EFFECT OF POLYMER LOADING ON ANTI-SWELLING EFFICIENCY AND FORMALDEHYDE EMISSION OF SESENDUK WOOD IMPREGNATED WITH LOW MOLECULAR WEIGHT PHENOL FORMALDEHYDE (LMWPF) AND UREA ADMIXTURE

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BY

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Special thanks to my beloved parents and family

Who always support me in whatever I do in my life and also always guide me in where I am today

ABSTRACT

A study was undertaken to determine the effect of polymer loading on dimensional stability and formaldehyde emission of sesenduk (*Endospremum diadenum)* wood treated with low molecular weight phenolic resin and urea admxiture. A total of 32 pieces air-dry wood strips were prepared in a dimension of 165 mm long x 50 mm wide x 5 mm thick. The cut wood strips were assorted according to density before treatments to ensure that each of the treatment group had the equal number of the same density to avoid variation. The wood with initial moisture content of 14 % were impregnated with LmwPF (20 % and 30%) weight by volume and admixture of LmwPF + 0-15 % urea based on solid PF by using vacuum-pressure cylinder. Initial vacuum was applied to the cylinder for 15 minutes followed by soaking under the pressure for 30 minutes. After that, the wood strips were partially cured at 70 °C for three hours and cured at 150 °C for one hours. Finally, the impregnated wood were conditioned at 25 °C±2, 65 ±2 % humidity and 12 % EMC. The results showed that the treatments increased the physical properties of the sesenduk such as WPG, density and ASE. The impreg sesenduk that had been treated with urea admixture had lower FE than those treated with LmwPF alone. Urea as a formaldehyde scavenger can reduce the formaldehyde emission and achieved E1 standard in EN120. This study also found that anti-swelling efficiency (ASE) of the treated sesenduk was highly correlated to the polymer loading. The higher the polymer loading, the higher the dimensional stability achieved by the treated sesenduk.

ABSTRAK

Satu kajian telah dijalankan untuk menentukan kesan pengambilan polimer pada kestabilan dimensi dan pelepasan formaldehid daripada kayu Sesenduk (*Endospremum diadenum*) yang dirawat dengan resin fenolik yang bersifat jisim molekul rendah (LmwPF) dan campuran urea. 32 keping kayu yang telah dikering udara telah disediakan dalam dimensi 165 mm panjang x 50 mm lebar x 5 mm tebal. Kayu-kayu tersebut telah dibahagikan mengikut ketumpatan sebelum rawatan. Ini adalah untuk memastikan bahawa setiap kumpulan rawatan mempunyai bilangan yang sama dengan kepadatan yang sama bagi mengelakkan variasi. Kayu-kayu dengan kandungan kelembapan sebanyak 14% telah diimpregnasi dengan LmwPF (20% dan 30%) dan campuran LmwPF + 0-15% urea berdasarkan pepejal fenol formaldehid dengan menggunakan silinder tekanan vakum. Sedutan vakum awal pada silinder tersebut selama 15 minit dan kayu-kayu direndamkan di bawah tekanan selama 30 minit. Selepas itu, kayu-kayu diawet secara sebahgaiannya pada suhu 70 ° C selama tiga jam dan diawet secara keseluruhan pada suhu 150 ° C selama satu jam. Akhirnya, kayu-kayu yang siap diimpregnasi ditempatkan dalam tempat yang bersuhu 25 ° C ± 2, kelembapan 65 ± 2% dan kandungan kelembapan keseimbangan sebanyak 12%. Hasil keputusan menunjukkan bahawa rawatan impregnasi telah meningkatkan sifat fizikal kayu sesenduk seperti peratusan berat, kepadatan dan ASE. Kayu-kayu Sesenduk yang telah dirawat dengan campuran urea didapati mempunyai pelepasan formaldehid yang lebih rendah daripada yang dirawat dengan LmwPF sahaja. Urea sebagai penyembur formaldehid boleh mengurangkan pelepasan formaldehid dan boleh mencapai tahap E1 dalam EN120. Kajian ini juga mendapati bahawa kestabilan dimensi sesenduk yang dirawat berkorelasi dengan muatan polimer. Semakin tingginya muatan polimer, semakin tingginya kestabilan dimensi yang dicapai oleh impreg sesenduk.

