UNIVERSITI PUTRA MALAYSIA

INFLUENCE OF EXTRACTIVES ON THE POROSITY OF OIL PALM (Elais guineensis Jacq.) STEM

BALKIS FATOMER BINTI A. BAKAR

IPTPH 2014 2

INFLUENCE OF EXTRACTIVES ON THE POROSITY OF OIL PALM (*Elais guineensis* Jacq.) STEM

By

BALKIS FATOMER BINTI A. BAKAR

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

May 2014

COPYRIGHT

To my beloved husband

Nizam Hakim Md. Ishak

My beloved parents

Hj. A. Bakar Othman

Hjh. Farida Amin

My beloved sisters and brother

Suhailey Bakar

Nathrah Bakar

Ghazaly Bakar

Thank you for being the people that encouraged me the most.

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

INFLUENCE OF EXTRACTIVES ON THE POROSITY OF OIL PALM (*Elaeis guineensis* Jacq.) STEM

By

BALKIS FATOMER A. BAKAR
May 2014

Chairman : Professor Paridah Md. Tahir, PhD

Institute : Institute of Tropical Forestry and Forest Products (INTROP)

In this study, an investigation was conducted to determine the basic properties (moisture content and density) of the oil palm stem and amount of extractives content that can be extracted from the sample. Porosity studies were also conducted on the oil palm stem in different exposure conditions (dried and green) and the influence of extractive on the porosity was examined. Oil palm trees were selected randomly from the species *Elaeis guineensis* Jacq. from Taman Pertanian Universiti located in Universiti Putra Malaysia, Serdang, Malaysia. Each of the tree were cut along the tree height into three main parts namely bottom, middle and top. Each part was further cut into three sections labelled as outer, inner and centre across the transverse direction of oil palm stem. Technical Association of the Pulp and Paper Industry (TAPPI) standards were employed for water extractives (cold water and hot water) and also acetone extractives. The green moisture content of the oil palm stem was found higher at the middle with average of 221.8% and lowest was at bottom with 158.4%. Across the transverse direction, centre section always had higher moisture content regardless of the tree height and the lowest was found at outer section with average of 260.7% and 115.3%, accordingly. The density of oil palm stem was found inversed with moisture content as the highest density was found at bottom with average of 0.46 g/cm^3 and the lowest was at middle with 0.37 g/cm^3. Outer consistently gave higher density compared to centre section with 0.55 g/cm^3 and 0.30 g/cm^3. The coefficient of determination (R^2) obtained between moisture content and density was high with 0.83. In non-sequential method, hot water extractives gave higher results compared to other solvents with average of 26.8% of total extracted compounds. Whereas in the sequential method, cold water was found higher with average of 21.3%. Comparing the methods, sequential extraction method gave greater amount of extractives as the samples had gone through three different solvents continuously. Whilst, parenchyma cells is proven to contribute three times higher of extractives content compared than vascular bundles.

For theoretical porosity in dried and green condition, samples taken from centre section at middle part had highest average percentage of 79.4% and 78.2%, respectively and the least was found at outer section at bottom part with 71.7% and 69.0%, accordingly. Whereas, experimental porosity was found higher at centre section at top part for dried condition and at centre section of middle part along the oil palm tree height for green condition. Experimental porosity surpassed the theoretical porosity values as a result from the effects of condition exposure of the samples at the upper part of the oil palm tree (middle and top). However, there is no dependency of extractives content towards porosity found in this study. This study concluded that moisture content and density of oil palm stem was affected by the location (longitudinal and transverse direction) of the sample taken. Extractives content was found higher at sample which consist higher portion of parenchyma cells. Oil palm stem sample in green condition resulted higher experimental porosity compared to dried condition. Porosity of oil palm stem has low influence by its extractives content rather than its anatomical structure. The study suggests that oil palm stem can be treated by impregnation or preservation process in green condition.

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

PENGARUH EKSTRAKTIF TERHADAP KELIANGAN BATANG KELAPA SAWIT (*Elaeis guineensis* Jacq.)

Oleh

BALKIS FATOMER A. BAKAR

Mei 2014

Pengerusi : Profesor Paridah Md Tahir, PhD

Institut : Institut Perhutanan Tropika dan Produk Hutan (INTROP)

Dalam kajian ini, satu ujikaji telah dijalankan untuk menentukan sifat-sifat asas (kandungan air dan ketumpatan) daripada batang kelapa sawit dan juga jumlah kandungan ekstraktif yang boleh diekstrak daripada sampel tersebut. Kajian keliangan juga dijalankan pada batang kelapa sawit dan pengaruh ekstraktif pada keliangan kayu dikaji. Pokok kelapa sawit telah dipilih secara rawak daripada spesies *Elaeis guineensis* Jacq. dari Taman Pertanian Universiti yang terletak di Universiti Putra Malaysia, Serdang, Malaysia. Setiap pokok dipotong kepada tiga bahagian utama iaitu bahagian bawah, tengah dan atas disepanjang ketinggian pokok. Setiap bahagian pula dipotong menjadi tiga bahagian kecil yang dilabel sebagai luar, dalam dan pusat di arah melintang batang kelapa sawit. Piawaian (Persatuan Teknikal Industri Pulpa dan Kertas) TAPPI digunakan untuk eksperimen keterlarutan air (air sejuk dan air panas) dan juga aseton ekstraktif. Kandungan lembapan hijau batang kelapa sawit didapati lebih tinggi di tengah dengan purata 221.8% dan terendah adalah di bahagian bawah dengan 158.4%. Pada arah melintang, bahagian pusat sentiasa mempunyai kandungan lembapan yang lebih tinggi tanpa mengira ketinggian pokok itu dan yang paling rendah didapati di bahagian luar dengan purata 260.7% dan 115.3%. Ketumpatan batang kelapa sawit didapati songsang dengan kandungan lembapan sebagai kepadatan paling tinggi didapati di bahagian bawah dengan purata 0.46 g/cm³ dan yang paling rendah adalah di tengah dengan 0.37 g/cm³. Bahagian luar secara konsisten memberikan kepadatan yang lebih tinggi berbanding dengan bahagian tengah dengan 0.55 g/cm³ dan 0.30 g/cm³. Pekali penentuan (R^2) diperolehi antara kandungan lembapan dan ketumpatan adalah tinggi dengan 0.83. Dalam kaedah tidak berurutan, keterlarutan air panas memberikan jumlah yang lebih tinggi berbanding dengan pelarut lain dengan purata sebanyak 26.8% daripada jumlah sebatian yang diekstrak. Manakala, dalam kaedah berurutan, kelarutan air sejuk didapati lebih tinggi dengan purata 21.3%. Apabila membandingkan kaedah, kaedah pengekstrakan berurutan memberikan jumlah yang lebih besar kerana sampel batang kelapa sawit telah melalui tiga pelarut yang berbeza dalam satu proses.

Tambahan lagi, sel parenkima terbukti menyumbang tiga kali lebih tinggi kandungan ekstraktif berbanding daripada berkas vaskular.

