres bonded together into a solid panel with a resin binder under controlled heat and pressure (Maloney,1991). As such, it is susceptable to biological degradation and dimensionally unstable when in contact with water.

Wood fibres which composed of lignin and carbohydrates are biologically degraded because organisms recognize these polymers and possess specific enzyme systems capable of hydrolyzing them into digestable units (Rowell,1983). Of these polymers, the hemicelluloses are probably the first to be attacked because they are the most accessible. The accessible portion of cellulose is attacked next. Because the high-molecular-weight cellulose is primarily responsible for the strength in wood, its biological degradation through oxidation, hydrolysis, and dehydration reactions causes wood to lose strength. Attack by brown-rot fungi, for example, greatly reduces the degree of polymerization in the holocellulose fraction, even when accompanied by very low wood weight loss (Rowell et al., 1988).

Similar to solid wood, MDF is hygroscopic in nature. It shrinks and swells in response to changing relative humidities in the surrounding air. Wood fibres change dimension because the cell wall polymers contain hydroxyl and oxygen-containing groups that attract moisture through hydrogen bonding. Compared to solid wood, swelling in MDF is compounded through the occurrence of reversible and irreversible swelling caused by the release of residual compressive stress imparted to the board during the pressing process. It is generally accepted that thickness swelling in composite wood product is associated with deterioration of the mechanical and physical properties of the board (Suchsland and Woodson,1991; Vital et al.,1980).

Development of MDF with greater dimensional stability, improved physical and mechanical properties and enhanced biodegradability would be necessary. Such development would diversify its end uses, apart from the mainstream interior furniture making and would also widen the overall size of its market.

Earlier report suggested that it is possible to reduce the rate of biodegradation and the dimensional instability through chemical modification of individual cell-wall polymer components (Youngquist and Rowell, 1988). Rowell (1983) defines chemical modification as any chemical reaction between some reactive part of a wood cell wall component and a single chemical reagent, with or without a catalyst, that results in the formation of a covalent bond between the components. The most abundant reactive chemical sites in wood are the functional hydroxyl groups of cellulose, hemicelluloses, and lignin. Most of the research done in the area of chemical modification involves the reaction between chemical reagents with these hydroxyl groups (Rowell,1975). However, certain problems arised in treating bigger wood dimension because reaction can only take place when the reagent is in contact with the reactive site. Furthermore, to initiate the reaction, it is necessary to apply heat. Since wood is not a good thermal conductor, the rate and extent of the reaction may be limited by heat flow factors. But, when wood is in fibre form, these constraints are minimised because the wood fibre cell wall is considerably thin and this facilitates the penetration of reagent gaining accessibility to cell wall polymers. Similarly, heat has to flow only the same distance from a hot liquid or vapour environment in order for activation to occur. Thus, chemical modification technology has the potential to be applied in the production of biologically resistant and dimensionally stable MDF.

Rowell (1983) stated that chemical reagents used in the modification of wood must contain functional groups that can react with hydroxyl groups of the wood components. Rowell (1984) further reviewed many different types of reagents that have been used to react with many species of wood and non wood materials. The chemicals used in these studies include anhydrides, epoxides, isocyanates, lactones, acetals, and alkyl chlorides. Catalysts were also used which among others include zinc chloride, dimethyl formamide, sodium acetate, urea ammonium sulfate and pyridine. However, pyridine and dimethyl formamide were noted to cause 20 to 25 % more swelling to wood (Risi and Arseneau, 1957; Ashton, 1973). This would further facilitate penetration of reacting chemicals. Although considerable research has been conducted on epoxides (Rowell and Ellis, 1984) and isocyanates (Rowell and Ellis, 1981), the most economically promising chemical modification technique at present is acetylation of wood with acetic anhydride (Rowell,1982). This procedure only involves a single dip in acetic anhydride and requires no solvents or catalysts. The reaction time is greatly shortened and the recovery of reusable and by-product chemicals simplified. Nonetheless, different wood species behaved differently to acetylation as indicated by Imamura and

Nishimoto,1987; Rowell,1991; Hadi and Febrianto,1991; Jalaluddin,1993. This study is therefore conducted to produce chemically modified medium density fibreboard with enhanced properties from plantation grown *Acacia mangium* wood fibres.

Objectives

The specific objectives of this study are as follows:

1. To determine the major chemical constituents of *Acacia mangium* wood.

2. To determine the rate of acetylation of *Acacia mangium* wood fibres with acetic anhydride.

3. To fabricate Medium Density Fibreboard using acetylated and untreated (control) *Acacia mangium* wood fibres using phenol formaldehyde (PF) resin as binder.

4. To investigate the dimensional stability, physical, mechanical and biodegradation properties of acetylated and untreated *Acacia mangium* Medium Density Fibreboard.

CHAPTER II

LITERATURE REVIEW

A Short Note on *Acacia mangium*

Acacia mangium Willd. is a leguminous tree species that belongs to the Leguminosae family, Mimosoidae Sub-family. The genus Acacia includes about 1200 species of trees and shrubs which occur in Africa, The Americas, Asia, and Australia, with the majority of species found in Australia, Papua New Guinea, and Indonesia (National Reseach Council,1983).

Acacia mangium was introduced into Sabah, Malaysia in 1966 (Tham, 1976). This introduction consisted of a small quantity of seed collected from a single tree standing beside a bridge over Lacey's Creek, on the road between Mission Beach and El Arish in Queensland, Australia. The initial seedlings were planted as a firebreak around trial plots of pines in Ulu Kukut in Jalan Madu and as trial plots in Gum-Gum and Sibuga in Sabah. The trees grew very well and out-performed *Eucalyptus deglupta* and *Gmelia arborea* in