



***EFFECT OF CARBOXYLIC ANHYDRIDE TREATMENTS ON PHYSICAL
AND MECHANICAL PROPERTIES OF *Hevea brasiliensis* Mull.Arg.,
Acacia mangium Willd. AND *Elaeis guineensis* Jacq. WOOD***

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By

MOHD AFIQ BIN MOHTAR

**Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in
Fulfillment of the Requirements for the Degree of Master Science**

February 2015

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Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of requirement for the degree of Master of Science

EFFECT OF CARBOXYLIC ANHYDRIDE TREATMENTS ON PHYSICAL AND MECHANICAL PROPERTIES OF *Hevea brasiliensis* Mull.Arg., *Acacia mangium* Willd. AND *Elaeis guineensis* Jacq. WOOD

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February 2015

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The objectives of the study was to investigate the reactivity of acid anhydride treatments, to determine the physical and mechanical properties and anti-swelling efficiency(ASE) as well as its relation between the properties. The rubberwood (*Hevea brasiliensis*), acacia (*Acacia mangium*) and oil-palm wood (*Elaeis guineensis*.) were modified with acetic, propionic and butyric anhydride in this study.

The sample were cut into size of 300 mm X 100 mm X 25 mm (L X W X T) and vacuum impregnated before being reacted using a microwave. The scanning electron microscopy(SEM) observations shows that no damage occur to the cell wall structures during the modification procedure takes place while the fourier transform infrared(FTIR) analysis indicates that the bonding of cell wall polymer hydroxyl group with anhydride did happened.

The results showed that the Oil palm wood(OPW) retained the highest anhydride solution followed by rubberwood and acacia with regardless of anhydrides. In contrast to uptake, the weight percent gain(WPG) was highest in rubberwood followed by OPW and acacia, regardless of anhydride. Overall, the modified rubberwood had a higher bulking coefficient (BC) followed by acacia and OPW. The result of density increment shows that the wood density was increased due to the modification process for all species. The void volume changes were negative for all wood species, except for acacia modified with acetic and butyric anhydride.

Generally, treatment of wood with anhydride did not give any improvements to modulus of rupture(MOR) and modulus of elasticity(MOE). The compression strength was improved in modified rubberwood and acacia, but not in modified OPW. The hardness was not improved with either treatment with anhydride and this trend was consistent with all wood species. Regardless of anhydride, the impact strength was improved in modified rubberwood and OPW, but not in the case of acacia. Generally, modified rubberwood and acacia with propionic anhydride gave the highest ASE (4th cycle). Overall, the maximum improvement in terms of dimensional stability and

mechanical properties was achieved in modified rubberwood and acacia with butyric anhydride.



Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan ijazah Master Sains

KESAN RAWATAN ASID ANHYDRIDE KARBOKSILIK KE ATAS SIFAT-SIFAT FIZIKAL DAN MEKANIKAL KAYU *Hevea brasiliensis* Mull.Arg., *Acacia mangium* Willd. DAN *Elaeis guineensis* Jacq.

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Objektif kajian yang dilakukan adalah untuk menyiasat ke-reaktifan oleh rawatan asid anhydride terhadap kayu, menentukan sifat fizikal, mekanikal dan anti pengembangan serta kaitan antara sifat-sifat tersebut. Kayu getah, acacia dan kayu minyak sawit telah di rawat dengan acetic, propionic dan butyric anhydride di dalam kajian ini.

Sampel kayu telah di potong kepada saiz 300 mm X 100 mm X 25 mm (L X W X T) dan telah di impregnasi secara vakum sebelum di tindak balas menggunakan ketuhar gelombang mikro. Perhatian melalui imbasan mikroskop electron menunjukkan tiada kerosakan berlaku terhadap sel kayu sewaktu proses modifikasi di jalankan dan analisa daripada fourier transform infra-red (FTIR) menunjukkan bahawa ikatan antara polimer sel kayu hidroksil dengan anhydride berlaku.

Keputusan menunjukkan bahawa kayu minyak sawit mendapat penyerapan anhydride yang tertinggi di ikuti dengan kayu getah dan akasia tanpa mengira jenis anhydride. Berbeza dengan penyerapan anhydride, peratus pertumbuhan berat adalah yang tertinggi untuk kayu getah di ikuti dengan kayu minyak sawit dan akasia tanpa mengira jenis anhydride. Secara keseluruhannya, kayu getah yang di ubahsui menunjukkan kadar pengembangan efisien yang tinggi di ikuti dengan akasia dan kayu minyak sawit. Keputusan peningkatan ketumpatan menunjukkan ketumpatan kayu meningkat di sebabkan oleh proses modifikasi untuk ketiga-tiga spesis. Perubahan ruang kosong adalah negative untuk semua spesis kecuali akasia yang di tindak balas dengan acetic dan butyric anhydride.

