

ISSN : 2459-9867



PROCEEDING
THE 6TH INTERNATIONAL SYMPOSIUM OF
INDONESIAN WOOD RESEARCH SOCIETY
12-13 November 2014

‘The Utilization of Biomass from Forest and
Plantation for Environment Conservation Efforts’



Supported by

Organized by :



UNIVERSITY OF SUMATERA UTARA



**INDONESIAN WOOD RESEARCH
SOCIETY (IWORS)**



PROCEEDINGS
THE 6TH INTERNATIONAL SYMPOSIUM OF INDONESIAN
WOOD RESEARCH SOCIETY

**“The Utilization of Biomass from Forest and
Plantation for Environment Conservation Efforts”**

12 – 13 November 2014
Garuda Plaza Hotel, Medan, North Sumatera
INDONESIA

Edited by

Dr. Rudi Hartono, S.Hut, M.Si
Dr. Apri Heri Iswanto, S.Hut, M.Si
Dr. Kansih Sri Hartini, S.Hut, M.Si
Dr. Arida Susilowati, S.Hut, M.Si
Dr. Deni Elfiati, SP., MP
Dr. Muhdi, S.Hut, M.Si
Dr. Ma’rifatin Zahra, S.Hut, M.Si
Siti Latifah, S.Hut, M.Si, Ph.D
Ridwanti Batubata, S.Hut, MP.
Nelly Anna, S.Hut, Msi.
Tito Sucipto, S.Hut, MSi
Irawati Azhar, S.Hut, MSi

INDONESIAN WOOD RESEARCH SOCIETY (IWORS)
2015

PROCEEDINGS

THE 6TH INTERNATIONAL SYMPOSIUM OF INDONESIAN WOOD RESEARCH SOCIETY

Organized by

**Forestry Department, Faculty of Agriculture
University of Sumatera Utara
&
Indonesian Wood Researc Society (IWoRS)**

In Collaboration with

**Forestry Department of North Sumatera Province
Forestry Research Institute of Aek Nauli
Government of Samosir Distric
PT. Gunung Raya Utama Timber Industries (GRUTI)
PT. Sumber Karindo Sakti
PT. Toba Pulp Lestari (TPL)
PT. Perkebunan Nusantara IV
Indonesian Oil Palm Research Institute (IOPRI)
PT. Perkebunan Sumatera Utara**

Editor Team : Rudi Hartono, Apri Heri Iswanto, Kansih Sri Hartini, Arida
Susilowati, Deni Elfiati, Muhdi, Ma'rifatin Zahra, Siti Latifah,
Ridwanti Batubata, Nelly Anna, Tito Sucipto, Irawati Azhar
Cover Design : Kansih Sri Hartini

Published by :

Indonesian Wood Researc Society (IWoRS)

Research Center for Biomaterials

Indonesian Institute of Sciences

Jl. Raya Bogor KM.46 Cibinong Bogor 16911

Telp./Fax: 021-87914511 / 021-87914510

e-Mail : secretariat@mapeki.org

Website : <http://www.mapeki.org>

The first edition: Mei, 2015

ISSN 2459-9867

PREFACE

The 6th International Symposium of Indonesian Wood Research Society (IWORS) was done on November 12-13, 2014 at Garuda Plaza Hotel, Medan, Indonesia. Theme of this symposium was “The Utilization of Biomass from Forest and Plantation for Environment Conservation Efforts”. Forest degradation resulted the lack of wood supply for industry. Several scientific researches on the biomass utilization of fast growing species from estate forest and plantation for wood substitute materials have been reported to be one of the solution to solve this problem. Oil palm and rubber plantations were dominant commodity in North Sumatera. The plantation biomass was not optimally exploited. Integration of biomass utilization from estate forest and plantation was therefore expected to reduce natural forest exploitation in order to maintain the sustainability.

The 6th International Symposium of Indonesian Wood Research Society 2014 attracted the interest of over 145 scientists from 7 countries including Philiphine, Japan, Korea, Nigeria, Iran, Malaysia, and Indonesia. The symposium covered the disciplines of wood based properties; biocomposite; wood quality, laminated board quality and wood engineering; wood biodegradation and non wood forest product; wood chemistry and bioenergy; and general forestry. The technical program consisted of 106 oral presentations and 22 poster presentations over a period of two days.

On the behalf of the committee, we would like to thank to all of you for the enthusiasm in this symposium and also to all attendants. We would like to extend our gratitude to Prof. Dr. Nan-Hun KIM from Kangwon Nasional University, Republic of Korea; Prof. Prof. Dr. Shigehiko SUZUKI, from Shizuoka University, Japan; Prof. Dr. Dodi NANDIKA from Bogor Agricultural University, Indonesia; and Prof. Dr. Nobuaki HATTORI from Tokyo University and also as The President of Wood Technological Association of Japan, as our Keynote Speakers for the symposium

This symposium could not be conducted without the support and cooperation from many sources. We would like also thank to Government of Samosir District, Forestry Research Institute of Aek Nauli, Forestry Department of North Sumatera Province, PT. Toba Pulp Lestari, PT. Perkebunan Nusantara IV (PTPN IV), Indonesian Oil Palm Research Institute (IOPRI), PT. Gunung Raya Utama Timber Industries (GRUTI), PT Sumber Karindo Sakti (SKS) and PT. Perkebunan Sumatera Utara. Also, we want to say thank to the steering committee, all of committee, and students as volunteers in this symposium.

Medan, Mei 2015

Dr. Rudi Hartono
Chairman

CONTENTS

PREFACE	iv
KEYNOTE SPEECHES	
CURRENT RESEARCH TRENDS IN BIOENERGY FROM LIGNOCELLULOSIC BIOMASS <i>Nam-Hun Kim, Jae-Hyuk Jang, Seung-Hwan Lee</i>	1-6
EVOLUTION OF ELEMENT IN WOOD-BASED PRODUCTS FROM LAMINA TO NANO <i>Shigehiko SUZUKI</i>	7- 10
COMPARISON OF WOODEN BUILDING WITH STEEL AND REINFORCED CONCRETE ONES BY LIFE CYCLE ASSESSMENT <i>Nobuaki HATTORI</i>	11
THE ZONATION OF THE SUBTERRANEAN TERMITE HAZARD IN WEST AND EAST JAKARTA : A PRELIMINARY STUDY <i>Dodi Nandika, Kara Gus Lantera, and Yogie Z. Pratama</i>	12-25
INVITED PAPER	
BRIDGING THE NETWORK ON RESEARCH OF RESTORATION FOREST ECOSYSTEM BASED ON COMMUNITY AS AN EFFORTS TO REDUCE GREEN HOUSES GASES EFFECT <i>Gusti Hardiansyah, Fahrizal, Farah Diba</i>	27-31
ORAL PRESENTATION	
WOOD BASED PROPERTIES	
TOTAL UTILIZATION OF OIL PALM TRUNK <i>Wahyu Dwiarto, Teguh Darmawan, Fitria, and Dwi A. Pramasari</i>	33- 40
WOOD ANATOMY AND RELATED PROPERTIES OF NATURALLY GROWN PHILIPPINE TEAK (<i>Tectona philippinensis</i> Benth. & Hook.f.) <i>Arsenio B. Ella, Emmanuel P. Domingo, and Elvina O. Bondad</i>	41- 60
VARIATIONS IN MOISTURE CONTENT AND ITS EFFECT ON THE SHRINKAGE OF <i>Gigantochloa scortechinii</i> AND <i>Bambusa vulgaris</i> AT DIFFERENT HEIGHT OF BAMBOO CULM <i>R Anokye, R M Kalong, E S Bakar, J Ratnasingam, A A Khairul</i>	61-69
EFFECT OF HEATING TEMPERATURE ON THE PHYSICAL AND MECHANICAL PROPERTIES OF OKAN WOOD (<i>Cylicodiscus gabunensis</i> (Taub.) Harms) <i>Wahyu Hidayat, Jae-Hyuk Jang, Se-Hwi Park, Nam-Hun Kim</i>	70-74
BIOCOMPOSITE	
MECHANICAL PROPERTIES OF COMPOSITE BASED ON POLY (LACTIC ACID) AND KRAFT PULP OF OIL PALM EMPTY FRUIT BUNCH <i>Lisman Suryanegara, Yudhi Dwi Kurniawan</i>	75-79
FIBRILLATED OIL PALM FROND CELLULOSE FIBERS IN POLYLACTIC ACID- POLYPROPYLENE BLENDS COMPOSITE <i>Firda Aulya Syamani, Subyakto, Sukardi, Ani Suryani</i>	80-86

EFFECTS OF DENSITY AND RESIN LEVEL ON THE PERMEABILITY AND WATER ABSORPTION OF KENAF-RUBBERWOOD PARTICLEBOARD <i>Juliana Abdul Halip, Paridah Md Tahir, Adrian Choo Cheng Yong, AlinaghiKarimi Mazraehshahi</i>	87-91
PERFORMANCE MEASUREMENTS OF OIL PALM STEM AS POTENTIAL RAW MATERIAL IN CERTIFIED PLYWOOD PRODUCTION <i>Aida Adnan, Paridah Md.Tahir, Rosli Saleh and Khamuruddin Mohd. Nor</i>	92-99
 WOOD QUALITY, LAMINATED BOARD AND WOOD WORKING	
EFFECT OF STEAMING AND COMPRESSION ON THE PHYSICO-MECHANICAL PROPERTIES OF COMPREG OPW TREATED WITH THE 6-STEP PROCESSING METHOD <i>Alhassan Y. Abare, Edi S. Bakar, and Zaidon Ashaari</i>	100-104
APPLICATION OF NON-DESTRUCTIVE TEST FOR CHECKING AVAILABLE TIMBER FOR CONSTRUCTION MATERIALS IN THE MARKET <i>Ajun Hariono and Anita Firmanti</i>	105-111
DEVELOPMENT AND CHARACTERIZATION OF FINGER-JOINTED LAMINATED BAMBOO TIMBER FOR FURNITURE CONSTRUCTION <i>Rogerson Anokye, Edi Suhaimi Bakar, Jegatheswaran Ratnasingam, Zaidon Ashaari, Khairul Awang</i>	112-119
 WOOD BIODEGRADATION AND NON WOOD FOREST PRODUCT	
COMPARING THE POTENTIAL ABILITY OF FUNGI ISOLATED FROM TROPICAL AND TEMPERATE FOREST, TO DECOLORIZE FOUR TYPE DYES <i>Asep Hidayat and Sanro Tachibana</i>	120-126
THE TREATABILITY OF ANGGRUNG WOOD (<i>Trema orientalis</i>) BY COPPER SULFATE <i>Taman Alex</i>	127-129
TERMITE RESISTANCE OF THREE LAYER PARTICLEBOARD <i>Shorea Leprosula</i> Miq. FROM NATURAL AND PLANTATION FOREST <i>Yuliaty Indrayani, Gusti Hardiansyah, Gustan Pari</i>	130-133
DAMAGE INTENSITY OF HOUSE BUILDING AND TERMITE DIVERSITY IN PERUMAHAN NASIONAL BUMI BEKASI BARU, RAWALUMBU, BEKASI <i>Arinana, Noor Farikhah Haneda, Dodi Nandika, Windi Ayu Prawitasari</i>	134-142
 WOOD CHEMISTRY AND BIOENERGY	
QUALITY TRAITS OF LEAF BLEACHED KRAFT PULP (LBKP) OF LOCAL WOOD SPECIES, TERENTANG AND BINJANG <i>Eka Novriyanti, Dodi Frianto, and Ahmad Rojidin</i>	143-149
 GENERAL FORESTRY	
GROWTH EVALUATION OF EBONY (<i>Diospyros Ebenum</i> Koenig.) FOR 22 nd MONTH AGE IN ARBORETUM OF MANADO FORESTRY RESEARCH INSTITUTE <i>Julianus Kinho</i>	150-155
THE POTENCY OF INDIGENOUS SPECIES AS A MERCURY PHYTOREMEDIATOR ON ILLEGAL EX-GOLD MINING RECLAMATION <i>Wiwik Ekyastuti and Emi Roslinda</i>	156-161

TROPICAL PEATLAND FOREST DEGRADATION: EFFECTS ON FOREST-REGENERATION BIOMASS, GROWTH, MORTALITY, AND FOREST MICROCLIMATE CONDITIONS <i>Dwi Astiani, Mujiman, Ruspita Salim, Muhammad Hatta, and Deddy Dwi Firwanta</i>	162-169
THE CONTENT OF HEAVY METAL LEAD (PB) IN THE DRAGON FRUIT AND CASSAVA ON COAL MINED LANDS IN THE VILLAGE OF PURWAJAYA TENGGARONG DISTRICT EAST KALIMANTAN <i>Budi Winarni, Nur Hidayat, Sri Ngapiyatun</i>	170-172
BREADFRUIT (<i>Artocarpus communis</i> Forst) SEEDLING GROWTH RESPONSE TO SOME KIND OF WATERING TO SOIL DERIVED FROM THE CATCHMENT AREA OF LAKE TOBA <i>Budi Utomo, Afiffuddin Dalimunthe and Irma Y Sembiring</i>	173-177
SPATIAL ANALYSIS FOR LAND CAPABILITY ASSESSMENT IN THE UPSTREAM OF WAMPU WATERSHED USING GEOGRAPHIC INFORMATION SYSTEM <i>Rahmawaty, Sari Adryana, Ahmad Sofyan, Abdul Rauf</i>	178-181
LAND USE CHANGES AND IMPACT OF FOREST DISTURBANCES ON HUMAN WILDLIFE CONFLICT IN SUMATERA <i>Pindi Patana, Ma'rifatin Zahra</i>	182-190
PRODUCTION AND PALATABILITY OF FEED PLANTS OF SUMATRAN ELEPHANT (<i>Elephas maximus</i> Sumatranus) IN JANTHO PINUS NATURE RESERVE, ACEH <i>Ma'rifatin Zahrah and Retno Widhiastuti</i>	191-197
THE EFFECT OF SKIDDING TO SOIL POROSITY BY REDUCED IMPACT LOGGING AT NATURAL TROPICAL FOREST OF PT. INHUTANI II, EAST KALIMANTAN, INDONESIA <i>Muhdi</i>	198-201
THE DIVERSITY OF FORAGE PLANT AND HONEY YIELD OF Apis cerana AT SIMALUNGUN REGENCY <i>Dwi Endah Widyastuti, Darma Bakti Nasution, Sutarman</i>	202-205
GALL RUST INFESTATION ON THE PRIVATE FOREST OF <i>Falcataria moluccana</i> IN KEPAHANG DISTRICT, BENGKULU PROVINCE, INDONESIA <i>Enggar Apriyanto, Deselina, Siswahyono, and Hemamalini Tagatorop</i>	206-209
POSTER	
EFFECT OF AGE ON CHEMICAL COMPONENT OF PLATINUM TEAK WOOD – A FAST GROWING TEAK WOOD FROM LIPI <i>Dwi Ajjas Pramasari, Ika Wahyuni, Danang Sudarwoko Adi, Yusup Amin, Teguh Darmawan, Wahyu Dwianto</i>	211 - 216
MECHANICAL CHARACTERISTIC OF COCONUT AND OIL PALM EMPTY FRUIT BRUNCH FIBER BASED COMPOSITES WITH SOAKING TREATMENT IN VERTICAL GARDEN BOARD APPLICATION <i>M. Gopar and Ismadi</i>	217-220
MECHANICAL CHARACTERISTIC OF COCONUT FIBER BASED COMPOSITES WITH TIME WATERING VARIATION IN VERTICAL GARDEN BOARD APPLICATION <i>Ismadi, M. Gopar, Ismail Budiman, and Subyakto</i>	221-225
MORPHOLOGY AND PHYSICAL CHARACTERISTICS OF POLYPROPYLENE- PULPED EMPTY FRUIT BUNCH FIBER COMPOSITES WITH CHITOSAN AS FILLER <i>Kurnia Wiji Prasetyo and Lisman Suryanegara</i>	226-232

THE EFFECTIVENESS OF ANTIARIS AND KI PAHIT BARK EXTRACTS AGAINST SUBTERRANEAN TERMITE <i>Coptotermes curvignatus</i> THROUGH MACERATION AND SOXHLET METHODS <i>Arief Heru Prianto</i>	233-237
STUDY ON THE INFLUENCE OF NEEM BARKS EXTRACT TO INTESTINAL PROTOZOA, <i>Coptotermes gestroi</i> <i>Arief Heru Prianto and Sulaeman Yusuf</i>	238-241
VARIATION OF SURFACE LAYER AND GLUE SPREAD LEVEL ON LAMINATED BOARD WITH CORE OF OIL PALM TRUNK <i>Rudi Hartono, Tito Sucipto, Felix Simarmata, Bastanta Ginting, Rahmat Hidayat, David Pangihutan Pasaribu, Wahyu Dwianto</i>	242-246
APPENDIX	
COMMITTEE OF IWORS	248
SCHEDULE OF IWORS	249
PARTICIPANT OF IWORS	250-253

KEYNOTE SPEECHES

CURRENT RESEARCH TRENDS IN BIOENERGY FROM LIGNOCELLULOSIC BIOMASS

Nam-Hun Kim, Jae-Hyuk Jang, Seung-Hwan Lee

*Department of Forest Biomaterials Engineering, College of Forest and Environmental Sciences,
Kangwon National University, Republic of Korea
kimnh@kangwon.ac.kr*

The demand for energy has accelerated, and the lack of petroleum resources and concern over global climate change has placed great emphasis on the development of new alternative energy technologies that can be used to replace fossil transportation fuels (Himmel et al., 2007; Labbe et al., 2008; Lee et al., 2009a,b,c; Teramoto et al., 2008, 2009). In this context, many countries have initiated extensive research and development programs for bioenergy. Bioenergy can be classified into the three kind of solid, liquid and gas bioenergy. For the effective production and utilization of these three types of bioenergy, different technologies are required (Figure 1). Lignocellulosic biomass, such as wood and agricultural residues, are widely distributed and easily accessible at relatively low costs. Of these, wood has the benefit of having a higher energy content per volume, lower ash content and nitrogen content. In this review, recent research trends and advances in bioenergy from lignocellulosic biomass will be summarized from the author's point of view.

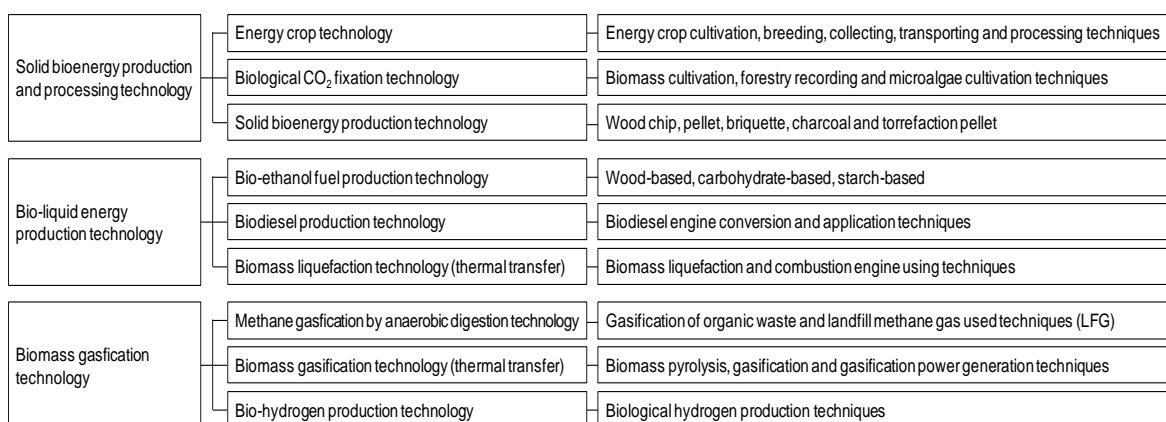


Figure 1. Classification of bioenergy technologies.
(New & Renewable Energy Center, Korea Energy Management Corporation)

1. SOLID BIOENERGY

1.1. Wood charcoal

Wood charcoal is generally produced by pyrolysis at temperatures ranging from 600-1100°C under insufficient oxygen for complete combustion. Depending on the pyrolysis temperature and fire extinguishing system, charcoal can be classified into black and white charcoal (Kim et al., 2001). Generally, black charcoal is easy to ignite, but burns rapidly. White charcoal, on the other hand, is covered with ash and is difficult to ignite, but burns for a longer period. In addition, charcoal has been attracting attention in many fields because of its unique characteristics. Charcoal has numerous tiny cavities resulting in a high surface area of approximately 300–600 m²/g (Ishihara, 1996). These cavities can absorb various substances including heavy metals. This property of charcoal has applications in various fields, such as soil modification, water purification, and the carbon industry. To obtain effective carbonization process, it is important to understand carbonization mechanism of wood.

The proposed mechanism involved in the transition from wood to charcoal is as follows: (1) water is evaporated up to a temperature of 150°C; (2) residual water is driven off of the wood structure between 150°C and 260°C; (3) decomposition and depolymerization of the wood begins breaking C-O and C-C bonds

resulting in the evolution of water, CO, and CO₂, between 260°C and 400°C; and (4) graphitic layers are formed above 400°C (Greil, 2001). It is also known that thermally induced decomposition and rearrangement reactions are largely terminated above 800°C, leaving a carbon structure (Mopoung, 2008). Analysis of the pyrolysis of wood using a heating rate of 5°C min⁻¹ suggests that hemicelluloses are decomposed at temperatures ranging from 170°C-240°C, cellulose between 240°C-310°C, and lignin between 320°C-400°C (Zerriouh and Belkbir, 1995). Kwon et al. (2010 and 2012) investigated the characteristics of the transition from wood to charcoal to understand the transformation mechanism and found that the volume, vessel diameter, and cell wall thickness of the wood decreased with increasing temperature. On the other hand, the weight loss, pH, and heating value increased with the increase in the carbonization temperature. SEM images indicated that the layering structure of the cell walls of wood fibers and parenchyma cells were present at 330°C-340°C. However, the cell wall layering structures disappeared at temperatures over 350°C and changed radically into an amorphous-like structure. X-ray diffraction patterns showed that the cellulose crystalline structure was present at 340°C, but it was not detected over 350°C. From FT-IR spectroscopy, signals from the vibration of aromatic rings had maximum intensities at 390°C, and those from ether groups decreased with increasing temperature. The heating value gradually increased from 4530 to 8200 cal/g over the temperature range of 200°C-1000°C, as shown in Table 1. Rhee and Cho (2008) also reported that the fuel ratio (fixed carbon/volatile combustible), carbon content, and heating value of the carbonization residue increased, but the yield of the residue decreased, with increasing carbonization temperature.

Table 1. Heating value of *Quercus variabilis* charcoals (Kwon et al., 2010)

Temp.	Control	200°C	250°C	300°C	350°C	400°C	600°C	800°C	1000°C
Heating value (cal/g)	4326	4530	4728	5099	5871	6699	7239	8183	8200

1.2. Wood pellets

The pelletization of biomass involves the mass and energy densification of materials such as sawdust, straw, and other herbaceous energy crops with low bulk densities. This process reduces transportation costs and provides better handling, less dust formation, and more efficient feeding of the biomass into the pyrolysis process (Garcia-Maraver et al., 2011). In general, pellet quality depends on the chemical, mechanical, and physical properties of biomass in terms of thermal utilization (Kaliyan and Vance, 2009; Obernberger and Thek, 2004). Wood Pellets can be produced from roundwood but have mostly been made from cheaper waste residues derived from other wood processing activities, primarily sawdust and shavings from sawmills and furniture factories. If made from roundwood, the full range of steps involving debarking, chipping, drying, and hammer milling must be done. Residues require less processing because they are already reduced in size, mostly bark free, and dried (Spelter and Toth, 2009). In either case, the moisture content is critical and must be confined within a range of approximately 12% to 17% (Majiejewska, 2006). Pellets from different regions might be shown different properties (Kwon et al., 2009). Calorific value can be increased by addition of other substrates, such as wood-tar and wood-vinegar (Kwon et al., 2010). Table 2 shows the characteristics of first grade commercial wood pellets in several countries.

Table 2. Properties of first grade commercial wood pellet in several countries

Contents	United States ¹⁾	Germany ²⁾	Austria ²⁾	South Korea ³⁾
Thickness (mm)	5.84-7.25	4-10	4-10	6-8
Length (mm)	>38.1	50	5 x thickness	<32
Bulk density (kg/m ³)	640-737	1000-1400	>1120	>640
Moisture content (%)	<8	12	<10	<10
Ash content (%)	<1	1.5	<0.5	<0.7
Heating value (kcal/kg)	>4445	3704-4660	>4302	>4300

¹⁾ISO 17225-1, 2014; ²⁾Garcia-Maraver et al., 2011; ³⁾Ahn et al., 2014.

