EFFECTS OF SUPERHEATED STEAM TREATMENT ON PROPERTIES OF LIGHT RED MERANTI AND KEDONDONG

RASDIANAH DAHALI

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By

RASDIANAH DAHALI

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

November 2018

DEDICATION

Special Dedication to:

My Supervisor
Prof. Dr. Zaidon Ashaari

My Senior
Dr. Lee Seng Hua

My Parents
Dariah Selamat and Dahali Biro

My Family Members
Hamzah, Darwin, Zafri, Dahlan, Mohd Yusuf, Dahlia, Rashid, Masri & Siti Rahmah

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

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Chairman : Professor Zaidon Ashaari, PhD
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Light red meranti (*Shorea spp.*) and kedondong (*Canarium spp*.) are known to be non-durable and dimensionally unstable. Due to the aforementioned matters, a proper treatment is required to enhance the properties of these woods. Heat treatment is one of the potential methods to solve the problems of these materials. A study was undertaken to determine the effects of superheated steam (SHS) treatment on the performance of light red meranti and kedondong woods and to optimise its parameters for optimum biological, physical and mechanical properties of these woods using response surface methodology (RSM). The range of treatment temperature and time studies were between 172 to 228 °C and 95 to 265 min respectively. Air-dry samples with nominal dimensions of 410 mm long × 25 mm wide × 25 mm thick were proposed in this study. An oven equipped with a boiler and heater to produce a SHS was used to heat the samples. The response analysis such as resistance against white-rot fungus (*Pycnoporus sanguineus*) and subterranean termite (*Coptotermes curvignathus*), weight loss (WL) due to SHS treatment, equilibrium moisture content (EMC) and moisture excluding efficiency (MEE), modulus of rupture (MOR) and modulus of elasticity (MOE) in static bending. The results were presented in this study and showed that SHS treatment improved the durability, hydrophobicity and dimensional stability of treated wood. Moreover, as an effects from SHS treatment, the colour of treated samples becomes darker compared to untreated due to chemical degradation. In contrary, the MOR and MOE were adversely affected by this treatment. The reduction of these properties were more severe on the increment of heating temperature. Between these two species, the strength of kedondong wood was affected severely by SHS treatment. The changes in chemical constituents were the primary reason for the changes in wood properties and the results were confirmed by the Fourier transform infrared analysis (FTIR). The results also revealed that the optimum heating parameters suggested by the RSM to obtain optimum improvement in the

performance of the wood were 210 °C and 197 min, and 218 °C and 120 min for light red meranti and kedondong respectively.

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

KESAN RAWATAN STIM PANAS LAMPAU TERHADAP SIFAT-SIFAT KAYU MERANTI MERAH MUDA DAN KEDONDONG

Oleh

RASDIANAH DAHALI

November 2018

Pengerusi : Profesor Zaidon Ashaari, PhD
Fakulti : Perhutanan

Kayu meranti merah muda (*Shorea spp.)* dan kedondong (*Canarium spp.)* diketahui tidak tahan lama dan mempunyai dimensi yang tidak stabil. Disebabkan perkara-perkara tersebut, rawatan yang sewajarnya diperlukan bagi meningkatkan sifat-sifat kayu tersebut.

Rawatan haba adalah salah satu kaedah yang berpotensi untuk menyelesaikan masalah material ini. Kajian dijalankan untuk menentukan kesan rawatan stim panas lampau (SHS) terhadap prestasi kayu meranti merah muda dan kedondong dan untuk mengoptimumkan parameter untuk sifat biologi, fizikal dan mekanikal kayu ini dengan menggunakan metodologi tindak balas permukaan. Julat suhu dan masa rawatan yang dikaji masing-masing antara 172 °C hingga 228 °C dan 95 min hingga 265 min. Sampel yang dikering udara dengan dimensi nominal 410 mm panjang × 25 mm lebar × 25 mm tebal telah dicadangkan dalam kajian ini. Ketuhar yang dilengkapi dengan dandang dan pemanas untuk menghasilkan SHS digunakan untuk memanaskan sampel. Analisis tindakbalas seperti rintangan terhadap kulat reput putih (*Pycnoporus sanguineus*) dan anai-anai bawah tanah (*Coptotermes curvignathus*), kehilangan berat (WL) kerana rawatan SHS, keseimbangan kandungan lembapan (EMC) dan lembapan tidak termasuk kecekapan (MEE), modulus pecah (MOR), dan modulus keanjalan (MOE) dalam lenturan statik. Hasil dibentangkan dalam kajian ini dan menunjukkan bahawa rawatan SHS meningkatkan daya ketahanan, hidrofobisiti dan kestabilan dimensi kayu yang dirawat. Selain itu, sebagai kesan daripada rawatan SHS, warna sampel dirawat menjadi lebih gelap berbanding yang tidak dirawat kerana degradasi kimia. Sebaliknya, MOR dan MOE telah terjejas teruk oleh rawatan ini. Pengurangan sifat-sifat ini lebih teruk dengan kenaikan suhu pemanasan. Antara dua spesies ini, kekuatan kayu kedondong terjejas teruk oleh rawatan SHS. Perubahan dalam unsur

