UNIVERSITI PUTRA MALAYSIA

TREATMENT OF OIL PALM VENEER WITH LOW MOLECULAR WEIGHT PHENOL FORMALDEHYDE FOR HIGH GRADE LAMINATED VENEER LUMBER

KHAIRUL BIN MASSEAT

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By

KHAIRUL BIN MASSEAT

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

June 2017

Specially dedicated to:

My Mother
MARINI BINTI THAMIAS

My Beloved Late Father
MASSEAT BIN KARIS
(Al-Fatihah)

and

My Family

NOORIZAN MOHAMAD MOZIE
KHAYRA NUR IZYAN
KAISER MUHAMMAD NAQI

Your love has made me a better and stronger person.

You are always in my heart.

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

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Chairman: Associate Professor Edi Suhaimi Bakar, PhD
Faculty: Forestry

The depletion of our tropical timber has encouraged the Malaysian wood based industry to seek alternative raw materials such as fast growing plantation tree also lignocellulosic materials for board production. Oil palm tree (*Elaeis guinensis*) from agricultural residues is one of the potential alternative raw material in year future especially to be used as components in furniture making. Researches on laminated veneer lumber (LVL) manufactured from oil palm veneers are being developed in line to reduce waste from oil palm biomass. However, there are no information available concerning the effects of oil palm veneer treatment at wet or high moisture content, treated oil palm LVL boards and using high moisture content before hot press to form LVL on physical and mechanical properties. As we know, the properties of oil palm lumber or veneer is less and not as good as wood. Modification and treatment to the raw material from oil palm are needed to enhance the quality and make it stable as normal wood. Therefore, the main objective of this study is to determine the physical and mechanical properties of LVL made from oil palm veneer (OPV) treated with low molecular weight phenol formaldehyde (LMWPF) resin with different resin solid content (30 and 45%) with different initial moisture content (100, 70, 30 and 15%) of veneer before treatment. OPVs were soaked into LMWPF solution and re-dried to 10% MC before being hot pressed. After the optimum or the best initial moisture content before treatment and resin solid content being gathered, other samples by using optimum parameters with moisture content before hot press was targeted at 15% to compare which parameter produced better physical and mechanical properties of oil palm LVL. There was no any additional resin was added to bond the veneers to form the LVL boards. From the study, by using 45% solid content of LMWPF at 15% initial OPV MC before treatment and re-dried to 10% MC before hot press, it’s showed better performance in terms of physical and mechanical properties of oil palm LVL compared to other parameters. The density results were in the same range between treated LVL and untreated LVL which in the range of 446.72 to 653.32 kg/m^3 and 591.77 kg/m^3

respectively. However, there were significantly different to others physical and mechanical properties test with treated and untreated oil palm LVL. As for thickness swelling (TS) and water absorption (WA), treated LVL showed 0.76 and 24.40% respectively as compared to 2.99 and 63.03% for untreated LVL. While for treated LVL on MOR and MOE parallel to the grain, it produced 38.97 and 4843.5 MPa respectively compared to untreated LVL which only 15.43 and 570.27 MPa respectively. From the result gained, it can be concluded that OPV need to do treatment before product making to enhance quality and comparable to normal wood also can be suggested as a good raw material as a supplement for furniture components in the future.

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

RAWATAN VENIR KELAPA SAWIT MENGGUNAKAN PEREKAT FENOL FORMALDEHID MOLEKUL RENDAH UNTUK PAPAN VENIR BERLAPIS BERGRED TINGGI

