UNIVERSITI PUTRA MALAYSIA

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

SINING UNCHI

FH 1996 5
ACETYLATION OF *Acacia mangium* WOOD FIBRES
AND ITS APPLICATION IN THE
MEDIUM DENSITY FIBREBOARD

BY

SINING UNCHI

Dissertation Submitted in Fulfilment of the
Requirements for the Degree of
Doctor of Philosophy
in the Faculty of Forestry,
Universiti Pertanian Malaysia.

June 1996
ACKNOWLEDGEMENTS

I am greatly indebted to Assoc. Prof. Mohd. Zin Jusoh, Chairman of the Supervisory Committee, for his constant guidance, assistance and suggestions throughout the preparation of this thesis. I would also like to express my profound gratitude to Dr. Jalaluddin Harun and Assoc. Prof. Dr. Faujan Ahmad for their invaluable suggestions and constructive comments.

Sincere gratitude is due to the Sabah State Government for the scholarship grant. Sincere appreciation is also directed to the Public Service Commission and Sabah Forestry Department for their kind permission to study at the Universiti Pertanian Malaysia.

Acknowledgements are extended to the State Forestry Director of Negeri Sembilan for kindly providing the research materials, and the Director General of Forest Research Institute of Malaysia and Dean of the Faculty of Forestry, Universiti Pertanian Malaysia for their permission to use the facilities available. Cooperation from other staff members of these organisations is also greatly appreciated.

Heartiest gratitude is also due to my colleagues, Mr. Herman Anjin, Mr. Eric Juin, Mr. Fedilis Bajau, Mr. Joseph Ahlan, Mr. Johnly Kulik and others for their constant support and encouragements.

To my wife, children and relatives, I render my gratitude and thanks for their patience, concern and support.
## TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACKNOWLEDGMENTS</td>
<td>ii</td>
</tr>
<tr>
<td>LIST OF TABLES</td>
<td>vi</td>
</tr>
<tr>
<td>LIST OF FIGURES</td>
<td>ix</td>
</tr>
<tr>
<td>ABSTRACT</td>
<td>xiii</td>
</tr>
<tr>
<td>ABSTRAK</td>
<td>xvi</td>
</tr>
<tr>
<td>CHAPTER</td>
<td></td>
</tr>
<tr>
<td>I INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>Objectives</td>
<td>6</td>
</tr>
<tr>
<td>II LITERATURE REVIEW</td>
<td>7</td>
</tr>
<tr>
<td>A Short Note on Acacia mangium</td>
<td>7</td>
</tr>
<tr>
<td>Importance of Acacia mangium</td>
<td>8</td>
</tr>
<tr>
<td>Growth and Yield</td>
<td>9</td>
</tr>
<tr>
<td>General Characteristics and Properties of Wood</td>
<td>11</td>
</tr>
<tr>
<td>Wood Utilisation for Composite Products</td>
<td>16</td>
</tr>
<tr>
<td>Major Chemical Constituents of Wood</td>
<td>17</td>
</tr>
<tr>
<td>Cellulose</td>
<td>18</td>
</tr>
<tr>
<td>Hemicelluloses</td>
<td>20</td>
</tr>
<tr>
<td>Lignin</td>
<td>21</td>
</tr>
<tr>
<td>Extraneous Constituents</td>
<td>22</td>
</tr>
<tr>
<td>Chemical Modification of Wood</td>
<td>23</td>
</tr>
<tr>
<td>Proofs of Bonding of Chemical to Wood Polymers</td>
<td>27</td>
</tr>
</tbody>
</table>