kimia adalah sebab utama perubahan sifat kayu dan hasilnya disahkan oleh analisis ubah inframerah Fourier (FTIR). Keputusan juga menunjukkan bahawa parameter pemanasan optimum yang dicadangkan oleh RSM untuk mendapatkan peningkatan optimum dalam prestasi kayu adalah 210 °C dan 197 min, dan 218 °C dan 120 min masing-masing untuk meranti merah muda dan kedondong.

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I certify that a Thesis Examination Committee has met on 13 November 2018 to conduct the final examination of Rasdianah Dahali on his thesis entitled "Effects of Superheated Steam Treatment on Properties of Light Red Meranti and Kedondong" 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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LIST OF ABBREVIATIONS

ANOVA	Analysis of Variance
ASTM	American Society for Testing and Material
°C	Celcius
CCA	Chromated copper arsenate
CCD	Central Composite Design
CH_3COOH	Acetic Acid
EMC	Equilibrium Moisture Content
ft	Feet
FTIR	Fourier Transform Infrared
g	Gram
h	Hour/s
H_2SO_4	Sulfuric Acid
IGC	Inverse gas chromatography
LHW	Light Hardwood
LOF	Lack of Fit
LRM	Light Red Meranti
KDG	Kedondong
kg	Kilogram
kW	Kilowatt
m	Meter
MATRADE	Malaysia External Trade Development Corporation
MC	Moisture Content
MEA	Malt Extract Agar
MEE	Moisture excluding Efficiency
Min	Minute/s

mg	Miligram
ml	Mililiter
m^3	Volume
mm	Milimeter
MOE	Modulus of Elasticity
MOR	Modulus of Rupture
MPa	Megapascal
MS	Malaysian Standard
MTC	Malaysian Timber Council
MTIB	Malaysian Timber Industry Board
N	Newton
N	Normality
$NaClO^2$	Sodium Chlorite
NaOH	Sodium Hydroxide
NATIP	National Timber Industry Policy
NOW	New Option Wood
OD	Oven-Dried
OHT	Oil Heat Treatment
pH	Potential Hydrogen
RH	Relative Humidity
R^2	Multiple Regression
rpm	Revolutions per minute
RSM	Response Surface Methodology
s	Second/s
SG	Specific Gravity
SHS	Superheated Steam
TAPPI	Technical Association of Pulp and Paper
UV	Ultraviolet
WL	Weight Loss

CHAPTER 1

INTRODUCTION

1.1 Background of the Study

The timber industry is one of the major contributions to Malaysian export earnings. Since the last two decades after the First Industrial Master Plan from 1986 until 1995, followed by the Second Industrial Master Plan in 1996 until 2005 continued with the ongoing Third Industrial Master Plan from 2006 until 2020, the industry is very profitable with massive growth rates (Zaidon, 2017). In 2017, the Malaysia's total export earnings achieved RM935.39 billion and RM23.22 billion from that were contributed by timber and timber product industries. Obviously, there were increments from previous years of RM2.4 billion (MATRADE, 2018; MTIB, 2018). Generally, the timber industry was the third most important commodity after palm oil (RM46.12 billion) and rubber (RM26.31 billion), (MATRADE, 2018).

Wooden furniture, plywood, and sawn timber have been the largest contributors and accounted for 71% of the total wood commodity export valued at RM16.56 billion (Figure 1.1). At about RM8.06 billion of the total export of wooden furniture was reported on 2017. The Minister of Plantation Industries and Commodities stated his confidence that by 2020, Malaysia will be able to achieve the export target of RM12 billion in revenue for the furniture industry (New Strait Time, 2018). Currently, Malaysia is the eighth largest furniture exporter in the world (MATRADE, 2017) with shipments to more than 160 countries including United States of America, Japan, Australia, Singapore and United Kingdom (MTIB, 2018).