1.3. Torrefied wood pellets

Torrefaction of wood can be described as a mild form of pyrolysis at temperatures typically ranging between 200°C and 320°C (Van der Stelt et al., 2011).. During torrefaction, the wood properties are altered to produce a higher fuel quality for combustion and gasification applications. The main principle of torrefaction from a chemical point of view is the removal of oxygen to produce a final solid product, torrefied wood, which has a lower oxygen/carbon ratio compared to the original wood. The thermal treatment not only disrupts the fibrous structure and firmness of the biomass but is also known to increase the calorific value. Torrefied wood has more hydrophobic characteristics that make storage of torrefied wood more attractive in comparison to non-torrefied wood, because of the tendency of non-torrefied wood to rot. During torrefaction, wood is partly devolatilized leading to a decrease in mass, but the initial energy content of the torrefied wood is largely preserved in the solid product. Therefore, the energy density of torrefied wood is higher than that of the original wood, making it less expensive to transport per unit of energy (Van der Stelt et al., 2011). Figure 2 shows a comparison of a typical pelletization and torrefaction process (Bergman et al., 2005). The pelletization process comprises the steps of drying, size reduction, steam pre-conditioning, densification, and cooling. However, the torrefaction process only consists of three steps, drying, torrefaction, and cooling. Table 3 summarizes the main characteristics of wood, torrefied wood, wood pellets, and torrefied wood pellets. In summary, torrefied wood pellets have a more hydrophobic characteristic, higher strength, and higher density than that of wood pellets(Bergman, 2005).

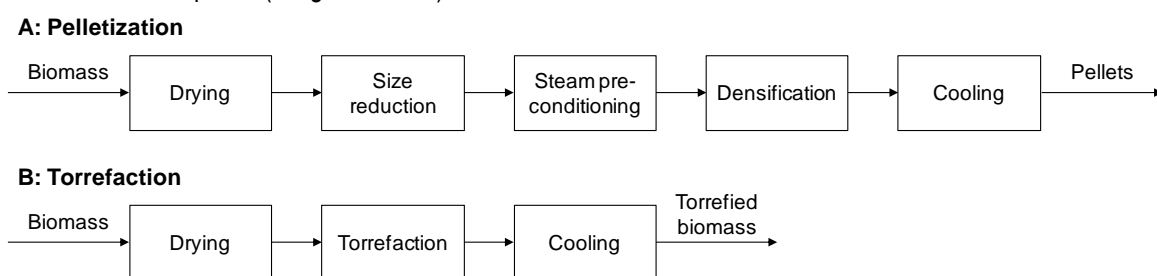


Figure 2. Schemes of pelletization (A) and torrefaction (B) processes.

Table 3. Characteristics of wood, torrefied wood, wood pellets, and torrefied wood pellets (Bergman, 2005)

Contents	Wood	Torrefied wood	Wood Pellets	Torrefied wood pellets
Moisture (wt%)	35	3	7	1
Net heating value				
Normal (MJ/kg)	10.5	19.9	16.2	21.6
Dry (MJ/kg)	17.7	20.4	17.7	22.7
Mass density (kg/m ³)	550	230	650	850

2. LIQUID BIOENERGY (BIOETHANOL)

Bioethanol is by far the most widely used biofuel for transportation worldwide. Production of bioethanol from lignocellulosic biomass is one way to reduce both the consumption of crude oil and environmental pollution. Biochemical conversion of lignocellulosic biomass through saccharification and fermentation is the primary pathway for bioethanol production. However, there are some difficulties in producing bioethanol from lignocellulosic biomass as a result of: (1) the resistant nature of biomass to breakdown; (2) the variety of sugars which are released when the hemicelluloses and cellulose polymers are broken down, and the need to find or genetically engineer organisms to efficiently ferment these sugars; and (3) the costs for collection and storage of low density lignocellulosic biomass (Balat, 2011). Figure 3 shows the basic process of producing bioethanol from lignocellulosic biomass, i.e., pretreatment, hydrolysis, fermentation, and product separation/distillation. A large number of pretreatment methods have been developed, including mechanical grinding, steam explosion, CO₂ explosion, ammonia fiber explosion, ozonolysis, hot water treatment, the organosolv process, and biological pretreatment(Kumar et al., 2009).

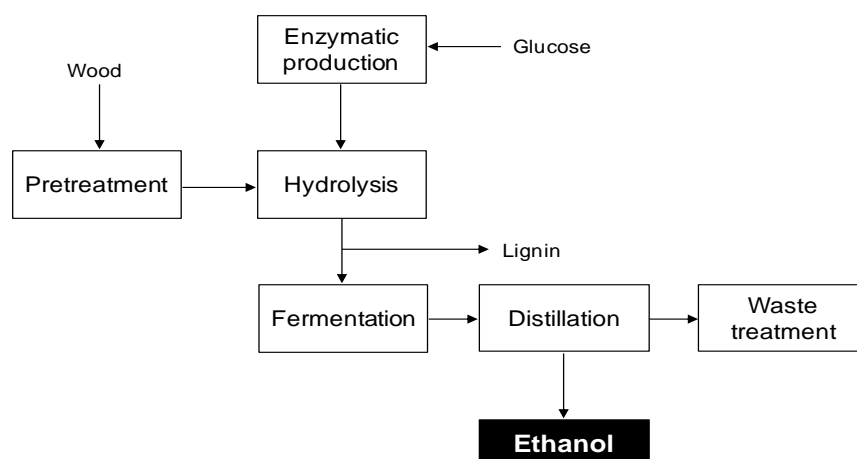


Figure 3. Production of bioethanol from lignocellulosic biomass.

The carbohydrate polymers in lignocellulosic materials must be converted to simple sugars before fermentation through a process called hydrolysis (Taherzadeh and Karimi, 2007). The most commonly applied methods can be classified in two groups: chemical hydrolysis (dilute and concentrated acid hydrolysis) and enzymatic hydrolysis (Balat, 2011). The dilute acid hydrolysis process involves a solution of approximately 1% H_2SO_4 in a continuous flow reactor at a high temperature. Most dilute acid processes are limited to a sugar recovery efficiency of around 50% (Farooqi and Sam, 2004). The acid concentration used in concentrated acid hydrolysis processes is in the range of 10%–30%. This process provides a complete and rapid conversion of cellulose to glucose and the conversion of hemicelluloses to five-carbon sugars with little degradation (Hayes, 2009; Iranmahboob and Nadim, 2002). In contrast, enzymatic hydrolysis is a slow process because enzymatic hydrolysis of cellulose is hindered by the structural parameters of the substrate, such as the lignin and hemicellulose content, and cellulose crystallinity (Pan et al., 2006). On the other hand, enzymatic hydrolysis is an environmentally friendly alternative that involves using carbohydrate-degrading enzymes (cellulases and hemicellulases) to hydrolyze lignocelluloses into fermentable sugars (Keshwani and Cheng, 2005). A comparison of the process conditions and performance of three cellulose hydrolysis processes is given in Table 4 (Hamelinck et al., 2005).

Table 4. Comparison of process conditions and performance of three hydrolysis processes (Hamelinck et al., 2005)

Contents	Consumables	Temperature(°C)	Time	Glucose yield (%)
Dilute acid	<1% H_2SO_4	215	3 min	50-70
Concentrated acid	30–70% H_2SO_4	40	2–6 h	90
Enzymatic	Cellulase	50	1.5 days	75 → 95

REFERENCES

- Ahn B.J., Cho S.T., Choi D.H. 2014. Quality standards of solid bioenergy from woody biomass. Proceeding of Annual Meeting of Korean Forest Bioenergy Society. May 16th, 2014. Seoul, South Korea. pp.33-36.
- Balat M. 2011. Production of bioethanol from lignocellulosic materials via the biochemical pathway: A review. *Energy conversion and Management*. 52:858-875.
- Bergman P.C.A. 2005. Combined torrefaction and pelletisation: the TOP process. Report ECN-C-05-073. Petten, The Netherlands: ECN; 2005.
- Bergman P.C.A., Boersma A.R., Zwart R.W.R., Kiel J.H.A. 2005. Torrefaction for biomass co-firing in existing coal-fired power stations “biocoal”. Report ECN-C-05-013. Petten, The Netherlands: ECN; 2005.
- Farooqi R, Sam AG. 2004. Ethanol as a transportation fuel. Centre for applied business research in energy and the environment (CABREE) climate change initiative, University of Alberta, Canada, April 29 2004.

- Garcia-Maraver A., Popov V., Zamorano M. 2011. A review of European standards for pellet quality. *Renewable Energy*. 36:3537-3540.
- Hamelinck C.N., Van Hooijdonk G., Faaij A.P.C. 2005. Ethanol from lignocellulosic biomass: techno-economic performance in short-, middle- and long-term. *Biomass Bioenergy*. 28:384-410.
- Himmel M.E., Ding S.Y., Johnson D.K., Adney W.S., Nimlos M.R., Brady J.W., Thomas D.F. 2007. Biomass recalcitrance: Engineering plants and enzymes for biofuels production. *Science*. 315:5813-5815.
- Iranmahboob J., Nadim F. 2002. Monemi S. Optimizing acid-hydrolysis: a critical step for production of ethanol from mixed wood chips. *Biomass Bioenergy*. 22:401-4.
- ISO 17225-1. 2014. Solid biofuels- Fuel specifications and classes, Part 1: General requirements.
- Kaliyan N., Vance R. 2009. Factors affecting strength and durability of densified biomass products. *Biomass and Bioenergy*. 33:337-359.
- Keshwani D.R., Cheng J.J. 2009. Switchgrass for bioethanol and other value-added applications: a review. *Bioresources Technology*. 100:1515-23.
- Kim N.H., Kwon G.J., Hwang W.J., Lee S.J., Park H.S. 2001. Development of an efficient process for manufacturing charcoal-variation of temperature in a traditional kiln during carbonizing process-. *Journal Industry University Regional Consortium Center, Kangwon National University*. 5:43-48.
- Kumar P., Barrett D.M., Delwiche M.J., Stroeve P. 2009. Methods for pretreatment of lignocellulosic biomass for efficient hydrolysis and biofuel production. *Industrial & Engineering Chemistry Research*. 48:3713-29.
- Kwon G.J., Kim N.H., Cha D.S. 2009. Characteristics of the commercial wood pellets. *Journal of Forest Science*. 25(2):127-130.
- Kwon G.J., Kwon S.M., Cha D.S., Kim N.H. 2010. Characteristics of pellet prepared from sawdust and wood-tar. *Journal of the Korean Wood Science and Technology*. 38(1):36-42.
- Kwon S.M. 2010. Transition characteristics of the wood cell walls during carbonization. Ph.D. thesis. Kangwon National University. Republic of Korea.
- Kwon S.M., Kim N.H., Cha D.S. 2009. An investigation on the transition characteristics of the wood cell walls during carbonization. *Wood Science and Technology*. 43:487-498.
- Kwon S.M., Kwon G.J., Jang J.H., Kim N.H. 2012. Characteristics of charcoal in different carbonization temperatures. *Journal of Forest Science*. 28(4):263-267.
- Labbe N., Lee S.H., Jeong M.K., Cho H.W., André N. 2008. Enhanced discrimination and calibration of biomass NIR data using nonlinear Kernel methods. *Bioresource Technology*. 99:8445-8452.
- Lee S.H., Teramoto Y., Endo T. 2009a. Enzymatic saccharification of woody biomass micro/nano-fibrillated by continuous extrusion process I-Effect of additives with cellulose affinity, *Bioresource Technology*. 100:275-279.
- Lee S.H., Teramoto Y., Endo T. 2009b. Enhancement of enzymatic accessibility by fibrillation of woody biomass using batch-type kneader with twin-screw elements. *Bioresource Technology*. 101:769-774.
- Lee S.H., Cho H.W., Labbe N., Jeong M.K. 2009c. Quick assessment of thermal decomposition behavior of lignocellulosic biomass by near infrared spectroscopy (NIR) and its statistical analysis. *Journal of Applied Polymer Science*. 114:3229-3234.
- New & Renewable Energy Center, Korea Energy Management Corporation.
- Obernberger I., Thek G. 2004. Physical characterization and chemical composition of densified biomass fuels with regard to their combustion behaviour. *Biomass and Bioenergy*. 27:653-669.
- Pan X., Gilkes N., Saddler J.N. 2006. Effect of acetyl groups on enzymatic hydrolysis of cellulosic substrates. *Holzforschung*. 60:398-401.
- Rhee S.W., Cho Y.H. 2008. A study on characteristics of carbonization residue produced from woody biomass. *Journal of Korea Solid Wastes Engineering Society*. 25(6):533-539.
- Spelter H., Toth D. 2009. North America's wood pellet sector. Research Paper FPL-RP-656FPL, USDA. USA.
- Taherzadeh M.J., Karimi K. 2007. Acid-based hydrolysis processes for ethanol from lignocellulosic materials: a review. *BioResources*. 2:472-99.
- Teramoto Y., Lee S.H., Endo T. 2008. Pretreatment of Eucalyptus wood chips for enzymatic saccharification using combined sulfuric acid-free ethanol cooking and ball milling. *Biotechnology and Bioengineering*. 99(1):75-85.

- Teramoto Y., Lee S.H., Endo T. 2009. Pretreatment of woody and herbaceous biomass for enzymatic saccharification using sulfuric acid-free ethanol cooking. *Bioresources Technology*.99:8856-8863.
- Van der Stelt M.J.C., Gerhauser H., Kiel J.H.A., Ptasinski K.J. 2011. Biomass upgrading by torrefaction for the production of biofuels: A review. *Biomass and Biotechnology*.35:3748-3762.
- Zeriouh A, Belkbir L. 1995. Thermal decomposition of a Moroccan wood under a nitrogen atmosphere. *Thermochim Acta* 258:243-248.

EVOLUTION OF ELEMENT IN WOOD-BASED PRODUCTS FROM LAMINA TO NANO

Shigehiko SUZUKI

Professor of Graduate School of Agriculture, Shizuoka University
Ohya-836, Suruga-ku, Shizuoka-shi, Japan 422-8529
Email: afssuzu@ipc.shizuoka.ac.jp

ABSTRACT

Wood-based material is one of the important key words of the wood science. It plays a role in providing wide range of wood-based products for humankind in their daily living. This paper discusses the recent development and prospect of wood-based products particularly in Japan and to exhibit our research works focused on the transition of element size. We have been working on technical issues of wood-based material as a main direction of our research group. In this paper, element that comprise the materials and its size are focused as a topic which was deeply related to forest resources and environmental issues. Some research works was introduced according to the element size from lamina to nanoscale structure, some of which were already concluded and some are currently in progress. An outline of the feature and trend of the element size is discussed regarding on lamina, veneer, strand, particle, fiber, fines and nano materials for wood-based products manufacture.

Keywords: wood-based material, production technology, element size

INTRODUCTION

Wood-based material is one of the important key words of the wood science. It plays a role in providing wide range of wood-based products for humankind in their daily living. Along with the increasing of population, demand for wood-based panels is steadily increasing and supported by the growth of the condominium market and new applications. Recovery and reconstruction after the Great East Japan earthquake in 2011 has affected wood demands mainly for housing and construction. However, the source of raw materials for panel production is now changing with the utilization of thinning and forest residues, mill residues and even demolition wood as raw materials. By introducing some statistic of a timber product and panel products, we would like to discuss an overview of the wood-based materials in Japan. The objectives of this paper were to discuss the recent development and prospect of wood-based products particularly in Japan and to exhibit our research works focused on the transition of element size.

In 2013, total supply wood-based panel in Japan was 9.5 million m³, consisting of 6.5 million m³ as plywood and 3.0 million m³ for mat-formed panel products such as fiberboard, medium density fiberboard (MDF), and particleboard [1]. Domestic plywood production of 8 million m³ near 1980 decreased to less than 3 million. This was the most prominent and important change that occurred in the history of the wood-based panel industry in Japan. This decline of 5 million m³ during two decades impacted not only the panel industry but also other construction sectors. Domestic plywood production has been replaced by imported plywood and imported mat-formed panels. The maximum demand of 10 million m³ panels was satisfied in response to favorable economic conditions.

We have been working on technical issues of wood-based material as a main direction of our research group. In this paper, element that comprise the materials and its size are focused as a topic which was deeply related to forest resources and environmental issues. Some research works was introduced according to the element size from lamina to nano-scale structure, some of which were already concluded and some are currently in progress. An outline of the feature and trend of the element size is discussed regarding on lamina, veneer, strand, particle, fiber, fines and nano materials for wood-based products manufacture.

RESEARCH ON ELEMENT SIZE FROM LAMINA TO NANO

Research works were conducted on element size of lamina, veneer, strand, particle, fiber, powder/fines, and nanoscale structures. Some of these had been terminated and some are currently in progress. Before reporting individual issues, an outline of the features and trends of element size is provided. Figure 1 shows a transition of the element size of wood-based materials. This figure is revised, based on Kawai [2]. GLT was invented in the 1890s. Assuming that the typical dimension of lamina is 25mm in thickness, 200 mm in width, and 2000 mm in length, the volume becomes in the order of 10 million mm³. In this figure, we can follow the progression of timber product development. The element of laminated veneer lumber (LVL) is veneer, of which typical volume can be estimated to be 5 million mm³, and the veneer strand for PSL is approximately 100,000mm³. Oriented strand lumber (OSL) is also a timber product with wood strands of 300 mm long that have been oriented and consolidated under heat and pressure. The element size of OSL is to be 10,000 mm³.

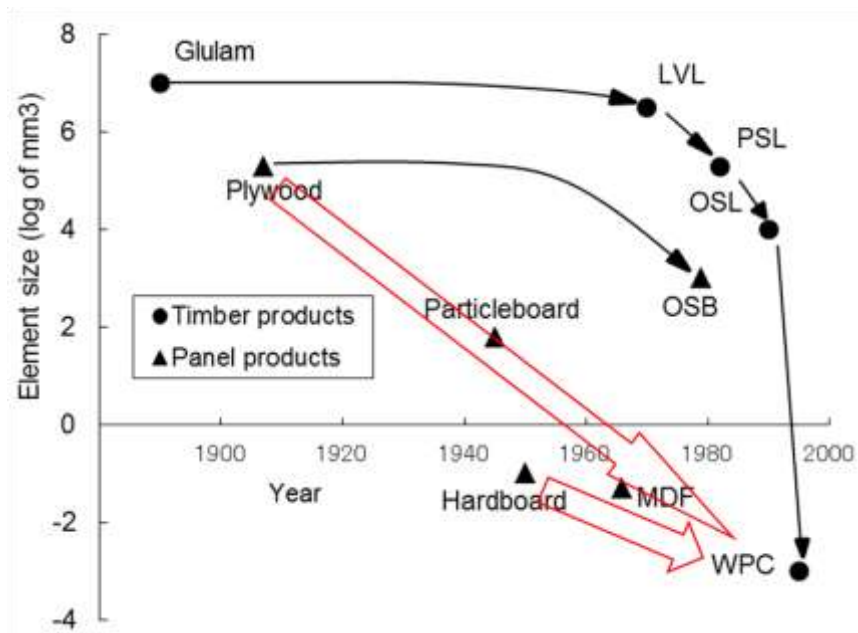


Fig. 1. Transition of the element size of wood-based materials. LVL: laminated veneer lumber, PSL: parallel strand lumber, OSB: oriented strand board, MDF: medium-density fiberboard, WPC: wood plastic composite.

Lamina

Glued laminated timber is a timber product consisting of lamina bonded with durable, moisture-resistant adhesives such as resorcinol-formaldehyde (RF), phenol-RF (PRF) and aqueous polymer isocyanate (API) resins. API resin is a non-formaldehyde and relatively new in structural application. The durability of API resin is not as well-known as the durability of RF resin or PRF resin. Various accelerated aging treatments were imposed to test the durability of API in a block-shear test. Glulam and solid wood from four species (*Picea* sp., *Pinus sylvestris*, *Cryptomeria japonica* and *Chamaecyparis obtusa*), and LVL made of *Larix kaempferi* (Lam.) veneer were fabricated in a commercial mill for this study [3]. Three accelerated aging treatments were: (1) cyclic boil-dry treatment, (2) cyclic soak in hot water-dry treatment, and (3) cyclic absorption-desorption treatment.

Veneer

Ten years ago, sugi was tested at Shizuoka University for suitability as a raw material for plywood production [4]. It was determined that the strength properties of sugi were insufficient for production of structural grade plywood. We tested *Eucalyptus grandis*, which is a plantation species and has strength properties comparable to *Shorea* spp., as a candidate to reinforce plywood produced. *Eucalyptus grandis* was chosen because it is imported from plantation forests. Larch from Siberia was the previously considered

candidate. *Eucalyptus grandis* veneer is used to produce face plywood. However, many people in Japan prefer the appearance of sugi plywood compared to plywood made from *Eucalyptus grandis*. Sugi veneer of high grade is used to produce face plywood despite the bending properties. There is sufficient scientific evidence to explain that wood has less of an impact on the environment than other fossil fuel based materials. Using plantation species, such as sugi and *Eucalyptus grandis*, is one of the ways that the plywood industry in Japan can be recognized as environmentally friendly.

Strand

A three-layer wood based panel [5,6], called J-OSB, was introduced as a panel product that utilizes recycled wood for the core layer and strands from sugi for the surface layers. At the time of introduction, the use of demolition wood and sugi thinning were major political issues for the forestry and wood industries.

Particle

Many experiments have been conducted to test wood species, density, furnish type, resin content, wax addition, layer structure, mat-moisture content, press temperature, and press time, in particleboard production [7-9]. Wood particle and particleboard are easy to manipulate in laboratory studies. The effects of temperature and vapor pressure during hot pressing are discussed by Rofii et al. [10-11]. The effects of furnish type, strand shape, and knife ring flaking have also been investigated.

Fiber

Fiber analysis for MDF production was one of the research topics in the laboratory. The effects of wood species and clearance of the defibrator discs on fiber properties and fiber length distribution were tested.

Powder/Fines

Wood plastic composite (WPC) is a composite material produced by thoroughly mixing wood fiber/wood flour and heated thermoplastic resins such as polyethylene and polypropylene. The common methods of production involve extrusion and injection moldings. In our laboratory, we initiated a study on WPC in 2006 [12, 13]. With support from the Ministry of Agriculture, Forestry and Fisheries, improvement of this compound was planned and conducted for utilization in low-quality forest residue material [14]. The study was initiated because element configurations and surface conditions are technical issues that must be investigated to increase performance and identify an effective method of utilizing low-quality wood resources.

The element size of WPC is plotted in Fig. 1. Assuming that wood powder is a cube of about 0.2mm, its volume becomes in the order of 10^{-2}mm^3 . It is difficult to define WPC as a timber product at present, as element orientation has not been determined. However, some WPC products are used as timber products for outdoor decking or fencing. Defining WPC as a timber product would have a significant impact on the history of wood-based materials. The element size of timber products started at 10^7mm^3 in GLT, declining to 10^3mm^3 in OSL, and dropping rapidly to 10^{-2}mm^3 in WPC.

Nanoscale

Research is currently focusing on the potential use of fibrillated surfaces and cellulose nanofibers as a binder. Results from a previous study demonstrated the binding effects of CNF on the mechanical properties of CNF/wood flourboards [15]. Wet ball-milling can form nanostructured fibers and a Nano scale fibrillated surface, which enhances the mechanical properties of wood-flourboards. Wet-pulverizing, using a disk mill is also effective in forming a nano scale morphology on fiber surfaces [16].

CONCLUSIONS

In general, selectivity of raw material increases when wood elements become smaller. This contributes to the effective use of wood resources, but a reduction in element size reduces the physical and mechanical properties of the products. Maintaining the strength and features of fiber direction in wood-based materials is a technical problem that remains to be solved.

REFERENCES

1. JFPMA (2014) "Fiberboard and Particleboard", Japan Fiberboard and Particleboard Manufacturers Association, Report No.131 (in Japanese).
2. Kawai, S. (1996) Toward the new generation of bio-based composite products, Proc. of the 3rd Pacific Rim Bio-based Composites Symposium, Kyoto, Japan. pp.1-4
3. Okada, T.; Kobori, H.; Kojima, Y.; Suzuki, S. (2014) Effect of three kinds accelerated aging treatments of adhesion durability performance of API bonded glulam, Proc. of the 3rd UGSAS-GU roundtable and symposium, Aug.5-6, Gifu, Japan, pp.62-63
4. Ikeda, K.; Yamada, M.; Suzuki, S.; Nabeta, T. (2004) Mechanical properties of structural plywood made from sugi and grandis (in Japanese), Bulletin of Shizuoka Prefectural Forest Research Center, No. 32, pp.29-35
5. Suzuki, S.; Takeda, K.: Production and properties of Japanese oriented strandboard I (2000) Effect of strand length and orientation on strength properties of sugi-oriented strandboard, J. Wood Science 46(4):289-295
6. Suzuki, S.; Kojima, Y. (2002) Production of three-layered structural board made from sugi strand and recycled wood particle, Proc. of the 4th International Wood Science Symposium, Serpong, Indonesia, pp.262-268
7. Suzuki, S. 1995. Particleboards Made from Recycled Wood. In: Ohama Y. (ed) Disposal and Recycling of Organic and Polymeric Construction Materials", pp.223-234, E & FN SPON, London.
8. Miyamoto, K.; Nakahara, S.; Suzuki, S.: Effect of particle shape on linear expansion of particleboard, J. Wood Science, 48(3), 185-190, 2002
9. Miyamoto, K.; Inagaki, T.; Iwata, R.; Suzuki, S. (2002) Effects of press closing time on mat consolidation behavior during hot pressing and on linear expansion of particleboard, J. of Wood Science, 48(4):309-314
10. Rofii, M.N.; Yamamoto, N.; Ueda, S.; Kojima, Y.; Suzuki, S. (2014) The temperature behavior inside the mat of wood-based panel during hot pressing under various manufacturing conditions, J. Wood Science 60(6):414-420
11. Rofii, M.N.; Yamamoto, N.; Kojima, Y.; Suzuki S. (2014) Effect of furnish on temperature and vapor pressure behaviors in the center of mat panels during hot pressing, J. Math. Fund. Science 46(2):175-182
12. Liu, H.; Wu, Q.; Han, G.; Yao, F.; Kojima, Y.; Suzuki, S. (2008) Compatibilizing and toughening bamboo floor-filled HDPE composites. Mechanical properties and morphologies, Composite Part A: Applied Science and Manufacturing, 39A(12):1891-1900
13. Han, G.; Lei, Y.; Wu, Q.; Kojima, Y.; Suzuki, S. (2008) Bamboo fiber filled high density polyethylene composites. Effect of coupling treatment and nanoclay, Journal of Polymers and the Environment 16:123-130
14. http://www.s.affrc.go.jp/docs/research_fund/2011/pdf/23045_gaiyo.pdf(in Japanese)
15. Kojima, Y.; Minamino, J.; Isa, A.; Suzuki, S.; Ito, H.; Makise, R.; Okamoto, M. (2013) Binding effect of cellulose nanofibers in wood flourboard. J. Wood Science 59(5):396-401
16. Kojima, Y.; Isa, A.; Kobori, H.; Suzuki, S.; Ito, K.; Makise, R.; Okamoto, M. (2014) Evaluation of binding effects in wood flourboard containing ligno-cellulose nanofibers, Materials 7(9): 6853-6864

COMPARISON OF WOODEN BUILDING WITH STEEL AND REINFORCED CONCRETE ONES BY LIFE CYCLE ASSESSMENT

Nobuaki HATTORI

Tokyo University of Agriculture and Technology, Fuchu, Tokyo, Japan

ABSTRACT

In order to assess various types of environmental angles of a building for its life cycle in Japan, one of popular tools will be CASBEE (Comprehensive Assessment System for Built Environmental Efficiency). Models of detached house made of wood, steel and concrete are proposed in CASBEE for their assessment through life cycle, though it does not say any details. In order to assess the difference in environmental loads of three types of detached house whose duration is fifty years, lists of all materials and parts used for three types of detached houses were made referring drawing sheets of the models. Durable years of all parts were also set referring literatures to know the environmental loads by renovation of the model. Environmental loads by energy consumption in residence were calculated for electricity, utility gas and water referring the guide line made by national institutes.