iii
<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distribution of Bonded Chemicals.</td>
<td>29</td>
</tr>
<tr>
<td>Properties of Chemically Modified Wood Product</td>
<td>30</td>
</tr>
<tr>
<td>Water Adsorption</td>
<td>30</td>
</tr>
<tr>
<td>Dimensional Stability</td>
<td>33</td>
</tr>
<tr>
<td>Mechanical Properties</td>
<td>37</td>
</tr>
<tr>
<td>Biological Resistance</td>
<td>42</td>
</tr>
<tr>
<td>Other Related Properties</td>
<td>45</td>
</tr>
<tr>
<td>Potential of Chemical Modification of Wood</td>
<td>47</td>
</tr>
<tr>
<td>RAW MATERIAL PREPARATION AND CHEMICAL CONSTITUENTS OF Acacia mangium</td>
<td>50</td>
</tr>
<tr>
<td>WOOD</td>
<td></td>
</tr>
<tr>
<td>Raw Material</td>
<td>50</td>
</tr>
<tr>
<td>Source of Raw Material and Background</td>
<td>50</td>
</tr>
<tr>
<td>Preparation of Raw Materials</td>
<td>52</td>
</tr>
<tr>
<td>Major Chemical Constituents of Acacia mangium Wood</td>
<td>53</td>
</tr>
<tr>
<td>Preparation of Samples</td>
<td>53</td>
</tr>
<tr>
<td>Ethanol-Acetone Extractives Determination</td>
<td>55</td>
</tr>
<tr>
<td>Holocellulose Determination</td>
<td>55</td>
</tr>
<tr>
<td>Alpha cellulose Determination</td>
<td>56</td>
</tr>
<tr>
<td>Hemicellulose Determination</td>
<td>57</td>
</tr>
<tr>
<td>Lignin Determination</td>
<td>57</td>
</tr>
<tr>
<td>Ash Determination</td>
<td>58</td>
</tr>
<tr>
<td>Data Analysis</td>
<td>58</td>
</tr>
<tr>
<td>Results and Discussion</td>
<td>58</td>
</tr>
<tr>
<td>IV</td>
<td>ACETYLATION CHARACTERISTICS OF Acacia mangium WOOD FIBRES</td>
</tr>
<tr>
<td>---</td>
<td>--------------------------------------------------------</td>
</tr>
<tr>
<td></td>
<td>Pilot Study</td>
</tr>
<tr>
<td></td>
<td>Materials and Methods</td>
</tr>
<tr>
<td></td>
<td>Results and Discussions</td>
</tr>
<tr>
<td></td>
<td>Bulk Acetylation</td>
</tr>
<tr>
<td></td>
<td>Materials and Methods</td>
</tr>
<tr>
<td></td>
<td>Results and Discussion</td>
</tr>
<tr>
<td></td>
<td>Evidences of Chemical Bonding</td>
</tr>
<tr>
<td></td>
<td>Colour</td>
</tr>
<tr>
<td></td>
<td>Infrared Data</td>
</tr>
<tr>
<td></td>
<td>Water Adsorption Theoretical Model</td>
</tr>
<tr>
<td>V</td>
<td>MANUFACTURING AND PERFORMANCES OF MEDIUM DENSITY FIBREBOARD</td>
</tr>
<tr>
<td></td>
<td>Manufacturing of Board</td>
</tr>
<tr>
<td></td>
<td>Materials and Methods</td>
</tr>
<tr>
<td></td>
<td>Results and Discussion</td>
</tr>
<tr>
<td></td>
<td>Performances of Board</td>
</tr>
<tr>
<td></td>
<td>Materials and Methods</td>
</tr>
<tr>
<td></td>
<td>Results and Discussion</td>
</tr>
<tr>
<td>VI</td>
<td>CONCLUSIONS AND RECOMMENDATIONS</td>
</tr>
<tr>
<td></td>
<td>Conclusions</td>
</tr>
<tr>
<td></td>
<td>Recommendations</td>
</tr>
<tr>
<td>REFERENCES</td>
<td>190</td>
</tr>
<tr>
<td>VITA</td>
<td>210</td>
</tr>
</tbody>
</table>
# LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Dbh, Height and Mean Annual Increments (MAI) of Dbh and Height Values for Acacia mangium of Different Ages</td>
<td>10</td>
</tr>
<tr>
<td>2. Major Chemical Constituents (%) of Acacia mangium Wood</td>
<td>59</td>
</tr>
<tr>
<td>3. Relationship of Extracted Materials to Chemical Weight Gain in the Acetylation of Acacia mangium Wood Fibres</td>
<td>75</td>
</tr>
<tr>