Untuk teori keliangan dalam keadaan kering dan hijau, sampel yang diambil daripada bahagian pusat di bahagian tengah mempunyai peratusan tertinggi purata 79.4% dan 78.2% masing-masing dan yang paling didapati di bahagian luar di bahagian bawah dengan 71.7% dan 69.0%. Manakala, eksperimen keliangan didapati lebih tinggi pada bahagian tengah di bahagian atas bagi keadaan kering dan di bahagian tengah bahagian tengah di sepanjang ketinggian pokok kelapa sawit bagi keadaan hijau. Eksperimen keliangan melepasi nilai teori keliangan sebagai hasil dari kesan pendedahan keadaan sampel pada bahagian atas pokok kelapa sawit (tengah dan atas). Walau bagaimanapun, tidak ada pergantungan kandungan ekstraktif terhadap keliangan didapati dalam kajian ini. Kajian ini mendapati bahawa kandungan lembapan dan ketumpatan batang kelapa sawit berubah mengikut lokasi sampel (arah ketinggian kelapa sawit dan melintang) yang diambil. Kandungan ekstraktif didapati lebih tinggi pada sampel yang mempunyai sel parenkima yang tinggi. Sampel batang kelapa sawit dalam keadaan hijau menghasilkan bacaan keliangan experiment yang lebih tinggi berbanding keadaan sampel yang dikeringkan. Keliangan batang kelapa sawit mempunyai pengaruh yang rendah oleh jumlah ekstraktif berbanding dengan struktur anatomi. Kajian ini juga mencadangkan bahawa batang kelapa sawit boleh dirawat dalam keadaan hijau.

ACKNOWLEDGEMENTS

All praises are due to Allah SWT who had given me blessing, strength and knowledge in finishing this thesis.

Special notes of gratitude to my main supervisor, Professor Dr Paridah Md Tahir, without whom my research would not have been possible and completed. I would also like to thank her for all the guidance and encouragement that she has shown me throughout the period of this research as a supervisor. To all my committee members Professor Dr Alinaghi Karimi, and Associate Professor Dr Edi Suhaimi Bakar, I extend to you my warmest thanks for being patient, understanding and providing me invaluable guidance. I would like to also say thank you to Professor Dr Zaidon Ashaari, Professor Dr Salim Hiziroglu and Dr Mohd Khairun Anwar Uyup for your willingness to spend some time to sharing knowledge with me and guiding me in writing this thesis.

Special thanks to my Head of Department of Forest Production, Dr. Rasmina Halis and Dean of Faculty of Forestry, Prof. Datin Dr. Faridah Hanum Ibrahim for the approval of my study leave and all the assistance and advice given. I would also like to extend my appreciation to all the staff of the Faculty of Forestry and the Institute of Tropical Forestry and Forest Products, especially Mr Azam, Mr Fakhruddin, Mr Zamani for all their help during my labwork.

To my fellow researchers, Dr Adrian Choo Cheng Yong, Dr. Juliana Halip, Aisyah Humaira, Norul Izani, Nor Hafizah, Husna, Lukman, all my ex-UiTM comrades and other colleagues, I sincerely appreciate all the help that you guys have given to me and I truly cherish our friendship.

My greatest and deepest gratitude goes to my parents, my parents in law and siblings for being understanding and supportive through the years. To my husband Hakim, thank you for always being there for me, being a good listener and encouraging me through the trials I faced in completing this thesis. I dedicate this thesis to all of you.

Balkis

I certify that an Examination Committee has met on **27th May 2014** to conduct the final examination of **BALKIS FATOMER A. BAKAR** on her **MASTER IN SCIENCE** thesis entitled "INFLUENCE OF EXTRACTIVES ON THE POROSITY OF OIL PALM **(*Elaeis guineensis* Jacq.)** STEM" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the student be awarded the relevant degree.

Members of the Examination Committee were as follows:

Azmah Hanim binti Mohamed Ariff, PhD
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

Rasmina binti Halis, PhD
Faculty of Forestry
Universiti Putra Malaysia
(Internal Examiner)

Rosfarizan binti Mohamad, PhD
Associate Professor
Faculty of Biotechnology and Biomolecular Sciences
Universiti Putra Malaysia
(Internal Examiner)

Rokiah Hashim, PhD
Professor
School of Industrial Technology
Universiti Sains Malaysia
(External Examiner)

____

PROF. DR. ZULKARNAIN ZAINAL, PhD
Professor and Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date:

This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfillment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows

Paridah Md Tahir, PhD
Professor
Institute of Tropical Forestry and Forest Products
Universiti Putra Malaysia
(Chairman)

Alinaghi Karimi, PhD
Professor
Institute of Tropical Forestry and Forest Products
Universiti Putra Malaysia
(Member)

Edi Suhaimi Bakar, PhD
Associate Professor
Faculty of Forestry
Universiti Putra Malaysia
(Member)

BUJANG BIN KIM HUAT, PhD
Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

Date:

DECLARATION

Declaration by graduate student

I hereby confirm that:

- this thesis is my original work;
- quotations, illustrations and citations have been duly referenced;
- this thesis has not been submitted previously or concurrently for any other degree at any other institutions;
- intellectual property from the thesis and copyright of thesis are fully-owned by Universiti Putra Malaysia, as according to the Universiti Putra Malaysia (Research) Rules 2012;
- written permission must be obtained from supervisor and the office of Deputy Vice-Chancellor (Research and Innovation) before thesis is published (in the form of written, printed or in electronic form) including books, journals, modules, proceedings, popular writings, seminar papers, manuscripts, posters, reports, lecture notes, learning modules or any other materials as stated in the Universiti Putra Malaysia (Research) Rules 2012;
- there is no plagiarism or data falsification/fabrication in the thesis, and scholarly integrity is upheld as according to the Universiti Putra Malaysia (Graduate Studies) Rules 2003 (Revision 2012-2013) and the Universiti Putra Malaysia (Research) Rules 2012. The thesis has undergone plagiarism detection software.

Signature: ________________________ Date: ___________________

Name and Matric No.: ____

Declaration by Members of Supervisory Committee

This is to confirm that:

- the research conducted and the writing of this thesis was under our supervision;
- supervision responsibilities as stated in the Universiti Putra Malaysia (Graduate Studies) Rules 2003 (Revision 2012-2013) are adhered to.

Signature:________________________

Name of
Chairman of
Supervisory
Committee:________________________

Signature:______________________

Name of
Member of
Supervisory
Committee:_____________________

Signature:_________________________

Name of
Chairman of
Supervisory
Committee:________________________

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

(-OH)	hydroxyl groups
ANOVA	Analysis of variance
CPO	Crude palm oil
EFB	Empty fruit bunch
EMC	Equilibrium moisture content
FSP	Fibre saturation point
GBP	Gympsum-bonded particleboard
ha	hectares
Lmw PF	Low molecular weight phenol formaldehyde
LSD	Least significant difference
LVL	Laminated veneer lumber
MDF	Medium-density fibreboard
MF	Mesocarp fibre
MIDA	Malaysian Industrial Development Authority
MPOB	Malaysian Palm Oil Board
PKO	Palm kernel oil
PKS	Palm kernel shells
POME	Palm oil mill effluent
R^2	Coefficient of determination
SAS	Statistical analysis variance
TAPPI	Technical Association of the Pulp and Paper Industry
TPU	Taman Pertanian Universiti

CHAPTER 1

INTRODUCTION

1.1 General View

Since early 1960's, the cultivation of oil palm plantation increased at a fast pace in line with the government's agricultural diversification program, which was introduced to reduce the country's economic dependence on rubber and tin (Rasiah and Shahrin, 2004). Later in the 1960's, the government introduced land settlement schemes for planting oil palm tree to eliminate poverty for the landless farmers and smallholders. Initially, oil palm tree was planted to harvest the palm oil from its fruits. The latest statistical data extracted from MPOB (2014) had reported that there was 5.23 million ha of oil palm plantation in 2013 compared to 5.08 million ha in 2012. The largest oil palm plantation was dominated by Peninsular Malaysia with 2.59 million ha, followed by Sabah (1.48 million ha) and Sarawak (1.16 million ha) (MPOB, 2014).

