STUDY ON ENHANCING COLOUR APPEARANCES AND CHEMICAL COMPOSITIONS OF 14 YEAR-OLD CULTIVATED *Acacia* Hybrid THROUGH OIL-HEAT TREATMENT PROCESS

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THESIS SUBMITTED IN FULFILLMENT FOR THE DEGREE OF MASTER OF SCIENCE

SCHOOL OF INTERNATIONAL TROPICAL FORESTRY
UNIVERSITI MALAYSIA SABAH
2009

DECLARATION

I hereby declare that the material in this thesis is my own except for quotations, excerpts, equations, summaries and references, which have been duly acknowledged.

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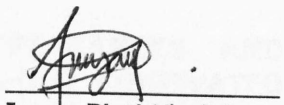

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IJAZAH: **SARJANA SAINS (WOOD PROCESSING AND INDUSTRY)**

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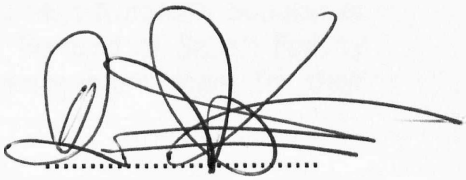

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ABSTRACT

STUDY ON COLOUR APPEARANCES AND CHEMICAL COMPOSTIONS OF 14 YEAR-OLD CULTIVATED *Acacia* Hybrid THROUGH OIL-HEAT TREATMENT PROCESS.

This study investigated the effect of an oil heat treatment process on the colour appearances of 14 year-old cultivated acacia hybrid. The effects of parameters such as temperatures and duration of treatments are taken in consideration due to their influences in enhancing the colour of the wood from the sapwood right through the heartwood. Natural and untreated acacia hybrid normally had the sapwood having lighter colour than the dark colour heartwood. Turning these timbers into plywood or furniture at this stage will result in uneven colour as the results of the mixture between the sapwood and heartwood. This will decrease the aesthetic value of the product. Heating the wood at varying temperatures and durations would enhance the colour appearance of the wood. The colour changes in the sapwood and heartwood were measured using Minolta Chroma-meter CR-310 and the results were presented according to the CIE L*a*b* a colour co-ordinates system. The results revealed that the rising temperature at certain duration resulted in darkening of wood tissues. The decreased of L* values caused the darkening of the wood surfaces while the increase values in a* caused the wood colour becomes redder and decrease in b* values caused the decrease yellow colour of acacia wood. The difference of chemical composition in wood probably is the main reason for dissimilar in colour. This study showed features change in the chemical composition of acacia wood. The degradation in chemical composition was recognized when acacia woods were exposed to oil-heat treatment process. Holocellulose, hemicellulose and cellulose degraded with the increasing of treatment temperature and time of heating exposure. These studies recommend oil-heat treatment technology can be used in wood industry to modify acquiring darker tonality of wood to suit the customer demand.

ABSTRAK

*Kajian ini mengkaji kesan rawatan haba menggunakan minyak terhadap warna kayu Acacia hybrid yang berumur 14 tahun yang ditanam secara ladang. Kesan-kesan parameter seperti suhu dan tempoh rawatan di kaji kerana mempunyai pengaruh di dalam meningkatkan warna kayu daripada kayu gubal terus kepada kayu teras. Biasanya di dalam keadaan yang semula jadi dan tidak dirawat, kayu acacia mempunyai warna kayu gubal yang lebih cerah berbanding kayu teras yang berwarna gelap. Memproses kayu acacia kepada papan lapis atau perabot pada peringkat ini akan menyebabkan warna menjadi tidak sekata hasil percampuran antara kayu gubal dengan kayu teras. Ini akan menurunkan nilai estatik produk tersebut. Merawat kayu pada suhu dan tempoh rawatan yang tertentu boleh mempertingkatkan penampilan warna kayu. Perubahan warna pada kayu gubal dan kayu teras diukur dengan menngunakan Minolta Chroma-meter CR-310 dan keputusannya ditampilkan berdasarkan sistem warna koordinat iaitu CIE L*a*b*. Hasil kajian ini menunjukkan bahawa peningkatan suhu pada tempoh rawatan tertentu menggelapkan tisu kayu. Penurunan di dalam nilai-nilai L* menggelapkan permukaan kayu sementara peningkatan nilai-nilai a* menyebabkan warna kayu berubah menjadi lebih merah dan penurunan nilai-nilai b* menyebabkan penurunan warna kuning pada kayu. Perbezaan di antara kandungan kimia di dalam kayu merupakan sebab kepada perbezaan warna kayu. Hasil kajian ini menunjukkan rawatan haba menyebabkan perubahan kepada sifat komposisi kimia kayu acacia. Penyusutan pada kandungan kimia kayu telah dikenalpasti apabila kayu acacia dirawat dengan proses rawatan haba minyak. Penyusutan holoselulosa, hemiselulosa dan selulosa berlaku dengan peningkatan suhu dan tempoh rawatan. Kajian ini menyarankan teknologi rawatan haba menggunakan minyak boleh digunakan di dalam industri perkayuan untuk mengubah suai tona warna kayu yang dikehendaki di dalam memenuhi permintaan pelanggan.*