The results are as follows. The biggest environmental load for all houses was emitted during residence. The load of wooden house was about 10 % less than those of other houses through their life cycle. The bigger environmental categories were global warming and resource consumption whose ratio were 60 % and 20 %, respectively. We already developed one hour fire-proof glulam for structural materials of fire-proof buildings conformed to the Building Standard Law of Japan revised in 2000. As the first building was built in the fire preventive area in downtown Tokyo, we have something on our mind whether a building made of this glulam (FR wood®) is an eco-friendly or not. Therefore, LCA of the office building made of FR wood® was assessed comparing with the same size of buildings made of steel and reinforced concrete.

Keyword: *comparison; wooden building; steel building; reinforced concrete building; life cycle assessment*

The Zonation of the Subterranean Termite Hazard in West and East Jakarta: *A Preliminary Study*

Dodi Nandika
Kara Gus Lantera
Yogie Z. Pratama

Department of Forest Products, Faculty of Forestry, Bogor Agricultural University
Bogor, Indonesia



Governor Decree No. 35 Year 2013

**GUIDELINE OF TERMITE HAZARD CONTROL
FOR PUBLIC BUILDING IN JAKARTA PROVINCE**



Governor Decree No. 35 Year 2013

GUIDELINE OF TERMITE HAZARD CONTROL FOR PUBLIC BUILDING IN JAKARTA PROVINCE

Article 4

(1) Any buildings own by Jakarta Province administration must be protected from termite hazard.

Article 6

(1) Any existing building that attacked by termite or has highly risk of termite attack must be treated by appropriate termite control system



J a k a r t a

- The Capital of Indonesia
- Population: 12 million
- Population Growth: 1.42%/year
- Population Density: 14,500 people/km²
- Settlement Infrastructure Growth: 1.5 – 2% /year
- Investment of building construction (2009–2013): IDR 40 Trillion
- Total Assets: IDR 500 Trillion
- Annual financial losses due to termite attack: IDR 67.5 billion

**Implementation of
Governor Decree
No. 35 Year 2013**


Scientific information on the risk of termite hazard



- scientific information on the risk of termite hazard on buildings in Jakarta is almost nonexistence.
- comprehensive information on the distribution of building damaging termite species has not been available.

RESEARCH FOCUS

(First Year, 2014)



The subterranean termite hazard zonation in West Jakarta and East Jakarta, as the first step toward introduction of assessment method of subterranean termite hazard zonation in urban areas.

ASSESSMENT METHOD—The variables and indicators

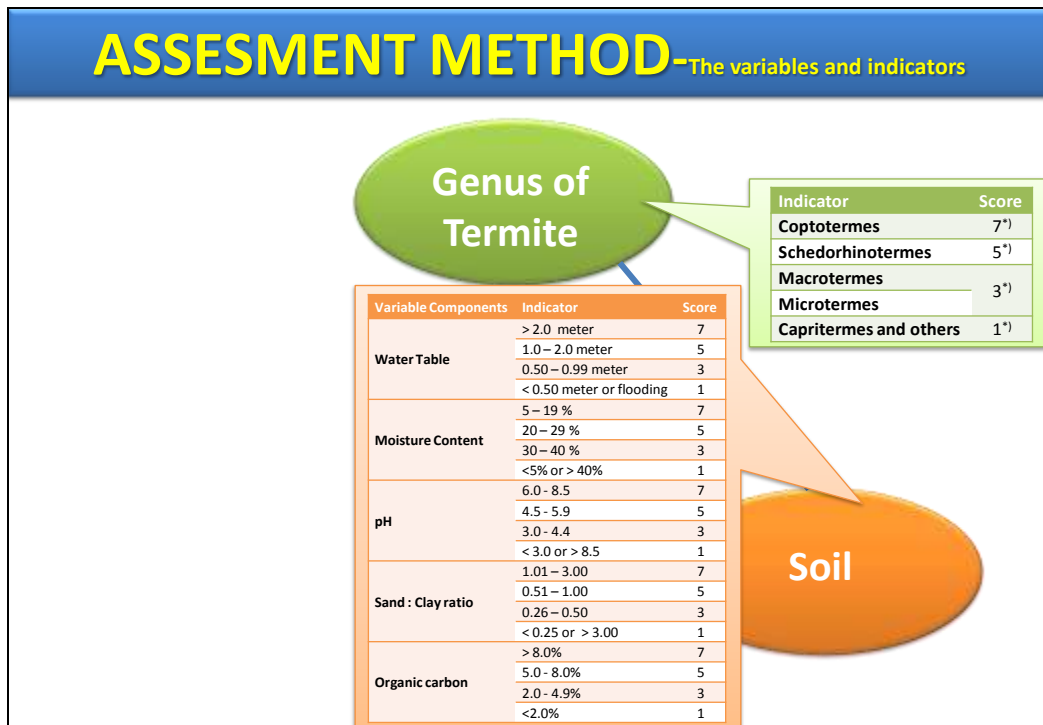


Genus of
Termite

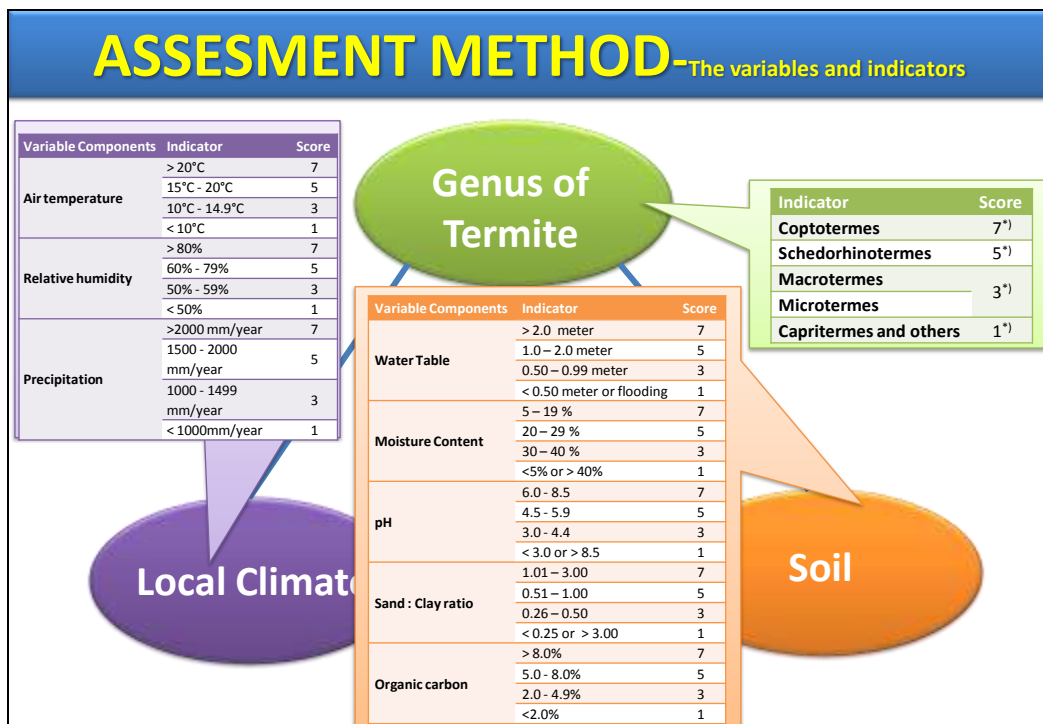
Local Climate

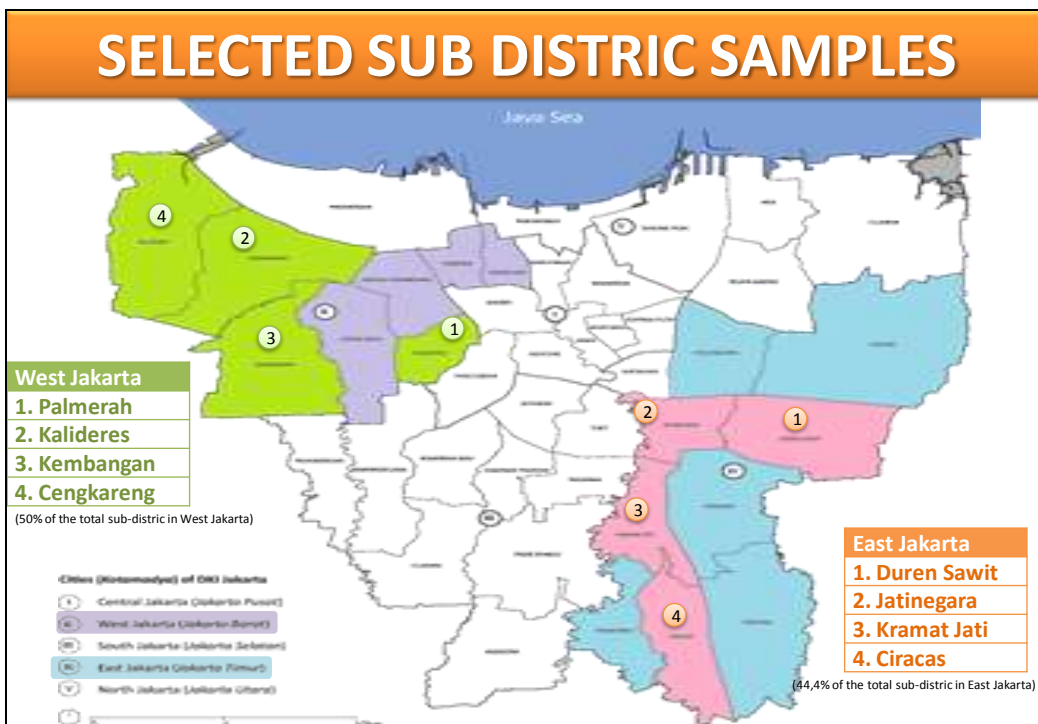
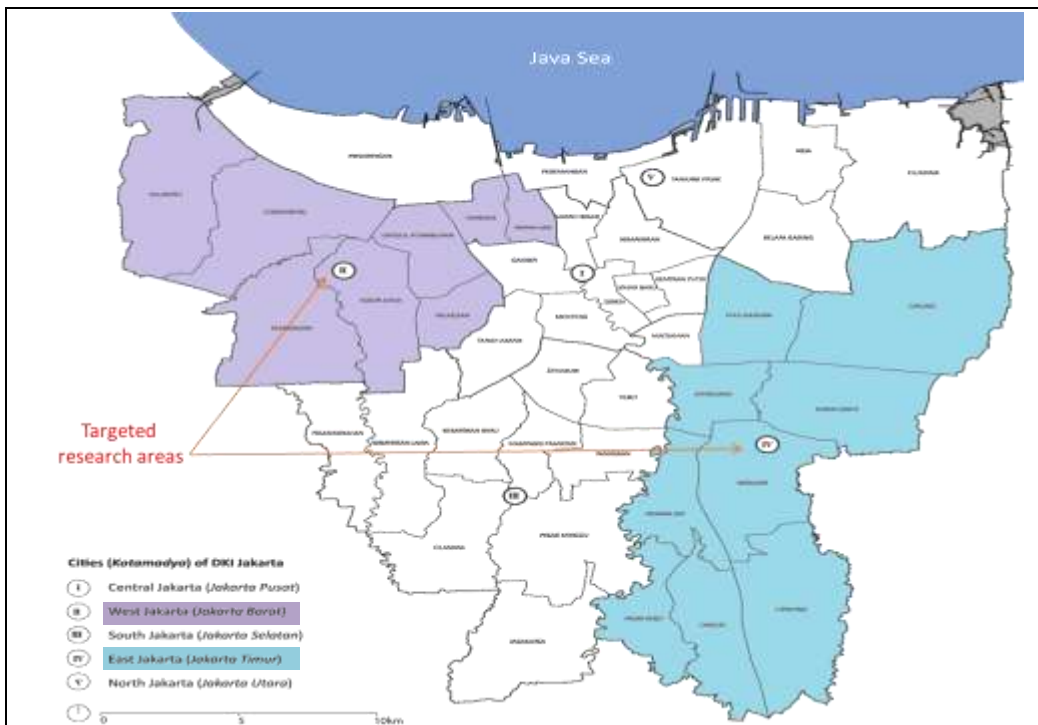
Soil

ASSESSMENT METHOD - The variables and indicators



ASSESSMENT METHOD - The variables and indicators





Score of all variables in each district was then assessed using formula:

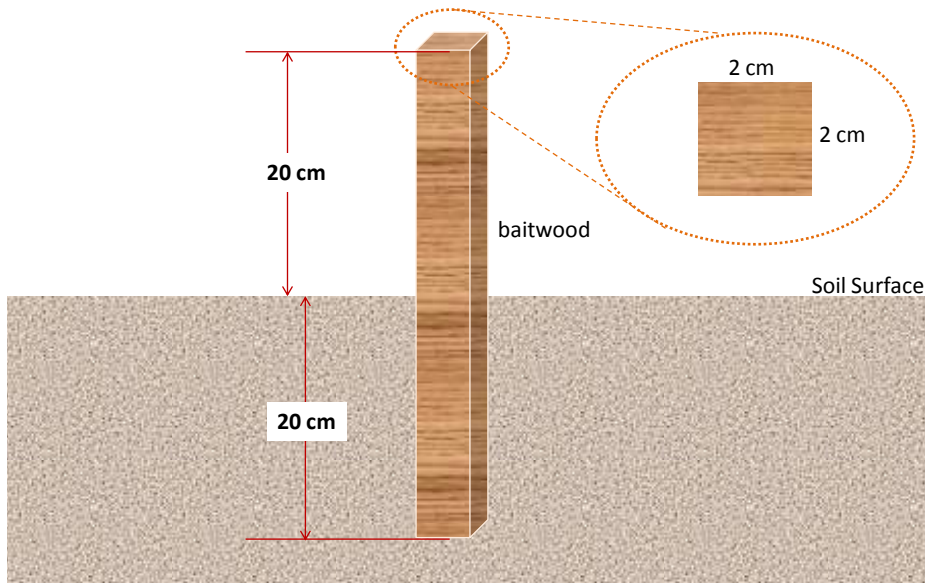
$$CS_i = T_{ij} + \sum_k \sum_p S_{ikp} + \sum_q \sum_s W_{iqs}$$

- CS_i = Total score for the ith sub district.
- T_{ij} = the score of termite the ith sub district for genus-j
- S_{ikp} = the score of the ith sub district for soil component-k with indicator p
- W_{iqs} = the score of the ith sub district for weather component-q with indicator s
- i = the sub district
- j = the termite genus (*Coptotermes*, *Schedorhinotermes*, *Macrotermes*, *Microtermes*, *Capritermes* and other genus)
- k = the soil variable component (*water table*, *moisture content*, *pH*, *organic carbon*)
- p = the indicator of the soil variable component
- q = the climate variable component (*air temperature*, *relative humidity*, *precipitation*)
- s = the indicator of the climate variable component

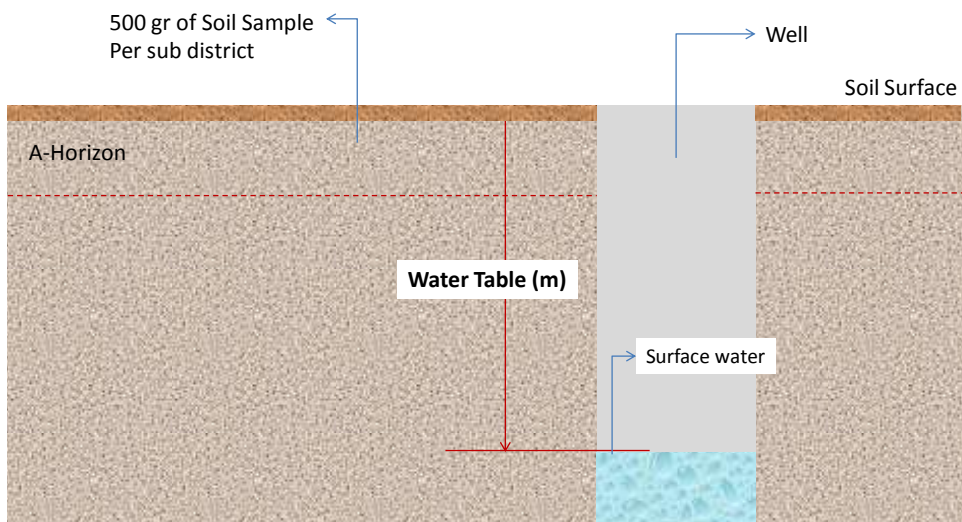
Classification of subterranean termite hazard class in Urban areas based on total score of termite, soil, and climate indicators

Cummulative Score	Termite Hazard Class	Description
53-63	I	The region with high risk of termite attack
43-52.9	II	The region with medium risk of termite attack
9-42.9	III	The region with low risk of termite attack

COLLECTING OF TERMITE SPECIMENS



SOIL CHARACTERISTICS DATA COLLECTION



LOCAL CLIMATE CHARACTERISTIC – DATA COLLECTION

- ✓ Annual Precipitation
- ✓ Air Temperature
- ✓ Air Relative Humidity

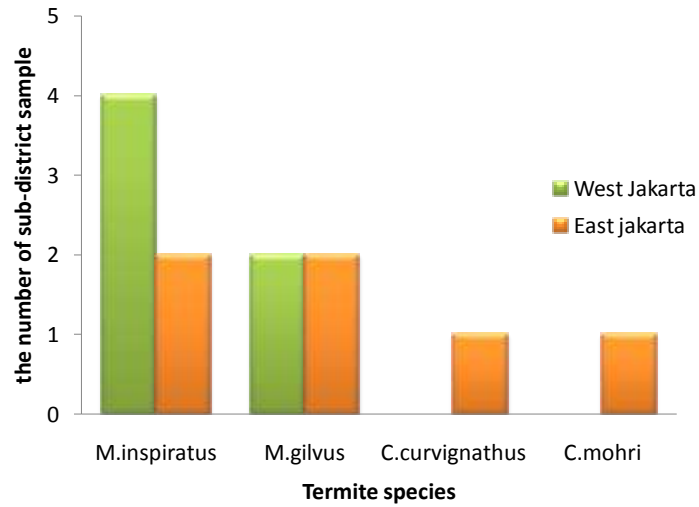


The Jakarta Office Of The Board Of Meteorology,
Climatology And Geophysics

RESULTS AND DISCUSSIONS

City/sub-district	Termite collecting location (villages)	Termite species
East Jakarta		
1. Ciracas	1. Ciracas	M. inspiratus
	2. Cibubur	M. gilvus
2. Kramat Jati	1. Cililitan	C. curvignathus
	2. Kramat Jati	M. inspiratus
3. Duren Sawit	1. Duren Sawit	M. gilvus
	2. Pondok Bambu	C. mohri
4. Jatinegara	1. Cipinang Muara	-
	2. Cipinang Besar	M. ispiratus
West Jakarta		
1. Palmerah	1. Slipi	M. inspiratus
	2. Palmerah	M. gilvus
2. Kalideres	1. Kamal	M. inspiratus
	2. Kalideres	M. gilvus
3. Kembangan	1. Kembangan Utara	M. inspiratus
	2. Kembangan Selatan	M. inspiratus
4. Cengkareng	1. Kapuk	-
	2. Cengkareng Timur	-

RESULTS AND DISCUSSIONS



The frequency of subterranean termite species occurrence in the West and East Jakarta

RESULTS AND DISCUSSIONS



The frequency of the subterranean termite species found in the West and East Jakarta.