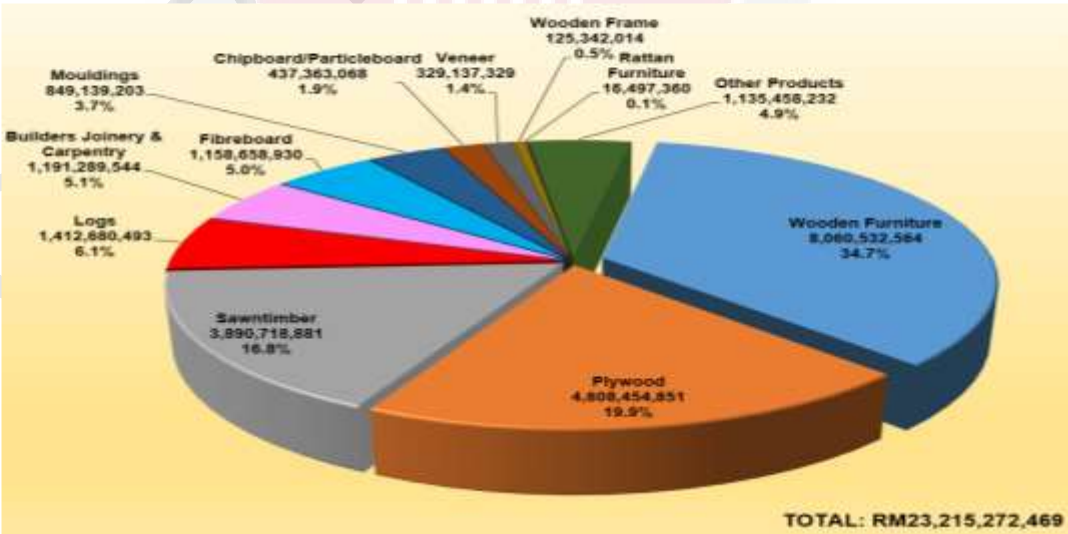

Figure 1.1 : Export of timber and timber products by Malaysia in 2017 (MTIB, 2018)

Plywood and sawn timber were the second and third largest foreign exchange earners (19.9% and 16.8%, respectively) for the timber industry in 2017. The export value of plywood and sawn timber products amounted to RM8.49 billion in the same year. According to (NATIP, 2009), the government expected the timber industry in Malaysia to contribute RM53 billion to the country's export earnings by 2020. This is more than double for the present revenue. In order to ensure that the projected goal of RM53 billion can be achieved, adequate and sustained supplies of raw materials for further development of the timber industry are needed.

Nonetheless, the timber industries in Malaysia face the challenge of lack of supply of raw materials. The supply of commercial hardwood from natural forests and plantations is insufficient to support the industry needs (Zaidon, 2017). As the majority of the commercial hardwood species that are converted to sawn timber, it would induce a high strength and durability such as balau, cengal, merbau and many more. Their growth rate however, are slower and the availability of these species is limited (Khairunnisa, 2015). Thus to meet the local demands, the wood based industries are looking for other alternatives to augment the diminishing supply of raw materials.

One way to overcome the problem is through the utilisation of low density wood. Most of low-density woods were classified as light hardwood (LHW) and some with poor properties such as dimensionally unstable and non-durable. In addition, these woods are easily degraded as they contain sugar and starch that act as a nutritive source for fungi, termites, and other organisms (Aydin et al., 2015). Hence, to enhance the properties of these woods, a proper treatment is needed to prolong the service life of the material. As stated in the European Standard (EN-350-2, 1994), the properties of non-durable wood can be enhanced through preservation. However, the preservation processes that involved chemicals, may contribute to mammalian hazardous and pollution to the environment.

1.2 Problem Statement

Heat treatment of wood is a viable alternative and environmentally friendly as wood protection method without the use of harmful conventional preservatives (Rasdianah et al, 2018; Sabiha, 2014). It has been known that heat treatment is an effective method in improving wood properties such as reducing moisture absorption, as well as improving dimensional stability and biological durability (Akgul & Korkut., 2012; Umar et al., 2016), especially for non-durable wood (Brosse et al., 2010; Tuong & Li., 2010). There are various type of heat treatment processes that have been developed such as Thermo Wood, Plato Wood, Le Bois Perdure, Rectification and Oil heat treatment (Talaei et al., 2014).