In spite of substantial plantation, ample oil palm stems are available during replanting process which happens after the trees reach 25 to 30 years. The stems generated approximately 15.39 million tonnes of lignocellulosic materials annually (Hartono, 2012).Previously, the discarded stems were burnt in the field as disposal of the wastes (Lim and Gan, 2005) or were left at the oil palm plantation as natural compost.

With proper treatment against bio-deteriorating agents, the oil palm stems have been proven to be used in various applications such as laminated veneer lumber (LVL) and plywood (Loh et al., 2011; Sulaiman et al., 2008: Nordin et al., 2004) are used as the core materials to produce framing materials for the manufacture of furniture. Oil palm stem usage is extended as well as to other composite panels, such as particleboard, medium-density fibreboard (MDF) and wood cement board. Rahim and Khozirah (1991) had introduced gympsum-bonded particleboard (GBP) by using fresh oil palm stem chips. Additionally, recent works done by several authors (Hoong et al., 2013; Nor Hafizah et al., 2012; Loh et al., 2011) had produced high grade oil palm plywood and veneers by impregnated low molecular weight phenol formaldehyde (LmwPF) into the samples.

However, there is no economic value of oil palm stem from structural point of view (Abdul Khalil, 2006), and the maximum utilization of oil palm stem still constrained with several factors such as variation in density (Loh et al., 2011; Choo et al., 2010; Bakar et al., 2008; Lim et al., 2003), high moisture content (Bakar et al., 2008; Shirley, 2002), high extractives content (Darmawan, 2006) and low dimensional stability (Bakar et al., 2008; Ibrahim, 1989). Therefore, various techniques have been implemented to enhance the properties of oil palm stem end products through polymer injection (Zugenmaier, 2006; Ibrahim, 1989), thermal treatment (Fukuta, 2008; Higashihara et al., 2000), chemical modification (Mahlberg et al.,2001; Xie et al., 2007) and resin impregnation (Nor Hafizah et al., 2014; Bakar et al., 2013 and

2008; Hoong et al., 2012; Loh et al., 2011; Irshad et al., 2010).In general, such processes aim to improve the weather and decay resistance, dimensional stability, strength, colour and paintability properties of materials (Herajarvi, 2009).

Most of the treatments particularly using chemical treatments are related to the basic properties of the woody or lignocellulose such as porosity and permeability value. Like wood, oil palm stem is a porous material (Kollmann and Cote, 1968) which composed of cell wall substances and cavities containing air and extractives (Tsoumis, 1991). The specific gravity of the cell wall practically constant for all woody material with value of 1.53 g/cm^3 on an oven dry mass and volume basis, and the cell wall materials are completely non-porous (Dinwoodie, 1981). What make oil palm stem differ from other wood such as rubberwood is it belongs to monocotyledon plants which means oil palm stem does not possess any vascular cambium, secondary growth, growth rings, ray cells, sapwood and heartwood, branches and knots (Killmann and Lim, 1985) compared to dicotyledon plants. Flow of fluid in oil palm stem is mainly through metaxylem vessels in vascular bundles (Shirley, 2002) and several researchers also found that parenchyma contributes to absorb more liquid as it have thin walled and high absorbency rate (Nordin, 2012; Paridah et al., 2006).

Moreover, oil palm stem is a much more porous, cellular and anisotropic in nature. Thus liquid such as water and low molecular weight compounds can rapidly absorbed and flow into the cell wall and lumen (Loh et al., 2011). Basically, wood porosity can ranged from 46 to 80% of total wood volume which can give significant effect to the depth and direction of fluid flows like preservatives and adhesives in treatment process (Vick, 1999). During the treatment process, penetration of liquid in wood pores depends on surface roughness, density, extractives content and properties of the liquid itself (Nor Hafizah et al., 2012). Oil palm stem also has been reported to contain high extractives content (10%) compared to other wood (Darmawan, 2006), and Olsson et al. (2001) believed that extractives are one of the main reasons for reduced transverse permeability of pine heartwood.

1.2 Problem Statement

Lignocellulosic material is chemically heterogeneous and its components can be divided into two groups; structural components of high molecular weight which includes cellulose, hemicellulose and lignin that contributes to the major cell wall components; and non-structural components of low molecular weight (extractives and inorganic components). The extractives are non-polymeric and may be separated from the insoluble cell wall materials by solving them in water or organic solvents (Vaicklenionis and Vaickelioniene, 2006). In general, the overall percent of the extractives in wood varies from 2 to 10% and oil palm stem consists the highest extractives content among other monocotyledon plants (Darmawan, 2006). The effects of extractives resulted in corrosion of metals in contact with wood, inhibition of setting of concrete, glue and finishes (David and Nobuo, 2001). During the drying process, extractives that presence in wood are transported to the surface in a heterogeneous distribution and deposited as solids when the water evaporates causing the interference with absorption and curing process of the substances.

Contamination of wood surface by having heavy deposits of extractives may reduce bonding strength by blocking the reaction sites and prevent true wetting by the adhesives (Hse and Kuo, 1988).

Moreover, Behr et al. (2011) stated that in Scots pine, extractives are believed to be one of the main reason for the reduced transverse permeability of pine heartwood. A small amount of distributed extractives is enough to encrust the bordered pits permanently and block them for liquids as extractives were related to reduce wood treatability (Zimmer et al., 2009). A vast number of experimental results have shown that the removal of extractives increases the dimensional changes of wood (Adamopoulos and Voulgaridis, 2012; Stamm and Loughborough, 1942). In study done by Adamopoulos and Voulgaridis (2012) on Black Locust wood had found that removal of extractives also resulted to a slight gradual increase in radial and tangential dimensional changes of the wood. Furthermore, Darmawan et al. (2012) reported that wood extractives and silica have a potential adverse effect on tool wear.

As in wood, the most crucial properties determining the ease of drying and treatment in oil palm stem is its porosity. Porosity is the fractional of void volume of wood and to be a permeable, a solid must be porous (Siau, 1984). However, having high porosity values does not mean that the material will have higher permeability values as a result from blockage or cell ruptured. The knowledge of porosity is important as a factor influencing the amount of liquid that can be absorbed in a given block volume and influenced the way preservative retention is expressed (Usta, 2006). For instance, the maximum amount of treating solution that can be injected into wood can be determined. Research on porosity has always been highlighted on the hardwoods and softwoods as compared to monocotyledons (Nordin, 2012; Plotze and Niemz, 2011). Only limit information has been found for porosity of oil palm stem and it is not sufficient to help boost the effect of the treatment that using liquid. Thus, hypothesis for this study is wood extractives that are presence in oil palm stem may block the voids in liquid absorption of oil palm stem.

1.3 Objectives

The main objective of this study was to evaluate the influence of extractives on the porosity of oil palm stem.