RESULTS AND DISCUSSIONS

The characteristics of soil in every sub district samples of the West and East Jakarta

City/sub district	Water Tabel ¹⁾ (m)	Moisture Content (%)	pH ²⁾	Sand to Clay Ratio ²⁾	Organic Carbon ²⁾
I. East Jakarta					
1. Ciracas	5,50	58	5,20	1,08**	2,54 ⁺
2. Kramat Jati	5,05	52	5,30	1.05**	2,20
3. Duren Sawit	4,55	54	5,00	0,79	2,00
4. Jatinegara	4,05	50	5,20	0,85	2,15
II. West Jakarta					
1. Palmerah	4,80	54	4,90	0,81	2,10
2. Kalideres	5,05	52	5,10	0,77	2,30
3. Kembangan	3,40	50	4,97	0,79	2,00
4. Cengkareng	1,95*	50	4.31	0,84	1,96

1) The average of two observation points (selected villages within each sub district)

2) Soil samples were collected from A-horizon during the rainy season (May – Juni 2014), subject to duple laboratory analysis

RESULTS AND DISCUSSIONS

The climate characteristics of the sub district samples

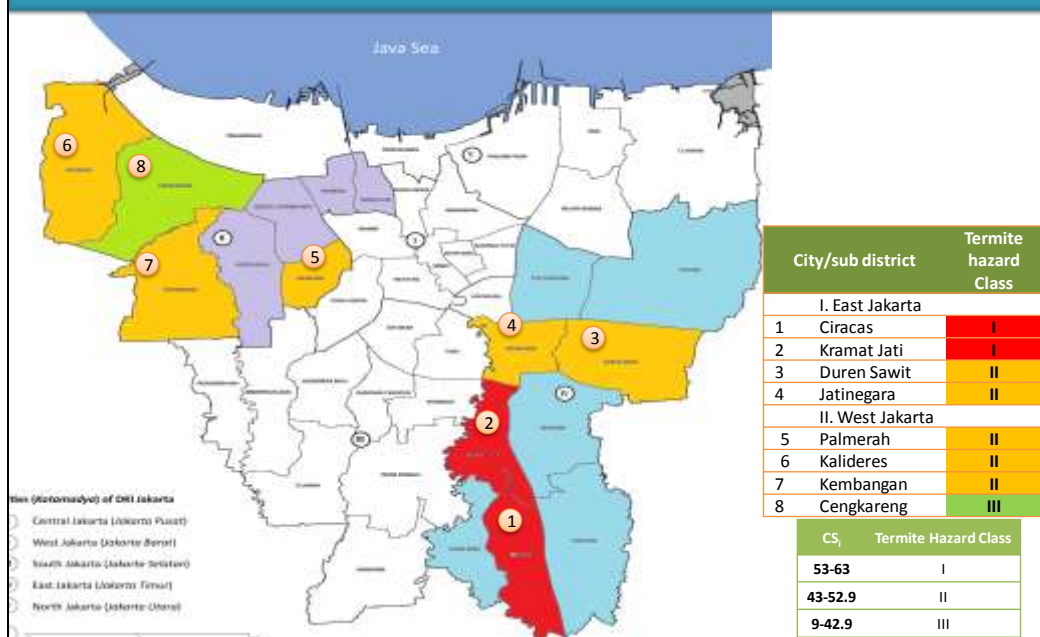
City/sub district	Rainfall (mm/yr) ¹⁾	Temperature (°C)	Humidity (%) ²⁾
I. East Jakarta			
1. Ciracas	2.994	28.6	84.5
2. Kramat Jati	2.994	28.6	84.5
3. Duren Sawit	2.994	28.5	76.8
4. Jatinegara	2.994	28.5	72.7
II. West Jakarta			
1. Palmerah	2.707	28.5	73.3
2. Kalideres	2.707	28.2	75.6
3. Kembangan	2.707	28.5	78.0
4. Cengkareng	2.707	28.5	89.0

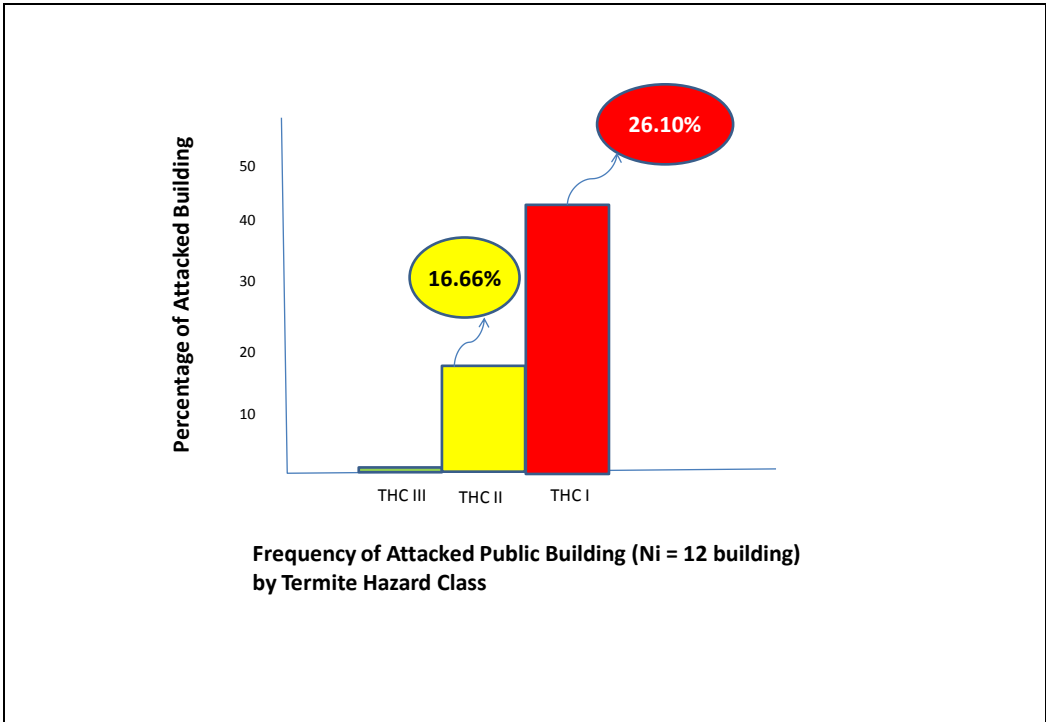
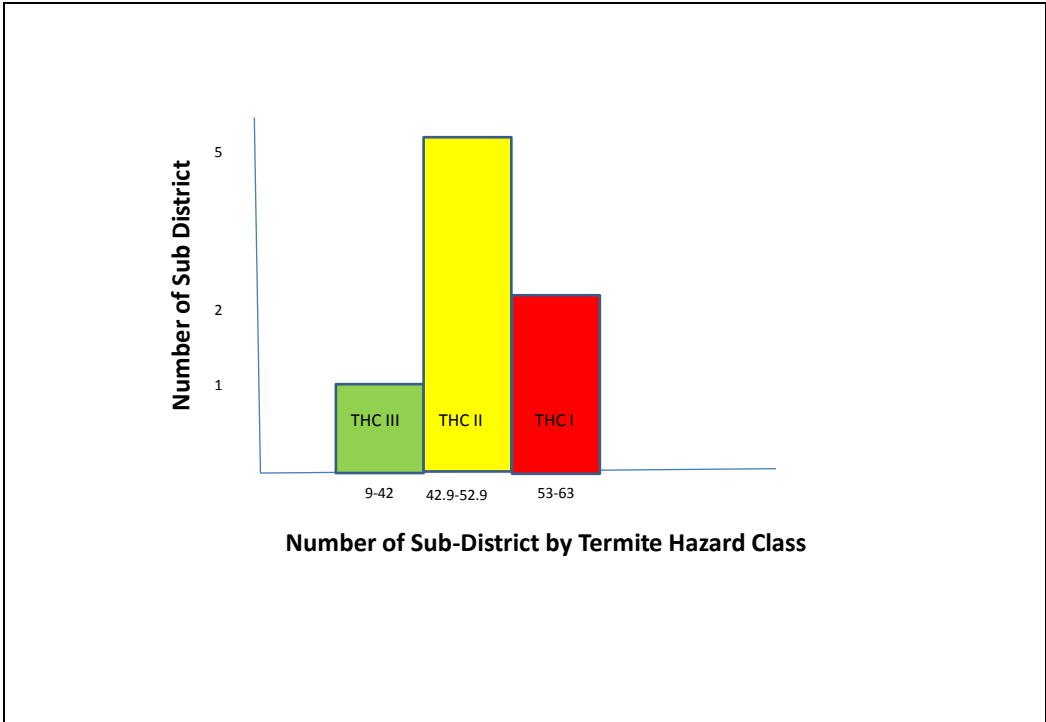
RESULTS AND DISCUSSIONS

Indicator Score of Termite soil, and Climate Variable of sub districts and their Total Score (Csi)

District/Sub District Sample	Score Indicator Variable/Component Variable									C _{Si}
	Termite Variable	Soil Variable					Weather Variable			
	Genus	Water Table	Moisture Content	pH	Sand : Clay Ratio	Organic Carbon	Air Temp	Humidity	Rain	
I. East Jakarta										
1. Ciracas	3	7	7	5	7	3	7	7	7	53
2. Kramat Jati	7	7	7	7	7	3	7	7	7	59
3. Duren Sawit	3	7	7	5	5	3	7	7	7	51
4. Jatinegara	3	7	7	5	5	3	7	7	7	51
II. West Jakarta										
1. Palmerah	3	7	7	5	5	3	7	7	7	51
2. Kalideres	3	7	7	5	5	3	7	7	7	51
3. Kembangan	3	7	7	5	5	3	7	7	7	51
4. Cengkareng	0	5	7	3	5	1	7	7	7	42

RESULTS AND DISCUSSIONS





CONCLUSIONS AND RECOMENDATION

1. The assement method of subterranean termite hazard zonation in West and East Jakarta based on termite genus, soil, as well as climate characteristics is promising to be developed. By using these method, the West Jakarta was considered to be classified into THC II and THC III, meanwhile the East Jakarta was considered to be classified into THC I and THC II.
2. A special consideration shoul be given to the existence of subterranean termite *C. curvignathus* in the districts of Kramat Jati, since this species is the most important wood destroying termite in Indonesia.
3. It is urgent for the Government of the Province of DKI Jakarta to mapping the termite hazard attack, and to formulate the technical standard of termite control on building based on termite hazard class. I

**THANK YOU
TERIMA KASIH
HORAS....**

INVITED PAPER

BRIDGING THE NETWORK ON RESEARCH OF RESTORATION FOREST ECOSYSTEM BASED ON COMMUNITY AS AN EFFORTS TO REDUCE GREEN HOUSES GASES EFFECT

Gusti Hardiansyah, Fahrizal, Farah Diba

Forestry Faculty Universitas Tanjungpura Indonesia

Email: gusti.hardiansyah@gmail.com, fahrizal.faisal@gmail.com, farahdiba1611@gmail.com

ABSTRACT

Global climate change has already had observable effects on the environment. The impacts of climate change are already being felt not only Indonesia but also in other countries. The main cause of climate change is the destruction of forest ecosystem. Tropical rain forest is a heart of environment and have important role for a supplier of oxygen, water infiltration, prevent flooding and provide economic benefits from non timber forest products, such as honey, rattan, bamboo and ecotourism. Restoration forest ecosystem based on community is important. This action needs more researchers on multi discipline such as socio cultural researcher, silvicultur, non timber forest product, medicinal plant from forest and forest carbon biomass. Empowerment of forest community capacity to support the resource management plan for sustainable forest is important. This research will give benefit on reduce green house effect.

Keywords: *forest restoration, community based, empowerment, network research, climate change*

INTRODUCTION

Forestry is an important sector and strategic on Indonesia national development. The characteristic of forestry industries were the commodity based on renewable resources, the product from wood industries is trade to foreign country and these industries employ much worker especially the people around the forest. Management and utilization of forest products is a source of a second foreign exchange earner of non-oil sector. The breadth dimension and interest of the parties to the forest resources has placed the forestry sector is able to create employment while absorbing significant amounts. Industrialization in the forestry sector has also been able to create new centers of economic growth and the opening up of isolated rural areas in the many forest land.

Forests and forestry industries have advantages in the creation of foreign exchange, as it has the following properties:

1. The international price of forest products and other dairy products are relatively the most stable, with a relatively steady rise, so it can be relied upon in the future.
2. Demand in the countries of the world will be the result of tropical forests continues growing steadily. In contrast to agricultural products in general tend to saturate, because the number of competitors from other countries. Trade barriers will be there if we manage forests as well as possible, in accordance with the principles of sustainability, or in terms of late meet the criteria of eco-labeling, SVLK and the issue of global warming.
3. Timber trade with other countries is very flexible, both in the form of raw materials, semi-finished goods or consumer goods, depending on the interests of bilateral relations required.

FAO (2000) states forestry and wood industrial was excellence in supporting development, especially in developing countries. Wood is the raw material that is multi-use and is required for many types of industries; and can be processed in the form of original timber (sawn timber and plywood); form of flakes and fibers (particle board, paper, etc.); even the form of chemicals (alcohol, sugar, rayon etc.). Consumption and market forest products is always growing steadily, both in high -income , middle- , and low, so that prospects and investment in forestry and industrial business is very good and low risk in the present and in the future (Janwsky and Becker, 2003). Mostly the products forms of wood industries are a semi-finished goods and raw materials of various kinds of other industries. It gives a huge economic impact of doubling the area of

development. On the other side is also almost entirely of wood processing using domestic materials, thus giving the double impact of major economic and foreign exchange saving as much as possible.

The level of technology and human resource capabilities is needed in forestry and industrial activities can be flexible from the lowest level to high advanced, then it will always be supportive of development in every stage of its development. The existence of an extensive selection, ranging from logging and sawmill using a hand axe, to high-tech industries such as paper, rayon, alcohol, etc. Forestry is spread to remote areas, because of the nature of the production process which should be close to sources of raw materials, so it can be a nucleus for economic development in the outposts, which means at the same time distributing development.

BIODIVERSITY RICHNESS IN WEST KALIMANTAN FOREST

Forest in West Kalimantan has a biodiversity of plants, animals and forest products were high. Wood products have a high economic value, not only for the timber industry, income for government and also for people surround the forest. Beside wood as a main product, non timber forest product also gives benefit to community people surround the forest. Non timber forest products are biological materials such as honey from the bee, rattan, bamboo, medicinal plant and other than timber produced from forests. This product plays an important role in sustainable forest management. Kilchling et al 2009 stated that in the previous decades, non timber forest products were considered as byproducts; however, there has been a change of paradigm from timber-based forest management to multi-function or multi-benefit-based forest management. Chamberlain et al (2002) said some non timber forest products are a source of income for rural communities. It is also happened in Philippines where the some forest communities can meet their needs from non timber forest products, such as bamboo and rattan for souvenir in tourist area (Lacuna-Richman 2003). Tewari (2012) has promoted the non timber forest products to alleviate poverty and hunger in rural South Africa. The non timber forest products are a source for food and income to people in rural communities surround the forest.

The product of non timber forest product consist of honey, medicinal plants, rattan, bamboo, fruit, plant for vegetable and ecosystem services for ecotourism and other. Honey has been used for sweetener for foods and as a medicine, such as burns and wounds. Honey is effective therapeutic agents (Kumar et al 2010). Honey from Danau Sentarum National Park in Kapuas Hulu District was famous and give high benefit on economic value to the people community surround the forest. This product now is a supplier of honey consumption in foreign country such as United States of America, Europe and Japan.

Medicinal plants used from West Kalimantan forest were more than 200 species (Diba et al 2013). This plant used to overcome the fever, hypertension, diabetes, and other sickness. Lone et al (2012) stated that 4 species is used as medicinal plants to overcome fever in Kupwara ethnic in Kashmir, India. Mirdeilami et al (2011) and Johnsy et al (2013) stated that preparation medicinal plants before consumption are boiling or extracted with water. This is the same methods used for medicinal plant in West Kalimantan Indonesia. The people surround the forest is used the plant to heal of the sickness due to the lack of doctor in their area. This knowledge was from the experience and has passed from one generation to other generation.

West Kalimantan Province have a big natural resources and biodiversity of medicinal plants. However, the existence of medicinal plants is feared to be lost with the decreasing of forest area. Threats to medicinal plant diversity by deforestation not only in West Kalimantan, Indonesia. Balick and O'Brien (2004) said that in Belize which located in central American country on the Caribbean coast, south of Mexico and east of Guatemala the annual of deforestation rate was 2.3%. The land clearing of forest area to be agricultural development made the habitat of medicinal plant damage and the plant become extinct, such as *Coniobolus* (*Aristolochia tribolata* L), greenstick (*Eupatorium morifolium* Mill), provision bark (*Pachira aquatica* Aubl), fig (*Ficus radule* Wild) and callawalla (*Phlebodium decumanum* Willd). Salafsky et al (1993) stated that the greater pressure for alternative land uses and the relatively poorly developed physical and social infrastructure for extraction in Kalimantan, may in fact make the opportunity costs of extractive reserves greater than in the Peten, Guatemala.

Rattan and bamboo also used in daily livelihood of people. This material used for furniture, music instruments, bag, and many others. Rattan is widely used for furniture and tools materials for cooking, meanwhile bamboo mostly for construction material, for housing and gazebo. Bamboo will play an important role in the world's pulp and paper industries. The fiber morphology of bamboo has average fiber length of 1.5-4.4 mm and fiber width widely ranging between 7-27 μm with an average of 14 μm . Pungbun Na Ayudhya

(2000) stated the potential bamboo for pulp industries is Sweet Bamboo. Sweet Bamboo is easy to grow and utilize more than the other bamboo species in Thailand.

The research of bioenergy from renewable resources is rapidly growing. The energy demand in Indonesia is increase due to a significant growth in population. One of the most prominent is the development of bioethanol as a result of fermentation of sugar or starch containing materials. Much kind of plants were transformed to oil, such as biodiesel and bioethanol. Bioethanol can further utilized as fuel when it is mixed with gasoline. The plants used were *Jatropha curcas*, palm oil, *Calophyllum inophyllum* and other biomass. Bioenergy is the gateway to the new bioeconomy: replacing fossil energy resources with biomass energy. These derive the energy chemicals and raw materials from biomass. Haisya (2011) has been research on utilization of siwalan palm sugar for bioethanol production. The utilization of bioenergy in Indonesia give a benefit such as strengthen supply of fuel security, renewable resources will support plantation and giving revenue to government.

The other richness of biodiversity in West Kalimantan forest is ecosystem services. Forest as a place for ecotourism and healing is grown as a need of human. This situation is happened in every forest region, not only in tropical rain forest, but also in temperate forest (Secretariat of Convention on Biological Diversity, 2001). Sheil et al (2002) stated ecotourism give benefit to local people; they can sell the fruit from forest to the tourist and made souvenir from rattan or bamboo. Tickin (2004) stated the non timber forest product play an important role on sustainable of local people inside the forest, and as one of the attractive matter to tourist when they come for an ecotourism's activities in the forest.

RESTORATION FOREST BASED ON COMMUNITY

Sardana et al (2011) reported that in 2010 the estimated forest cover will be decreasing rapidly achieve 1.962.614 ha or 21.51% of West Kalimantan province area due to the proposed changes of forest area to other uses area. The degradation of forest resulted environmentally, economically and aesthetically impoverished landscapes (Barrow et al, 2002). Rate of deforestation in Indonesia forest around 0.61 hectare/year. One effort to overcome forest degradation is making plantation forest. Econ (2002) stated the conventional approaches to plantation forestry are seldom capable of delivering the multiple values of forest and adequately addressing the needs of all interest groups (e.g. forest-dependent communities and downstream water users). There is an urgent need to both improve the quality of forest restoration and rehabilitation at the site level and to find effective ways to undertake these activities in the context of broader environmental, social, and economic need and interest (Hartanto et al 2003).

Local peoples in a forest area is very depends on plants grow on surrounding them for fulfill daily livelihood such as food, clothing, medicinal, construction material, etc. People knowledge in forest ecosystem maintenance was passed from generation to generation. Documentation and conservation of traditional knowledge from the local people is needed as a basic data to restoration forest ecosystem. Degraded forest in many tropical landscapes is common. Their location near human settlements and the fact that they are often considered dysfunctional and unproductive means that these forests tend to be under greater threat than more isolated blocks of intact primary forest (Kusumanto, 2005). Lamb and Gilmour (2003) stated the complete loss of forests would represent a further impoverishment of already degraded and modified landscapes and would extinguish any possibility of improving landscape level functionality in the immediate future.

Maginnis and Jackson (2002) stated forest degradation has two perspectives. From an economic perspective, the loss of forests would result in the decline of an area's timber commodity base with ensuing loss of jobs and livelihoods, while from a conservation perspective it would mean a local, possibly permanent, loss of forest biodiversity. Mather (2001) stated if restoration forest need the same commitment and understanding from decision makers, local communities and the private sector. Case in Thailand showed the restoration based on community is more effective than restoration based on private sector only (Marghescu (2001). The specific activities of forest restoration could include one or more of the following activities, such as rehabilitation and management of degraded primary forest, management of secondary forest, restoration of primary forest related functions in degraded forest lands, promotion of natural regeneration on degraded lands and marginal agricultural sites, ecological restoration, plantations and planted forest, and agroforestry and other configurations of on farm trees.

RESEARCH NETWORK

Tanjungpura University has a forest education area / arboretum which manage by Forestry Faculty. The location of arboretum was inside the campus and total area of arboretum was 3.3 hectare. This area consist of 750 species of tree and used for the students to study on forest ecology, measurement carbon from biomass, forest inventory, medicinal plant, biodiversity of insect, rattan, bamboo and others. Beside this area, Forestry Faculty has another two forest education areas. One is located in Kubu Raya District and one in Landak District. This area offer many field on collaboration research, such as forest carbon biomass measurement, program of REDD+, inventory the medicinal plant, measurement and inventory the non timber forest product, calculation the payment of economic services, ecotourism and other field of research.

REFERENCES

- Balick, MJ, and O'Brien H. 2004. Ethnobotanical and Floristic Research in Belize: Accomplishments, Challenges and Lesson Learned. *Journal Ethnobotany Research & Applications* 2:077-088
- Barrow E, Timmer D, White S and Maginnis S. 2002. *Forest Landscape Restoration: Building Assets for People and Nature – Experience from East Africa*. IUCN. Cambridge. UK
- Chamberlain JL, Robert JB, Hammet AL, Araman PA. 2002. Managing for Non Timber Forest Products. *Journal of Forestry* 100 (1):8-14
- Diba F, Yusro F., Mariani Y., Ohtani K., 2013. Inventory and Biodiversity of Medicinal Plants from Tropical Rain Forest Based on Traditional Knowledge by Ethnic Dayaknese Communities in West Kalimantan Indonesia. *Journal Kuroshio Science*. Vol 7 No 1:75-80, October 2013, ISSN 1882-823X
- Ecott T. 2002. *Forest Landscape Restoration: Working Examples from 5 Ecoregions*. WWF International / Doveson Press. Bristol. UK
- FAO. 2000. *An Introduction to Planning Forestry Development*. New York.
- Hartanto H, Lorenzo MCB, Valmores C, Arda-Minas L, Burton L and Prabhu R. 2003. *Learning Together: Responding to Change and Complexity to Improve Community Forests in the Philippines*. CIFOR, Bogor, Indonesia
- Haisya NBS, Utama BD, Edy RC, Aprilia HM. 2011. The Potential of Developing Siwalan Palm Sugar (*Norassus flabellifer* Linn) as One of the Bioethanol Sources to Overcome Energy Crisis Problem in Indonesia. 2nd International Conference on Environmental Engineering and Applications IPCBEE Vol 17 Singapore
- Janwsky VD, Becker G. 2003. Characteristics and Needs Different User Groups in the Urban Forest of Stuttgart. *Journal for Nature Conservation* 11:251-259
- Johnsy G., Beena S. and Kaviyaran V. 2013. Ethno-Botanical Survey of Medicinal Plants Used for the Treatment of Diarrhea and Dysentery. *International Journal of Medicine and Medical Sciences*. 3(1) : 332-338
- Kilchling P, Hansmann R, Seeland K. 2009. Demand for Non-Timber Forest Products. Survey of Urban Consumers and Sellers in Switzerland. *Forest Policy and Economic* 11:294-300
- Kusumanto T, Yuliani L, Macoun P, Indriatmoko Y and Adnan H. 2005. *Learning to Adapt: Managing Forests Together in Indonesia*, CIFOR, Bogor, Indonesia
- Kumar KPS, Bhowmik D, Chiranjib, Biswajir and Chandira MR. 2010. Medicinal Uses and Health Benefits of Honey: An Overview. *Journal Chemical Pharmacy Res* 2(1):385-395 ISSN 0975-7384
- Lacuna-Richman C. 2003. Ethnicity and the Utilization of Non-Wood Forest Products: Finding from Three Philippine villages. *Journal Silva Fennica* 37 (1):129-148
- Lamb D and Gilmour D. 2003. *Rehabilitation and Restoration of Degraded Forest*. IUCN. UK. x+110 pp
- Lone FA, Lone S, Aziz MA, and Malla FA, 2012. Ethnobotanical Studies in the Tribal Areas of District Kupwara, Kashmir, India. *Internasional Journal of Pharma and Bio Sciences* 3(4): (B) 399-411
- Maginnis S and Jackson W. 2002. Restoring Forest Landscapes. *ITTO Tropical Forest Update* 12(4):9-11
- Marghescu T. 2001. *Restoration of Degraded Forest Land in Thailand: the Case of Khao Ko*. *Unasylyva* 207 Vol 52. FAO. Rome. Italy
- Mather A. 2001. The Transition from Deforestation to Reforestation in Europe. In A Angelsen and D Kaimowitz (eds). *Agricultural Technologies and Tropical Deforestation*. Wallingford:CAB International, pp 35-52

- Mirdeilami, SZ., Barani H., Mazandarani M., and Heshmati GA. 2011. Ethnopharmacological Survey of Medicinal Plants in Maraveh Tappeh Region, North of Iran. *Iranian Journal of Plant Physiology* 2(1) : 327-338
- Pungbun Na Ayudhya P. 2000. Bamboo Resources and Utilization in Thailand, pp 6-12. In Puangchit L, Thaiutsa B and Thamincha S (eds), *Bamboo 2000 Proceedings of the International Symposium*. Royal Project Foundation. Asksorn Siam Printing. Bangkok
- Sardana A, Hernawati J, Dharma N.G.G.Y, Nugroho A.E and Aliyah N. 2011. Figure of Forest in West Kalimantan Province. BPKH Wilayah III Pontianak. Indonesia
- Sheil D, Puri R, Basuki I, van Heist M, Syaefuddin, Rukmiyati, Sardjono M, Samsodin I, Sidiyasa K, Chrisandini, Permana E, Angi E, Gatzweiler F and Wijaya A. 2002. *Exploring Biological Diversity, Environment and Local People's Perspectives in Forest Landscapes*. 2nd Edition. CIFOR, Ministry of Forestry and ITTO. Bogor. Indonesia
- Salafsky N, Dugelby BL, and Terborgh JW. 1993. Can Extractive Reserves Save the Rainforest: An Ecological and Socioeconomic Comparison of Non-Timber Forest Product Extraction Systems in Peten, Guatemala, and West Kalimantan, Indonesia. *Journal Conservation Biology* 7:39-52
- Secretariat of Convention on Biological Diversity. 2001. *Sustainable Management of Non Timber Forest Resources (CBD Technical Series No 6)*. Montreal: SCBD
- Tewari D. 2012. Promoting Non-Timber Forest Products (NTFPs) to Alleviate Poverty and Hunger in Rural South Africa: A Reflection on Management and Policy Challenges. *African Journal of Business Management* Vol 6 (47) pp 11635-11647
- Tickin T. 2004. The Ecological Implications of Harvesting Non-Timber Forest Product. *Journal of Applied Ecology* 41:11-21

ORAL PRESENTATION

TOTAL UTILIZATION OF OIL PALM TRUNK

Wahyu Dwianto, Teguh Darmawan, Fitria, and Dwi A. Pramasari

Research Center for Biomaterials, Indonesian Institute of Sciences,
Cibinong Science Center, Jl. Raya Bogor Km. 46, Bogor 16911, Indonesia

ABSTRACT

This research dealt with the utilization of outer part near the bark of oil palm trunk as plywood raw material and improvement of the physical and mechanical properties of inner part of oil palm trunk by compression and phenol formaldehyde (PF) impregnation. For the inner part of oil palm trunk, the samples were divided into three groups, i.e. compressed wood without soaking in PF resin solution (A group), soaking in 20% of PF resin solution and then compressed (B group), and compressed continued by impregnation and then re-compressed (C group). Density (ρ), moisture content (MC), modulus of elasticity (MOE), modulus of rupture (MOR), and shear-tensile strength type I and II for interior were measured according to SNI 01-5008.2 for Plywood. While, ρ , thickness swelling (TS), MOE, MOR, compressive strength parallel and perpendicular to the grain and shear strength parallel to the grain of compressive oil palm trunk were compared according to SNI 03-3527 for Wood Construction Grade. The results showed that average ρ , MC, MOE, MOR, shear-tensile strength of type I and II for interior were 0.55 g/cm³, 11.96%, 14,566.23 kg.f /cm², 340.63 kg.f /cm², 4.30 kg.f/cm², and 8.62 kg.f/cm², respectively. MC ($\leq 14\%$) and shear-tensile strength of type II (≥ 7 kg.f/cm²) fulfilled the requirements of SNI 01-5008.2 for Plywood. It was concluded that oil palm trunk could be used as plywood raw materials for interior type II, due to its weakness on moist and humid conditions. For the compressive oil palm trunk, most of the highest physical and mechanical properties were achieved by B group specimens, i.e. $\rho = 0.49$ g/cm³, TS = 6.83%, MOR = 412.24 kg.f/cm², and compressive strength perpendicular to the grain = 38.89 kg.f/cm²; followed by C group specimens, i.e. MOE = 38797.90 kg.f/cm² and compressive strength parallel to the grain = 191.22 kg.f/cm²; the highest value of A group specimens was only shear strength parallel to the grain = 18.51 kg.f/cm². The ρ has a strong correlation with mechanical properties of the specimen, thus the increasing of ρ due to compression and PF resin impregnation subsequently increased its mechanical properties.