<td>4. Weight Gain (%) of Acacia mangium Wood Fibres Acetylated at 90°C and 120°C</td>
<td>80</td>
</tr>
<tr>
<td>5. Weight Gain (%) of Acacia mangium Wood Fibres Acetylated for 6 hours with Various Concentrations of Acetic Anhydride and Different Catalyst</td>
<td>83</td>
</tr>
<tr>
<td>6. Weight Gain (%) of Acacia mangium Wood Fibres with Different Initial Moisture Content Acetylated at 120°C Uncatalysed and Catalysed with Pyridine</td>
<td>87</td>
</tr>
<tr>
<td>7. Weight Gain Percentage in Bulk Acetylation of Acacia mangium Wood Fibres</td>
<td>95</td>
</tr>
<tr>
<td>8. Relative Humidities Over Saturated Salt Solution at 20°C</td>
<td>104</td>
</tr>
<tr>
<td>9. Observed (Upper) and Calculated Values (Lower) of Equilibrium Moisture Content (%) of Unacetylated and Acetylated Acacia mangium Wood Fibres at Various Relative Humidities</td>
<td>108</td>
</tr>
<tr>
<td>10. Regression Coefficients, Correlation Coefficient, Hailwood-Horrobin Equation Parameters, Hydrated and Dissolved Water and Fibre Saturation Point (%) of Unacetylated and Acetylated Acacia mangium Wood Fibres</td>
<td>109</td>
</tr>
<tr>
<td>11. Equilibrium Moisture Content (%) of Acacia mangium MDF at Various Relative Humidities</td>
<td>131</td>
</tr>
<tr>
<td>Table</td>
<td>Page</td>
</tr>
<tr>
<td>-------</td>
<td>------</td>
</tr>
<tr>
<td>12.</td>
<td>Equilibrium Moisture Content (%) of Acacia mangium MDF (Reconditioned) After Exposure to Various Tests</td>
</tr>
<tr>
<td>13.</td>
<td>Thickness Swelling of Acacia mangium MDF After 2-hour Boiled in Water</td>
</tr>
<tr>
<td>14.</td>
<td>Thickness Swelling (%) of Acacia mangium MDF After 9 Cycles of Water Soak-dry Cyclical Trials</td>
</tr>
<tr>
<td>15.</td>
<td>Reversible Thickness Swelling (%) of Acacia mangium MDF After Cyclical Water Soaking</td>
</tr>
<tr>
<td>16.</td>
<td>Modulus of Elasticity (MPa) of Acacia mangium MDF After Exposure to Various Types of Treatment Conditions</td>
</tr>
<tr>
<td>17.</td>
<td>Modulus of Rupture (MPa) of Unaged Acacia mangium MDF and After Exposure to Various Type of Treatments</td>
</tr>
<tr>
<td>18.</td>
<td>Internal Bond Strength (MPa) of Unaged and After 2-hour Boiled Acacia mangium MDF</td>
</tr>
<tr>
<td>19.</td>
<td>Weight Loss (%) of Acacia mangium MDF After Exposure to Pycnoporus sanguineus Fungal Attack</td>
</tr>
<tr>
<td>20.</td>
<td>Weight Loss (%) of Acacia mangium MDF After Exposure to Coptotermes curvignathus Termites Attack</td>
</tr>
<tr>
<td>21.</td>
<td>Relationship of Mortality Rate of Coptotermes curvignathus with Type of Feed</td>
</tr>
</tbody>
</table>
# LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Map of Peninsular Malaysia Showing the Location of Source of Raw Material</td>
<td>51</td>
</tr>
<tr>
<td>2.</td>
<td>Sample Preparation for Chemical Constituents Determination and Board</td>
<td>54</td>
</tr>
<tr>
<td></td>
<td>Manufacturing</td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>Pilot Acetylation of Acacia mangium Fibres</td>
<td>64</td>
</tr>
<tr>
<td>4.</td>
<td>Reaction Rate of Acacia mangium Fibres Reacted with Acetic Anhydride at</td>
<td>73</td>
</tr>
<tr>
<td></td>
<td>120°C</td>
<td></td>
</tr>
<tr>
<td>5.</td>
<td>Reaction Rate of Acacia mangium Fibres Reacted with Acetic Anhydride and</td>