Specific objectives of the work were:

a) To determine the moisture content and density of oil palm stem along the tree height and transverse section.
b) To evaluate the extractives content in longitudinal and transverse section of oil palm stem.
c) To determine the porosity relationships with extractives content of oil palm stem along the tree height and transverse direction.

REFERENCES

Abdul Khalil, H.P.S., Hanida, S. Kang, C.W., and Nik Fuaad, N.A. (2007). Agrohybrid Composite: The Effects on Mechanical and Physical Properties of Oil Palm Fiber (EFB)/ Glass Hybrid Reinforced Polyester Composites. *Journal of Reinforced Plastics and Composites* 26(2): 203-218.

Abdul Khalil, H.P.S., Nurul Fazita, M.R., Bhat, A.H., Jawaid, M., and Nik Fuad, N.A. (2010). Development and Material Properties of New Hybrid Plywood from Oil Palm Biomass. *Materials and Design* 31(1): 417-424.

Abdul Khalil, H.P.S., Siti Alwani, M., Mohd Omar A.K. (2006). Chemical Composition, Anatomy, Lignin Distribution, and Cell Wall Structure of Malaysian Plant Waste Fibers. *Bioresources* 1(2): 220-232.

Abdullah, C.K., Jawaid, M., Abdul Khalil, H.P.S., Zaidon, A., and Hadiyane, A. (2012). Oil Palm Trunk Polymer Composite: Morphology, Water Absorption, and Thickness Swelling Behaviours. *Bioresources* 7(3): 2948-2959.

Abdullah, N., Sulaiman, F., and Gerhauser, H. (2011). Characterisation of Oil Palm Empty Fruit Bunches for Fuel Application. *Journal of Physical Sciences* 22(1): 1-24.

Abe, H., Murata, Y., Kubo, S., Watanabe, K., Tanaka, R., Sulaiman, O., Hashim, R., Sitti Fatimah, M.R., Zhang, C., Noshiro, S., and Mori, Y. (2013). Estimation of the Ratio of Vascular Bundles to Parenchyma Tissue in Oil Palm Trunks Using NIR Spectroscopy. *Bioresources* 8(2): 1573-1581.

Adamopoulos, S and Voulgaridis, E. (2012). Effect of Hot-Water Extractives on Water Sorption and Dimensional Changes of Black Locust Wood. *Wood Research* 57(1): 69-78.

Ahmad, Z, Saman, H.M., and Paridah, M.T. (2010). Oil Palm Trunk Fiber as a Bio-Waste Resource for Concrete Reinforcement. *International Journal of Mechanical and Materials Engineering (LIMME)* 5(2): 199-207.

Ali, R. A. S. and Halim, A. H. (1991). The Fffect of Oil Palm Wood Extractives on Growth of Decaying Microorganisms. *Proceedings Oil Palm Trunk and Other Palmwood Utilization*, Malaysia, Kuala Lumpur p73-80.

Antwi-Boasisko, C. & Pitman, A.J. (2009*)* .Influence of Density on The Durabilities of Three Ghanaian Timbers. *Journal of Science and Technology*, Vol. 29, No. 2. DOI 10.1007/s13196–010–0002–3.

Anwar, U.M.K., Zaidon, A., Hamdan, H., and Mohd Tamizi, M. (2005). Physical and Mechanical Properties of *Gigantochloa scortechinii* Bamboo Splits and Strips. *Journal of Tropical Forest Science* 17(1): 413-418.

Ari, L.H. (2005). Solubility of Structurally Complicated Materials: 1. Wood. *Journal Physics and Chemistry References Data* 35(1): 77-91.

Back, E. L. (1960) On the Relative Composition of Canal Resin and Ray Parenchyma Resin in Picea Abies (Karst.) Stemwood. The Resin in Parenchymatous Cells and Resin Canals of Conifers. *Svensk Papperstidning* 63 (19):647-651.

Back, E.L. (1991). Oxidation Activation of Wood Surfaces for Glue Bonding. *Forest Product* Journal 41(2): 30-36.

Bakar, E.S. (2000*). Utilization of Oil Palm Trunk as Housing and Furniture Material. Project Report*. Unpublished.

Bakar, E.S., Mohd Hamami, S. and H'ng, P.S. (2008). Anatomical Characteristics and Utilization of Oil Palm Wood. In: Nobuchi, T., Mohd. Hamami, D (Eds) the Formation of Wood in Tropical Forest Trees: *A Challenge from the Perspective of Functional Wood Anatomy*. Malaysia, Universiti Putra Malaysia, Serdang: Academic Press.

Bakar, E.S., Paridah, M.T., and Shahri, M.H. (2005). Properties Enchancement of Oil Palm Wood through the Compreg Method. *Proceeding International Symposium of Wood Science and Technology* 2: 91-92

Bakar, E.S., Paridah, M.T., Fauzi, F., Mohd, H.S. and Tang, W.C. (2007). Properties Enhancement of Oil Palm Wood through Modified Compreg Method*: A Comprehensive Solution to Oil Palm Wood's Properties Flaws (*pp 99-112). Utilization of Oil Palm Tree: Strategizing for Commercial Exploitation.

Bakar, E.S., Rachman, O., Darmawan, W., and Hidayat, I. (1999). Utilization of Oil Palm Trees as Building and Furniture Material (II): Mechanical Properties of Oil-palm Wood. *Journal Teknologi Hasil Hutan*, Fakulti Hutan IPB. Vol.XII (1): 10-20.

Bakar, E.S., Tahir, P.M., Sahri, M.H., Mohd Noor, M.S., Zulkifli, F.F. (2013). Properties of Resin Impregnated Oil Palm Wood (*Elaeis Guineensis* Jacq). *Pertanika Journal Tropical Agricultural Science* 36(S): 93-100.

Behr, G., Larnoy, E. and Bues, C.T. (2011). Treatability variation of Scots pine Heartwood from Northern Europe. *42nd Annual Meeting*, Queenstown, New Zealand.

BFPIC. (2009). Beijing Forestry and Parks Department of International Cooperation. http://www.bfdic.com/en/Features/Features/166.html

Boustingorry, P. Grosseau, P. Guyonnet, R. and Guilhot, B. (2005). The Influence of Wood Aqueous Extractives on the Hydration Kinetics of Plaster. *Cement and Concrete Research* 35(11): 2081-2086.

Brazier, J.D. and Howell, R.S. (1979). The Use of a Breast Height Core for Estimating Selected Whole Tree Properties of Stika Spruce. *Forestry* 52(2): 177-185.

Brown, H.P., Panshin, A.J. and Forsaith, C.C. (1952). *Textbook of Wood Technology. Vols 1 & 2*. Mcgraw-Hill Book Company Inc. London.

Butterfield, B.G., and Meylan, B.A. (1980). Three-dimensional Structure of wood- An Ultrastructure Approach. *The 2nd Pacific Regional Wood Anatomy Conference Forest Products Research and Development Institute Los Banos (College),* Lahuna, Philiponnes, p449-455.

Cave, I.D., and Walker, J.C.F. (1994). Stiffness of Wood in Fast-Grown Plantation Softwoods: The Influence of Microfibril Angle. *Forest Products Journal* 44(5): 43-48.

Chen, C.M. (1970). Effects of Extractive Removal on Adhesion and Wettability of Some Tropical Woods. *Forest Product Journal* 20(1):36-41.