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LIST OF ABBREVIATIONS

ANOVA	Analysis of Variance
ASTM	American Society for Testing and Material
CCA	Chrome-copper Arsenic
CIE	Commission Internationale de l'Eclairage
Df	Degree of freedom
Dur	Duration
DP	Degree of Depolyrimerization
FRIM	Forest Reserach Institute Malaysia
FSP	Fiber Saturated Point
IMC	Initial Moisture Content
ISO	International Organization for Standardization
MC	Moisture Content
MDF	Medium Density Fibreboard
Min	Minutes
MOE	Modulus of Elastic
MOR	Modulus of Rupture
MOSTI	Ministry of Science, Tecnology and Innovation
MTIB	Malaysia Timber Industry Board
Nssc	Neutral sulfite semi chemical
OHT	Oil-Heat Treatment
RH	Relative Humidity
SAFODA	Sabah Foresty Development Authority
SITF	School of International Tropical Forestry
TAPPI	Technical Association of the Pulp and Paper Industry
Temp	Temperature
Yr	Year

LIST OF SYMBOLS

B	Bottom
M	Middle
T	Top
L*	Lightness
a*	Reddish colour
b*	Yellowish colour
l	Longitudinal
r	Radial
t	Tangential
m	Meter
cm	Centimeter
mm	Millimeter
mm^3	Millimeter cube
m^2	Meter square
µm	Micrometer
nm	Nanometer
°C	Degree celsius
kg	Kilogram
mg	Milligram
g	Gram
ha	Hectare
N	Newton
S_1	Outer layer
S_2	Middle layer
S_3	Inner layer
P	Primary wall
M	Middle lamella

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Natural forests in Southeast Asia are faced with the declining in supply of large logs from Dipterocarp due to excessive logging and shifting cultivation. At the same time, the demand for timber products in the area is increasing. Since plantation forestry rotations are significantly shorter than in natural stands, it is an alternative way to patch the industries demand. Therefore, the effort to establish the plantation sector becoming more concern by government and private sector in order to cover the demand required from timber industries in the same way to conserve the natural forest from continually being vanished by logging activities. Thus improve the chances of sustainable forest management. Moreover, nowadays consumer countries such as Europe and North America are very sensitive towards logging activities of naturally grown species from natural tropical rain forest.

Malaysia has chosen *Acacia* species as an alternative for their forest plantation project. The project first started in 1982 and with the target to add for future timber supply which is expected to face a shortfall from the natural forests (Ahmad, 1995). As to why *Acacia* species has been chosen as a plantation species is based on its rapid growth better than average wood quality if to adapt to the soil types and its pH values (Pinyopusarerk *et al.*, 1993). *Acacia* species also is highly appreciated for its quality to produce exquisite furniture with lasting values at affordable cost. The furniture is valued mostly based on its strength, durability and aesthetic value such as grain orientation and colours. Moreover, acacia species such as *Acacia mangium*, *Acacia auriculiformis* and hybrid acacia is major fast growing plantation species not only for timber production but also for greening purposes in the tropical region (Yamamoto *et al.*, 2003; Semsuntud *et al.*, 1991; Hamami *et al.*, 1989).

Generally, the properties of naturally grown species seem to vary much more than that plantation species. *Acacia* is slightly durable species, especially for exposed condition and in ground contact uses. The preservative treatment has to be used in order to prolong the uses of the wood products for certain periods of time. However, woods treatment used preservative which mostly have heavy metals and discharge toxin to the environment.