<td>74</td>
</tr>
<tr>
<td></td>
<td>Catalysed with Pyridine at 120°C</td>
<td></td>
</tr>
<tr>
<td>6.</td>
<td>Components of Acetylated Wood of Acacia mangium with and without Extractives</td>
<td>76</td>
</tr>
<tr>
<td></td>
<td>Content</td>
<td></td>
</tr>
<tr>
<td>7.</td>
<td>Weight Gain Percentage of Acacia mangium Wood Fibres Acetylated at 90°C and</td>
<td>79</td>
</tr>
<tr>
<td></td>
<td>120°C</td>
<td></td>
</tr>
<tr>
<td>8.</td>
<td>Weight Gain Percentage of Acacia mangium Wood Fibres Acetylated with Various</td>
<td>82</td>
</tr>
<tr>
<td></td>
<td>Concentrations of Acetic Anhydride and Different Catalyst</td>
<td></td>
</tr>
<tr>
<td>9.</td>
<td>Weight Gain Percentage of Acacia mangium Wood Fibres with Different Initial</td>
<td>88</td>
</tr>
<tr>
<td></td>
<td>Moisture Content Acetylated at 120°C Uncatalysed</td>
<td></td>
</tr>
<tr>
<td>10.</td>
<td>Weight Gain Percentage of Acacia mangium Wood Fibres with Different Initial</td>
<td>89</td>
</tr>
<tr>
<td></td>
<td>Moisture Content Acetylated at 120°C with Pyridine</td>
<td></td>
</tr>
<tr>
<td>11.</td>
<td>Bulk Acetylation of Acacia mangium Wood Fibres</td>
<td>94</td>
</tr>
<tr>
<td>12.</td>
<td>Colour Variation of Acacia mangium Wood Fibres Acetylated to Various Levels</td>
<td>98</td>
</tr>
<tr>
<td></td>
<td>of Weight Gain</td>
<td></td>
</tr>
<tr>
<td>13.</td>
<td>An Illustration of Potassium Bromide Disc Preparation</td>
<td>100</td>
</tr>
<tr>
<td>14.</td>
<td>Infrared Spectra of Unacetylated and Acetylated Acacia mangium Wood Fibres</td>
<td>102</td>
</tr>
</tbody>
</table>
Figure | Page
--- | ---
15. The Calculated Curves of the Ratio H/M Against Relative Humidity for Acacia mangium Wood Fibres Acetylated at Various Levels of Weight Gain | 110
16. The Calculated Curves for Hydrated Water (Mh) and Dissolved Water (Ms) of Acacia mangium Wood Fibres with Various Weight Gain Percentage | 111
17. An Illustration of the Apparatus Used in the Decay Test | 124
18. Equilibrium Moisture Content (%) of Acacia mangium MDF at Various Levels of Relative Humidity | 132
19. Percentage Reduction of Equilibrium Moisture Content of Acacia mangium MDF Due to Acetylation | 133
20. Comparison of Equilibrium Moisture Content of Acacia mangium MDF and Fibres at Various Levels of Relative Humidity | 134
21. Equilibrium Moisture Content of Acacia mangium MDF (Reconditioned) After Exposure to Various Type of Treatment Conditions | 137
22. Percentage Increase in Equilibrium Moisture Content of Acacia mangium MDF After Exposure to Various Types of Test (Based on EMC of Unaged MDF) | 138
23. Thickness Swelling of Acacia mangium MDF After 2-hour Boiled in Water | 144
24. Antiswelling Efficiency of Acetylated Acacia mangium MDF of Various Weight Gain After 2-hour Boiled in Water | 144
25. Thickness Swelling of Acacia mangium MDF After 9 Cycles of Water Soak-dry Cyclical Trials | 147
26. Reversible Thickness Swelling of Acacia mangium MDF After 9 Cycles of Water Soak-dry Cyclical Trials | 150
27. Antiswelling Efficiency (%) of Acetylated Acacia mangium MDF of Various Weight Gains After 9 Cycles of Water Soak-dry Cyclical Trials .................................................. 151