Choo, A.C.Y. (2012*). Permeability and Moisture Distribution in Oil Palm Wood and Its Influence on the Development of an Effective Method for Veneer Moisture Reduction.* PhD. Thesis. Universiti Putra Malaysia, Malaysia.

Choo, A.C.Y., Paridah, M.T., Karimi, A., Bakar, E.D., Khalina, A., Azmi, I., Loh, Y.F. (2010) Density and Humidity Gradients in Veneers of Oil Palm Stems. *European Journal Wood Product*. DOI 10.1007/S00107-010-0483-1.

Choo, A.C.Y., Paridah, M.T., Karimi, A., Bakar, E.S., Khalina, A., Azmi, I., Balkis Fatomer, A.B. (2013). Study on the Longitudinal Permeability of Oil Palm Wood. *Industrial and Engineering Chemistry Research* 52(27): 9405-9410.

Christianse, A.W. (1994). Effect of Ovendrying of Yellow-Poplar Veneer on Physical Properties and Bonding. *Holz Roh- Werkstoff* 52: 139-149.

Cown, D.J., Young, G.D., and Burdon, R.D. (1992). Variation in Wood Characteristics of 20-year-old-half-sib Families of Pinus Radiata. N.Z *Journal of Forestry Science* 22: 63-67.

Darmawan, W., Rahayu, I. S., Nandika, D., and Marchal, R. (2012). The Importance of Extractives and Abrasives in Wood Materials on the Wearing of Cutting Tools. *Bioresources* 7(4): 4715-4729.

Darmawan, W., Rahayu, I.S., Tanaka, C. and Marchal, R. (2006). Chemical and Mechanical Wearing of High Speed Steel and Tungsten Carbide Tools by Tropical Woods. *Journal of Tropical Forest Science*, 18(4), 255-260.

David, H.N.S., and Nobuo, S. (2001). *Wood and Cellulosic Chemistry*, 2nd ed. p.914, Marcel Dekker, Inc., New York.

Dinwoodie, J.M. (1981). *Timber: Its structure, Properties and Utilisation*. 410. London. 6th edition. MacMillan Press Ltd.

Erwinsyah. (2008). *Improvement of Oil Palm Trunk Properties using Bioresin*. PhD. Dissertation. Faculty of Environment Sciences, Technische Universitas Dresden, Germany.

Fengel, D. and Wegener, G. (1984). *Wood: Chemistry, Ultrastructure Reactions*, New York: Walter de Gruyter.

Fernandez, M.P., Watson, P.A., Breuil, C. (2001). Gas Chromatography-Mass Spectrometry Method for the Simultaneous Determination of Wood Extractive Compounds in Quaking Aspen. *Journal of Chromatography a* 992:225-233.

Findlay. W.P.K. 1975. Preservative of Timber in the Tropic. Martinus Nijhoff/Dr

Foo, Y.N., Foong, K.Y., Basiron, Y, Sundram, K. (2011). A Renewable Future Driven with Malaysian Palm Oil-based Green Technology. *Journal of Oil Palm and the Environment* 2:1-7.

Fukuta, S., Asada, F., and Sasaki, Y. (2008). Manufacture of Compressed Wood Fixed by Phenolic Resin Impregnation through Drilled Holes. *Journal Wood Science* 54(2): 100-106.

Gardner, D.J., Wolcott, M.P., Wilson, L., Huang, Y., and Carpenter, M. (1995). Our Understanding of Wood Surface Chemistry. Proceeding No. 7296. *Wood Ahdesives.* Forest Products Society, Madison, WI, USA. p29-36

Grabner, M., Muller, U, Gierlinger, N and Wimme, R. (2005). Effects of Heartwood Extractives on Mechanical Properties of Larch. *IAWA Journal* 26(2): 211-220.

Grioui, N., Haloui, K., Zoulalian, A., Halouani, F. (2007). Experimental Study on Thermal Effect on Olive Wood Porous Structure During Carbonization. *Maderas. Ciencia y Tecnologia* 9(1): 15-28.

Golpayegani, A.S., Thevenon, M.F., Gril., J., Masson, E., and Pourtahmasi, K. (2014). Toxicity Potential in the Extraneous Compounds of White Mulberry Wood (Morus alba). *Maderas, Science of Technology* 16(2): 227-238.

Hancock, W. V. (1963). Effect of Heat Treatment on the Surface of Douglas-Fir Veneer. *Forest Product Journal* 13(2): 81-88.

Harold, P. (1998). Conservation of Architectural Heritage, *Historic Structures and Materials.*

Hartley, C.W.S. (1977). *The Oil Palm*. Third Edition, Longmans, Green and Co. Ltd. London. 37 – 49.

Hartono, R. (2012), Quality Enhancement of Oil Palm Trunk of Inner Part by Close System Compression Method and Compregnation Phenol Formaldehyde. Bogor Agricultural University. School of Postgraduate. Bogor Agricultural University.

Hashim, R, Nadhari, W.N.A.W., Sulaiman, O., Kawamura, F., Hiziroglu, S., Sato, M., Sugimato, T., Tay, G.S., and Tanaka, R. (2011). Characterization of Raw Materials and Manufactured Binderless Particleboard from Oil Palm Biomass. *Material and Design* 32(1):246-254.

Haslett, A.N. (1990). Suitability of Oil Palm Trunk for Timber Uses. *Journal of Tropical Forest Science*, 2 (5). 245-251.

Henson, I. E., Chang, K. C., Siti Nor Aisyah, M., Chai, S.H.,Hasnuddin Mhd, Y. and Zakaria, A. (1999) The Oil PalmTrunk as a Carbohydrate Reserve.

Herajarvi, H. (2009). Effect of Drying Technology on Aspen Wood Properties. *Silva Fennica* 43(3): 433-445.

Higashihara, T., Morooka, T., and Norimoto, M. (2000). Permanent Fixation of Transversely Compressed Wood by Steaming and Its Mechanism. *Mokuzal Gakkaishi* 46(4): 291-297.

Hillis, W.E. (1971). Distribution, Properties and Formation of Somewood Extractives. *Wood Sciences and Technology*, Vol. 5, 272-289.

Hishamudin, M.J. (1987). *The Oil Palm Industry in Malaysia. A Guide Book*. Palm Oil Research Institute of Malaysia. Bangi.

Holmbom, B. (1993). *Chapter 5 Extractives.* Book of Analytical Methods in Wood Chemistry, Pulping, and Papermaking (pp 125) by Eero Sjöström, Raimo Alén.

Hong, L.T. and Killman, W. (1989). Some Aspects of Parenchymatous Tissues in Palm Stems. *The 2nd Pacific Regional Wood Anatomy Conference, Forest Products Research and Development Institute Los Banos (College), Laguna, Philippine*s. 449-455.

Hoong, Y.B., Loh, Y.F., Chuah, L.A., Juliwar, I., Pizzi, A., Paridah, M.T., and Jalaluddin, H. (2013). Development a New Method for Pilot Scale Production of High Grade Oil Palm Plywood: Effect of Resin Content on the Mechanical Properties, Bonding Quality and Formaldehyde Emission of Palm Plywood. *Materials and Design* 52: 828-834.

Hoong, Y.B., Loh, Y.F., Nor Hafizah, A.B., Paridah, M.T., and Jalaluddin, H. (2012). Development of a New Pilot Scale Production of High Grade Oil Palm Plywood: Effect of Pressing Pressure. *Materials and Design* 36: 215-219.