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APPROVAL SHEET

I certify this research project report entitled "Effect of Polymer Loading on Anti-Swelling Efficiency and Formaldehyde Emission of Sesenduk Wood Impregnated with Low Molecular Weight Phenol Formaldehyde (LmwPF) and Urea Admixture" by Arleen Chua Huei Wen has been examined and approved as a partial fulfilment of the requirements for the degree Bachelor Wood Science and Technology in Faculty of Forestry, UPM.

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LIST OF ABBREVIATIONS

Lmw PF	low molecular weight phenol formaldehyde
FE	formaldehyde emission
WPG	weight percent gain
PF	phenol formaldehyde
UF	urea formaldehyde
MF	melamine formaldehyde
Lmw	low molecular weight
RL	resin loading
Mmw	medium molecular weight
ASE	anti-swelling efficiency
OSB	oriented strand board
JIS	Japanese Industrial Standard
JAS	Japanese Agricultural Standard
AS	Standard Australia
EN	European Standard
ASTM	American Society Testing Materials
MDF	medium density fibreboard
MC	moisture content
MAC	Malaysia Adhesive Chemicals
DDL	diacetyldihydrolutidine
ANOVA	analysis of variance

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

In 2014, Malaysia timber industry is third most important commodity after oil palm and rubber (MTIB, 2015). However, the export constituents of Malaysian wood-based industry has changed critically after some years. The industry has transformed from a large exporter of primary commodities included logs, sawn timber and plywood to a large exporter of value-added products. The examples of value-added products are furniture, moulding and joinery (Ratnasingam, 2011).

Next, the raw materials for the wood based industry majority come from the sources of natural forest, forest land and rubber replanting programme (Zaidon, 2017). Due to the depleting supply of high quality timber from natural land in Malaysia, wood manufactures are seeking for alternatives. One of the potential way is to utilise low density or underutilised timber species such as mahang (*Macaranga spp.*), sesenduk *(Endospermum diadenum)* and jelutong (*Dyera costulata*). This timber species are not fully explored because of their poor inherent properties. But, their properties can be improved through wood modification (Zaidon et. al., 2010).

Sesenduk is in the category of "lesser known species" (LKS) and light hardwood with density 385 to 655 kg/m^3. It also has poor dimensional stability, low mechanical strength, and they are very easy to be treated with chemicals (Zaidon et. al., 2015).

Firstly, the level of polymer loading is one of the factors to improve the properties and dimensional stability of treated wood. By increase polymer loading, density and mechanical properties of compressed wood will be improved and increased, respectively (Yano et. al., 2001). Secondly, dimensional stability of compressed wood relies on polymer loading and polymer distribution in the treated wood (Rowell & Konkol, 1987). The last factor in improving properties of wood is molecular weight of PF and we will further discussed it in the next chapter.

1.2 PROBLEM STATEMENT

The bulking treatment with low molecular weight phenol formaldehyde (LmwPF) is one of the treatment that can improve properties of low density wood (Zaidon et. al, 2015). However, this treatment will release high amount of formaldehyde from the treated wood. Phenol (C_6H_5OH) and formaldehyde (CH_2O) react to form hydroxymethyl groups, followed by partial polymerization to the oligomer that makes up the resin. The polymerisation is completed to form a cross-linked polymer network after impregnating into the substrate (Frihart, 2005). LmwPF is a linear pre-polymer and it contains large amounts of methylol groups in the oligomeric chains. Some of the metylol group are released as free formaldehyde when they are exposed to high temperature and humidity (Hoong et. al., 2010).

To overcome this problem, there is another study (Nabil et. al., 2015) involves incorporation of nanoparticles to the phenolic matrix. The use of high concentration LmwPF can be reduced thus reduced formaldehyde emission (FE) without affecting the other properties.

In this research, urea formaldehyde scavenger will be introduced into LmwPF solution to reduce FE from impreg wood. The other properties of treated wood is not affected at the same time.