28. Antiswelling Efficiency (%) of Reversible Thickness Swelling of Acetylated Acacia mangium MDF After 9 Cycles of Water Soak-dry Cyclical Trials .................................................. 152

29. Modulus of Elasticity of Unaged Acacia mangium MDF ........................................ 157

30. Percentage changes of Modulus of Elasticity of Acacia mangium MDF Due to Acetylation ... 157

31. Percentage Retention of Modulus of Elasticity of Acacia mangium MDF After 9 Cycles of Water Soak-dry Cyclical Trials .................................................. 159

32. Final Modulus of Elasticity of Acacia mangium MDF After Exposure to Various Treatment Conditions ................................................................. 161

33. Percentage Retention of Modulus of Elasticity of Acacia mangium MDF After Exposure to Various Type of Treatments .............................................. 162

34. Modulus of Rupture of Unaged Acacia mangium MDF ............................................. 164

35. Percentage changes of Modulus of Rupture of Acacia mangium MDF Due to Acetylation ...... 164

36. Modulus of Rupture of Unaged Acacia mangium MDF and After Exposure to Various Type of Treatment Conditions .................................................. 167

37. Percentage Retention of Modulus of Rupture of Acacia mangium MDF After Exposure to Various Treatments Conditions .............................................. 168

38. Internal Bond Strength of Unaged and After 2-hour Boiled Acacia mangium MDF ............. 171
<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>39.</td>
<td>Percentage changes of Internal Bond Strength of <em>Acacia mangium</em> MDF Due to Acetylation</td>
<td>172</td>
</tr>
<tr>
<td>40.</td>
<td>Weight Loss of <em>Acacia mangium</em> MDF After Exposure to <em>Pycnoporus sanguineus</em></td>
<td>175</td>
</tr>
<tr>
<td>41.</td>
<td>Percentage Reduction of Weight Loss of <em>Acacia mangium</em> MDF After Exposure to <em>Pycnoporus sanguineus</em> Due to Acetylation</td>
<td>175</td>
</tr>
<tr>
<td>42.</td>
<td>Weight Loss of <em>Acacia mangium</em> MDF After Exposure to <em>Coptotermes curvignatus</em></td>
<td>179</td>
</tr>
<tr>
<td>43.</td>
<td>Percentage changes of Weight Loss of <em>Acacia mangium</em> MDF After Exposure to <em>Coptotermes curvignatus</em> Due to Acetylation</td>
<td>179</td>
</tr>
</tbody>
</table>
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.

By

SINING UNCHI

JUNE 1996

Chairman : Associate Prof. Mohd. Zin Jusoh
Faculty : Forestry

The effective utilisation of low quality wood of Acacia mangium Willd. would be for the production of medium density fibreboard (MDF). However, MDF is susceptible 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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JUN 1996

Pengerusi : Prof. Madya Mohd. Zin Jusoh
Fakulti : Perhutanan

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 ditindakbalaskam 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

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 susceptible 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 arose 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, Mimosoidea 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 Research 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

7