Hse, C.Y. and Kuo, M.L. (1988). Influence of Extractives on Wood Gluing and Finishing-A Review http://www.iccrom.org/pdf/ICCROM_14_ARCLab Handbook01_en.pdf.

Ibrahim, M. M., Agblevor, F. A., and El-Zawawy, W. K. (2010). Isolation and Characterization of Cellulose and Lignin from Steam-Explode Lignocellulosic. Biomass. *Bioresources* 5: 397-418

Ibrahim, W.A. (1989). Densification and Stabilization of Oil Palm Stem by Treatment with Two Polymers. *Journal of Tropical Forest Science* 2(1):1-7.

Irshad, H.B., Abdullah, C.K., Abdul Khalil, H.P.S., Hakimi Ibrahim, M., and Nurul Fazita, M.R. (2010). Properties Enhancement of Resin Impregnated Agro Waste: Oil Palm Trunk Lumber. *Journal of Reinforced Plastics and Composites* 29(22): 3301-3308.

ITIS. (2007). Integrated Taxonomic Information System. *Standard Report Page*: *Elaeis guineensis*. http://www.itis.gov/servlet/SingleRpt/SingleRpt, May 2007.

Izekor, D.N., Fuwape, J.A., and Oluyege, A.O. (2010). Effects of Density on Variations in the Mechanical Properties of Plantation Grown *Tectona Grandis* Wood. *Applied Science Research* 2(6): 113-120.

Jaqoc, R.B. (1952). Oil Palm and Early Introduction of *Elaies guineensis* to Malaya. *Malaysia Agriculture Journal* 35: 3-10.

Jordon, D.L., and Wellons, J.D. (1977). Wettability of Dipterocarp veneers. Wood Science 10(1): 22-27.

Kasemsiri, P., Hiziroglu, S., Rimdusit, S. (2012). Characterization of Heat Treated Eastern Redcedar (*Juniperus virginiana L*.). Journal of Material Process Technology 212: 1324-1330.

Khalil, A.S., Alwani, M.S., Omar, A.M. (2006). Cell Wall of Tropical Fibers. *Bioresources* 1(2): 220-232.

Kilic, A. and Niemz, P. (2010). Extractives in Some Tropical Woods. *European Journal Wood Product*, DOI 10.1007/S00107-010-0489-8.

Killmann, W. and Lim, S.C. 1985. Anatomy and Properties of Oil Palm Stem. *Proceedings of the National Symposium of Oil Palm By-Products for Agro based Industries, Kuala Lumpur.* PORIM Bulletin no. 11: 18-42.

Kocaefe, D., Shi, J.L, Yang, D.Q., Bouazara, M. (2008). Mechanical Properties, Dimensional Stability, and Mold Resistance of Heat-Treated Jack Pine and Aspen. *Forest Product Journal* 58: 88-93.

Kollmann, F.F.P., and Cote, W.A. (1968). *Principles of Wood Science an Technology (I). Solid Wood*. p592. Berlin. Springer-Verlag.

Leofanti, G., Padovan, M., Tozzola, G., and Venturelli, B. (1998). Surface Area and Pore Texture of Catalysts. *Catalysis Today* 41(1-3): 207-219.

Li, X. (2004). *Physical, Chemical and Mechanical Properties of Bamboo and Its Utilization Potential for Fiberboard Manufacturing*. Master Thesis. Louisiana State University, USA.

Liang, C., Zhan, H., Li, B., and Fu, S. (2011). Characterization of Bamboo SCMP Alkaline Extractives and the Effects on Peroxide Bleaching. *Bioresources* 6(2): 1484-1498.

Liese, W. (1980). Anatomy of Bamboo in Lessard, G. Sc Chouinard, A. (Eds.) Bamboo Research in Asia. *Proceedings of the Seminar on Bamboo in Asia*. pp. 161-164. Singapore.

Lim, S.C. and Gan, K.S. (2005). Characteristics and Utilization of Oil Palm Stem. *Timber Technology Bulletin* 25. ISSN p139-258.

Lim, S.C., and Khoo, K.C. (1986). Characteristics of Oil Palm Trunk and Its Potential Utilisation. *The Malaysian Forester* 49(1):3-21.

Lim, S.C., Gan, K.S., and Choo, K.T. (2003). The Characteristics Properties and Uses of Plantation Timbers-Rubberwood and *Acacia Mangium*. *Timber Technology Bulletin* 26. ISSN p139-258.

Loh, Y.F., Paridah, M.T., Hoong, Y.B., Choo, A.C.Y. (2011). Effects of Treatment with Low Molecular Phenol Formaldehyde Resin on the Surface Characteristics of Oil Palm (*Elaeis quineensis*) Stem Veneer. *Materials and Design* 32: 2277-2283.

Lu, J.Z., Wu, Q., and Negulescu, I.I. (2002). The Influence on Maleation on Polymer Adsorption and Fixation, Wood Surface Wettability, and Interfacial Bonding Strength in Wood- PVC Composites. Wood Fibre Science 34(3). 434-459.

Mahlberg, R., Paajanen, L., Nurmi, A., Kivisto, A., Koskela, K. and Rowell, R.M. (2001). Effect of Chemical Modification of Wood on the Mechanical and Adhesion Properties of Wood Fiber/Polypropylene Fiber and Polypropylene/Veneer Composites. *Holz als Roh un Werkstoff* 59: 319-326.

Malik, J. and Santoso, A. (2011). Effect of Extractive-Dissolving Treatment on the Characteristics of Laminated Wood Assembled from Oily Keruing Wood. *Journal of Agricultural Science and Technology* B 1: 1191-1196.

Mantanis, G.I., Young, R.A., and Rowell, R.M (1995). Swelling of Wood. Part III. Effect of Temperature and Extractives on Rate and Maximum Swelling. *Holzforschung* 49:239-248.

Margot, S.P. (2005). Properties of Solid Wood. Responses to Drying and Heat Treatment. *Licentiate Thesis*. Lulea University of Technology, Sweden.

Mohd Husin, Zin, Z.Z., and Halim, A.H. (1985). Potentials of oil palm by-products as Raw Materials for Agro-Based Industries. *Proceedings of the National Symposium on Oil Palm By-Products for Agro-Based Industries*. Palm Oil Research Institute of Malaysia, Bangi.p7-15.

Mohd Zin, J. and Imamura, Y. (1989). Anatomical Characterization of Vascular Bundles in Oil Palm Trunks. *The 2nd Pacific Regional Wood Anatomy Conference Forest Products Research and Development Institute Los Banos (College*), Lahuna, Philiponnes, p449-455.

Mohd. Nor, M.Y., Khoo, K.C., and Lee, T.W. (1984) Preliminary Characterization of Oil Palm Stem as Raw Material for Pulp and Paper. *The Malaysian Forester* 47(1): 28-42.

MPOB. (2014). Malaysia Palm Oil Board (MPOB). Economics and Statistics. Accessed 1st Feb 2014, available at:http://bepi.mpob.gov.my/index.php/statistics/area/114area2013/639oilpalm /planted-area-dec-2013.html

Naibaho, P.M. (1998). *Teknologi Pengolahan Kelapa Sawit*. Palm Oil Research Centre Medan. Indonesia.