Secara umumnya, rawatan kayu menggunakan anhydride tidak memberikan peningkatan terhadap modulus ruyup dan modulus keanjalan. Kekuatan mampatan meningkat untuk kayu getah dan akasia yang di ubahsui tetapi tidak meningkat untuk kayu minyak sawit. Tidak mengira jenis anhydride dan spesis, sifat kekerasan juga tidak meningkat. Kekuatan impak meningkat untuk kayu getah dan kayu minyak sawit tetapi tidak untuk kayu akasia. Secara umumnya, kayu getah dan akasia yang telah di ubahsui dengan propionic anhydride memberikan kadar pengembangan

effisien kitaran ke-empat yang tinggi. Kesimpulannya, peningkatan maksima dalam erti kestabilan dimensi dan sifat mekanikal dapat di capai oleh kayu getah dan akasia yang di ubahsui dengan butyric anhydride.



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I certify that a Thesis Examination Committee has met on 13 February 2015 to conduct the final examination of Mohd Afiq bin Mohtar on his thesis entitled "Effect of Carboxylic Anhydride Treatments on Physical and Mechanical Properties of *Hevea brasiliensis* Mull.Arg., *Acacia mangium* Willd. and *Elaeis guineensis* Jacq. Wood" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science.

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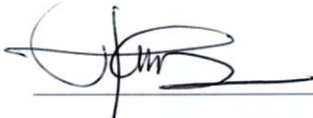
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LIST OF ABBREVIATIONS

ANOVA	Analysis of Variance
ASE	Anti-Swelling efficiency
BC	Bulking Coefficient
BS	British Standard
CCA	Copper Chrome Arsenic
df	Degree of Freedom
EMC	Equilibrium Moisture Content
FTIR	Fourier Transform Infra-Red Spectroscopy
IB	Internal bonding
IR	Infra-Red
L	Length
l	Longitunal
MOE	Modulus of Elasticity
MOR	Modulus of Rupture
MV	Molar Volume
NS	Not Significant
PU	Percent Uptake
r	Radial
RH	Relative Humidity
SEM	Scanning Electron Microscope
SG	Specific Gravity
T	Thickness
t	Tangential
V_{rel}	Volume Increase

W

Width

WPG

Weight Percent Gain



LIST OF SYMBOLS

CH ₃	Methyl
C ₂ H ₅	Ethyl
C ₃ H ₇	Propyl
cm	Centimeter
cm ⁻¹	Wavenumber
cm ³ mol ⁻¹	Cubic Centimeters Per Mole
g	Gram
in/min	Inch Per Minute
J	Joule
kg/m ³	Kilogram Per Meter Cube
kN	Kilo Newton
Mhz	Megahertz
Mm	Milimeter
mm/min	Milimeter Per Minute
Mpa	Mega Pascal
OH	Hydroxyl
W	Watt
%	Percent
°c	Degree Celsius
°	Degree
µm	Micrometer

CHAPTER 1

INTRODUCTION

1.1 Background

Wood is a renewable material and has been used for many applications such as furniture, outdoor applications and building materials. It has been used since the beginning of human existence. However, it has been used without modification for the most part. Wood continues to be used for many applications due to its many excellent properties such as good strength to weight ratio, attractive appearance, thermal insulator, reusable, recycle and recoverable but it also suffers from several disadvantages. Dimensional changes due to the cyclic humidity changes, susceptibility to biological attack and surface eroded when exposed to extreme weather restricts the potential end-uses of wood. Wood modification tends to solve or counter these disadvantages by changing the wood properties. According to Hill (2006), many wood properties are determined by its chemical constituents. In consequence, wood modification aims to change the chemical configuration of wood which the process known as chemical modification. The main objective of wood modification is to alter and to improve desired properties such as decay resistance, dimensional stability, weathering performance, and mechanical properties.

Chemical modification of wood can be defined as any chemical reaction between some reactive part of a wood cell wall component and a simple single chemical reagent, with or without catalyst that forms a covalent bond between the two components (Rowell, 1991). The chemicals are including acetic, butyric and propionic anhydrides. Chemical modification of wood by using acetic anhydride is called acetylation and has been extensively studied all over the world. It has been reported that acetylation is a very effective way for enhancing wood properties. Wood properties can be improved considerably by converting hydrophilic hydroxyl (OH) groups into larger more hydrophobic groups. Dimensionally stable material is created because the cell wall itself will be permanently in swollen state that will attract no or very little water (Homan and Jorissen, 2004).