Keywords: outer part, inner part, oil palm trunk, plywood raw material, compression, impregnation.

INTRODUCTION

Oil palm (*Elaeis guineensis* Jacq) was first planted in Indonesia by the Dutch Government in 1848 (Jamilah 2009). In 1911, the first oil palm plantation was developed in the east coast of Sumatera (Deli) and Aceh with a total area of 5.123 ha. Soon after that, many forest areas have been converted into oil palm plantation due to its high economic value and short production period. Since 1967, 105,808 ha oil palm plantation has been created and in 2000, 3,174,276 ha plantation area has been recorded with an increasing rate of 8.5% a year. In 2009, the area has reached 8.25 million ha spread across 22 provinces (Departemen Pertanian 2010), where the largest area was in Riau and North Sumatera. It was estimated that world oil palm production would have increased 20 million tones before 2020 thus 300,000 ha new plantation area will be opened up annually for the next 30 years (Santoso 2005).

With this large area, large amount of waste will be generated. Oil palm waste is produced from the residue of left over plant when a site is opened for farming, rejuvenation and harvesting of oil palm. The waste can be in the form of post harvest trunk, frond, empty fruit bunch, shell, kernel, and weeds. So far, oil palm research mostly focused on the empty fruit bunch and kernel, while the trunk is mostly used only as firewood, not yet utilized (Bakar *et al.* 2000). This is due to the weakness of oil palm trunk, such as dimension stability, strength, durability and low machining properties. According to Febrianto and Bakar (2004), rejuvenation of oil palm plantation can produce 50.1 m³/ha saw wood originated from hard outer part of the trunk while 2/3 of its soft inner part still becomes waste.

Some previous researches have reported that the density of oil palm ranged from 0.28 - 0.75 g/cm³ (Prayitno 1995); 0.11 - 0.40 g/cm³ (Bakar *et al.*, 2000); and 0.23 - 0.74 g/cm³ (Febrianto and Bakar 2004). This is due to the various anatomical structure of oil palm trunk from hard outer part dominated by vascular bundles with thick wall to the softer inner part dominated by parenchymatous ground. Vascular bundle tissues have higher density than its surrounding tissues. The hard outer part has denser vascular bundles resulted in higher density (Bakar *et al.* 2000; Prayitno 1995; Erwinsyah 2008).

The difference of this anatomical structure causes the oil palm trunk having various characteristics from the outer part to the center of the trunk and from the bottom to the top. Due to having more parenchyma, the inner part of the trunk has several weaknesses, e.g. low strength and high moisture and starch content. Bakar (2003) stated that the high moisture content ranged between 345 - 500%. This causes the low dimension stability of the trunk. Chemical analysis shows that the trunk's inner part has up to 40% starch (Bakar *et al.* 1998), making it susceptible to the decay fungi, insects (Iswanto *et al.* 2010) and termites (Rahayu 2001). The starch can inhibit gluing process in plywood production. Soaking the trunk before further treatment can be used as a method to reduce the starch content.

Modulus of rupture (MOR), modulus of elasticity (MOE), cleavage, shear strength, hardness and impact bending decreased from soft inner part and from the bottom to the top (Bakar *et al.* 1999). In transversal direction, all these properties deeply decreased from the hard outer part and slightly decreased from inner part to the center. This was mainly due to the density difference of vascular bond caused by distribution of vascular bundles and parenchyma in each part. Compared to other woods, the MOE, MOR, shear strength, and hardness of outer trunk part were almost equal to the strength of Sengon wood and was classified into strength class IV-V (Bakar *et al.* 1999).

Oil palm trunk grows vertically and is wrapped by leaf frond base. The trunk is cylindrical and can achieve 0.5 m in diameter in mature plant. The bottom part is commonly bigger (Lubis 1992). Due to its big potential and cylindrical morphological shape, the trunk can be utilized as high value products if the application can suit the trunk characteristics, considering or increasing its anatomical, chemical, physical and mechanical characteristic weaknesses.

In this research, 1/3 of hard outer part from no longer productive plant was made into veneer as the raw material for plywood. Plywood is artificial board with certain size that is made from several layers of veneers in an uneven number, attached with the grain perpendicularly crossed to each other and then glued with special adhesive in high pressure that suits the purpose of plywood utilization (APKINDO 1978; Dumanauw 1990; BSN 1992; Youngquist 1999). The advantages of plywood compared to solid wood are more stable dimension, the edge is not easily cracked if nailed, higher tensile strength perpendicular to the grain, it is lighter considering its surface area, it can cover wide area in short time, has higher screw withdrawal and the texture and fiber colour can be made uniform to make symmetric motive or pattern (Iswanto 2008).

The types of woods that are usually used as plywood materials are Meranti, Kapur, Mersawa, Jelutung, Teak, Ebony and Sonokeling. However, the availability of these woods is decreasing and the price is expensive. Therefore, in this research the plywood will be produced from oil palm trunk. The research on the utilization of 1/3 of the outer part of the trunk is not common before. The adhesive, Phenol Formaldehyde (PF) was used in this research due to its weather durable (Tsoumis 1991). The physical and mechanical properties of the oil palm trunk plywood will be improved to meet the requirement of SNI 01-5008.2 (BSN 2000).

The physical and mechanical properties of soft inner part of oil palm trunk can be increased by compression and resin impregnation. Wood compression technique was carried out in order to increase the hardness in the surface and the strength of wood. This technique was applied to fast growing trees that generally have low quality through density improvement (Amin and Dwianto 2006). PF impregnation on wood can increase dimension stability (Ohmae *et al.* 2002; Furuno *et al.* 2004; Rowell 2005) and reduce wood higroscopic property (Hill 2006). PF can also significantly increase wood mechanical properties (Shams *et al.* 2004; Shams *et al.* 2006; Shams and Yano 2009). Even though many studies on PF impregnation have been conducted, research on the use of PF with Close System Compression (CSC) method is still not commonly done. It was expected that PF application together with CSC method can increase PF penetration to the wood and also can improve oil palm trunk properties, either dimension stability and physical and mechanical properties and can meet the quality requirement of SNI 03-3527 (BSN 1994) for construction wood.

MATERIALS AND METHODS

The 22 years-old oil palm trunk was obtained from no longer productive plant in an oil palm plantation in Ciomas, Bogor. The PF adhesive produced by PT. Dover Chemical with initial solid content of 50% was used (BSN 1998), that then diluted with water to get 20% concentration. PF is an exterior adhesive (Iswanto 2008) that is resistant to humidity, weather and water (Tsoumis 1991).

The equipments used in this study were chainsaw, tape meter and desiccator. Physical testing equipments used were caliper, digital balance and drying oven, while mechanical properties testing was conducted by using Universal Testing Machine (UTM).

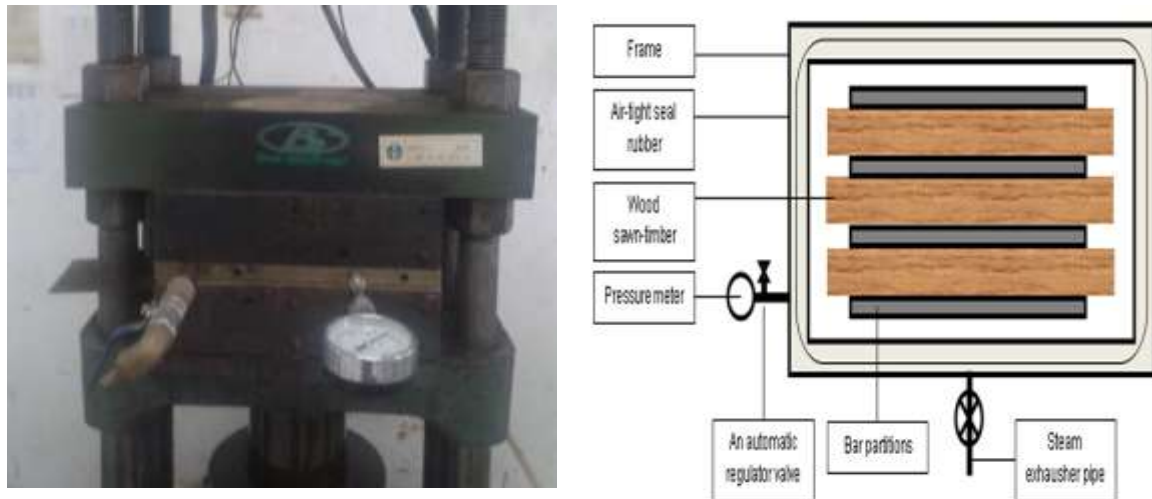


Figure 1. Hot-press machine (left) equipped with CSC (right)

Compression of oil palm trunk was conducted by using hot pressed machine equipped with CSC (**Figure 1**). CSC is a frame made from stainless steel in same sides square and whose size is the same as the hot press plate, i.e. 25 x 25 cm. The top and bottom of the CSC were surrounded by air tight silicon rubber that is used as closure plate support. This CSC has two holes as the measurer of inside vapour pressure and valve pipe used to release the vapour when the compression has finished. This CSC frame was placed between two hot press plates.

Oil palm trunk plywood

According to Dumanauw (1990), veneer can be produced by using (1) peeling machine to get thin veneer, where wood rotates in adverse direction to the blade that can peel the wood to desired thickness; and (2) band saw to produce thicker veneer. In this study, second method was used, i.e. using band saw due to not having peeling machine. Before samples were produced, the oil palm trunk was converted into board with the size of 100 x 20 x 2 cm, and then oven dried at 60°C for 7 days to reduce its water content to prevent fungal attack. The veneers were then made from the board with the size of 20 x 20 x 0.5 cm. The veneer were then soaked in water and autoclaved for 30 min to reduce the starch content and then re-dried at 60°C for 24 h. Next, the veneers was spread with PF adhesives with spread weight of 200 g/m², attached with each other, perpendicular to the grain for 3 layers and pressed with hot press machine at 150°C for 15 min. Before testing, the plywood was air-dried for 7 days.

The physical property measurements carried out were density (ρ) and moisture content (MC) with a sample size of 10 x 10 x 1.5 cm while the mechanical properties measured were Modulus of Elasticity (MOE) and Modulus of Rupture (MOR) with a sample size of 20 x 5 x 1.5 cm, and shear-tensile strength with a sample size of 10 x 2.5 x 1.5 cm. The testing was conducted in five replicates based on SNI 01-5008.2 (BSN 2000) for general use plywood.

ρ and MC determination were conducted by measuring the dimension, volume (V_o), and initial sample weight (W_o). The samples were dried in the oven at 103°C \pm 2°C for 24 h and the oven dried weight was measured (W_i). The ρ of the samples (gr/cm³) was calculated with the formula $\rho = W_o/V_o$, while the MC (%)

were calculated with the formula $MC = [(W_o - W_i)/W_i] \times 100$, where W_o = initial weight of samples, W_i = oven-dried weight of samples, V_o = initial volume of samples.

The MOE testing was carried out using the same samples as MOR. The MOE value was calculated by the function of MOE (kg.f/cm^2) = $\delta PL^3/\delta y 4wt^3$, while the MOR was calculated with the formula of MOR (kg.f/cm^2) = $3PL/2wt^2$, where P = maximum load (kg.f), δP = load before proportional limit (kg), δy = deflection (cm), L = span length (cm), w = sample width (cm), t = sample thickness (cm).

According to SNI 01-5008.2 (BSN 2000), plywood is classified into 4 types based on its adhesive bond strength, i.e.: (a) exterior I type, resistant to weather for a relatively long time, (b) exterior II type, resistant to weather in a relatively short time, (c) interior I type, resistant to high air humidity, (d) interior II type, resistant to low air humidity.

In this research, the shear-tensile strength was only conducted for interior I and II types. For interior I type, samples were soaked in hot water at $60^\circ\text{C} \pm 3^\circ\text{C}$ for 3 h and then dipped into cold water until achieved room temperature and then tested in wet condition, while the samples were tested in dry condition without pre-treatment for interior II type. The shear-tensile strength (kg.f/cm^2) was obtained from formula $P/(Lw)$, where P = tensile load (kg), L = shear area length (cm), w = shear area width (cm).

Oil palm trunk compression

In this research, 3 groups of treatment were applied, i.e. compressed wood without soaking in PF resin solution (A group), soaking in 20% of PF resin solution and then compressed (B group), and compressed continued by impregnation in 20% PF and then re-compressed (C group).

Before compression, group A and C samples were softened in autoclave at 140°C for 30 min, and then pressed with a target of 50% from initial thickness. Compression temperature for group A was 140°C , while for group C was 100°C for 30 min with a pressure of 40 kg/cm^2 . Group A samples were not soaked in PF while group B and C were, with PF concentration of 20% at only 100°C applied to group C. It was expected that thickness recovery process would still occur and absorb more PF. In the following step, group B and C samples were pressed with a target of 50% of initial thickness at 140°C for 30 min.

Table 1 shows the dimension of samples for each testing. The testing carried out was physical and mechanical properties according to SNI 03-3527 (BSN 1994) (**Table 2**). For ρ testing, the samples were oven dried at 60°C for 3 days, weighted and the volume was measured with the same formula with the samples of plywood from oil palm trunk. TS testing was conducted by soaking the samples at room temperature for 24 h. TS was measured with the formula $TS (\%) = [(T_o - T_i)/T_i] \times 100$, where T_o = initial thickness of samples, T_i = sample's thickness after soaking.

Tabel 1. Sample dimensions.

No	Type of testing	Size (cm)
1	Density (ρ) & thickness swelling (TS)	2 x 2 x 2
2	Modulus of Elasticity (MOE) & Modulus of Rupture (MOR)	30 x 2 x 2
3	Compression parallel to the grain	8 x 2 x 2
4	Compression perpendicular to the grain	2 x 2 x 2
5	Shear parallel to the grain	4 x 2 x 2

Table 2. Quality requirements of SNI 03-3527 for Wood Construction Grade (BSN 1994).

Strength Class	Density	MOE (1000 kg.f/cm^2)	MOR (kg.f/cm^2)	Compressive strength		Shear strength parallel to the grain (kg.f/cm^2)
				Parallel to the grain (kg.f/cm^2)	Perpendicular to the grain (kg.f/cm^2)	
I	> 0.9	> 161	> 1221	> 630	> 171	> 93
II	0.6 - 0.9	112	795	411	114	59
III	0.4 - 0.6	75	437	266	76	37
IV	0.3 - 0.4	56	278	193	57	26
V	< 0.3	< 56	< 278	< 193	< 57	< 26

The determination of values of MOE and MOR were done with the same formula with the samples of plywood from oil palm trunk while tension parallel/perpendicular to the grain and shear strength perpendicular to the grain (kg.f/cm²) were measured with the formula of $P/(wt)$, where P = load (kg), w = width (cm), t = thickness (cm) of samples.

RESULTS AND DISCUSSION

Oil palm trunk plywood

The result showed that ρ of plywood from oil palm trunk was in the range of 0.47 - 0.65 g/cm³ (average 0.55 g/cm³). According to SNI 01-5008.2 (BSN 2000), ρ was not affected to quality of plywood. Initial MC of oil palm trunk was 92.96% and decreased into 11.96% after drying at 60°C for 7 days. MC ($\leq 14\%$) was full-filled the requirements of SNI 01-5008.2 (BSN 2000).

MOE and MOR values plywood from oil palm trunk was 14566.23 kg.f/cm² and 340.62 kg.f/cm², respectively. However, MOE and MOR values were not available in SNI 01-5008.2 (BSN 2000), as well. While, the average shear-tensile for interior I type tested was 4.30 kg.f/cm², and that for interior II type was 8.62 kg.f/cm². Therefore, oil palm trunk plywood was not full-filled the requirements of SNI 01-5008.2 (BSN 2000) for interior I type, where the shear-tensile should be ≥ 7 kg/cm². That was due to hygroscopic properties of oil palm trunk which could adsorb lot of water, although it has already used the water-pool resin such as PF.

Oil palm trunk compression

The results of physical and mechanical properties of inner part oil palm trunk compression are showed in **Table 3** and **Table 4**. The ρ of A group oil palm trunk compression increased 2-fold (0.4 g/cm³) than its initial ρ , and were increasing more for B and C groups by PF impregnation (0.48 - 0.49 g/cm³). Hence, by the combination of compression and PF impregnation, the inner part of oil palm trunk could be classified into strength class III (**Table 2**). Murhofiq (2000) reported that 50 % compression could be increased the density of Agathis wood from 0.41 to 0.79 g/cm³, while that for Sengon wood increased from 0.23 to 0.48 g/cm³. Sulistyono *et al* (2003) also investigated density of Agathis wood and stated that the density increased from 0.43 - 0.46 g/cm³ to 0.70 - 0.85 g/cm³.

The requirement of TS for construction was 12%, therefore B and C groups were accepted in requirements of TS ($\leq 12\%$), which was used PF impregnation (**Table 3**). A group has a highest TS, because it was only compressed at 140°C for 30 min, while it was needed 180°C for 30 min to reach the fixation of compression by CSC (Amin and Dwianto 2006; Amin *et al*. 2007).

Table 3. Physical properties of oil palm trunk compression.

Group	Initial Density (g/cm ³)	Density after compression (g/cm ³)	Thickness swelling (%)
A	0.20 - 0.24	0.40	19.02
B	0.20 - 0.24	0.49	6.83
C	0.21 - 0.24	0.48	11.71

Table 4. Mechanical properties of oil palm trunk compression.

Group	MOE (kg.f/cm ²)	MOR (kg.f/cm ²)	Compressive strength		Shear strength parallel to the grain (kg.f/cm ²)
			Parallel to the grain (kg.f/cm ²)	Perpendicular to the grain (kg.f/cm ²)	
A	25581.53	245.460	145.86	28.73	18.51
B	29963.95	412.240	164.94	38.89	10.92
C	38797.90	397.260	191.22	33.89	12.38

The results showed that the highest MOR (412.240 kg.f/cm²) and compressive strength perpendicular to the grain (38.89 kg.f/cm²) was achieved by B group (**Table 4**). Meanwhile, the highest MOE (38797.90 kg.f/cm²) and compressive strength parallel to the grain was achieved by C group. However, according SNI 03-3527 (BSN 1994) the three of sample group was classified into strength class IV-V (**Table 2**). The shear strength parallel to the grain was not related with PF impregnation, due to the highest of its value was achieved by A group which was only compressed without any PF impregnation.

These values were slightly higher compared with results conducted by Hartono *et al* (2010). They reported that density of oil palm trunk increased from 0.30 to 0.57 g/cm³ by 50% compression at 140°C for 30min. Their MOR, MOE, compressive strength parallel to the grain of oil palm trunk compression was 130.13 kg.f/cm², 20131 kg.f/cm², and 105.84 kg.f/cm²; by PF impregnation without pre-compression increased 29397, 384.96, and 169.83 kg.f/cm²; and by PF impregnation with pre-compression were 25289, 359.38, and 146.06 kg.f/cm², respectively.

Table 5 showed the average value of physical and mechanical properties for the three of group samples (A, B and C group) based on SNI 03-3527 (BSN 1994). It was concluded that to enhance the physical and mechanical properties of inner part of oil palm trunk was not only by compression (A group) but also PF impregnation (B and C groups). However, it was not found the significant different between B group without pre-compression and C group with pre-compression.

Table 5. Comparison between physical and mechanical properties based on SNI 03-3527 (BSN 1994)

Treatment		Group samples		
		A	B	C
Physical properties	Density	IV	III	III
	Thickness swelling	Not Accepted	Accepted	Accepted
Mechanical properties	MOE	V	V	V
	MOR	V	IV	IV
	Compressive strength parallel to the grain	V	V	V
	Compressive strength perpendicular to the grain	V	V	V
	Shear Strength Parallel to the Grain	V	V	V

CONCLUSIONS AND SUGGESTIONS

Based on the research and according to SNI 01-5008.2 (BSN 2000), it was concluded that 1/3 of outer part near the bark of oil palm trunk could be used for plywood raw material (type II for interior). The density of inner part oil palm trunk increased 2-fold than its initial density after 50% compression from 0.22 to 0.40 g/cm³ after compression (A group). It was more increasing after PF impregnation to 0.48 - 0.49 g/cm³ (B and C groups). However, due to the value of thickness swelling was less than 12%, only PF impregnation groups (B and C groups) were accepted for construction.

The increasing of density has a strong correlation with mechanical properties of inner part oil palm trunk. According to SNI 03-3527 (BSN 1994), all the inner part oil palm trunk compression and PF impregnation were still classified into strength class IV-V. To enhance the physical and mechanical properties of inner part of oil palm trunk by compression should be followed by PF impregnation. Even, it was not found the significant difference between treatment without pre-compression and treatment with pre-compression.

It should be used at least more than 22 years-old oil palm tree and more bigger trunk diameter to get more veneers from outer part of oil palm trunk for plywood raw materials. Plywood from oil palm trunk has slight rough surface area, so that it necessary to cover by fancy veneer with smooth surface, decorative pattern and texture. Further researches should be done for the plywood from oil palm trunk especially to get more stabilize and resistance againts high humidity conditions.

REFERENCES

- Amin, Y., W. Dwianto. 2006. Pengaruh Suhu dan Tekanan Uap terhadap Fiksasi Kayu Kompresi dengan Menggunakan *Close Sytrunk Compression*. Jurnal Ilmu dan Teknologi Kayu Tropis 4(2): 55-60.
- Amin, Y., T. Darmawan, I. Wahyuni, W. Dwianto. 2007. Pengaruh Perendaman NaOH Terhadap Fiksasi Kayu Kompresi dengan Menggunakan *Close Sytrunk Compression*. Prosiding Seminar MAPEKI X Pontianak. pp. 240-247.
- Asosiasi Produsen Kayu Lapis Indonesia [APKINDO]. 1978. Petunjuk Umum Tentang Kayu Lapis. Apkindo-Jakarta.
- Badan Standardisasi Nasional. 1992. SNI 01-2704-1992. Kayu Lapis.
- Badan Standardisasi Nasional. 1994. SNI 03-3527-1994. Mutu Kayu Bangunan.
- Badan Standardisasi Nasional. 1998. SNI 06-4567-1998. Syarat Perekat Phenol Formaldehida.
- Badan Standardisasi Nasional. 2000. SNI 01-5008.2-2000. Kayu Lapis Penggunaan Umum.
- Bakar, E.S., O. Rachman, D. Hermawan, L. Karlinsari, N. Rosdiana. 1998. Pemanfaatan Batang Kelapa Sawit (*Elaeis guineensis* Jacq) sebagai Bahan Bangunan dan Furniture (I): Sifat Fisis, Kimia dan Keawetan Alami Kayu Kelapa Sawit. Jurnal Teknologi Hasil Hutan 11(1): 1-11.
- Bakar, E.S., O. Rachman, W. Hermawan, I. Hidayat. 1999. Pemanfaatan Batang Kelapa Sawit (*Elaeis guineensis* Jacq) Sebagai Bahan Bangunan dan Furniture (II): Sifat Mekanis Kayu Kelapa Sawit. Jurnal Teknologi Hasil Hutan 12(1): 10-20.
- Bakar, E.S., Y. Massijaya, T.L. Tobing, A. Ma'mur. 2000. Pemanfaatan Batang Kelapa Sawit (*Elaeis guineensis* Jacq) Sebagai Bahan Bangunan dan Meubel (III): Sifat Keterawetan Kayu Sawit dengan Basilit-CFK dan Impralit-BI. Jurnal Teknologi Hasil Hutan 12(2): 13-20.
- Bakar, E.S. 2003. Kayu Sawit Sebagai Substitusi Kayu dari Hutan Alam. Forum Komunikasi Teknologi dan Industri Kayu Vol. 2. Jurusan Teknologi Hasil Hutan. Fakultas Kehutanan IPB.
- Departemen Pertanian. 2010. Statistik Pertanian 2010.
- Dumanauw, J.F. 1990. Mengenal Kayu. Kanisius. Yogyakarta.
- Erwinskyah 2008. Improvement of Oil Palm Wood Properties Using Bioresin. Institut für Forstnutzung und Forsttechnik. Fakultät für Forst-, Geo- und Hydrowissenschaften. Technische Universität Dresden. Dissertation.
- Febrianto, F., E.S. Bakar. 2004. Kajian Potensi, Sifat-sifat Dasar dan Kemungkinan Pemanfaatan Kayu Karet dan Biomassa Sawit di Kabupaten Musi Banyuasin. Kerjasama antar Pemerintah Daerah Musi Banyuasin dengan Lembaga Manajemen Agribisnis Agroindustri IPB.
- Furuno, T., Y. Imamura, H. Kajita. 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 Sci. Technol. 37(5): 349-361.
- Hartono R., F. Febrianto, I. Wahyudi, W. Dwianto, T. Morooka. 2010. Pengaruh Waktu Impregnasi dan Konsentrasi Phenol Formaldehyde Terhadap Sifat Fisis dan Mekanis Batang Kelapa Sawit Terpadatkan. Jurnal Ilmu dan Teknologi Hasil Hutan 3(2): 61-65.
- Hill, C. 2006. Wood Modification: Chemical, Thermal and Other Processes. Jhon Wiley & Sons. England.
- Ohmae, K., K. Minato, M. Norimoto. 2002. The Analysis of Dimensional Changes due to Chemical Treatments and Water Soaking for Hinoki (*Chamaecyparis obtusa*) Wood. Holzforschung 56(1): 98-102.
- Iswanto, A.H. 2008. Kayu Lapis (*Plywood*). Ilmu dan Teknologi Hasil Hutan (1): 1-5.
- Iswanto, A.H., T. Sucipto, I. Azhar, Z. Coto, F. Febrianto. 2010. Sifat Fisis dan Mekanis Batang Kelapa Sawit (*Elaeis guineensis* Jacq) Asal Kebun Aek Pancur-Sumatera Utara. Jurnal Ilmu dan Teknologi Hasil Hutan (1): 1-7.
- Jamilah, M. 2009. Kualitas Papan Komposit dari Limbah Batang Kelapa Sawit (*Elaeis guineensis* Jacq) dan *Polyethylene* Daur Ulang. Jurnal Teknologi Hasil Hutan (1): 4-21.
- Lubis, A.U. 1992. Kelapa Sawit (*Elaeis guineensis* Jacq) di Indonesia. Pematang Siantar: Pusat Penelitian Perkebunan Marihat.
- Murhofiq, S. 2000. Pengaruh Pematatan Arah Radial Disertai Suhu Tinggi terhadap Sifat Fisis dan Mekanis Kayu *Agathis* (*Agathis loranthifolia* Salisb) dan Sengon (*Paraserianthes falcataria* (L.) Nielsen). Jurusan Teknologi Hasil Hutan, Fakultas Kehutanan, Institut Pertanian Bogor. Skripsi. Tidak Dipublikasikan.
- Prayitno, T.A. 1995. Bentuk Batang dan Sifat Fisis Kayu Kelapa Sawit. Buletin Fahutan UGM 28: 43-59.