Nasrin, A.B., Ma, A.N., Choo, Y.M., Mohamad, S. Rohaya, M.H., Azali A., and Zainal Z. (2008). Oil Palm Biomass as Potential substitution Raw Materials for Commercial Biomass Briquettes Production. *American Journal of Applied Sciences* 5(3): 179-183.

Nor Hafizah, A.B., Paridah, M.T., Yuziah, N.M.Y., Zaidon, A., Choo, A.C.Y., and Norazowa, S. (2014). Influence of Resin Molecular Weight on Curing and Thermal Degradation of Plywood Made From Phenolic Prepreg Palm Veneers. *The Journal of Adhesion* 90(1):1-20.

Nor Hafizah, A.B., Paridah, M.T., Hoong, Y.B., Zaidon, A., Yuziah, N.M.Y., Anwar, U.M.K., and Shahri, M.H. (2012). Adhesion Characteristics of Phenol Formaldehyde Pre-Preg Oil Palm Stem Veneers. *Bioresources* 7(4): 4545-4562.

Nordin, I. (2012). *Treatability and Fluid Pathway in Oil Palm Wood and Rubberwood.* Master Thesis. University Putra Malaysia. Malaysia

Nordin, K., Jamaludin, M.A., Ahmad, M., Samsi, H.W., Salleh, A.H., and Jallaludin, Z. (2004). Minimizing the Environmental Burden of Oil Palm Trunk Residues Through the Development of Laminated Veneer Lumber Products. *Management Environmental Quality* 15(5): 484-490.

Norralakmam, S.Y. (2007*). Particleboard. In; Turning Oil Palm Residues into Products. Research Pamphlets No 127*. Forest Research Institute Industry (FRIM), Kepong, Malaysia.

Nyren, V. and Back, E. 1960. Characteristics of Parencymateous Cells and Tracheidal Ray Cells in Picea Abies Karst. *Svensk Papperstidning Och Svensk Pappersförädlingstidskrift* 63(16), 501-509.

Ohmae, Y. and Nakano, T. (2009). Water Adsorption Properties of Bamboo in the Longitudinal Direction. *Wood Science Technology* 43: 415-422.

Olsson, T., Megnis, M., Varna, J., Lindberg, H. (2001). Study of The Transverse Liquid Flow Paths in Pine and Spruce using Scanning Electron Miscroscopy. *The Japan Wood Research Society*. 282-288.

Paridah, M. T., Loh, Y. F., Jalaluddin, H., and Zaidon, A. (2006). Improving the Performance of Oil Palm Trunk Plywood by Optimising the Veneer Density Distribution. *Processing on Second International Symposium on Veneer Processing and Products*. May 9 and 10, 2006. Vancouver, BC, Canada. Pp 389-396.

Parthasarathy, M.V. and Klotz, L.H. (1976). Palm 'wood' I. Anatomical aspects. *Wood Science and Technology* 10: 231-246. Springer-Verlag. New York.

Polge, H. (1966). Two Examples of the Use of Curves for Wood-Density Variation in Studies of Tree Physiology. *Memorial Society of Botany 1968*: 123-128.

Poltze, M. and Niemz, P. (2011). Porosity and Pore Size Distribution of Different Wood Types as Determined by Mercury Intrusion Porosimetry. *European Journal of Wood Products* 69: 649-657.

Rahayu, I.S. (2001) *Basic Properties of Vascular Bundles and Parenchyma Tissues of Oil Palm Trunk*. Unpublished Master Dissertation, Bogor Agriculture University, Indonesia.

Rahim, S., Abdul Razak, M.A., Zakaria, M.A. (1988). Chemical Components in Oil Plam Trunk Influencing Wood-Cement Board Making. *The 2nd Pacific Regional Wood Anatomy Conference Forest Products Research and Development Institute Los Banos (College), Lahuna, Philippines,* p449-455.

Rahim, S., and Khozirah, S. (1991). *Utilisation of Oil Palm Trunks for Cement-Bonded Particleboard Manufacture. National Seminar on Oil Palm Trunk and Other Palmwood Utilization*, Ming Court Hotel, Kuala Lumpur, Malaysia.

Ralph, M.N., and Magdalena, S. (2007). The Effect of Wood Extractive Content and Glue Adhesion and Surface Wettability of Wood. *Wood and Fibre Science* 34(1): 57-71.

Rasiah, R. and Shahrin, A. (2004). *Development of Palm Oil and Related Products in Malaysia and Indonesia*. Unpublished report. Universiti Malaya, Malaysia.

Ratnasingam, J., Nyugen, V., and Ioras, F. (2008). Evaluation of Some Finishing Properties of Oil Palm Particleboard for Furniture Application. *Journal of Applied Sciences* 8(9): 1786-1789.

Richardson, B. (2002). Defects and Deterioration in Building. 2nd Edition. Published in Canada and USA. p81.

Satish, K. and Dobriyal, P.B. (1992). Treatability and Flow Path Studies in Bamboo Part 1. *Dendrocalamus strictusnees*. *Wood and Fibre Science* 24(2):113-117.

Scheller, H.V. and Ulvskov, P. (2010). Hemicellulose. *Annual Review of Plant Biology* 61: 263-289.

Schniewind, A.P. (1989). *Concise Encyclopedia of Wood and Wood-Based Materials*. Pergamon Press. p248.

Sharma, S.N. (1988). Seasoning Behaviour and Related Properties of Some Indian Species of Bamboo. *Indian Forester* 114(10): 613-621.

Shebani, A.N., Reene, A.J., and Meincken, M. (2008). The Effect of Wood Extractives on The Thermal Stability of Different Wood Species. *Thermochimica Acta* 47(1-2): 43-50.

Sheshmani, S., Ashori, A., and Farhani, F. (2011). Effects of Extractives on the Performance Properties of Wood Flour-Polypropylene Composites. *Applied Polymer Science.* 123(3): 1563-1567.

Shirley, M B. (2002) *Cellular Structure of Stem and Fronds of 14 and 25 Years Old Elaeis Guineensis* Jacq. Master Dissertation, Universiti Putra Malaysia, Malaysia.

Shuit, S.H., Tan, K.T., Lee, K.T., and Kamaruddin, A.H. (2009). Oil Palm Biomass as a Sustainable Energy Source: A Malaysian Case Study. *Energy* 34(9):1225-1235.

Siau, J.F. (1984). *Transport Processes in Wood*, Springer-Verlag, Berlin.

Siau, J.F. (1971). *Flow in Wood*, Syracuse University Press, and New York Standard book No: 8156-50280, Catalog Card No: 70-155829; p131.

Silva, M.R.D., Machado, G.D.O., Deiner, J., and Junior, C.C. (2010). Permeability Measurements of Brazilian *Eucalyptus*. *Material Research* 13(3): 281-286.

Siti Noorbaini, S. (2009). *Effect of Cold Setting Adhesives and Glue Spread on Properties of Oil Palm Trunk Laminated Veneers.* Master dissertation. Universiti Sains Malaysia.

Sitti Fatimah, M.R., Othman, S., Hashim, R., Arai, T., Kosugi, A., Abe, H., Murata, Y., Mori, Y. (2012). Characterization of Parenchyma and Vascular Bundle of Oil Palm Trunk as Function of Storage Time. Lignocellulose 1(1): 33-44.