Oleh

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Jun 2017

Pengerusi: Profesor Madya Edi Suhaimi Bakar, PhD
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Kekurangan kayu tropika telah menggalakkan industri berasaskan kayu Malaysia untuk mencari bahan mentah alternatif seperti pokok hutan ladang yang cepat tumbesaran dan juga bahan lignoselulosik untuk pengeluaran papan. Pokok kelapa sawit (*Elaeis guinensis*) dari sisa-sisa pertanian adalah salah satu bahan mentah alternatif yang berpotensi di masa akan datang terutamanya digunakan sebagai komponen pembuatan perabot. Penyelidikan mengenai kayu venir berlamina (*LVL*) yang dihasilkan daripada venir kelapa sawit sedang dibangunkan untuk mengurangkan sisa dari biomas pokok kelapa sawit. Walau bagaimanapun, tiada maklumat tersedia mengenai kesan rawatan venir kelapa sawit terhadap kandungan kelembapan (*MC*) pada keadaan basah, papan *LVL* kelapa sawit yang dirawat dan menggunakan kelembapan yang tinggi sebelum tekanan panas untuk membentuk *LVL* pada segi sifat fizikal dan mekanikal. Seperti yang kita ketahui, sifat-sifat kayu kelapa sawit atau venir adalah kurang dan tidak setanding dengan kayu biasa. Pengubahsuaian dan rawatan kepada bahan mentah daripada kelapa sawit diperlukan untuk meningkatkan kualiti dan menjadikannya stabil seperti kayu biasa. Oleh itu, objektif utama kajian ini adalah menentukan sifat fizikal dan mekanikal *LVL* yang diperbuat daripada venir kelapa sawit (*OPV*) yang dirawat dengan fenol formaldehid bermolekul rendah (*LMWPF*) dengan kandungan pepejal resin berbeza (30 dan 45%) dengan berlainan kandungan lembapan awal venir (100, 70, 30 dan 15%) sebelum rawatan. *OPV* yang telah direndam ke dalam larutan *LMWPF* akan dikeringkan semula kepada 10% kandungan lembapan sebelum tekanan panas. Selepas kandungan pepejal resin dan kandungan kelembapan awal yang terbaik diperoleh, sampel lain dengan menggunakan parameter optimum tersebut dibuat dan kandungan kelembapan sebelum tekanan panas disasarkan pada 15% untuk membandingkan parameter yang terbaik bagi menghasilkan sifat fizikal dan mekanikal *LVL* kelapa sawit. Tiada resin tambahan yang ditambah bagi melekatkan venir untuk membentuk papan *LVL*. Daripada kajian ini, dengan menggunakan kandungan pepejal 45% *LMWPF* pada *OPV MC* awal 15% sebelum rawatan dan dikeringkan semula

hingga 10% *MC* sebelum tekanan panas, menunjukkan prestasi yang lebih baik dari segi sifat fizikal dan mekanikal *LVL* kelapa sawit berbanding dengan parameter lain. Keputusan ketumpatan berada dalam julat yang sama di antara *LVL* yang dirawat dan *LVL* yang tidak dirawat yang masing-masing berkisar antara 446.72 hingga 653.32 kg/m^3 dan 591.77 kg/m^3. Walau bagaimanapun, terdapat perbezaan yang signifikan terhadap ujian fizikal dan mekanikal yang lain dengan *LVL* kelapa sawit yang dirawat dan tidak dirawat. Bagi ketebalan bengkak (*TS*) dan penyerapan air (*WA*), *LVL* terawat menunjukkan 0.76 dan 24.40% berbanding 2.99 dan 63.03% untuk *LVL* yang tidak dirawat. Walaupun untuk *LVL* yang dirawat pada *MOR* dan *MOE* selari dengan ira, ia menghasilkan 38.97 dan 4843.5 MPa masing-masing berbanding *LVL* yang tidak dirawat yang hanya 15.43 dan 570.27 MPa masing-masing. Daripada hasil yang diperoleh, dapat disimpulkan bahawa *OPV* memerlukan rawatan sebelum membuat produk untuk meningkatkan kualiti dan setanding dengan kayu biasa serta dapat disarankan sebagai bahan mentah yang baik sebagai tambahan untuk komponen perabot di masa hadapan.