- Rahayu, I.S. 2001. Sifat Dasar Vascular Bundle dan *Paranchyma* Batang Kelapa sawit (*Elaeis guineensis* Jacq.) Dalam Kaitannya dengan Sifat Fisis, Mekanis serta Keawetan. Program Studi Ilmu Pengetahuan dan Kehutanan. Program Pascasarjana IPB. Thesis. Tidak Dipublikasikan.
- Rowell, R. 2005. Chemical Modification of Wood. In: Rowell RM (ed) Handbook of Wood Chemistry, Wood Composites, Chap. 14. CRC Press, Boca Raton. pp. 381-420.
- Santoso, T. 2005. Sifat Fisik dan Mekanik Kayu Kelapa Sawit Terkompegnasi dengan Menggunakan Phenol Formaldehida. Skripsi Fakultas Kehutanan IPB. Bogor.
- Shams, M.I., N. Kagemori, H. Yano. 2004. Compressive Deformation of Wood Impregnated with Low Molecular Weight Phenol Formaldehyde (PF) Resin I: Effects of Pressing Pressure and Pressure Holding. J. Wood Sci. 50: 337-342.
- Shams, M.I., H. Yano, K. Endou. 2006. Compressive Deformation of Wood Impregnated with Low Molecular Weight Phenol Formaldehyde (PF) Resin III: Effects of Sodium Chlorite Treatment. J. Wood Sci. 5(1): 234-238.
- Shams M.I., H. Yano. 2009. A New Method for Obtaining High Strength Phenol Formaldehyde Resin-impregnated Wood Composite At Low Pressing Pressure. Journal of Tropical Forest Science 21(2): 175-180.
- Sulistiyono, N. Nugroho, S. Surjokusumo. 2003. Teknik Rekayasa Pemadatan Kayu II: Sifat Fisis dan Mekanis Kayu Agathis (*Agathis loranthifolia* Salibs) Terpadatkan dalam Konstruksi Bangunan. Buletin Teknik Pertanian 17 (1).
- Tsoumis, G. 1991. Science and Technology of Wood. Van Nostrand Reinhold. New York.
- Youngquist. 1999. Wood Based Composites and Panel Product. Wood Hand Book: Wood As An Engineering Material. USA.

WOOD ANATOMY AND RELATED PROPERTIES OF NATURALLY GROWN PHILIPPINE TEAK (*Tectona philippinensis* Benth. & Hook. f.)

*Arsenio B. Ella¹, Emmanuel P. Domingo¹ and Elvina O. Bondad¹

¹ Researchers, Forest Products Research and Development Institute (FPRDI),
Department of Science and Technology (DOST),
College, Laguna 4031 Philippines

ABSTRACT

The wood anatomical characteristics of the Philippine teak (*Tectona philippinensis* Benth. & Hook. f.) was studied to identify its potential uses for optimum utilization. Naturally grown trees were gathered in Lobo, Batangas as wood samples. Macroscopic observations and other physical attributes showed that the wood of Philippine teak is light yellow, grain is slightly wavy and texture is fine, glossy, hard and heavy. Fiber mensuration indicates that Philippine teak is medium-sized and thin-walled. Rays are observed to be of two kinds: uniseriate and multiseriate and are classified as extremely low with an average height of 0.3298 mm. Philippine teak wood could be differentiated from teak (*Tectona grandis* L. f.) with the former having smaller pores and thinner rays. The most common anatomical features of the two *Tectonas* are the presence of whitish to yellowish deposits and tyloses. No significant differences were noted in physical and mechanical properties except for shrinkage, hardness at end and shear. Philippine teak has a relative density of 0.710. It falls under high to moderately high strength group of Philippine timber species, hence, recommended for heavy duty construction and for structural timber.

Keywords: Tectona, Philippine teak, Lobo, structural timber, wood anatomy, strength properties

INTRODUCTION

At present there is a growing interest among Filipino scientists and educators to utilize fully the country's endemic forest tree species like the Philippine teak (*Tectona philippinensis* Benth. & Hook. f.) of the family Verbenaceae. It is also known as *bunglas* (*P. Bisaya*), and *malapangit* (*Tag.*) (Madulid and Agoo 1990). Hugh Cuming, an English botanist first collected the specimen in 1836-1840 in Batangas. Based on this specimen, G. Benthon and J. D. Hooker first described the species in a book *Gennra Plantarum 2*, London (1876) 1152.

The species is less popular compared to teak (*Tectona grandis* L.) which is naturally grown in India, Myanmar, the Lao People's Democratic Republic, and Thailand. Teak is easily distinguishable from Philippine teak because it has bigger leaves and trunk size. Also, teak has smaller pores and thinner rays. The Philippine teak tree is medium-sized with an average of 30 cm diameter breast height (DBH), reaching a height of 25-30 m and a diameter of 60-80 cm, cylindrical and with a regular bole from 12-15 m long; dark green above while pale beneath with thin flaking bark similar to guava (*Psidium guajava*). The leaves are scabrous, opposite and ovate to elliptic, 12-22 cm long x 6-10 cm wide. The petiole is 1-3 cm long, and the veins are of 5-8 pairs, alternate. The flower structure is 10-15 mm L x 5-10 mm in diameter arranged in dome-shape panicle; peduncle is 10-15 mm long; corolla is 5, whitish with very fine purple hair-like appearance, 6-11 mm long at the center from which the 6 anthers with yellow pollen sacs develop. The fruit is like a panicle, pale-brownish in color, hard and round drupes about 13 cm long and hairy (Caringal and Castillo 2002).

Natural stands are predominantly found in dry exposed ridges of southeastern Batangas, particularly in the municipalities of Lobo, Taysan, Batangas City, and San Juan. As of 2002, the population size of Philippine teak in Batangas is 4,325+ stands (Caringal and Castro 2002). Earlier investigation conducted by Merrill (1923) revealed that it is also found in thickets and secondary forests of Iling Island in Occidental Mindoro, particularly in Barangay Katayungan and Baclayon, and Mt. Makiling in Laguna. It is also said to be found in areas from Northern Luzon to Palawan, Nueva Viscaya, Quezon, Cavite and Mindanao (ERDB 1998, Generalao 1972, Follosco and Castañeto 2001, and Pangga 2002). So far however, Lobo, Batangas is the

only verified and documented habitat of Philippine teak (Figure 1). The town of Lobo is located at 20 kilometers east of Batangas province, 13° 38' 8" N latitude and 121° 12' 6" E longitude.

The species is still found in the remaining patches of molave forest which were converted to atis (*Anona squamosa* L.) and banana (*Musa sapientum* L.) plantations. Other remaining patches of the species are found in ravine and abyss. Elevation range is 300-500 m above sea level with slope of 70-90%.

Its general environment and habitat is in secondary forests on sedimentary igneous rock and volcanic rock formations. Sites are observed to have patches of kaingin and crop plantation. Possibly due to the weathering of limestone, the soils in the sites are clayey, shallow, and moderately drained. The soil is slightly acid to mildly alkaline and is naturally fertile. (Madulid and Agoon 1990). As per the floristic composition of the Philippine teak forest, 33 species distributed to 30 genera and 19 families were identified. Included are 25 small to medium-sized trees, two species of orchids, grasses, herbs, and one species of *Cycas* and lichens (Caringal and Castillo 2002).

The southeastern part of Batangas has pronounced dry and wet seasons. This influences the reproductive stages of the Philippine teak. The mass of flowering starts usually on the onset of rainy season which is May-June. By the time of rainy season, July-August, the fruits are matured. Rainfall causes the matured drupes to fall. It has been observed that the drupes remain dormant in the forest floor for almost a year. On the onset of the next rainy season, the seeds burst from dormancy. During this season, hundreds of germinants can be gathered from the forest floor. These are recommended to be adapted to nursery conditions for optimum survival and regeneration of the species. Two years after, the seedlings can be reintroduced to their natural habitat (Caringal and Castillo 2002).

At present, it is listed as Critically Endangered under criterion B of the IUCN Red list of Threatened Species. There are several activities that are observed to pose threat to the Philippine teak habitat: 1) ecotourism development of sites where areas are converted to resorts and residential areas; 2) increased demand for farmlots that result to conversion of forest to atis, coconut, banana and mango plantations; 3) kaingin activities and firewood gathering; 4) accidental fire during summer months; 5) quarry operations; 6) prolonged droughts like caused by El Niño phenomenon; and 7) timber cutting for local use.

In terms of propagation, cutting was found to be more feasible and successful than other methods such as direct seeding and barefoot wildings (Generalao 1970). It was suggested that wilding should be potted to allow hardening for a month before actual planting. Further, nicking method for viability test may damage the seed of the species. It was done to let water enter the viable seeds to break dormancy (Pangga 1993).

The wood of Philippine teak is classified as comparatively heavy and durable and can be used as substitute for molave (*Vitex parviflora* Juss.) and dungon (*Heritiera sylvatica* Vidal). The Philippine teak serves as forest protection and coastal zone stabilizer. Teak wood is known to withstand the effects of weathering and resist the attacks of insects. Because of its strength, it is commonly used for posts, general construction and building Spanish galleons. Even the local residents use it in such manner. Furthermore, other potential uses include analgesic activity of the leaf extract, bark as source of tannins, roots as source of saponins, and the anti-diarrheal activity (Caringal and Castillo 2002).

Teak (*Tectona grandis* L.) is of major importance in the forestry economies because of its being one of the world's premier hardwood timbers. It is famous and in demand in international market because of its strength and aesthetic qualities (Pandey and Brown 2000). The Philippine's own species of teak has not yet been investigated in terms of its potential as first class timber. No comprehensive studies have been reported on the wood anatomy of Philippine teak. In the same manner, literatures on the variations in structural, anatomical features and wood properties within and between trees of Philippine teak are nil. Study of the basic wood properties of the species like wood anatomy would ultimately lead to the optimum utilization of the species.

It is the purpose of this study to identify the anatomical properties of Philippine teak and determine the patterns of variation of some wood quality indicators, e.g. relative density and fiber length; and evaluate the species and related properties. Specifically, the study aims to: 1) study the macroscopic and microscopic characteristics of naturally grown Philippine teak and determine their distinct features that could possibly help in their identification; and 2) identify other potential uses of Philippine teak according to its anatomical, physical, strength and related properties



Figure 1. Map of Batangas Province showing collection site of experimental log materials for the study.

MATERIALS AND METHODS

Field Sampling

Three experimental trees of naturally grown Philippine teak were collected in Barangay Sawang, Lobo, Batangas. For each tree, three-meter bolt were taken representing the height levels (butt, middle and top portions). Bolts were labeled with corresponding tree number and height levels. Discs 152 mm thick were cut from the end portion of each bolt where the anatomical (including fiber and vessel mensurations) and physical properties specimens were taken (Appendix 2). The remaining portion of the bolt, sticks or fitches of about 64 mm x 64 mm were sawn for mechanical properties tests.

Table 1. Collection data of experimental trees in Lobo, Batangas

Tree No.	DBH (cm)	Merchantable Height (m)	Total Height (m)
1	40	4.8	5.4
2	40	3.5	6.2
3	28	5.0	5.8

The log samples were transported to the FPRDI sawmill located in the University of the Philippines Los Baños – College of Forestry and Natural Resources (UPLB-CFNR) Campus, Los Baños, Laguna. These were processed into experimental/sample materials. Sampling scheme used in the study is presented in Figure 2. The ASTM Standard for Testing Small Clear Specimens of Timber (D143-94) was followed in the evaluation of specimens.



Figure 2. Ocular inspection and reconnaissance survey of appropriate experimental Philippine teak.



Figure 3. Sampling, collection and log preparation of experimental materials in the collection site



Figure 4. Naturally grown Philippine teak collected as tree samples

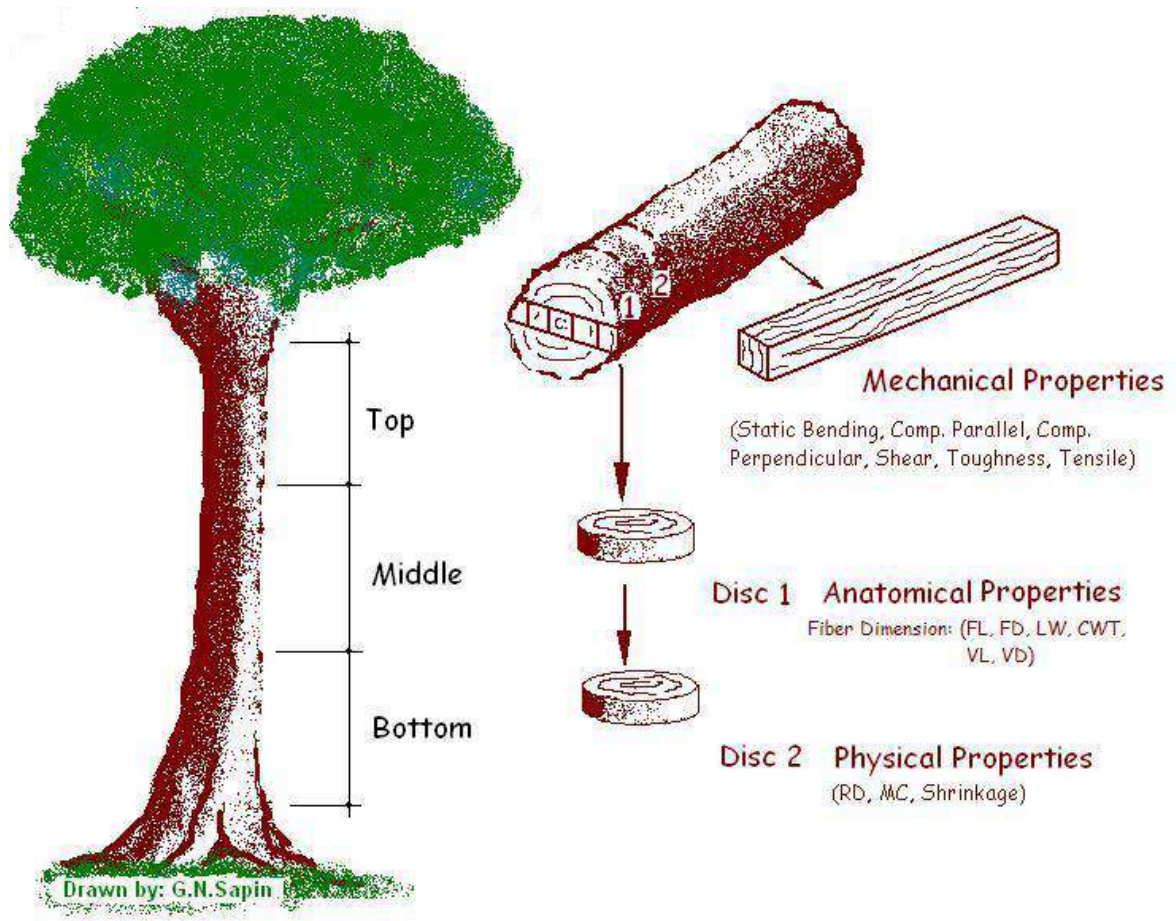


Figure 5. Sampling scheme used in the study

Laboratory Sampling Procedure

A. Observation of Anatomical Properties

1. Fiber Vessel and Mensuration

Samples for fiber and vessel measurements were chipped into match-sized splints and macerated using the method of Franklin (1945). The macerating fluid consisted of a mixture of equal volumes of 50% hydrogen peroxide and 50% glacial acetic acid. The splints were placed in test tube with sufficient macerating solution to submerge the samples (Appendix 3). The samples were boiled until the splints turned whitish and soft (about 1 to 2 hours). The macerating fluid was decanted and the splints were washed with running water until acid-free. Fifty percent (50%) ethyl alcohol was poured on the samples prior to soaking to separate the fibers. For greater visibility, the fibers were stained with Safranin before these were placed on slide for observation in the microscope.

2. Microscopic Description

The microscopic descriptions of the anatomical properties of the wood were based on the Standards and Procedures for Description of Dicotyledonous Woods (Tamolang et al. 1963) and IAWA List of Microscopic Features for Hardwood Identification (Wheeler et al. 1989)

Sample blocks were measured 1 x 1 x 2 cm cut from the three-inch disc and located the true wood rays section. The blocks were cleaned and boiled in tap water until softened (about 3 hours) and undergone slide sectioning. Slides sectioned, normally 25 µm in thickness were cut from cross, radial and tangential sections of the wood. Permanent section slides were prepared following the standard microtechnique procedure. Cross, radial, and tangential sections of the wood were washed in 50, 75, 85 and 95% ethyl alcohol, respectively. Further, samples/sections rinsed in tertiary butyl alcohol (TBA), clove oil and xylene. For greater visibility, the fibers were stained with Safranin. Sample sections were placed on slide and covered with a cover slip for observation in the microscope.

3. Macroscopic Description

The physical or morphological properties such as the grain, color, texture, and figure of Philippine teak were noted. The grain was classified as either straight, cross (sloping) interlocked or wavy. The color of the sapwood and heartwood was observed in both fresh and dry samples. The texture refers to the size of abundance of wood elements. It was determined through a hand lens and was defined as uniform/even or uneven, coarse or fine. Lastly, the figure was determined based on the natural arrangement of wood elements, color, grain variations and irregularity in the tree.

B. Observation of Physical Properties

1. Moisture Content and Relative Density

Raw wood samples were soaked into water to maintain its green weight after collection (Appendix 7). Wood samples were prepared at 25 x 25 mm specimens cut from the 9-inch disc and surfaced all sides and shaved smoothly at the ends. Both moisture content and relative density determinations were made on the same block. Each specimen weighs at green condition and its volume was determined by immersion method (water-displacement method). All specimens were open-piled and were allowed to air-dry under room conditions. These were later dried in an oven at 103 ± 2 °C until a constant weight was attained. Moisture content (MC) and relative density (RD) were computed as follow:

$$C (\%) = \frac{Wg - Wo}{Wo} \times 100\% \qquad RD = \frac{Wo}{Vg \times Dw}$$

where:

Wg = green weight

Wo = oven-dry weight

Vg = green volume

Dw = density of water = 1.0 gm/c

2. Shrinkage

To determine the shrinkage characteristics, wood samples of 25 x 25 x 102 mm were prepared (Appendix 8). Each sample was marked three points each in radial, tangential and at the longitudinal (end) side. Weight and dimensions were identified. Radial, tangential, longitudinal and volumetric shrinkage at green, 5% and 12% MC to oven-dry condition were also computed.

C. Observation of Mechanical Properties

All tests followed the procedures specified in the American Society for Testing Materials D143-94 (2000): Standard Methods of Testing Small Clear Specimen of Timber

1. Static Bending

Wood samples of 25 x 25 x 410 mm were prepared. After the actual size was measured, load was applied through the block to the tangential surface nearest the pith. Maximum load and deflection were then recorded (Appendix 9).

2. Compression Parallel to Grain

Wood samples of 25 x 25 x 100 mm specimens were prepared. Load was applied axially through a spherical bearing block of self-aligning type to ensure uniform distribution of stress over the whole cross section of the specimens. Load and deformation readings were taken up to maximum load (Appendix 10). From the data obtained, Maximum Crushing Strength (MCS) was determined.

3. Compression Perpendicular to Grain

Wood samples of 50 x 50 x 150 mm were prepared. After the actual size was measured, load was applied through a metal bearing plate 50 mm in width, placed across the upper surface of the specimen at equal distances from the ends at the right angle to the length. Actual bearing plate was measured. Load-compression curve was recorded. Speed of the machine was 0.30 mm/min (Appendix 10).

4. Shear Parallel to Grain

Wood samples of 50 x 50 x 63 mm specimens notched to produce failure on a 51 x 51 mm surface were prepared. The actual dimensions of the shearing surface were measured (Appendix 11).

5. Hardness

Wood samples of 50 x 50 x 150 mm were prepared. Load was applied on the side (radial and tangential) and end grain surfaces of the samples using a 12.28 mm steel ball to embed ½" its diameter (Appendix 12). Load was recorded. Speed of the machine was at 6.0 mm/min.

6. Toughness

Wood samples of 20 x 20 x 280 mm were prepared. Center loading and a span of 240 mm were used. The load was applied to radial or tangential surface on alternate specimens. The test was made in a pendulum-type toughness machine.

D. Data Analysis

The data was computed using the standard formula for the evaluation of the anatomical, physical and mechanical properties. Computed test results were fed in a computer for statistical analysis using a simple Complete Randomized Design (CRD) with sub-sampling.

1. Statistical Design

Treatment	Parameters (variables) to be measured Anatomical : FL, FD, LW, CWT, vessel measurements Physical : RD, MC, Shrinkage Mechanical : SB, Comp parallel & perpendicular to grain, Shear, Hardness, toughness both in green and 12% MC
Number of replicates 3 trees/butt, middle, top/2 samples	Total number of samples $3 \times 3 \times 2 = 18$ samples per properties $18 \times 4 = 72$ $18 \times 12 = 216$ samples for mechanical properties $18 \times 3 = 54$ samples for physical properties Total samples = 342
Experimental/ survey design CRD with sub-sampling ANOVA	

2. ANOVA

SV	df	SS	MS	F Ratio
Difference b/w trees (T)	T-1	SST	MST	MST/MSP
Difference b/w portion (P) w/in trees (T)	T (P-1) TP (r-1)	SSE	MSP	MSP/MSE
Residual (E)				
Total	TPr-1			

RESULTS AND DISCUSSION

A. Anatomical Properties

1. Microscopic Features

The important microscopic features of Philippine teak are shown in Table 3. **Fibers** (Figure 6) are medium-sized from 0.828 to 1.070 mm (ave 1.020 mm). Fiber diameter did not significantly vary among the three trees investigated at an average diameter of 0.020. On the other hand, cell wall thickness was considered “thin” because the lumen was greater than the wall thickness. Lumen width is at 0.009 mm and the cell wall thickness is at 0.0052 mm. This is in accordance with the IAWA Standard terms for cell wall thickness of wood fibers.



Figure 6. Macerated fibers (35x).

Table 3. Important microscopic features.

