PHYSICAL, MECHANICAL AND NANOSTRUCTURAL PROPERTIES OF *ACACIA MANGIUM* WOOD FROM SABAH USING X-RAY DIFFRACTION AND SMALL-ANGLE X-RAY SCATTERING METHODS

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DAN X-RAY SMALL ANGLE SCATTERING

IJAZAH: DOKTOR FALSAFAH (BIOFIZIK)

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DECLARATION

This thesis is the result of my own work with the exception of quotations, excerpts, equations, summaries and references, the sources of which have been duly acknowledged.

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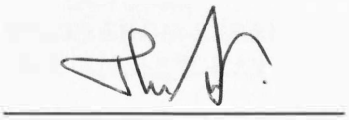

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ABSTRACT

PHYSICAL, MECHANICAL AND NANOSTRUCTURAL PROPERTIES OF *ACACIA MANGIUM* WOOD FROM SABAH USING X-RAY DIFFRACTION AND SMALL-ANGLE X-RAY SCATTERING METHODS

The main purpose of this study is to provide the knowledge and data on the physical, mechanical and nanostructural properties of *Acacia mangium* wood from Sabah. A further objective was to examine the influence of microfibril angle (MFA) on strength, stiffness, tree age, the distance from pith to bark and the internal structure of the wood and to predict the perfect growth age which produces pure crystalline cellulose and more ordered. The results show that the fully grown which produce fully crystalline cellulose will denote as the optimum age (a_o) was found to be 23.45 year for the pith region, a_o was about 23.29 year for the bark region and for the pith - bark region about 22.04 ± 0.05 year. The mean length of cellulose crystalline ranged from 3.86 Å in the 3-year-old disc to 23.43 Å in the pith region of 15-year-old disc. MFA was found to decrease whilst tree age increased for the pith and bark regions. The general trend was for the MFA to be greatest in the young wood of age 3-year-old about 26.13°, and to decrease gradually with increasing the tree age. The lowest was found in the pith region of tree at 15-year-old where the angle varied from 1.99° to 0.20°. Small-Angle x-ray scattering analysis showed that fibre length, L increased from pith to bark for wood disc of 10-year-old. An inverse relationship between surface area of the single fibre, S and the distance from pith to bark was evident in this study within a single tree of 10-year-old. It was also found that *Acacia mangium* wood swells and shrinks in length but at the same time swells and shrinks less in the tangential and radial directions. A strong negative linear relationship was found to exist between MFA and modulus of elasticity, MOE. This trend has also been observed between MFA and modulus of rupture, MOR. An inversely correlation was evident between glass transition, T_g and MFA in *Acacia mangium* wood. The regression analysis of MFA and T_g data shows that about 66.4% of the variation in T_g was explained by MFA. It was found that *Acacia mangium* wood of age 3 year-old has the highest relaxation length (83.33 cm) and half-thickness value (57.75 cm). Tree of 15 year-old has the least relaxation length and half-thickness of 28.65 cm and 19.85 cm respectively. Neutron transmission test showed that the actual water uptake inside the vessels and through the fibres composite is ranged from 4.445% to 6.981% after 20 hours drying under 105 C° ±1C°.

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ABSTRAK

Tujuan kajian ini dijalankan adalah untuk mengkaji sifat fizikal, mekanikal dan struktur nano kayu Acacium mangium dari Sabah. Dalam kajian ini, pengaruh sudut mikrofibril terhadap kekuatan, kekakuan, struktur dalaman kayu, umur pokok dan jarak daripada empulur ke kulit kayu dikaji. Selain itu, umur pertumbuhan pokok yang sempurna untuk menghasilkan hablur selulosa asli yang teratur juga akan diramalkan. Keputusan yang didapati menunjukkan pertumbuhan pokok yang dapat menghasilkan hablur selulosa yang dikatakan sebagai umur optimum pokok tersebut adalah 23.45 tahun untuk bahagian empulur, 23.29 tahun untuk bahagian kulit kayu dan untuk bahagian empulur – kulit kayu pula 22.04 ±0.05 tahun. Purata panjang hablur selulosa adalah dalam julat 3.86 Å untuk pokok yang berumur 3 tahun hingga 23.43 Å untuk pokok yang berumur 15 tahun. Untuk bahagian empulur dan kulit kayu, MFA didapati menurun sejajar dengan pertambahan umur pokok. Kebiasaannya nilai MFA adalah besar untuk pokok yang masih muda (dalam lingkungan umur 3 tahun), iaitu 26.13° dan akan menurun secara berperingkat dengan pertambahan umur pokok tersebut. Nilai yang paling rendah didapati pada bahagian empulur pokok yang berumur 15 tahun di mana sudutnya adalah dalam julat 1.99° - 0.20°. Analisis Small-Angle x-ray scattering menunjukkan bahawa panjang fiber, L telah bertambah daripada bahagian empulur ke kulit kayu untuk pokok yang berumur 10 tahun. Songsangan perhubungan antara permukaan fiber tunggal , S dan jarak daripada empulur ke kulit kayu merupakan bukti dalam kajian yang telah dijalankan pada pokok yang berumur 10 tahun. Kayu Acacia mangium juga didapati mengembang dan mengecut pada arah pemanjangan tetapi dalam masa yang sama, ia kurang mengembang dan mengecut pada arah tangential dan radial. Keputusan kajian menunjukkan perhubungan garis lurus yang negatif antara MFA dan elastik modulus (MOE). Perhubungan antara MFA dan (modulus of rupture) MOR juga bersifat garis lurus negatif. Hubung kait antara T_g dan MFA adalah songsang. Analisis regresif daripada data MFA dan T_g menunjukkan bahawa 66.4% variasi pada T_g ditunjukkan oleh nilai MFA. Daripada kajian, didapati bahawa pokok Acacia mangium yang berumur 3 tahun mempunyai nilai Panjang santaian maksimum 83.33 cm dan nilai separuh kelebaran 57.75cm, iaitu lebih tinggi nilainya jika dibandingkan dengan pokok yang berumur 15 tahun yang mempunyai Panjang santaian maksimum 28.65cm dan nilai separuh kelebaran 19.85cm. Ujian neutron transmission menunjukkan penyerapan air sebenar ke dalam vesel dan melalui komposit fiber adalah dalam julat 4.445% - 6.981% selepas 20 jam dikeringkan pada suhu 105C° ±1C°.

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