***PHYSICAL AND MECHANICAL PROPERTIES OF RUBBERWOOD PARTICLEBOARD MADE WITH FURFURYL ALCOHOL ADDED UREA FORMALDEHYDE RESIN***

**SEK BIH FANG**

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# PHYSICAL AND MECHANICAL PROPERTIES OF RUBBERWOOD PARTICLEBOARD MADE WITH FURFURYL ALCOHOL ADDED UREA FORMALDEHYDE RESIN

By

SEK BIH FANG



**A Project Report Submitted in Partial Fulfillment of the Requirements for the Degree of Bachelor of Wood Science and Technology in the Faculty of Forestry**
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## DEDICATION

For my beloved family:

Sek Powi Tie

Chiu Bee Kian

Also my siblings.

To all my friends,

Thank you for your encouragements supports

And the sacrifices that you have given.

Last but not least,

I dedicated this dissertation to Prof. Paridah Md Tahir,

Dr. Lee Seng Hua and Dr. Mohamad Roslan Bin Mohamad Kasim

Who has encouraged me, helped and gave so much support

During conducting this research and in my study.

Thank you for everything.

## ABSTRACT

The objective of this study was to determine the dimensional stability properties and mechanical strength of the rubberwood particleboard made after addition of furfuryl alcohol to urea formaldehyde resin. The main issue in this research was the dimensional instability of rubberwood particleboard as wood is a hygroscopic material which loses and gains moisture as a result of changes in humidity. Chemical modification on the rubberwood particleboard such as acetylation and furfurylation are great in improving the dimensional of particleboard. In this study, the chemical treatment by applying furfuryl alcohol added UF resin was used to treat the rubberwood particleboard due to the significant performance improvement of modified woods and small environmental impact. This study proposed a procedure in which rubberwood particleboard was treated with furfuryl alcohol added UF resin followed by the condition of palm oil addition or without palm oil in the particleboard samples fabrication. Properties such as mechanical strength, dimensional stability and density of the particleboard made with treated and untreated particles were examined. The results showed that there was highly significant effect of furfuryl alcohol added UF resin treatment to water absorption, thickness swelling, MOR, MOE and IB of the rubberwood particleboard. These findings in turn support that furfuryl alcohol added UF resin treatment have greatly enhanced the dimensional stability and mechanical properties of rubberwood particleboard.

# ABSTRAK

Objektif kajian in adalah untuk mengkaji sifat kestabilan dimensi dan kekuatan mekanik papan partikel kayu getah yang diperbuat selepas penambahan alkohol furfuril ke dalam resin urea formaldehid. Isu utama dalam kajian ini adalah ketidakstabilan dimensi papan partikel kayu getah memandangkan kayu merupakan bahan higroskopik yang mampu membebaskan dan menyerap molekul air akibat daripada perubahan dalam kelembapan persekitaran. Modifikasi bahan kimia pada papan partikel kayu getah seperti pengasetilan dan *furfurylation* mampu menambahbaikkan sifat kestabilan papan partikel. Dalam kajian ini, rawatan kimia dengan aplikasi alkohol furfuril tambah resin UF telah digunakan untuk merawat papan partikel kayu getah. Hal ini demikian kerana prestasi penambahbaikkan oleh kayu modifikasi yang ketara dan kesannya yang kecil pada persekitaran. Kajian ini mengusulkan prosedur di mana papan partikel kayu getah telah dirawat dengan alkohol furfuril tambah resin UF dan diteruskan dengan keadaan adanya penambahan minyak sawit atau tanpa minyak sawit dalam proses penghasilan sampel papan partikel. Sifat-sifat seperti kekuatan mekanik, kestabilan dimensi dan ketumpatan papan partikel yang diperbuat daripada partikel yang telah dirawat serta partikel tanpa rawatan telah diuji. Keputusan kajian menunjukkan bahawa rawatan alkohol furfuril tambah resin UF berimpak tinggi pada penyerapan air, perluasan ketebalan, *MOR*, *MOE* dan *IB* papan partikel kayu getah. Hasil kajian ini secara langsung telah menyokong fakta berkenaan bahawa rawatan alkohol furfuril tambah resin UF telah banyak meningkatkan dimensi kestabilan dan sifat mekanikal papan partikel kayu getah.

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## APPROVAL SHEET

I certify that this research project report entitled "Physical and Mechanical Properties of Rubberwood Particleboard made with Furfuryl Alcohol added Urea Formaldehyde Resin" by Sek Bih Fang had been examined and approved as a partial fulfilment of the requirements for the Degree of Bachelor of Wood Science and Technology in the Faculty of Forestry, Universiti Putra Malaysia.