1.3 HYPOTHESIS AND JUSTIFICATION

FE increases when high concentration of LmwPF is used as a treating solution. (Zaidon, 2017). Higher formaldehyde emission (12.19 mgL^{-1}) was found when wood was treated with 20% of LmwPF concentration. (Zaidon, et. al., 2015). FE increased from 64 mgL^{-1} to 110 mgL^{-1} when compreg Sesenduk was treated PF from 20 % to 40 % (Izreen et. al., 2011). The relationship of polymer loading and FE in treated products from low density wood is not known.

1.4 OBJECTIVES

1. To evaluate the polymer loading in term of weight percent gain (WPG) of sesenduk wood impregnated with LmwPF and urea admixture.
2. To determine anti-swelling efficiency and FE of the impregnated wood.
3. To determine the correlation between WPG and Density, WPG and ASE and ASE and Density of the impregnated wood.

REFERENCES

Adawiah, M. A., Zaidon, A., Izreen, F. A., Bakar, E. S., Hamami, M. & Paridah, M. T. (2012). Addition of Urea as Formaldehyde Scavenger for Low Molecular Weight Phenol Formaldehyde Treated Compreg Wood. *Journal of Tropical Forest Science*, 24(3), 248-357.

Amarullah, M., Bakar, E. S., Zaidon, A., Sahri, M. H. & Fevrianto, F. (2010). Reduction of Formaldehyde Emission from Phenol Formaldehyde Treated Oil Palm Wood through Improvement of Resin Curing State. *Journal of Tropical Wood Science Technology,* 8, 9–14.

American Society for Testing and Materials, ASTM D446. (2008). *Standard Test Method for Anti-Swelling Effectiveness of Water-Repellent Formulations and Differential Swelling of Untreated Wood When Exposed to Liquid Water Environments.* West Conshohocken: ASTM International.

Ashaari, Z., Barnes, H. M., Lyon, D. E., Vasishth, R. C. & Nicholas, D. D. (1990). *Effect of Aqueous Polymer Treatments on Properties Part 11: Mechanical Properties.* New Zealand: International Research Group on Wood Preservation.

Athanassiadou, E., Tsiantzi, S. & Nakos, P. (2001). *Wood Adhesive Made with Pyrolysis Oils.* Thessaloníki: European Network of Bioadhesion Expertise (ENBA).

Breyer, R., Arndell, B. & Stompel, S. (1997). *Method of Scavenger Formaldehyde Using a Low Mole Ration Melamine-Urea- Formaldehyde Resin.* Atlanta: Georgia-Pacific Resins Inc.

Costa, N., Pereira, J., Martins, J., Ferra, J., Paulo, C., Fernao, M., Adelio, M. & Luisa, C. (2012). Alternative to Latent Catalysts for Curing UF Resins Used in the Production of Low Formaldehyde Emission Wood-Based Panels. *International Journal of Adhesion and Adhesives*, 33, 56 – 60.

Cown, D. J. & Hutchison, J.D. (1983). Wood Density as an Indicator of the Bending Properties of Pinus Radiata Poles. *Journal of Forestry Science,* 13(1), pp. 87-99.

Dong, J., Chen, L., Liang, B., Kong, J., Zhao, H. & Liang, F. (2009). Research and Application Progress of Water Soluble PF. *Adhesive*, 18(10), 37-41.

European Standard, EN 120. (1992). *Wood Based Panels- Determination of Formaldehyde Content-Extraction Method called the Perforator Method*. Brussels: European Committee for Standardization (CEN).

European Standard, EN322. (1993). *Wood-based panels —Determination of Moisture Content.* European Committee for Standardization (CEN).

Frihart, C. R. (2005*). In Handbook of Wood Chemistry and Wood Composites*. Wisconsin: CRC Press.

Furuno, T., Imamura, Y. & Kajita, H. (2004). The Modification of Wood by treatment with Low Molecular Weight Phenol-Formaldehyde Resin: A Properties Enhancement with Neutralized Phenolic-Resin and Resin Penetration into Wood Cell Walls. *Wood Science and Technology*, 37(5), 349–361.