Tree No./ Portion	Fiber Dimension (mm)				Vessel				Multiseriate Rays			Uniseriate Rays	
	Fiber Length (Range, ave.)	Diameter (Range, ave.)	Lumen Width (Range, ave.)	Cell Wall Thickness (Range, ave.)	No. per mm ² and ave.	Average Length (mm)	Average Tangential Diameter	Pore Size Classification	Height (mm)	No. of Cells Wide	Width (mm)	Height (mm)	No. of Cells High
1	0.864-1.153 1.011	0.017-0.023 0.020	0.006-0.013 0.010	0.0048-0.0059 0.0052	20-91 49.31	0.217	0.0903	20 μ Extremely small	0.24	2-3	0.041	0.085	2-10
2	0.965-1.114 1.070	0.016-0.019 0.018	0.005-0.008 0.007	0.0047-0.0066 0.0055	29-88 56.59	0.231	0.0884	18 μ Extremely small	0.26	2-3	0.042	0.128	3-9
3	0.828-1.068 0.977	0.020-0.024 0.022	0.011-0.013 0.012	0.0047-0.0054 0.0050	28-87 57.09	0.245	0.0900	22 μ Extremely small	0.27	2-3	0.035	0.133	3-7
Ave:	1.020	0.020	0.009	0.0052	54.33	0.231	0.0895	20 μ	0.26	2-3	0.039	0.115	2-10

Vessels or pores (Figure 7) are rounded, moderately small with an average of 0.0895 μ in tangential diameter, ring-porous, and very numerous with an average count of 54 per mm². Lengths of vessel elements are very short from 0.081 to 0.099 mm (ave of 0.231 mm). Distribution is radial pore multiple of 2-4 with variable proportion of solitary vessel. Intervascular pitting is alternate; circular to oval shape (Figure 8).

Parenchyma (Figure 9) is visible only with a hand lens as narrow sheath to the pores; vasicentric and terminal. It is very few, apotracheal – marginal as observed in terminal bands – and diffuse in short uniseriate bands; predominantly paratracheal (confluent to narrow vasicentric); strands mostly of 3-5 or slightly more cells wide.

Rays (Figure 10) are very numerous, 9-18 (ave 11 per mm²); heterocellular composed of procumbent cells; of two kinds, uniseriate and multiseriate; the multiseriate heterocellular, 2-3 (mostly 3 cells wide); the uniseriate composed mostly of square to upright cells (2-10 cells with an average of 2.23 mm). Ray width are fine to moderately fine, 38-54 μ (ave. 45.04 μ); and ray height is extremely low from 0.2732 to 0.4180 mm (ave. 0.3298 mm).

Tyloses (Figure 11) are abundantly present. Whitish to yellowish deposits are also observed in some pores.



Figure 7. Cross section showing almost exclusively solitary pores with confluent parenchyma (40x).

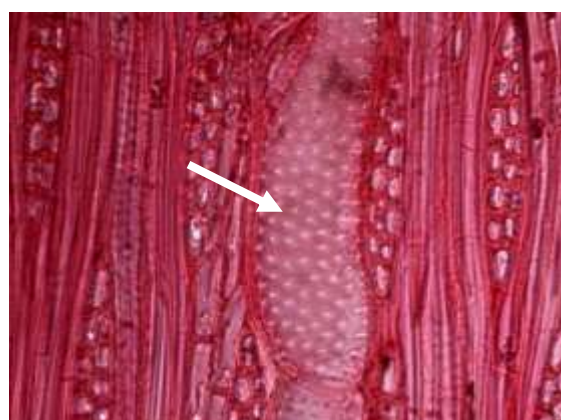


Figure 8. Alternate intervascular pits (400x)



Figure 9. Axial parenchyma predominantly paratracheal (aliform and confluent) (100x).

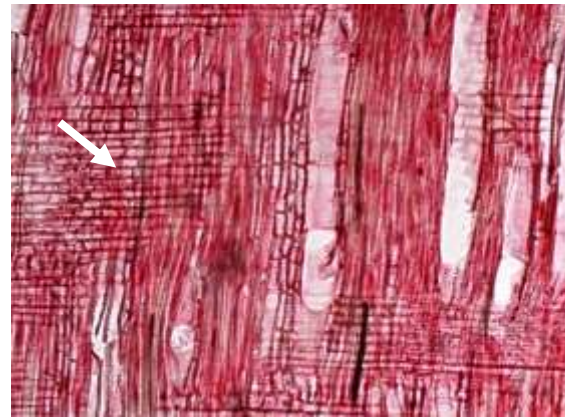


Figure 10. Rays with procumbent, square and upright cells mixed throughout the ray (100x).

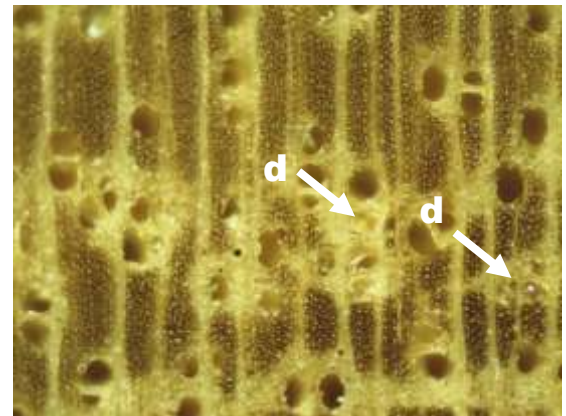
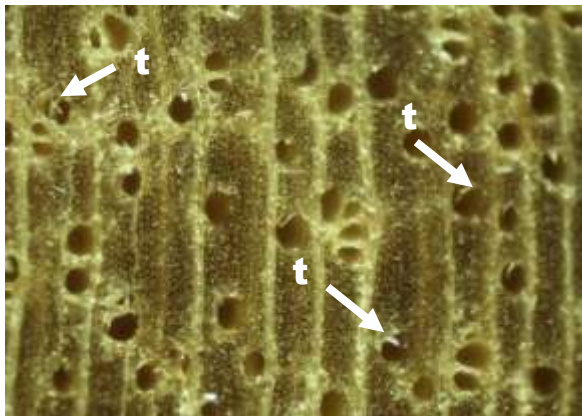


Figure 11. Tyloses (t) and deposits (d) (100x).

2. Macroscopic Features

The **grain** is slightly wavy. **Sapwood** is whitish to light yellow not sharply marked off from the heartwood which is yellow turning dark yellow to brown with age. **Texture** is moderately fine to fine, glossy, hard, heavy and tough. **Growth rings** are distinct to the naked eye, solitary and in radial multiples of 2 to 3 (Fig. 8). Indeed the wood is durable. The native Philippine teak resembles that of the popular teak (*Tectona grandis* L.) in terms of anatomical structure.



Figure 12. A typical wood (cross section) of Philippine teak as seen in the naked eye.

B. Physical Properties

Table 4. Mean values of physical properties of Philippine teak at different height level at green condition¹

Property Tested	Height Level			Tree Mean
	Butt	Middle	Top	
Moisture Content (%)	58.56 ^a	59.22 ^a	61.35 ^a	59.71
Relative Density ²	0.730 ^a	0.701 ^a	0.698 ^a	0.710
Shrinkage (%)				
- Radial	6.59 ^a	5.34 ^b	5.74 ^{ab}	5.89
- Tangential	6.68 ^a	5.97 ^{ab}	5.65 ^b	6.10
- Volumetric	12.84 ^a	10.99 ^b	11.07 ^b	11.63

¹ Determined in accordance with ASTM D143-09: Standard Method of Testing Small Clear Specimens of Timber.

² Based on volume at test and weight when oven-dry.

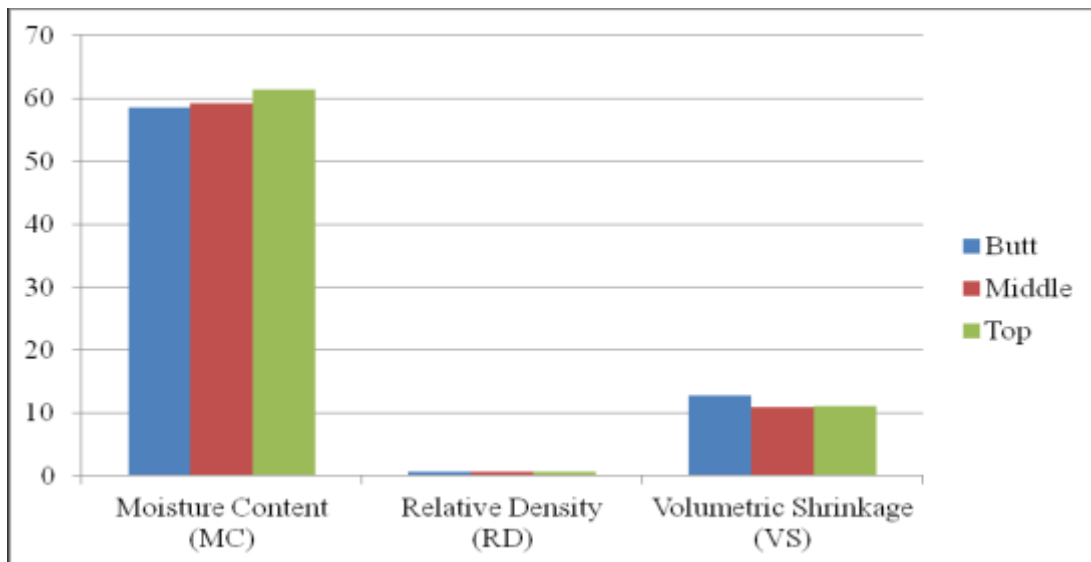


Figure 13. Mean values of physical properties of Philippine teak at different height level at green condition

Table 5. ANOVA results for physical properties.

SOURCE OF VARIANCE	DF	RD		MC (%)	
		MS	F Value	MS	F Value
Portion/Height Level	2	0.0075	2.96ns	51.15	0.81ns
Error	69				
Corrected Total	71				
CV%	7.10			13.28	

ns = not significant

Table 6. Shrinkage characteristics mean values of Philippine Teak at different condition and height level/portion¹ (Means with the same letter are not significantly different).

Property Tested	Height Level			Tree Mean
	Butt	Middle	Top	
Shrinkage (%)				
Green Condition:				
- Radial	6.59 ^a	5.34 ^b	5.74 ^{ab}	5.89
- Tangential	6.68 ^a	5.97 ^{ab}	5.65 ^b	6.10
- Volumetric	12.84 ^a	10.99 ^b	11.07 ^b	11.63
At 5% Moisture Content:				
- Radial	4.76 ^a	3.81 ^b	4.19 ^{ab}	4.25
- Tangential	5.30 ^a	4.67 ^{ab}	4.30 ^b	4.76
- Volumetric	9.82 ^a	8.37 ^b	8.40 ^b	8.86
At 12% Moisture Content:				
- Radial	2.51 ^a	1.72 ^b	1.89 ^b	2.04
- Tangential	2.94 ^a	2.69 ^a	2.54 ^a	2.72
- Volumetric	5.21 ^a	4.35 ^b	4.38 ^b	4.65

Table 7. ANOVA for shrinkage properties of Philippine teak from different moisture content condition.

SOURCE OF VARIANCE	DF	Tangential Shrinkage		Radial Shrinkage		Volumetric Shrinkage	
		MS	F Value	MS	F Value	MS	F Value
From Green to 12% MC							
Portion/Height Level	2	0.98	1.41ns	4.20	4.14*	5.71	5.97**
Error	69						
Corrected Total	71						
CV (%)	30.73			49.37		21.03	
From Green to 5% MC							
Portion/Height Level	2	6.11	3.85*	5.41	4.08*	16.38	15.70
Error	69						
Corrected Total	71						
CV (%)	26.49			27.05			
From Green to Oven-dry							
Portion/Height Level	2	6.67	4.31*	9.73	4.20*	26.05	15.07**
Error	69						
Corrected Total	71						
CV (%)	20.41			25.85		11.30	

*significant at $\alpha = 0.05$

** highly significant at $\alpha = 0.01$

ns = not significant

The mean values of physical properties are shown in Table 4 and Figure 9. Philippine teak has moisture content (MC) of 59.71%, relative density (RD) of 0.710, and volumetric shrinkage (VS) of 5.89%. There is an inverse relationship between MC and RD. The MC slightly increased from butt to top while the RD slightly decreased. The trend of RD and VS variations along height level was not consistent. The variation in RD indicates that the wood at the butt is denser than those of the middle and top. The VS decreased from butt to middle but increased from middle to top.

The Analysis of Variance (ANOVA) for physical properties is shown in Tables 5 and 7. The difference of RD and MC was not statistically significant, but shrinkage properties displayed significant differences. Among these are TS from green to 5% MC and from green to oven-dry, and RS from diff MC which showed significant difference at 0.05. Further, VS from green to 12% MC and green to oven-dry showed highly significant difference at 0.01. Wood shrinkage variation in different degrees over a given moisture range can be attributed to the anisotropy of the material such as its structure varies along tangential, radial, and longitudinal direction (Bondad et al. 2001).

The effect of height levels on shrinkage was not significant. Radial shrinkage (RS) from green to oven-dry decreased from butt to middle and increased towards the top. The same trend was observed for VS. Tangential shrinkage (TS) consistently decreased from butt to top at different condition.

Results of the three tree samples were not shown in detail since the differences among the trees were not statistically significant; the mean values of the tree properties along height level were computed instead. This could be attributed to the fact that all the tree samples were of the same age, naturally grown and from the same site.

C. Mechanical Properties

Table 8. Mean values of mechanical properties at different height level at green condition¹

Property Tested	Height Level			Tree Mean
	Butt	Middle	Top	
Static Bending				
Stress at proportional limit (MPa) ²	78.56	88.11	95.27	87.31
Modulus of rupture (MPa)	92.93	105.49	112.30	103.57
Modulus of elasticity (GPa) ³	7.49	7.77	8.50	7.92
Compression parallel to grain				
Maximum crushing strength (MPa)	38.26 ^a	37.63 ^a	38.06 ^a	37.98
Compression perpendicular to grain				
Stress at proportional limit (MPa)	12.44	12.15	11.87	12.15
Hardness⁴				
Side grain (kN)	9.65 ^a	9.26 ^a	8.57 ^a	9.16
End grain (kN)	9.53 ^a	9.49 ^a	9.87 ^a	9.63
Shear parallel to grain (MPa)	11.17 ^a	10.05 ^b	11.75 ^a	10.99
Toughness				
Average of radial and tangential (Joule /specimen)	47.70 ^a	47.77 ^a	45.63 ^a	46.93

¹ Determined in Accordance with ASTM D143-09: Standard Method of Testing Small Clear Specimens of Timber.

² MPa = 145.0377 psi = 10.2kg/cm²

³ GPa = x 1000 MPa

⁴ Load required to embed a 11.28 mm steel ball to ½" its diameter

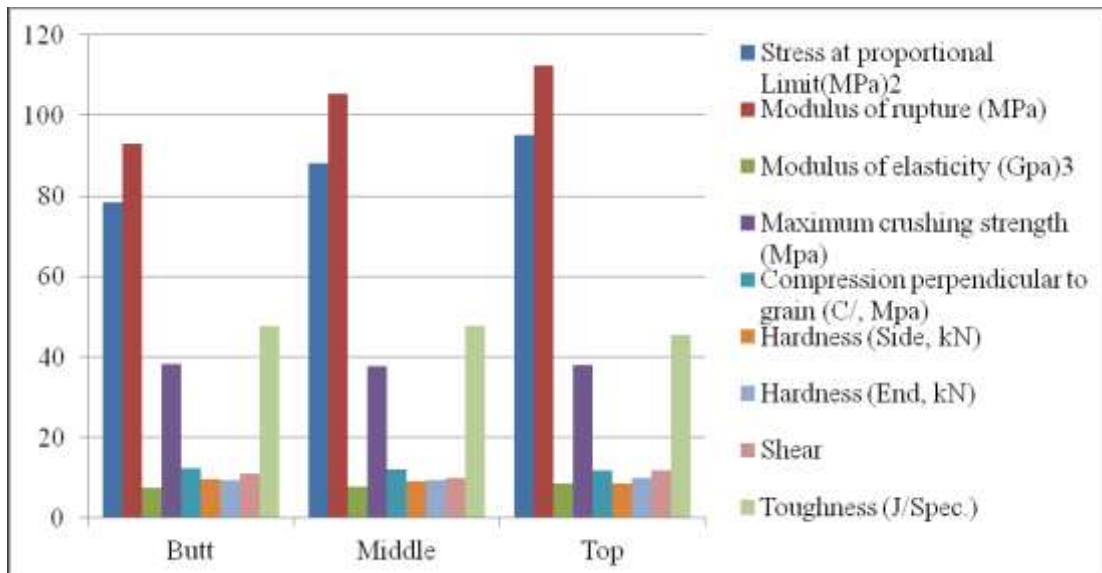


Figure 14. Mean values of mechanical properties at different height level at green condition

Table 9. ANOVA for mechanical properties in green condition and 12% MC.

SOURCE OF VARIANCE	DF	HS		HE		T		S		C//	
		MS	F Value	MS	F Value	MS	F Value	MS	F Value	MS	F Value
Green Condition											
Portion/Height Level	2	1.81	1.19ns	0.26	0.31ns	7.81	0.12ns	4.47	5.68	0.61	0.02ns
Error	15										
Corrected Total	17										
CV (%)		13.44		9.52		17.05		8.08		16.08	
12% MC											
Portion/Height Level	2	1.38	1.67ns	4.31	6.90**	32.34	0.49ns	17.49	0.71**	58.02	1.09ns
Error	15										
Corrected Total	17										
CV (%)		8.20		6.36		16.59		8.75		13.29	

Mechanical properties at different height level at green condition are shown in Table 8 and Figure 10. Generally, based on the mean values of mechanical properties at different height level at green condition, the top and middle portions were higher than those in the butt except in toughness. However, the differences were not significant. Other strength properties along height level are almost the same. This similarity of trends among properties can be attributed to the predominant effect of relative density and maturity of all tree samples (Bondad et al. 2001) which is represented in Fig. 7. RD correlates positively with strength properties. Based on FPRDI (FORPRIDECOM 1980), the wood at different height levels at green condition falls under C1 (high strength) and may be used for heavy duty construction.

On the other hand, the ANOVA for mechanical properties are shown in Table 9. Among these properties, hardness at end (HE) and shear (S) at 12% MC showed significant difference at 0.01 along height level. There was no significant difference in hardness at side (HS), HE, toughness (T), S and compression perpendicular to grain (C//) along height level at green condition. The values on each property are higher on green condition compared to those in 12% MC except for S. Significant effect along the height may be due to the random variations within and among trees (Bondad et al. 2001).

Table 10 shows the physical and mechanical property values and the corresponding classification of Philippine teak at different MC conditions. Based on strength grouping devised by FPRDI, the wood falls under C1 (high) to C2 (moderately high) and may be used for heavy duty construction. Among the strength properties that fall under C1 are RD, MOR, ompression parallel to grain, and shear parallel to grain. However, the volumetric shrinkage falls under C4 (moderately low) and may be used for carving, drafting, and conventional furniture.

Table 10. Physical and mechanical property values and corresponding classification of Philippine Teak at different moisture content conditions.

Property Tested	Moisture Content Condition (%)	Mean Values	Classification
Relative Density	Green	0.710	High Strength
	12 %	0.802	High Strength
Volumetric Shrinkage (%)	Green	11.63	Medium
	5%	8.86	Moderately Low
	12 %	4.65	Low
Static Bending			
	Modulus of rupture (MPa)		
	Green	103.57	High
	12 %	151.14	High
	Modulus of elasticity (GPa)		
	Green	7.92	Medium
	12 %	9.68	Medium
Compression parallel to grain			
Maximum crushing strength (MPa)			
	Green	37.98	Moderately High
	12 %	54.94	Moderately High
Compression perpendicular to grain			
Stress at proportional limit (MPa)			
	Green	12.15	High
	12 %	16.53	High
Shear parallel to grain (MPa)			
	Green	10.99	High
	12 %	16.19	High

Potential Uses of Philippine Teak

Looking through the anatomical, physical and other related properties determined the Philippine teak's strength and ability to resist applied external force. In addition to the wood's strength, it has aesthetic qualities – wood color is light yellow and glossy – and would be of use in furniture-making and decorative shipbuilding. Its fine texture makes it a good material for wood carvings. Based on the strength grouping devised at FPRDI (FORPRIDECOM 1980), the Philippine teak falls under C1 (high) and C2 (moderately high). The recommended end-uses of the wood per strength class are as follows (Alipon and Bondad 1980):

Class 1 (High Strength): For heavy duty construction such as ship building, railway sleepers, friction and bearing blocks, pulley sheaves and rollers, bridge and wharf timber, telephone and telegraph poles, mine timbers, posts, high-grade beams, girders, rafters, chords and purlins, window sills, balustrades, treads, stairs, and highway railway rail guards, salt and freshwater pilings, vehicle spokes and frames, and dumb bells.

Class 2 (Moderately High Strength): For medium-heavy construction. This includes heavy-duty furniture and cabinets, medium-grade beams, girders, rafters, chords and purlins, flooring, door panels and frames, paving blocks, boot and shoe lasts, bobbins, spindles and shuttles, bowling pins, picker sticks, sailboat parts, gunstocks, tool handles, wheel shafts and axles, cant hooks and peavies, parquetry, veneer and plywood face, studs for car and truck bodies, airplane construction, sporting equipment like baseball bats, checkerboards and golf clubs, tripods, T-squares and kitchen implements like mortars and pestles.

CONCLUSIONS AND RECOMMENDATIONS

Specific identification of the Philippine teak wood based on macro-anatomical structure is not complicated. Microscopic features like minute details, e.g., pore sizes, rays and fiber dimensions are sufficient criteria for specific identification of the species. The result of the study on anatomical characteristics of Philippine teak has differentiated it from the more popular *Tectona grandis* L. with the former having smaller pores and thinner rays. However, the most common anatomical features present in the two *Tectonas* are the whitish deposits and tyloses.

The ANOVA for physical properties was not statistically significant except for shrinkage. Among mechanical properties, hardness at end and shear at 12% MC displayed significant difference along height level. As reflected on the physical and mechanical property values at different MC conditions, the Philippine teak falls under C1 (high) to C2 (moderately high) and could be used for heavy duty construction and for structural timber.

As mentioned by Pandey and Brown (2000), the general trend in teak will be towards the production and utilization increase of plantation-grown teak because the supply of teak from the natural forests is diminishing yet the demand is continuously increasing. This being said, mass propagation of the species is a potential source of income for Lobo, Batangas and neighboring towns where they are found growing. It is recommended as raw material in the wood-based using industries and has a strong potential for establishments of plantations to widen raw material source. It can demand better prices in the world market since the wood can be a material to develop high-end products.

It is recommended that collection of other Philippine teak woods from other sources where it abounds, e.g., Iling Island (Mindoro) and Verde Island (East Batangas) be carried out for further wood property studies. Also, there should be further studies regarding Philippine teak plantation establishment and management.

ACKNOWLEDGMENT

The authors wish to extend their heartfelt gratitude to the following institution and organization and individuals who made valuable contributions to the success of this project:

- National Research Council of the Philippines (NRCP) for funding and supporting this project;
- Department of Environment and Natural Resources (DENR) Region IV-A, CALABARZON Regional Executive Director Nilo B. Tamoria, Provincial Environment and Natural Resources Officer Oliver B. Viado and Community Environment and Natural Resources Officer Laudemir S. Salac;
- LGU of Lobo, Batangas through the assistance of Mayor Efren B. Diona;
- Batangas State University – Lobo Campus through the assistance of Dr. Anacleto M. Caringal;
- Barangay Officials of Sawang, Lobo, Batangas headed by Barangay Captain Rogidante C. Arguelles;
- Foresters Kharina G. Bueser, Sheryll C. Micoso, and Scientist Ramiro P. Escobin for providing assistance on photo capture of microscopic features of specimens; and
- Ms. Eleanor C. Jacinto for the statistical analysis.

LITERATURE CITED

- Alipon, M. A. and E. O. Bondad. 2008. Strength Grouping of Philippine Timbers for Various Uses. Forest Products and Research Development Institute Trade Bulletin (4): 5-6.
- American Society for Testing and Materials. 2000. Standard Method of Testing Small Clear Specimens of Timber. ASTM D143-94. *Annual Book of ASTM Standards*. Part 16. Pa., USA.
- Bondad, E. O., M. A. Alipon, P. C. Cayabyab, and Z. L. Cabral. 2001. Physical and Mechanical Properties of *Acacia mangium* Willd. Terminal Report. Forest Products and Research Development Institute. College, Laguna. pp. 4-5.
- Caringal, A. M. and J. R. Castillo. 2002. Conservation Status of Philippine Teak (*Tectona philippinensis* Benth. & Hook. f. Verbenaceae): An Academe's Research Initiative on Mountain Ecosystems Management in Southeastern Batangas. Paper presented at the National Conference and Scientific Meeting on Mountain Ecosystems Management of the Environmental Education Network of the Philippines, Inc. (EENP), 22-24 October 2002. Cebu Grand Hotel, Cebu City, Philippines, pp. 3-4.