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I certify that a Thesis Examination Committee has met on 13 June 2017 to conduct the final examination of Khairul bin Masseat on his thesis entitled "Treatment of Oil Palm Veneer with Low Molecular Weight Phenol Formaldehyde for High Grade Laminated Veneer Lumber" 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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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirements for the degree of Master of Science. The members of the Supervisory Committee were as follows:

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ASTM	American Society for Testing and Materials
BS EN	British Standard European Norm
FRIM	Forest Research Institute Malaysia
CBR	Cyclic Boil Resistance
^{o}C	Degree Celsius
cm	Centimeter
m	Meter
m^3	Meter cube
ft	Feet
ha	hectare
kg	Kilogram
kg/cm^2	Kilogram Per Centimeter Square (unit measurement)
kg/cm^3	Kilogram Per Centimeter Cube (unit measurement)
LVL	Laminated Veneer Lumber
PLV	Parallel Laminated Veneer
MC	Moisture Content
LSD	Least Significant Different
LMWPF	Low Molecular Weight Phenol Formaldehyde
MDF	Medium Density Fiberboard
MOE	Modulus of Elasticity
MOR	Modulus of Rupture
OD	Oven Dry
EFB	Empty Fruit Bunch
OPF	Oil Palm Frond

OPT	Oil Palm Trunk
OPV	Oil Palm Veneer
OSB	Oriented Strand Board
PF	Phenol Formaldehyde
R&D	Research & Development
SAS	Statistical Analysis System
Sdn. Bhd.	Sendirian Berhad
SS	Shear Strength
UF	Urea Formaldehyde
WA	Water Absorption
TS	Thickness Swelling
WPG	Weight Percent Gain

CHAPTER 1

INTRODUCTION

1.1 General Background

In Malaysia, rubberwood is well known for solid furniture and wood based products such as Medium Density Fiberboard (MDF), particleboard and plywood. Due to the high demand of the wood which is higher than the supply, the price of rubberwood sawn timber has increased year by year. The supply of rubberwood has kept decreasing and failed to meet the demand as more rubber plantations were converted to oil palm plantations (Figure 1.1) and development of housing areas. Considering the huge availability of oil palm measured in terms of its stem volume, this study have been conducted on utilization of the trunk for value added products.

Oil palm trunk is no doubt can become a great substitute or supplement for rubberwood when converted it into reconstituted panel products. However, because of their inherent problems, anatomical and physical characteristics, its make oil palm unsuitable material to replace wood (Killman and Lim, 1985). Nevertheless, the latest study have revealed that oil palm wood can be used as wood alternative upon properly treated (Bakar *et al.*, 2008) and converted into veneer to produce plywood or laminated veneer lumber (LVL) (Razak *et al.*, 2008).

Figure 1.1: Oil Palm Plantation
(Source: Anon, 2008a)

Oil palm (*Elaeis guineensis Jacq*.) originated from the coastal swamplands and fresh water riverine of Central and West African (Anon, 2008a). This plant was then, spread to 16 different tropic countries with Malaysia and Indonesia as the most active and advance countries in promoting and planting this multi-purpose plant (Anon, 2008b). Oil palm was introduced in early 1990's and become one of the main agriculture commodities in Malaysia. In 1960's, only 54,000 ha of oil palm trees was planted, then, the planting area is consistently increase year by year and in year 2016, it reached 5.74 million ha (MPOB, 2016). Considering that the economic life of an oil palm tree is about 25 to 30 years, many of the oil palm stands are now due for replanting because at this age, their productivity are declining and the trees are too tall to harvest.

In one hectare of oil palm plantation, there are about 120 to 130 matured stem in which each stem has a volume of about 1.5 m^3. This mean that 180 to 195 m^3 oil palm trunks (OPT) can be generated from each replanting hectare (Bakar *et al.*, 2008). The rate of oil palm replanting has increased from 88,891 ha in 2012 to 89,798 ha in year 2013. Under the National Key Economic Area (NKEA) palm oil, the objective was to clear the backlog of oil palm aged above 25 years which was estimated at 365,000 ha (Anis *et al*., 2014). For 100,000 ha of oil palm trees have been replanted, it can be estimated that in future, 13.6 million OPT will be able to be harvested annually from the planted oil palm trees (Mohamed *et al.*, 2003). Mohd Husin *et al.* (2000) estimated there are about eight million tonnes of OPT, 22 million tonnes of oil palm frond (OPF) and about five million tons of empty fruit bunch (EFB) obtained from each harvesting activity.