Hellas, C. (2008). Update on the Formaldehyde Release from Wood Based Panels. *FormaCare. Socio- Economic Benefits of Formaldehyde to the European Union (EU) and Norway, 1, 14-16.*

Hill, C.A.S. (2006). Modifying the Properties of Wood. *Wood Modification: Chemical, Thermal and Other Process*. Chichester: John Wiley & Sons Ltd.

Homan, W. & Jorissen, A. (2004). *Wood Modification Developments* (pp.19-44). Netherlands: Eindhoven University of Technology.

Hoong, Y. B., Paridah, M. T., Loh, Y. F., Koh, M. P., Luqman, C. & Zaidon, A. (2010). *Acacia mangium* Tannin as Formaldehyde Scavenger for Low Molecular Weight

Phenol Formaldehyde Resin in Bonding Tropical Plywood. *Journal of Adhesion Science and Technology*, 24, 1653-1664.

Huang, Y., Fei, B. H. & Zhao, R. J. (2014). Investigation of Low-Molecular Weight Phenol Formaldehyde Distribution in Tracheid Cell Walls of Chinese Fir Wood. *Bio-Resources*, 9(3), 4150-4158.

International Programme on Chemical Safety (IPCS). (1998) *Formaldehyde.* Switzerland: World Health Organization Geneva.

Ratnasingam, J. (2011). Wood product and Industry Development in the Formal Sector. *Proceedings of the Art and Joy of Wood conference,* Bangalore, India.

Kamke, F. A. & Lee, J. N. (2007). Adhesive Penetration in Wood. *Wood and Fiber Science*, 39(2), 205-220.

Kim, M. G, Watt, C. & Davis, C. J. (1996). Effects of Urea Addition to PF Resin Binders for Oriented Strand Board. *Journal of Wood Chemistry and Technology*, 16(1).

Lu, K., Lin, S., Su, S. & Hu, K. (2004). The Acid-Catalyzed Phenol–Formaldehyde Reaction Critical Runaway Conditions and Stability Criterion. *Process Safety and Environmental Protection*, 82, 37-47.

Mohamad, A. (2010). *Formaldehyde Emission and Properties of Phenol Formaldehyde-Treated Oil Palm Wood.* (Unpublished master's thesis). Faculty of Forestry, Universiti Putra Malaysia, Serdang.

.

MTIB. (2015). *Export of Major Timber Products Malaysia 2015*. Kuala Lumpur: Ministry Of Plantation Industries and Commodities.

Myers. G. (1989). Advances in Methods to Reduce Formaldehyde Emission. *Composite Board Products for Furniture and Cabinets-Innovations in Manufacture and Utilization,* 58-64.

Nabil, F., Zaidon, A., Khairun, A. U., Bakar, E.S., Paridah, M. T., Anuar, R. S., Aizat, G. & Lee, S. H. (2015). Characterisation of Phenolic Resin and Nanoclay Admixture and Its Effect on Impreg Wood. *Journal of Wood Science Technology*, 49(6), 1209-1224.

Izreen, F. A., Zaidon, A., Adawiyah, M. A., Bakar, E. S., Paridah, M. T., Hamami, S. M. & Anwar, U. M. (2011). Enhancing The Properties of Low Density Hardwood Dyera Costulata through Impregnation with Phenolic Resin Admixed with Formaldehyde Scavenger. *Journal of Applied Science*, 11(20), 3474-348.

Panagiotis, N. (2008) *Determination of Formaldehyde Emission of Particleboard: Comparison of Methods*. Greece: A. R. I. Ltd.

Purba, T. P., Zaidon, A., Bakar, E. S. & Paridah, M. T. (2014). Effects of processing factors and polymer retention on the performance of phenolic-treated wood. *Journal of Tropical Forest Science*, 26(3), 320-330.

Rowell, R. M. & Banks, W. B. (1985). *Water Repellency and Dimensional Stability of Wood*. Madison: General Technical Report (GTR).