The level of property changes is depending heavily on the process, wood species and its characteristic properties, initial moisture content of the wood, surrounding atmosphere, treatment time and temperature. Among all the factors mentioned above, the treatment temperature and time are the most important factor that may affect many of the wood properties (Johansson & Moren, 2006; Talaei et al., 2014). Previous studies by Rowell et al., (2009) reported that the wood degraded more rapidly when heated in either steam or water compared to heating in dry conditions. Meanwhile, Stamm (1956) in their study explained that the wood heated in the presence of oxygen degraded more rapidly than the wood heated in the absence of oxygen. In addition, treatments in air could result in oxidation reactions, which could deteriorate the mechanical properties of the treated wood (Boonstra & Tjeerdsma, 2006).

Even though the heat treatment offers various advantages, but it also has several limitations. Based on the results from previous researches, it has been revealed that the strength of wood was affected and most of the mechanical properties of wood decreased after the treatment process (Ozcan et al., 2012; Balkis et al., 2013; Sabiha, 2014; Rasdianah et al., 2018). As the treatment temperature and time increases, the brittleness of the treated wood was also increasing (Edlund, 2004). Moreover, the treated woods are exposed to the danger of fire due to the high temperatures during the heat treatment process.

1.3 Justification

Superheated steam (SHS) that was generated the temperature above the boiling point of water has been used for drying wood since early 1900s in Germany (Park & Yeo, 2012). Hence, wood drying process using SHS might have many advantages. One of the crucial advantages was the use of low energy because of easy to condense when utilizing the SHS in drying and energy recovery. Other than that, the absence of oxidation and the additional effects of sterilization or deodorization when using high-temperature vapour generated high level of safety. Moreover, this method also crucial due to its fast drying rate and thus easily to combine with other methods. Because of the above reasons, SHS treatment was proposed as a heating medium in this study.

Light red meranti (LRM) and kedondong (KDG) were selected as the treated materials. Both species are LHW and non-durable against fungal decay and termite attack. In addition, the woods are dimensionally unstable and difficult to be treated with preservative as in intercellular canal of LRM that was plugged with white colour resin as well as in the vessel of KDG that was contained abundant of tyloses (MTIB, 2010). This resin and tyloses would make these woods were highly resistant to preservative treatment since it blocked the penetration of solution into the wood. Hence, the SHS treatment could be a potential thermal treatment to enhance the biological and physical properties of these woods.

Unfortunately, there are limited studies on the effectiveness of heat treatment on the properties of tropical hardwood. Previous studies on heat treatment were more focused on temperate wood species. Temperate hardwood might be different from tropical hardwood in terms of chemical compositions and anatomical structures. Therefore, the effects of SHS treatment on LRM and KDG as well as study on the optimisation and effectiveness of heat treatment parameters on these woods are worth to be investigated and explored.

1.4 Objectives of the Study

The main objectives of this study are including the sub-objectives as follows:

I. To determine the effects of Superheated steam (SHS) treatment on the performance of light red meranti (LRM) and kedondong (KDG) woods.
II. To optimise the SHS treatment parameters for optimum biological, physical and mechanical properties of these woods using response surface methodological (RSM) approach.

1.5 Research Questions

i. How the wood properties are affected by SHS treatment and to what extent is the treatment on the properties?
ii. What are the optimum process variables of SHS treatment to attain the desired properties?
iii. What are the limitations of the current study?

1.6 Significance of the Study

This study is significantly important to explore an economical and environmentally friendly method for enhancing the inferiority of non-durable wood so that the wood can be utilised and developed as value-added products. The treated materials are able to substitute commercial timbers, in which the supplies are dwindling. As for the manufacturers, the result of this study can be regarded as a guideline on the heat treatment to enhance the properties of non-durable wood. Furthermore, the findings and new discoveries will add more reference sources for future research, especially in the field of wood quality enhancement.

1.7 Limitations of the Study

The limitations of the study are as follows:

- Parameters: Heating temperature and time used in this study are in the range from 172 to 228 °C and from 95 min to 265 min, respectively.
- Species: The non- durable wood species used in this study are LRM and KDG.
- Size: The size of the wood sample subjected to heat treatment is 410 mm long × 25 mm wide × 25 mm thick.
- Equipment: The heat treatment process has been conducted using a laboratory-scale SHS oven.

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