Previously, most of the OPT and the other oil palm parts are left to rot in the field as agricultural waste (Figure 1.2) or are burnt in the field later if the excessive production is not fully utilized. However, according to the anti-pollution laws introduced in year 1990, the unused materials are not allowed to be burnt as it will encourage pollutions to the environment. They are only allowed to be left to rot. Unfortunately, when they are left to the ground, they caused soil infertility (Anon, 2009).

Therefore it is essential to find environmental friendly way to make use the unutilized OPT. Based on this situation, there is a great potential to utilize the OPT residues available for timber industry as alternative material. More than a decade ago, many studies on utilization oil palm biomass such as OPT, EFB, OPF for particle-based, fiber-based, wood-based as well as veneer-based was done to minimizing wood supply shortage as well as reducing the existence residues in the oil palm industry (Bakar *et al.*, 2008).

Figure 1.2: OPT and the Other Parts Will Be Left to Rot in the Field as Agricultural Waste
(Source: Abdul Hamid S., 2012)

Even though it is similar to wood, not all part of the OPT can be used for product development. The outer region of the trunk is economically suitable for this purpose as the center region of the trunk contains only soft parenchyma tissue, from which the sugar contained can be extract for biodiesel production.

Previous researches had proven the usefulness of OPT to be transformed into value added products. In recent study, a researcher from Japan has discovered that fibre of OPT is effective as a functional food to provide anti-oxidants and improve digestion (Anon, 2009). A researcher, has found that oil palm trunk fibres are suitable to be pressed with rubberwood to geotextiles called BIO-GEOMAT, which can be used to cover the steep part of highlands to prevent the top soil from eroding (Fauziah, 2006).

Previous research also found that OPT is suitable to be transformed to oil palm veneer (OPV). When OPT was peeled for veneer and processed into LVL, better properties of it was recorded, even though the properties were slightly inferior to LVL made from rubberwood (Razak *et al.*, 2008). However, the main problem in producing LVL or plywood from OPV is on drying the veneer prior to the fabrication, as OPV recovery is normally affected by the drying result. Hashim *et al.* (2004) reported that the suitable moisture content (MC) of OPV for LVL manufacturing was 6%. To achieve that MC, it was reported to take a time about 60 minutes using conventional steam-heated roller dryer at 0.5 and 0.7 m/min speeds. Abdul Hamid and Zulhazmi (2004) showed that the recovery rate of dried veneer are about 30 to 40%, where the shrinkage around 10 to 15% of its green thickness. This indicate that a good drying method for OPV need to be established, which not only can help in producing veneer that has superior stability and strength, but also may help to reduce cost and power consumption during its production.

Although the OPT can be peel for veneer for plywood or LVL board, the veneers only suitable for use as a core layer with normal hardwood veneers are used as face and back layers. The difficulty of peeling was produced low grade quality of veneers also low recovery of about 25% can be produced (Bakar *et al.*, 2008). The bonding strength also need to be improve through new glue formulation and optimizing gluing conditions.

This project was carried out to determine the effectiveness of low molecular weight phenol formaldehyde (LMWPF) resin in increasing the strength and dimensional stability of OPV as well as LVL boards. The veneer, with different initial MCs were dipped into different solid contents of LMWPF to allow the resin to be absorbed by the veneer partially occurred before the veneer was processed to form LVL. Apart from that, the project was intended to expand the utilisation of OPT waste, as a continuation effort to use the waste for value added products.

1.2 Problem Statement and Justification

Nowadays, the forest is facing depletion and unable to meet the demand for sawn lumber and wood-based products production. Generally most forest trees take more than 30 years in order to be in the best condition to be harvested for sawn lumber. With that length period of time, it is hard for the forest to recover after it has been harvested and this can cause many problems such un-productivity and instability of the forest biodiversity. Due to this, research has been look on oil palm trunk as an alternative source of timber for the wood-based industry. Thus, research on OPT is important in overcoming the shortage supply of timber that traditionally been made from wood without depleting the nation's wood resources from the natural forest and forest plantations.