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Date: January 2019

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## LIST OF ABBREVIATIONS

| | |
|---|---|
| ANOVA | Analysis of Variance |
| DMDHEU | Dimethylol Dihydroxy Ethylene Urea |
| DOSM | Department of Statistics Malaysia |
| FA | Furfuryl Alcohol |
| FAO | Food and Agriculture Organization of the United Nations |
| FD | Forest Department |
| FDPM | Forestry Department Peninsular Malaysia |
| IB | Internal Bonding |
| LE | Linear Expansion |
| MC | Moisture Content |
| MDF | Medium-density Fibreboard |
| MOE | Modulus of Elasticity |
| MOR | Modulus of Rupture |
| NATIP | National Timber Industry Policy |
| RW | Rubberwood |
| SFD | Sarawak Forestry Department |
| SPSS | Statistical Package for the Social Sciences |
| TS | Thickness Swelling |
| UF | Urea Formaldehyde |
| WA | Water Absorption |

# CHAPTER 1

# INTRODUCTION

## 1.1 Background of Study

*Hevea brasiliensis*, better known as the rubber tree, is the primary source of natural rubber. It is native to Brazil (parts of the Amazon Basin and Matto Grosso) and the Guianas, but most of the world's rubber comes from the plantations in Indonesia, Thailand and Malaysia. Vernacular names applied to the timber of *Hevea brasiliensis* (Euphorbiaceae) include kayu getah (Peninsular Malaysia and Sabah), rubberwood (Peninsular Malaysia, Sabah and Sarawak) and para rubber (Peninsular Malaysia, Sabah and Sarawak).

Rubberwood is an important raw material in the country, used extensively for the manufacture of furniture. Rubberwood has a dense grain that is easily controlled in the kiln drying process. It has very little shrinkage making it one of the most stable materials available for furniture, toys and kitchen accessories. Besides, it is easily worked, and takes on stains uniformly. As with all hardwoods, rubberwood comes in varying degrees of quality. While for the availability of rubberwood, it is rarely exported in raw lumber form, but is instead worked into a variety of furniture, kitchen, and other household items and then exported and sold elsewhere.

Table 1.1: Malaysia - Projected annual production of logs from Malaysian Rubberwood plantations, 2006 - 2020

| Five year period | Peninsular Malaysia | Sabah | Sarawak | Malaysia |
|---|---|---|---|---|
| | million $m^3$ | | | |
| 2006 - 2010 | 2.1 | n.a. | n.a. | 2.1 |
| 2011 - 2015 | 1.9 | 0.1 | n.a. | 2.0 |
| 2016 - 2020 | 1.7 | 0.1 | n.a. | 1.8 |

Sources : FDPM, SFD and FD Sarawak (2009)
Note : n.a. not available

In 2016-2020, an estimation of 1.8 million $m^3$ rubberwood logs are produced annually (NATIP, 2009). Malaysian Rubberwood logs are generally obtained as a by-product of rubber trees from agricultural rubber estates, established for the production of latex. However, the supply of Malaysian Rubberwood logs can also be obtained from rubber tree plantations which grows trees solely for the production of logs. In fact, Malaysia has close to 1.1 million hectares of rubber estates to sustain demand for timber downstream businesses (New Straits Times, 2017).

The products from rubberwood and its applications in Malaysia are increasing in a wide variety, for instance laminated products, particleboard, MDF, plywood mostly for furniture, flooring. Salleh (1984) reported 61 different products made from rubberwood. The most important uses are: furniture and furniture parts, parquet, panelling, wood-based panels (particleboard, cement and gypsum-bonded panels, medium-density fibreboard (MDF), kitchen and novelty items, sawn timber for general utility and fuel (FAO, 2001).

In view of the need to maximise the utilisation of wood resources, the industry has diversified into the production of high value-added reconstituted panel products such as particleboard and medium density fibreboard. The particleboard industry in Malaysia has grown and currently there are 32 mills in operation. The industry, over the years has successfully exported its products particularly for use in the furniture industry (Ministry of International Trade and Industry, 2017).

Particleboard was being established commercially by the end of the 1940s when there was a lack of timber available to manufacture plywood affordably. It also known as chipboard, was much more readily accessible at the time as it's made from a combination of waste materials - such as planer shavings, offcuts or sawdust – and mechanically produced wood chips (International Timber, 2015).