A lot of efforts have been put to develop new wood preservatives. In addition, developed countries have totally banned the use of Chrome-copper Arsenic (CCA) in their woody materials (Berard *et al.*, 2006). Increased in environmental awareness by the general public, combined with increasingly stringent legislature in recent years has led to greater restrictions in the use and disposal of many of the conventional preservative systems (Jones and Hill, 2007). In recent years, advanced in environmental awareness and the effective of policies which support the use of renewable resources and environment friendly chemicals have resulted in high interest in "non-biocidal". Another environment friendly technique is the use of biogradable substances in wood protection (Hyvonen *et al.*, 2006).

One of the new environmentally friendly preservative systems is heat treatment. Heat treatment seemed to be a suitable treatment for woods because of its advantage to be non toxin and does not require chemicals. Razak *et al.* (2007) has successfully conducted studies on enhancing the durability of *Gigantochloa scortechinii* by using oil palm oil as the medium of heat transfer. While, Sidorova (2009) conducted the oil heat treatment of spruce, pine and aspen in rape seed oil in the deep fryer to enhance the properties of oil heat treated wood.

The aim of this study was to investigate how heat-treatment improved the properties of wood, especially on enhancing wood colour appearance and the effect of the process on the chemical component of *Acacia* hybrid. The result of this study will benefit immensely in terms of improving the technologies in treated wood for the local wood industry in producing good quality acacia products.

1.2 Justification

Acacia species has early maturity age. The maturity is ranged from 8 to 14 years depending on what final products these timbers are going to be turned into. Most plantation owner, however tend to harvest the timber at much shorter period lead to limited information on their finishing properties. Therefore, it is important to study certain physical and technologies properties to provide the information in order to improve utilization of this species for specific end uses.

However, *Acacia* has dissimilar sapwood and heartwood. The sapwood's colour is lighter than heartwood. Dark heartwood together with light sapwood, these colour differences with definite irregular colour margins reduce the value of wood considerably. The less appealing and extremely inhomogeneous colour causes serious marketing problems of products. In order to be competitive on the market, the colour appearance of the wood, particularly of products with large surfaces, such as flooring or furniture fronts, need to be technically modified and homogenized before secondary processing (Tolvaj *et al.*, 2006). The colour compatibility of components is important when matching a pair individual piece into final products (Resch *et al.*, 2000).

To overcome this problem, the wood industry mostly applied staining or dark finishing material to make the sapwood in colour with the heartwood. Painting or staining the wood mainly have two objectives. One is colouring, the other is to protect the wood surface. This remedy is effective but however, only the surface of the timber is coated with the finishing material and once the top surface is removed (during planning and cutting) the lighter color of the sapwood is exposed. Furthermore, the emission of volatile organic compounds such as toluene and xylene from paint is a health concern while colouring by heat treatment emits no volatile organic compounds and is very simple (Mitsui *et al.*, 2001).

Heating is known to darken the sapwood of all species; the phase and intensity of darkening are different in relation to wood species, the moisture content, the temperature and the duration of heating exposure (Charrier et al., 2002). The proposed study will make use of the heat treatment process with

control parameters such as temperature, media of transfer heat, and duration of treatment to darken the color of the sapwood from the surface right to interior and in the same way to provide the information the ability of this species at developing appropriate drying schedules. This process will darken the whole timbers in planks or veneer forms. Planning and cross-cutting of the heat treated wood will pose no problem, especially to the furniture industry as the woods maintain their colour.

1.3 Objectives

The main goal of this study is to enhance the sapwood appearances and durability of cultivated *Acacia* hybrid by applying the environmental friendly heat treatment process. This can be achieved by the following objectives:

1. To assess colour changes of wood colour appearances in *Acacia* hybrid by the heat process.

2. To assess the physical, mechanical and chemical of heat-treated *Acacia* hybrid.

CHAPTER 2

LITERATURE REVIEW

2.1 *Acacia* Hybrid

Acacia species have been chosen for trial and large-scale planting in the previous years in order to meet demand of the production. *Acacia* is a plant genus belonging to the family of *Leguminosae*, and sub-family of *Mimosoideae*. *Acacia* species have wide distribution in Asia, Africa, America and Ocenia. *Acacia* genus has about 1200 species world-wide. During the last 20 years in tropical Asia, especially in Southeast and South Asia, *acacia* species have played a specially importance role in greening and reforestation programs where the best known species are *Acacia mangium* and *Acacia auriculiformis* (Nguyen and Pham, 2007).