There are few studies on LVL manufacturing using OPV as raw material. Razak *et al*. (2008) stated that OPV can be used for LVL making even though the properties are inferior to LVL made from rubberwood veneer. They conducted the study by using untreated/normal OPV. Even though the study was succeed, improvement on the raw material (OPV) still continue. Products from oil palm are hygroscopic, which could lose and gain moisture when there is a change in relative humidity. This resulted effect the dimensional stability of the oil palm products especially the strength when there is occurrence of moisture changes. Many researcher started to improve the properties of OPV by treated with resin. Paridah *et al*. (2009) and Loh *et al*. (2011) were conducted studies about treated OPV for plywood production. They did treatment of dried OPV with resin and glued with other resin such as Urea Formaldehyde (UF) before hot press process. While in this study, wet OPV will be treated with LMWPF with no additional resin used before hot press to manufacture LVL.

Rapid development of buildings, infrastructures and furniture industry has created a high demand for sawn timber, MDF, particleboard, plywood and LVL. The importance of this research is to discover the potential of the OPV use as a raw material for these industries (focus on LVL manufacturing). An efficient and cost-saving production system is very essential to speed up the volume of production with less cost and time involved. Unfortunately, cost and time-saving production seemed impossible to achieve due to the difficulty faced by manufacturers in drying raw materials, especially those who are dealing with OPT, whether in solid or veneer form. This disadvantage needs to be studied and to reduce the drying time of the raw material prior to fabrication of LVL.

This study was to overcome the disadvantage on difficulty and high production cost to dry the OPV by using wet OPV before treated with LMWPF and then reduced the MC again before LVL production. By using phenol formaldehyde with low molecular weight, the resin still can absorbed into the OPV cells even though the veneer in high MC. The study also focused on different resin solid content used for OPV treatment as studied by Hoong *et al.*, 2013 on oil palm plywood. It is important to know which resin solid content suit to be used for wet OPV. Other parameters in this study was initial MC of OPV before treatment, which targeted to reduce time and cost of drying the OPV. Different initial MCs was used to determine which stages of high MC will produced better physical and mechanical properties of treated LVL. MC before hot press to form LVL also was studied to know whether the resin can be cured uniformly by using MC above 10%.

LVL is formed by arrangement of parallel veneer grain and pressing layers of veneers using hot press machine. The pressed veneers are first treated with resin to improve the properties of veneer and this resin also being used in creating bond between veneers. Previously, UF resin was often used for that bonding purpose (Razak *et al.*, 2008). However, UF resin was known as a less stable resin among wood-based product researchers and manufacturers. The resin is tending to absorb moisture from surrounding and cause bad dimensional stability to wood-based products. The disadvantage, of course can lengthen the production time and adding cost. This inefficiency of UF resin in particleboard was confirmed by Izran *et al.,* (2009). He used UF resin to fabricated kenaf core particleboard and found that longer pressing time with temperature as high as 160°C was needed to sufficiently cure the resin in the particleboard. The high temperature was chosen in order to remove moisture absorbed by the resin during mixing stage. They also found that the resin was reduced by more than 50% the dimensional stability of the particleboard. Similar results were obtained by Razak *et al.,* (2008) when they used UF resin to produce laminated oil palm veneer lumber. Therefore, this study was using a low molecular weight resin, namely LMWPF not only as veneer treatment, but also as bonding agent to manufacture laminated oil palm veneer lumber. Investigation the effectiveness of the boards in promoting good strength and dimensional stability, hence it will reducing the production cost and time.

1.3 Research Objectives

General objective of this study was to produce high performance laminated veneer lumber (LVL) from oil palm trunk veneer treated with Low Molecular Weight Phenol Formaldehyde (LMWPF).

The specific objectives of this study were:

1. To evaluate the effect of LMWPF resin solid content with different initial moisture contents of oil palm veneer on physical and mechanical properties of oil palm LVL.

2. To determine the optimum moisture content of the veneer before hot press on the physical and mechanical properties of oil palm LVL.

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