Recent studies by Larsson and Simonson (1999) reported that, microwave heating can be used for the acetylation of wood in lumber thickness which aimed to reduce reaction time and to provide a uniform heating pattern in wood. However, chemical modification using a microwave heating has not been studied on rubberwood, acacia and oil palm wood. The reaction of these woods with anhydrides and its effect on anatomy, chemical structure, dimensional stability, physical and mechanical properties are still not completely known. A specific research on this subject is crucially needed so that these woods can be used beyond its natural limits.

The aim of this study is to modify rubberwood (*Hevea brasiliensis*), acacia (*Acacia mangium*) and oil-palm wood (*Elaeis guineensis*) with carboxylic acid anhydrides

(acetic anhydride, butyric anhydride and propionic anhydride). The target output from this research is not only to help releasing the great demands of timber from natural forest but also to promote the use of low quality wood as a main material for high end furniture and building materials.

1.2 Problem Statement

Rubberwood, acacia and oil-palm wood are three wood species that has abundant resources in Malaysia. The resource is ready able and sustainable. However, these three wood species need to undergo pre-treatment processes to make it possible to be used especially outdoor applications. For example, rubberwood need to be treated with wood preservatives such as Copper Chrome Arsenic (CCA) and creosote to improve its decay resistance, dimensional stability, strength and durability. As well as acacia and oil-palm wood, which need to be coated, apply wax during forming process for reconstituted woods or impregnation with phenolic resin to enhance the performance of wood.

However, such treatments are not permanent, which the coating may be failed by cracking, the chemical leach out and erode during the lifetime of the product. The loss of performance occurs because the treating agent is not chemically bonded to or otherwise immobilized within the wood structure. During the lifetime of the treated product may be a very low hazard associated with in service use, this may well change at the end of life of the product. Therefore, potential loss of the preservative into the environment may become a problem in disposal or recycling situations. When this occurs, the biocidal action of the preservatives remains and this can cause a negative impact to the environment.

Chemical modification of wood with anhydride provides a process that alters the properties of the material such that during the lifetime of a product no loss of the enhanced performance of the wood should occur. These modification processes with anhydride requires a lot of time using conventional heating to acquire the optimum properties wood and obtain maximum performance possible. However, using microwave, the reaction temperature of 120-130°C can be reached in a comparatively short time and provide a uniform heating.

Acetic anhydride has been widely used in chemical modification experiments and the results compared to other chemical were also better while wood treated with anhydride leave no harm to the environment (Rowell, 2006). Wood treated with anhydride provides consistent and optimum result for Anti-Swelling Efficiency (ASE) and biological resistance. However, the effect of modification on strength properties such as static bending, compression, hardness and impact strength were dependent on the degree of modification as well as species.

Therefore it is necessary to study the effect of carboxylic acid anhydride treatments on physical and mechanical properties rubberwood, acacia and oil-palm wood so that the

properties can be determined and indirectly can be used beyond its limitation without give any harm to the environment.

1.3 Research Objectives

The general objective of this study is to improve the physical and mechanical properties of rubberwood, acacia and oil palm wood. The specific objectives of the study are:

- 1) To investigate the reactivity of carboxylic acid anhydride treatments on the rubberwood, acacia and oil palm wood through scanning electron microscopy (SEM) observation and fourier transform in-frared (FTIR) analysis.
- 2) To determine the effect of carboxylic acid anhydrides treatments on the basic, physical and mechanical properties and dimensional stability of modified wood.
- 3) To determine the correlation (pearson's) of modified and unmodified wood between basic, physical and mechanical properties.

1.4 Significance of Research

The rubberwood, acacia and oil palm wood are the three main wood resources after natural forest timber in Malaysia. However, a pre-treatment for these three species is necessary to ensure that their performance is acceptable for high end-multipurpose product applications and those treatments were time consuming and involving a lot of money. Chemical modification of wood with anhydride using microwave can provide a uniform heating while reduce reaction time but also prevent the environment from negative impacts. The purpose of this research is to determine whether the physical and mechanical properties of rubberwood, acacia and oil-palm wood can be improved through chemical modification with anhydride using microwave heating method. The results of this study will determine whether the improved properties of wood can meet with the industrial specification, requirements and acceptable used by local wood industries. This study will also be beneficial to the Malaysia economic growth by maximising the utilization of lignocellulosic material.

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