According to Department of Statistics Malaysia (DOSM), particleboard is one of the important timber product in Malaysia. Its exportation value in 2017 is RM437.36 million which is 1.9% of the total export value, RM23.21 billion.

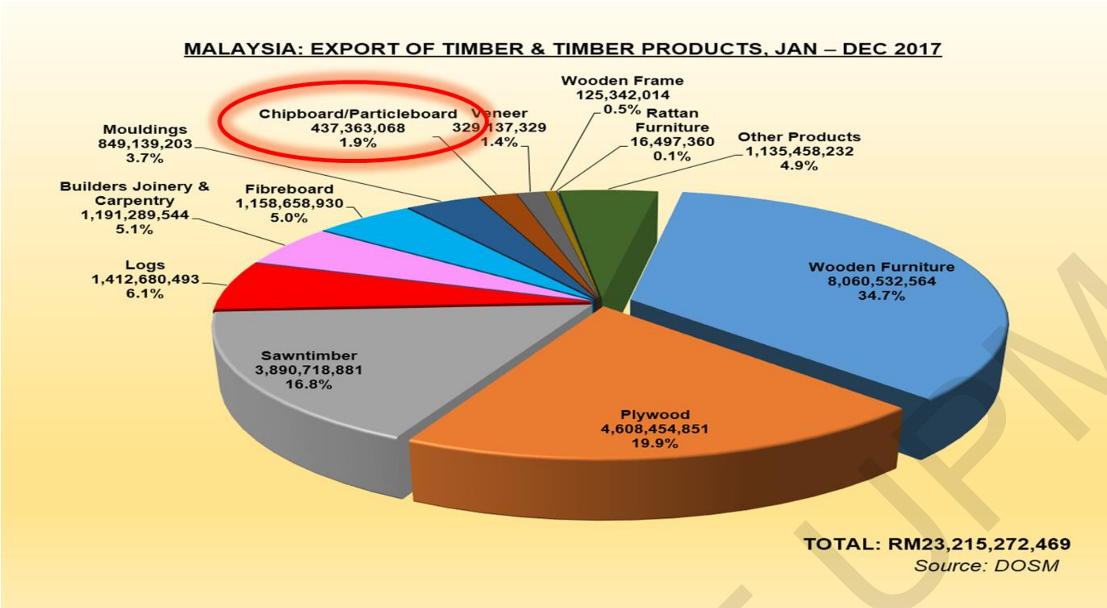


Figure 1.1: Malaysia: Export of Timber & Timber Products, Jan – Dec 2017

It is often used in furniture and interior applications, because standard particleboard isn't suitable for areas that are prone to wetting or high humidity and is more affordable than solid timber.

In spite of that, the major disadvantage of rubberwood particleboard is that it is very prone to expansion and discoloration due to moisture, particularly when it is not covered with paint or another sealer. Therefore, it is rarely used outdoors or places that have high levels of moisture, with the exception of some bathrooms, kitchens and laundries, where it is commonly used as an underlayment beneath a continuous sheet of vinyl floor covering.

In order to improve the physical and mechanical properties of wood and its composites, there has been a rapid increase in the application of chemical treatments to modify the wood, such as acetylation, impregnation with phenol formaldehyde resin, furfurylation and oil heat treatment. Modification of wood aims to change its chemical constituents and subsequently affects its final properties.

Research relating to chemical modification of wood with furfuryl alcohol ($C_5H_6O_2$), or so called 'furfurylation of wood', was initiated by Goldstein (1959) and Stamm (1977). By using cyclic carboxylic anhydrides, mainly maleic anhydride, as key catalysts, furfurylated wood, having properties superior to those of the wood produced with the early developed systems, was achieved by Prof. M. Schneider (1995) in Canada. Novel research was also carried out by Dr. M. Westin and his coworkers (Westin, 1996; Westin et al., 1998; Lande et al., 2004a, 2004b), at SP Sweden, which led to a new technology based on stable solutions with good impregnating capacity, as well as some promising properties such as resistance to decay.

## 1.2 Problem Statement and Justification

Dimensional instability of rubberwood particleboard is the main issue in this research study. Wood is a hygroscopic material which loses and gains moisture as a result of changes in humidity and lead to dimensional changes.