Rowell, R. M. (1983). *Chemical Modification of Wood.* Madison: General Technical Report (GTR).

Rowell, R. M. (2005). Chemical Modification of Wood. *Handbook of Wood Chemistry and Wood Composites*. (pp. 381–420). Wisconsin: CRC Press.

Rowell, R.M. & Konkol, P. (1987). *Treatments that enhance Physical Properties of Wood.* Madison: General Technical Report (GTR).

Rowell, R.M. & Young, R.L. (1981). *Dimensional Stabilization of Wood in Use*. Madison: General Technical Report (GTR).

Ryu, J. Y., Imamura, Y., Takahashi, M. & Kajita, H. (1993). Effects of Molecular Weight and Some Other Properties of Resins on the Biological Resistance of Phenolic Resin Treated Wood. *Journal of Mokuzai Gakkaishi*, 39(4), 486–492.

Schwab, H., Marutzky, R. & Meyer, B. (2007). *European Regulations for Formaldehyde.* Braunschweig: Fraunhofer Institute for Wood Research Wilhelm-Klauditz-Institute.

Shams, M. I & Yano, H. (2004). Compressive Deformation of Wood Impregnated with Low Molecular Weight Phenol Formaldehyde (PF) Resin II. Effects of Processing Parameters. *Journal of Wood Science*, 50, 343−350.

Shams, M. I., & Yano, H. (2011). Compressive Deformation of Phenol Formaldehyde (PF) Resin-Impregnated Wood Related to the Molecular Weight of Resin. *Journal of Wood Science and Technology*, 45, 73-81.

Sosef, M., Hong, L. & Prawirohatmodjo, S. (1998). Plant Resources of South-East Asia. *Timber Trees: Lesser-Known Timbers* 5(3).

Trondheim, B. T. (1998). *Hygroscopic Moisture Transport in Wood*. New Zealand: Department of Building and Construction Engineering.

Wang, J. (2009*). Benefit Compositions and Formaldehyde Scavengers for Same*. Cincinnati: The Procter & Gamble Company.

Yano, H., Hirose, A., Collings, P. J. & Yazaki, Y. (2001). Effects Of Matrix Substances as a Pre-treatment in the Production of High Strength Resin-Impregnated Wood Based Materials. *Journal of Material Science Letters*, 20, 1125–1126.

Young, S. (2004). *Formaldehyde Emissions – Understanding the Standards.* L.A: Stephen Young & Associates Limited.

Zaidon, A., Kim, G. H., Bakar, E. S. & Rasmina, H. (2014). Response Surface Methodology Models of Processing Parameters for High Performance Phenolic Compreg Wood. *Sains Malaysiana*. Bangi: Universiti Kebangsaan Malaysia.

Zaidon, A. (2017). *Inaugural Lecture Series: Low Density Wood from Poor to Excellent*. Serdang: Universiti Putra Malaysia Pres.

Zaidon, A., Bakar, E. & Paridah, M. T. (2010). Compreg Laminates Made From Low Density Tropical Hardwood. *Proceedings of the International Convention of Society of Wood Science and Technology and United Nations Economic Commission for Europe - Timber Committee.*

Zaidon, A., Lee, S. H., Aziz, M. & Nordin, M. (2016). Addition of Ammonia Hydroxide as Formaldehyde Scavenger for Sesenduk (*Endospermum diadenum*) Wood Compregnated using Phenolic Resins. *European Journal of Wood and Wood Products*, 74(2), 277-280.

Zaidon, A., Lee, S. H. & Effendi, B. R. (2015). Effects of Ammonium Carbonate Post Treatment on Phenolic Resin Treated Sesenduk (*Endospermum diadenum*). *Wood Sains Malaysian*, 44(7), 987–994. Bangi: Universiti Kebangsaan Malaysia.

Zaidon, A., Mohd Khairun, A. U., Bakar, E.S. & Paridah, M.T. (2015). Characterisation of Phenolic Resin and Nanoclay Admixture and Its Effect on Impreg Wood. *Wood Science and Technology*, 49(6), 1209-1224.