Sjostrom, E. (1993). *Wood Chemistry, Fundamentals and Applications*. 2nd Edition. Sjostrom, E. (1981). *Wood Chemistry, Fundamentals and Applications*. London: Academic Press.

Smith, D. N., and Williams, A.I. (1969). Wood Preservation by Boron Diffusion Process-Effect of Moisture Content on Diffusion Time. *Journal Institute of Wood Science* 22: 3-10.

Song, H. (2012). *Impact of Drying Conditions, Wood Extractives and Surface to Uneven Distribution of Preservatives in Scots Pine*. Lulea University of Technology. Sweden.

Stamm, A.J. (1946). *Wood and cellulose science*. New York: Ronal Press.

Stamm, A.J., and Loughborough, W.K. (1942). Variation in Shrinking and Swelling of Wood. *America Society Mechanical Engineering* 64: 379-386.

Sulaiman, O., Hashim, R., Razak, W., Hashim, W.S., and Azmy, M. (2008). Evaluation on Some Finishing Properties of Oil Palm Plywood. *Holz Roh Werks*t. 66: 5-10.

Sulaiman, O., Mohd Fahmi, A.W., Hashim, R., and Mondal, M.I.H. (2012). The Effect of Relative Humidity on the Physical and Mechanical Properties of Oil Palm Trunk and Rubberwood. *Cellulose Chemistry and Technology* 46(5-6): 401-407.

TAPPI (1999). Standards T 207 "*Water Solubility of Pulp and Wood*". TAPPI T 207 cm 99. p1-3.

TAPPI (2007). Standards T 280 "*Acetone Extractive of Pulp and Wood*". TAPPI T 204 cm 99. p1-3

Taylor, A.M, Gartner, B.L., and Morrell, J.J. (2002). Heartwood Formation and Natural Durability- a review. *Wood Fiber Science* 34: 587-611.

Teoh, C.H. (2002) *The Palm Oil Industry in Malaysia: From Seed to Frying Pan*. WWF Switzerland: WWF Malaysia.

Teutonico, J.M. (1988). *A Laboratory Manual for Architectural Conservators*. International Centre for the Styudy of the Preservation and the Restoration of Cultural Property (ICCROM). p35.

Thuvander, F., Wallstrom, L., Berglund, L.A., Lindberg, K.A.H. (2001). Effects of an Impregnation Procedure for Prevention of Wood Cell Wall Damage Due to Drying. *Wood Science and Technology* 34: 473-480.

Tomimura, Y. (1992). Chemical Characteristics of Oil Palm Trunk. *Bulletin Forestry and Forestry Product Residue Institute* 362: 133-144.

Tomlinson, P.B. (1961). *Anatomy of the Monocotyledons II, Palmae*. Clarendon Press Oxford. p9 – 24.

Tomlinson, P.B. (1990). *The Structural Biology of Palms*. Oxford University Press. New York.

Tsoumis, G.T. (1991). *Science and Technology of Wood: Structure, Properties, Utilization*. 494. New York: Van Nostrand Reinhold.

Ulvcrona, T., Lindberg, H., and Bergsten, U. (2006). Impregnation of Norway spruce (*Picea abies* L. Karst.) Wood by Hydrophobic Oil and Dispersion Patterns in Different Tissues. *Forestry* 79(1): 1223-134.

Usta, I. (2003). Comparative Study of Wood Density by Specific Amount of Void Volume (Porosity). *Turkey Journal Agricultural Forestry* 27: 1-6.

Usta, I. (2006). Comparative Characterization of the Effects of the Climate-Tree-Growth Relationship in Anatolian Black Pine (*Pinus nigra* Arnold *subsp. pallasiana* (Lamb.) Holmboe) on Wood Treatability. *Turkey Journal of Agriculture Forestry* 30: 305-315.

Vaickelionis, G. and Vaickelioniene, R. (2006). Cement Hydration in the Presence of Wood Extractives and Pozzolan Mineral Additives. *Ceramics-Silikaty* 50(2): 115-122.

Vick, C.B. (1999). *Chapter 9. Adhesive Bonding of Wood Materials*. Wood Handbook. Wood as an Engineering Material. Madison, WI, U.S. 463. W.Junk Publisher Dordrect.

Walinder, M. (2000). *Wetting Phenomena on Wood; Factors Influencing Measurements of Wood Wettability*. Doctoral Thesis, KTH- Royal Institute of Technology, Stockholm.

Walker, J.C.F., and Butterfield, B.G. (1996). The importance of Microfibril Angle to the Processing Industries. *New Zealand Forestry* 40: 34-40.

Wan rosli, W.D., Zainuddin, Z., Law, K.N., and Asro, R. (2007). Pulp from Oil Palm Fronds by Chemical Processes. *Industrial Crops and Products* 25(1): 89-94.

Wengert, E.M. (2006). *Principles and Practices of Drying Lumber*. Brooks Forest Products Center. Virginia Polytechnic Institute and State University, Virginia, USA.

Wenzl, H. (1970). *The Chemical Technology of Wood*. Academy Press. New York.

Whitmore, T.C. (1973). *The Palms of Malaya*. Longmans, Selangor, Malaysia.

Wilson, K., and D.J.B. White (1986). *The Anatomy of Wood: Its Diversity and Variability*. Stobart and Son Ltd, London.

Xie, H., King, A., Kilpelainen, I., Granstrom, M., and Argyropoulos, D.S. (2007). Thorough Chemical Modification of Wood-Based Lignocellulosic Materials in Ionic Liquids. *Biomacromolecules* 8: 3740-3748.

Yamamoto, S., Nakano, T, Norimoto, M and Miyazaki J. (2005). Analysis of Water Adsorption of Bamboos on the Basis of Hailwood and Horrobin Theory. *Mokuzai Gakkaishi* 51: 372-379.

Yusof, B. (2007). Palm Oil Production through Sustainable Plantations. *European Journal of Lipid Science and Technology* 109: 289-295.

Zaidon, A. (1995). *The Structure and Properties of Rattan in Relation to Treatment with Boron Preservatives*. PhD. Thesis. University of Aberdeen. p222.

Zaidon, A., and Petty, J.A. (1997). Absorption of Water by Rattan (Calamus Spp.) During Three Treatment Process. *Journal of Tropical Forest Products* 3(2): 194-208.

Zaihan, J., Hill, C.A.S., Hashim, W.S., Mohd Dahlan, J., and Sun, D.Y. (2011). Analysis of the Water Vapour Sorption Isotherms of Oil Palm Trunk and Rubberwood. *Journal of Tropical Forest Science* 23(1): 97-105.

Zakiah, A., and Azmi, I. (2010). Drying Shrinkage Characteristics of Concrete Reinforced with Oil Palm Trunk Fiber. *International Journal of Engineering Science and Technology* 2(5): 1441-1450.

Zimmer, K., Larnoy, E., and Koch, G. (2009). Wood Properties Influencing the Penetration of Scots Pine (*Pinus sylvestris*) Sapwood with the Wood Modification Agent Furfuryl Alcohol. *The International Research Group on Wood Protection* Document No IRG/WP 09-40470.

Zugenmaier, P. (2006). Materials of Cellulose Derivatives and Fiber-Reinforced Cellulose-Polypropylene Composites: Characterization and application. *Pure Applied Chemistry* 78(10): 1843-1855.

APPENDICES