Plantations of *acacia* species create a green and beautiful landscape and also contribute to soil improvement and environment protection. *Acacia* wood is in use for various purposes, producing various kinds of products dependent on different species and different level of their age (refer to Table 2.2). At the age between 6 and 8, almost all kinds of *Acacia* wood are used for pulp, chip, finger joint boards and MDF boards. Only a few trees with larger diameter used for sawn timber and construction materials. Wood of *Acacia* can be used as raw materials for forest industries and serve other living requirements. Bark, leaves have useful utilizations and honey bee can be reared under *Acacia* plantations (Nguyen and Pham, 2007).

Acacia mangium and *Acacia crassicarpa* form the largest area of industrial plantations in Malaysia and Indonesia, with a hybrid involving *Acacia mangium* and *Acacia auriculiformis* gaining in importance in Vietnam and Thailand. The plantings of acacia in these countries are dominated by the private sector, which also own the pulp and paper mills which utilize the pulpwood logs. In Malaysia, acacias are well established in Sabah and Peninsular Malaysia. Other plantings by the private sector are being designed for sawn timber production for the furniture trade and

other similar high value uses. The main areas of acacia plantations in Asia in 2007 as indicated in Table 2.1 (Morton and Applegate, 2007).

Table 2.1: Location of main acacia plantations in Asia in 2007

Country	Planted area (ha)	Growth rates (m^3/ha/yr)
Pen. Malaysia	75,000	18-24
Sabah	120,000	18-24
Sarawak	60,000	20-24
Indonesia	1,700,00	16-24
Vietnam	Uncertain (< 127,000)	8-15

Source: Morton and Applegate (2007)

Natural hybrids between *Acacia mangium* and *Acacia auriculiformis* have been found first in 1970s in Sabah, Malaysia (Nguyen and Pham, 2007). It grows in Indonesia, Malaysia, Thailand, Vietnam, and China (Kha, 1996). *Acacia* hybrid wood has some good characteristics hereditary from both its father and mother species. Some characteristics are like big straight trunk, few branches and knots. Sapwood and heartwood of *Acacia* hybrid are quite clear. Moreover, color of the wood is brighter than *Acacia mangium* wood (Nguyen and Pham, 2007). When *Acacia* hybrid is young, the bark is greenish white, similar to the bark of *Acacia auriculiformis*. As it ages, the bark turns greenish brown or brown. It is as smooth as the bark of *Acacia auriculiformis*, with slightly scalely and shallow furrows at the foot of the tree (Kha, 1996).

Content of cellulose within *Acacia* hybrid is equal to *Acacia mangium* and higher than *Eucalyptus camaldulensis* and *Eucalyptus urophylla*. *Acacia* hybrid gives high productivity and quality as compare to *Acacia auriculiformis*, *Acacia mangium*, *Eucalyptus camaldulensis* and *Eucalyptus urophylla* for pulp production. Paper product generated from *Acacia* hybrid wood is better than those other species such as *Styrax tonkinensis* and *Manglietia conifera*. In woodwork production aspects, *Acacia* hybrid is not the right choice because it is brittle contained huge wood-fibre and rough wood surface (Nguyen and Pham, 2007). According to Kha (1996), the wood properties of *Acacia* hybrid are similar to those of *Acacia mangium*, although the hybrid has a slightly higher wood density which is 0.46 g/cm^3. Characteristic of Acacia hybrid

Table 2.2: Characteristic of *Acacia* hybrid

SPECIES
ACACIA spp. (*Acacia* hybrid)

SILVICULTURE

Planting materials	: Seeds, cuttings, tissue culture
Rotation	: 15 years (5-7 years for woodchips)
Growth	: Mean diameter > 30 cm after 15 years

ECONOMICS

Established cost	: RM 8200/ha
Log price	: RM 245/m^3
Market potential	: Good

TECHNICAL PROPERTIES

Density	: 420-560 kg/m^3
Natural durability	: Non durable for exposed condition
Treatability	: Stains well, pressure treats satisfactorily
Seasoning characteristics	: Seasons well, but air drying slow, kiln drying good, shrinkage: radial-3.4%, tangential-6.5%
Working quality	: Easy to saw, prone to split, bow and warp (in small dimension), easy peeling and slicing for veneer, liable to spin out due to soft core, easy to drill, turn, rout and plane, sands and glues well.
Strenght group	: 5-6

USES AND VIABILITY OF SPECIES

The wood is suitably used for sawn timber (low recovery; 7% furniture grade, 47% clear cutting grade, 46% boxing grade), plywood, slice veneer, laminated veneer lumber, cement board, MDF, pulp and paper (sulphate & Nssc pulping)

Source : Malaysian Timber Industry Board (2007)