Hygroscopicity is one of the most distinctive properties of wood. As a result, the rubberwood particleboard will absorb and desorb moisture from the surrounding air until it reaches equilibrium moisture content, a balance point between the wood product's moisture content and that of the surrounding environment. Furthermore, urea formaldehyde (UF) resin used in the manufacturing of particleboard is very poor in water resistance. Therefore, in humid environment, the particleboard in use swells and affects its performance visually and functionally.

Application of water repellent during the blending process did helps to improve the dimensional stability of the particleboard to a limited extent. However, addition of water repellent is usually limited to 1% as further addition did not brings any worthwhile improvement in dimensional stability. Instead, mechanical properties of the particleboard are adversely affected by addition of water repellent with more than 1%. Chemical modification is therefore a sought-after method in improving the dimensional of wood and its composites. However, the current issue that being emphasize in the manufacturing industry is the environmental safety issue of using chemicals in particleboard treatment. Therefore, any new method for enhancement needs to be considered of its impact to the environment.

On account to that, one of the most potential way is to use furfuryl alcohol. Furfurylation treatment can be used to treat the rubberwood particles in order to improve the dimensional stability of rubberwood particleboard. Moreover, furfuryl alcohol is environmentally friendly used chemical in which ecotoxicology of furfurylated wood and leachates from furfurylated wood shown no significant ecotoxicity (Pilgård et al., 2010). Furfurylated wood is nontoxic and it is extremely resistant to marine borers at high levels (>50%) of weight percentage gain (Westin et al., 2016).

Furfural that is manufactured from renewable biomass materials by acid digestion, in turn, can be transformed into furfuryl alcohol by a simple hydrogenation process (Kim et al., 1997). Furfuryl alcohol is a polymerizing chemical that causes wood to swell, and most of the swelling becomes permanent by the homopolymerization (Goldstein, 1960). Its molecules are sufficiently small and polar so that they enter wood cell walls. Thus, they can be cured there to form a cell wall wood polymer composite with good dimensional stability and resistance to acids and bases (Goldstein, 1955; Yun, 1991).

Due to the significant performance improvement of modified woods and small environmental impact, the furfurylation process has been regaining increasing attention from industry over the last 10 years, especially in Europe (Lande et al., 2008). This process impregnates furfuryl alcohol (FA), a strong polarity and low-molecular organic chemical derived from corn cobs or sugar cane residues into wood cavities and even cell walls. It is then thermally polymerized *in-situ*, resulting in a wood polymer composite with excellent comprehensive performances (Hadi et al., 2005; Lande et al., 2008; Szymona et al., 2014). Furfurylated woods have greatly improved dimensional stability, mechanical properties and resistance to various biological attacks (Bryne et al., 2010; Gobakken and Westin, 2008; Hadi et al., 2005; Westin et al., 2006). Due to this potential, a pilot-scale plant for wood furfurylation was established in Norway in 2003 and the first full-scale factory (25,000 $m^3$) was opened in 2009.

Wood furfurylation researches were initiated in the fifties in the previous century (Goldstein and Dreher, 1960; Stamm, 1977) by impregnation of wood consecutively with zinc chloride catalyst and furfuryl alcohol (FA). However, zinc chloride catalyst has drawbacks as salt of strong acid hydrolyses by moisture and forms hydrochloric acid that decomposes wood. At the beginning of the 1990s the cyclic anhydrides organic acids have been used to catalyse FA polymerisation due to good solubility in FA (Lande et al., 2004).

Earlier works used strong acids as catalysts in wood furfurylation process but they reduced mechanical properties of wood and showed significant effect on fire-resistance. It is expected that furfuryl alcohol-boron complexes can provide wood with better biological resistance. However, information on the furfurylation of wood composites are relatively scarce. Therefore, this study proposed a procedure in which rubberwood particles were treated with furfuryl alcohol followed by the condition of palm oil addition or without palm oil in the particleboard samples fabrication.

In this study, addition of furfuryl alcohol into the urea formaldehyde resin was attempted to enhance the properties of particleboard, particularly the dimensional stability. Study was carried out to test the effect of addition of furfuryl alcohol on the rubberwood particles and the particleboard made from it. Properties such as mechanical strength, dimensional stability and density of the particleboard made with treated and untreated particles were examined.

## 1.3 Objectives

The aim of this research is to determine the effects of addition of furfuryl alcohol into UF resin on the properties of particleboard. Specifically, subjects to be studied included:

i. To determine the dimensional stability properties of particleboard bonded with furfuryl alcohol added UF resin.
ii. To determine the mechanical strength properties of particleboard bonded with furfuryl alcohol added UF resin.

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