- Ecosystems Research and Development Bureau. 1998. Some Important Philippine Forest Trees Named Before the Turn of the Twentieth Century. Research Information Series on Ecosystems (RISE) 10 (1):3
- Forest Products Research and Industries Development Commission (FORPRIDECOM). 1980. Guidelines for the Improved Utilization and Marketing of Tropical Wood Species. RP/HQ 1979-5 RO, FAO, Rome.
- Generalao, M. M. and F. Lapitan. 1970. Growing Philippine Teak (*Tectona philippinensis*) in Mt. Makiling. Research Note, Bureau of Forestry, Research Division, Los Baños Experimental Station, College, Laguna.
- Lantican, C.B. 1975. Variability and control of wood quality. Inaugural Lecture. 13 August 1975. University of the Philippines Los Baños Laguna, College of Forestry, Laguna, Philippines, pp. 45.
- Lemmens, R. H. M. J., and I. Soerianegara (Eds.). 1993. Plant Resources of South-East Asia. No. 5(1) Timber Trees: Major Commercial Timbers. Pudoc Scientific Publishers, Wageningen, 448 - 454 pp.
- Madulid, D. A. and E. M. G. Agoo. 1990. Conservation Status of *Tectona philippinensis* Benth. & Hook. f., A Threatened Philippine Plant. Acta Manila (38):41-55.
- Meniado, J. A., F. N. Tamolang, F. R. Lopez, W. M. America and D. S. Alonso. 1975. Wood Identification Handbook for Philippine Timbers. Vol. 1. Government Printing Office, Manila. pp. 351-352.
- Merrill, E. D. 1923. An Enumeration of Philippine Flowering Plants, Vol. 3, Bureau of Printing, Manila. 403 pp.
- Pandey, D. and C. Brown. 2000. Teak: A Global Overview. Excerpted from Unasylva, An International Journal of Forestry and Forest Industries. 51 (2): 1-12. <http://pacificteak.com/teak%20trends.pdf>.
- Pangga, I. C. 1993. Ex-Situ Genebank for Philippine Teak (*Tectona philippinensis*). Unpublished Report. PAWB, DENR, Diliman, Quezon City.
- Reyes, L. J. 1938. Philippine Woods. Commonwealth of the Philippines. Department of Agriculture and Commerce. Bureau of Printing. Manila. Technical Bulletin 7.
- Tamolang, F. N., R. R. Valbuena, J. A. Meniado and B. C. De Vela. 1963. Standards and Procedures for Description of Dicotyledonous Woods. Forest Products Research Institute, College, Laguna. 46 pp.
- Wheeler, E. A., P. Baas and P. E. Gasson. 1989. IAWA List of Microscopic Features for Hardwood Identification. IAWA Bulletin n.s. 10(3):219-332.

APPENDICES



Appendix 1. Negotiations/coordination with involved parties/cooperators.



Appendix 2. Discs preparations for anatomical, strength and related properties.



Appendix 3. Preparations of specimens for fiber and vessel mensurations.



Appendix 4. Preparations of wood samples for relative density and moisture content determination.



Appendix 5. Preparations of wood samples for other mechanical properties determination.



Appendix 6. Specimens/wood samples prepared for a) wood anatomical observations and descriptions; b) fiber and vessel mensurations; and c) strength and related properties determination.



Appendix 7. Weighing of wood sample for moisture Content and relative density determination



Appendix 8. Shrinkage test



Appendix 9. Static bending test



Appendix 10. Compression parallel and perpendicular to grain test.



Appendix 11. Shear test.

VARIATIONS IN MOISTURE CONTENT AND ITS EFFECT ON THE SHRINKAGE OF *Gigantochloa scortechinii* AND *Bambusa vulgaris* AT DIFFERENT HEIGHT OF BAMBOO CULM

R Anokye¹, R M Kalong¹, E S Bakar^{1,2*}, J Ratnasingam¹, A A Khairul³

¹ Department of Forest Production, Faculty of Forestry, University Putra Malaysia, 43400, Serdang, Selangor Darul Ehsan, Malaysia

²Institute of Tropical Forestry and Forest Products, UPM, 43400, Serdang, Selangor Darul Ehsan, Malaysia

³Forest Research Institute of Malaysia, 52109, Kepong, Malaysia.

* Corresponding author: edisuhaimi@upm.edu.my

ABSTRACT

The advancement of technology throughout the world has made bamboo one of the popular raw materials in the wood-based industry and has recently been considered as an engineering material. Malaysia has a good number of bamboo species but few that can be utilised commercially. Unfortunately, Malaysia still lacks some basic information about the properties of bamboo, especially on local bamboo species. This study provides a basic and details information about some physical properties of two the most popular local bamboo species, *Gigantochloa scortechinii* and *Bambusa vulgaris*. The study covered moisture content variation at different heights at both nodal and internodal portions of the bamboo culm. Comparison between the portions and between the nodes and internodes as well as between the species were carried out which showed significantly, no difference among the MC along the bamboo culm. The shrinkage at the three perpendicular axis directions showed that the radial shrinkage was slightly greater than tangential and was much greater than in longitudinal direction. Nodes appeared to have lower moisture content and high percentage of shrinkage compared to internodes. These variations were expected to be related with the anatomical structure different between the two categories of the bamboo culms.

Keywords: Bamboo, node, internode, moisture content, shrinkage

INTRODUCTION

The advancement of technology throughout the world has made bamboo one of the popular raw materials in the wood-based industry and has recently been considered as an engineering material. This has become necessary in the era of fast reduction of wood supply from the forest. Several concerns have been raised about the promotion of bamboo as alternative material for wood from the diminishing forest. Bamboo has a very fast growth rate and has the ability to replenish itself after harvesting (Janseen, 1995a). Comparing with wood, bamboo has a higher strength to weight ratio that makes it easier to be harvested and transported and working with. It is a fast growing plant where it takes a short period of time to mature and can be harvested and utilised within 3 to 4 years.

Many researches have been carried out to improve the quality of utilization and how value-added products can be competitively manufactured from bamboo. This is to prepare it as a ready raw material that can substitute wood in the wood-based industry in order to sustain the supply of raw materials in the future. It is generally known that restrictions in processing and utilization are often related to unsuitable properties. Therefore a thorough understanding of the relations between structures, properties, behaviour in processing and qualities are necessary for promoting the utilization of bamboo (Liese, 1987).

Bamboo is a very well-known material for its versatility of uses. It has been used since the ancient times. Traditionally, people have used bamboo for a variety of purposes such as containers, chopsticks, joss paper, joss stick, toothpick, woven mats, fishing poles, cricket boxes, handicrafts, chairs and baskets. Apart from household products, bamboo has also been used traditionally for construction, houses, pipes and bridges. It is one of the oldest building materials used by human kind (Abd. Latif et al. 1990). Its versatility and availability has made bamboo become good substitution materials to solid wood.

Nowadays, bamboo has been a very versatile material used by the industry. It is no more as a handicraft materials or basketry products. Bamboo has been utilised commercially to make high-value added products of panels, parquets, furniture and construction materials with extremely high viability with an internal rate of return (IRR) varying from 27 to 30 percent (depending upon the scale of manufacturing and cost of raw materials) (Pande and Pandey, 2008). As a result of its excellent tensile strength (Nordahlia et al., 2011), bamboo can be used in manufacturing value added products such as laminated bamboo, plybamboo and cross laminated bamboo.

In some countries, laminated bamboo is used in non-structural applications such as flooring, fencing, furniture and crafts. For bamboo native countries, laminated bamboo is used as structural building materials. In Asia countries, laminated bamboo is used in low rising buildings, short span foot bridges, and construction platforms (Chung & Yu, 2002). Bamboo have been chosen to be used as raw material in construction because of availability and environmental friendly (Yu et al., 2011).

The high potential of bamboo and its versatility characteristics has open a wide area of study for bamboo (Gonzalez et al., 2002). Bamboo has been the focus for research in recent years, especially for construction material (Acre, 1993).

The special natural characteristics of bamboo have attracted people's attention to utilise bamboo as a raw material in wood-based industry. There are many factors influencing the quality and possibility of the bamboo to be utilised widely and commercially as the wood alternative material. The factors include the physical and mechanical properties. There are only a few species of local bamboo that have been used commercially in the industry because there are no basic information on the properties of the bamboo species. Detailed information about the basic properties of some local bamboo species in Malaysian does hardly exist.

It is expected that the existence of node gives negative effects on the strength, shrinkage, processing and the appearance of the materials. However there are no or very limited information about the variation properties between node and internodes of bamboo and these need to be studied.

This study was to evaluate the variations in moisture content and shrinkage between the nodes and internodes along the culm of *Gigantochloa scortechinii* and *Bambusa vulgaris* species. The interaction between moisture content and shrinkage of the two species was also evaluated. These properties are very important as they affect the dimensional stability and the strength of the material. The study was specifically focused on the variation of MC and the shrinkages of nodes and internodes at different heights along the bamboo culm of the two most popular bamboo species in Malaysia. This information is especially important in the effort to use these bamboo species for high grade material.

MATERIALS AND METHODS

Preparation of materials

Five 4-year-old and above culms each of *G. scortechinii* and *B. Vulgaris* were extracted randomly from selected clumps around Universiti Putra Malaysia campus at Serdang, Malaysia. The mature culms were selected based on the characteristics specified by Abd. Razak et al. (2007). The culm were cut 30 cm above the ground level and only 9m length were taken, while the remaining upper portion was discarded due to its small diameter and thin wall. It was subsequently subdivided into three equal portions and labelled as bottom, middle and top. Each portion was immediately separated into nodes and internodes for the various tests.

Moisture content determination

As many as 20 replicates for each condition (2 species, 3 portions and 2 categories) were cut from the four culms for MC determination with the samples sized of 20 mm x 20 mm x thickness. The samples were weighed for their initial weight (W_i). The samples were then oven-dried at a temperature of 103 ± 2 °C until constant weight is reached (W_o). The moisture content were calculated using equation 1.

$$MC, \% = \frac{(W_i - W_o)}{W_o} \times 100\% \dots\dots\dots 1$$

Where: W_i : initial weight before drying (g)
 W_o : oven dried weight (g)

Preparation of Shrinkage Samples

Shrinkage for each condition (2 species, 3 portions, 2 categories) was tested on round samples and strip samples. In this case the tangential and longitudinal shrinkages were measured from round-shaped node and internodes of 20 mm and 50 mm long respectively. Tangential, radial and longitudinal shrinkages on the internodes strip of 20 mm x 150 mm x thickness was tested for comparison (Figure 1). As many as 20 samples were prepared for each type of sample to make the total of 360 samples.

Shrinkage determination

The round node and internodes samples were dried in an oven until a constant weight. The final dimensions were then recorded and used to determine the percentage shrinkage of the culm along length (Longitudinal) and the circumference (Tangential) using equation (2).

$$\text{Shrinkage, \%} = \frac{D_i - D_f}{D_i} \times 100\% \dots\dots\dots (2)$$

Where, D_i : initial dimension before oven-dry (mm)
 D_f : final dimension after oven-dry (mm)

Another set of strip samples were dried in an oven until a constant weight, after which a final dimensions were recorded on tangential, radial and longitudinal direction. The percentage of shrinkage for each dimension was then calculated with equation 2.

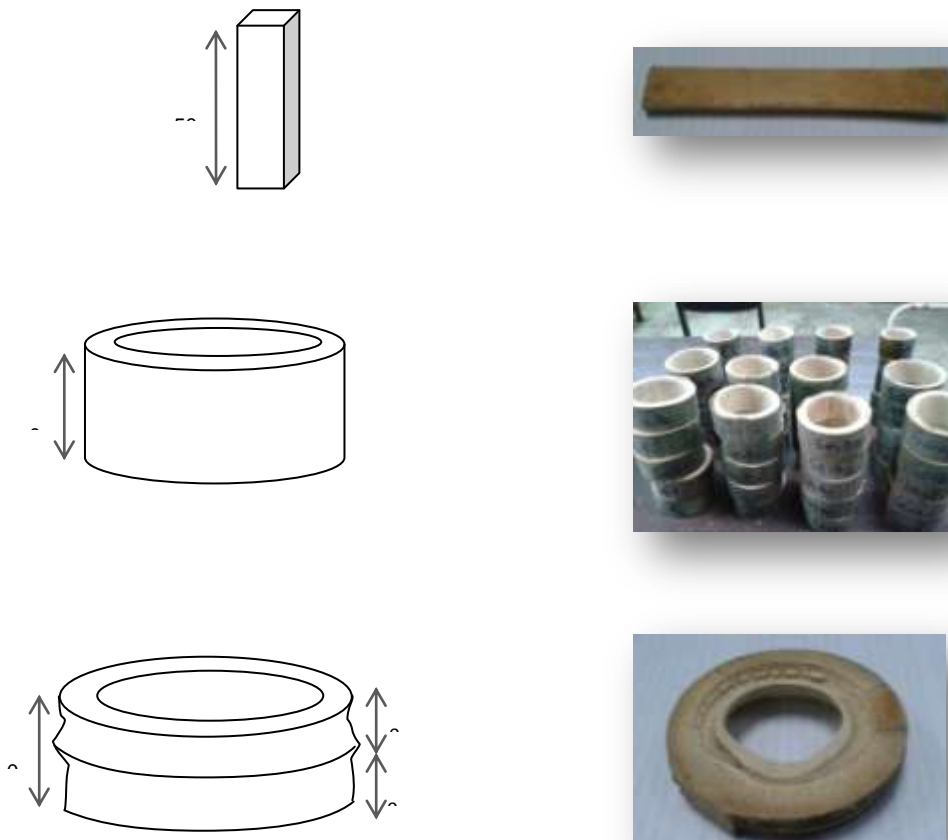


Figure 1. Diagrammatic sample for strip (a), internodes (b) and node (c) with dimension in mm, and photogrammetric sample of strip (d), internodes (e), and node (f) used for the shrinkage test.

Statistical analysis

The data were analysed statistically to assess the significant difference within the section (basal, middle, top) and category (internodes, node) of the culm in terms of moisture content and the shrinkage using statistical product and service solutions (SPSS). Regression analysis was performed to determine the relationship between MC and the position along the culm height of the two bamboo species. The MC and the shrinkage properties were analysed using analysis of variance (ANOVA)

RESULTS AND DISCUSSION

The results on moisture content and shrinkage of the bamboo among the three sections and the two categories of the two bamboo species are presented in Table 1. Table 2 to Table 4 show statistical analysis of moisture content and shrinkage for the two species.

Table 1. Mean data of moisture content and shrinkage of nodes and internodes for *G. scortechinii* and *B. vulgaris*

Species	Section	MC (%)		Shrinkage (%)						
				Round culm				Strip		
		Node	Internodes	Node	Internodes	Node	Internodes	Tangential	Radial	Longitudinal
<i>G. scortechinii</i>	Basal	90.71	95.66	1.98	0.24	4.34	6.47	7.13	8.1	0.11
		(14.33)	(36.80)	(1.03)	(0.04)	(0.59)	(0.67)	(2.47)	(3.04)	(0.12)
	Middle	82.7	87.25	2.66	0.27	4.47	6.37	11.33	7.75	0.13
		(13.52)	(23.53)	(3.39)	(0.26)	(0.72)	(0.70)	(3.79)	(1.85)	(0.04)
	Top	76.25	84.37	2.88	0.30	5.29	7.72	11.47	5.82	0.19
		(12.34)	(14.19)	(3.71)	(0.12)	(1.47)	(3.53)	(1.21)	(3.48)	(0.15)
	Mean	83.22	89.09	2.5	0.27	4.7	6.85	9.98	7.22	0.14
<i>B. vulgaris</i>	Basal	95.80	99.99	1.07	0.56	10.58	12.32	7.46	6.26	0.19
		(23.17)	(33.38)	(0.66)	(0.12)	(3.01)	(4.19)	(2.35)	(6.26)	(0.11)
	Middle	94.10	95.05	1.54	0.72	10.50	13.63	10.29	11.29	0.23
		(29.47)	(27.50)	(1.42)	(0.45)	(3.11)	(3.59)	(2.34)	(2.2)	(0.19)
	Top	85.02	92.81	0.52	0.49	10.95	12.11	12.38	11.9	0.2
		(19.40)	(37.28)	(0.30)	(0.27)	(2.92)	(2.08)	(6.25)	(5)	(0.11)
	Mean	91.64	95.95	1.34	0.59	10.68	12.69	10.04	11.57	0.21

Note: Values in parentheses are standard deviations

Table 2. ANOVA for moisture contents of *G. scortechinii* and *B. vulgaris*.

Species	Variable	F value	P value
<i>G. scortechinii</i>	Section	0.493 ^{ns}	0.618
	Category	2.374 ^{ns}	0.139
<i>B. vulgaris</i>	Section	0.131 ^{ns}	0.878
	Category	0.146 ^{ns}	0.707

Note: ^{ns} indicate no significant different at $p > 0.05$, * indicate significance different at $p < 0.05$, ** indicate significance different at $p < 0.005$, and *** indicate significance different at $p < 0.0001$.

Table 3. ANOVA on culm shrinkages among the section of sample at different species, category and direction.

Species	Category	Direction	F value	P value
<i>G. schortechinii</i>	Nodes	L	4.409*	0.044
		C (T)	1.051 ^{ns}	0.389
	Internodes	L	172.525***	0.0001
		C (T)	0.508 ^{ns}	0.618
<i>B. vulgaris</i>	Nodes	L	1.229 ^{ns}	0.337
		C (T)	0.025 ^{ns}	0.975
	Internodes	L	0.699 ^{ns}	0.522
		C (T)	0.233 ^{ns}	0.797

Note: ^{ns}indicate not significant, $p>0.05$, *indicate significance up to 95%, $p<0.05$, ** indicate significance up to 99.5%, $p<0.005$, *** indicate significance up to 99.99%, $P<0.0001$, L: Longitudinal and C: Circumference.

Table 4. ANOVA on strips shrinkages among the section of sample at different species and direction.

Species	Direction	F value	P value
<i>G. schortechinii</i>	L	172.525***	0.0001
	T	3.733 ^{ns}	0.066
	R	1.046 ^{ns}	0.390
<i>B. vulgaris</i>	L	0.243 ^{ns}	0.789
	T	0.102 ^{ns}	0.904
	R	0.507 ^{ns}	0.618

Note: ^{ns}indicate not significant, $p>0.05$, *indicate significance up to 95%, $p<0.05$, ** indicate significance up to 99.5%, $p<0.005$, *** indicate significance up to 99.99%, $P<0.0001$, L: Longitudinal, T: Tangential and R: Radial

Green Moisture Content

The MC results for *G. scortechinii* and *B. vulgaris* for internodes and nodes of the culm (Table 1) showed the same trend whereby it decreased from basal section to the top though the ANOVA showed no significant difference (Table 2).

Generally, internodes presented slightly higher MC than the nodes as in both species. The MC decreased along the culm from basal sections to the top sections with *B. vulgaris* internodes recording the highest (99.99%) and *G. scortechinii* the lowest (76.25%). Khabir et al. (1995) reported similar trend in other species of bamboo (*Dendrocalamus hamiltoni*), while Bakar et al., (2000, 2008) observed a similar trend on oil palm trunk (OPT) and attributed it to the increasing vascular bundle proportion and decreasing parenchyma tissue proportion from basal to the top. Bamboo has a similar anatomical structure of higher presence of vascular bundles to parenchyma cells that serve as site for water storage (Abd Latif & Mohd Zin, 1992) in the internodes than nodes which may contribute to the higher MC in the internodes. The decreasing trend from the basal to the top might be due to the proportion of vascular bundles being less at the basal section and increases to the top section. Abd. Latif & Tarmizi (1992), reported that the highest mean concentration of vascular bundles was observed at the top location. The higher density of vascular bundles at the top portion of bamboo has been explained by Grosser & Liese (1971) as a results of the decrease in culm thickness. Nevertheless, the MC variation along the culm is not significant from basal, middle and top section.

Comparing to the work of Hamdan et al. (2009), the MC results recorded was slightly lower. However Anwar et al (2005) also had similar results which was a lower than what was obtained by Hamdan and others even though the samples were coming from the same location. Liese (1980) reported that a difference in MC may occur with season.

Regression analysis (Fig. 2) showed a strong linear relationship between moisture content and the section of the two bamboo species. The coefficient of determination recorded for both node and internodes of the two species were found to be between 0.865 and 0.996. The negative relationship indicated decrement in MC with culm height which manifested in node and internodes of both species. The higher MC present in the internodes than in the node may have been due to the higher percentage of conducting tissues occurring in the internodes than the node (Florian et al. 1991). This feature greatly affects seasoning and penetration of preservatives in the node.

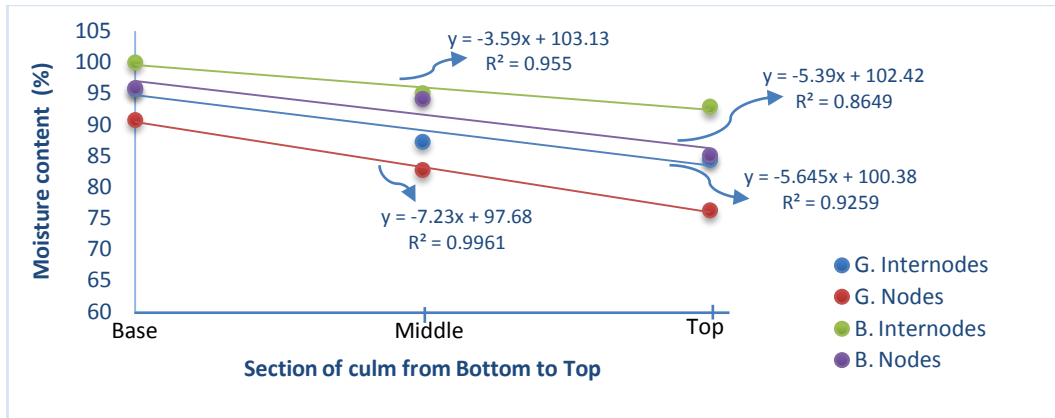


Figure 2. Moisture content of green *G. scortechinii* and *B. vulgaris* at node and internodes along the culm height

Shrinkage

Figure 3 shows the mean shrinkage of nodes and internodes for *G. Scortechinii* and *B. Vulgaris* along the culm height. The longitudinal shrinkage increased from basal to the top for both species and on both node and internodes except the *B. Vulgaris* top which dropped by a slight margin in both node and internodes. The longitudinal shrinkage recorded mean values of 2.5% and 0.27% at the node and 1.34% and 0.59% at the internodes for *G. Scortechinii* and *B. Vulgaris* respectively. The percentage of shrinkage of the node was observed to be four times to that of internodes. This may be due higher presence of lignin in the elongated parenchyma cells which are common in the internodes than the nodes (Parameswaran, Liese, 1975).

Circumference shrinkage on the other hand which was actually the tangential shrinkage, showed a similar trend as with the longitudinal shrinkage for the three sections as the basal section recorded the lowest shrinkage compared to middle and top section (Fig 3) in both node and internodes. It would seem possible that the shrinkage differences are related to differences in density in the three sections. Pliura et al. (2005), found a negative correlation between wood density and longitudinal shrinkage and a positive correlations between density and both radial and tangential shrinkages suggesting that selection for high wood density may lead to increased transverse wood shrinkage but decreased longitudinal shrinkage.

■ G. Basal ■ G. Middle ■ G. Top ■ B. Basal ■ B. Middle ■ B. Top

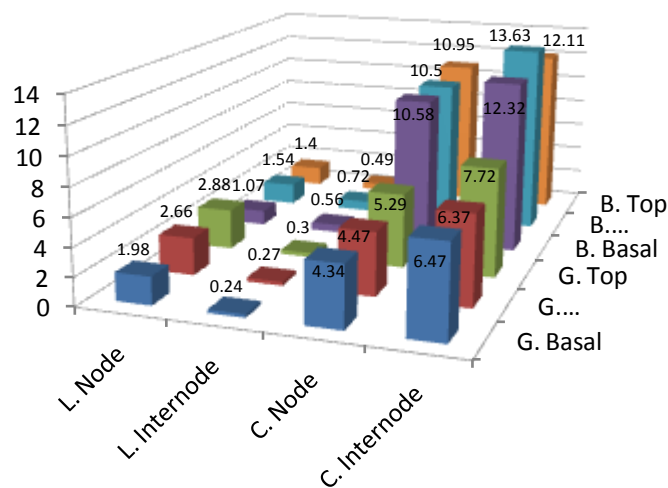


Figure 3. Comparison of shrinkage (longitudinal (L) and circumference (C)) between *G. Scortechinii* and *B. Vulgaris* along the culm height

Across the culm wall the fiber length often increases from the periphery towards the middle and decreases towards the inner part. More parenchyma but few fibers and conducting cells were found to be present in the inner part of the culm's wall than in the periphery (Razak et al. 2010). This structure cause the culm to have higher stress at the inner which cause the outer part of the culm to shrink towards the inner and some of the bamboo culm were observed to be splited during the drying process.

Another possible reason for the shrinkage difference in the circumference to the longitudinal direction is the difference in vascular bundle (fiber) elongation, which is longitudinally at internodes and randomly at node as supported by Grosser and Liese (1971). This fiber irregularity in node section is also expected to give adverse effect on the strength and the machinability of the section.

Table 1 shows the mean shrinkage (L, R, T) of strips samples between the three sections, two categories and the two species. The shrinkage increased from the basal to the top in all the three axis directions, except for the tangential direction of the *G. scortechinii* which had a reverse trend. The radial shrinkage was higher than the tangential although the difference was not significant. It was also observed that the trend of shrinkage was inversely proportional to the trend of MC of the along the culm height. This indicates that the MC has a strongly close correlation to shrinkage of the bamboo as shrinkage starts simultaneously with the decrease of MC (Liese, 1985).

The results also shows that the internodes strips tend to shrink slightly more at the radial direction compared to the tangential and longitudinal direction. This is of almost the same trend discovered by Liese (1985) in *Phyllostachys pubescens*. The percentage of shrinkage at the radial direction (Figure 4) is slightly higher than the percentage of shrinkage at the tangential direction. The top section still has the highest percentage of shrinkage at radial direction the same pattern in both species.

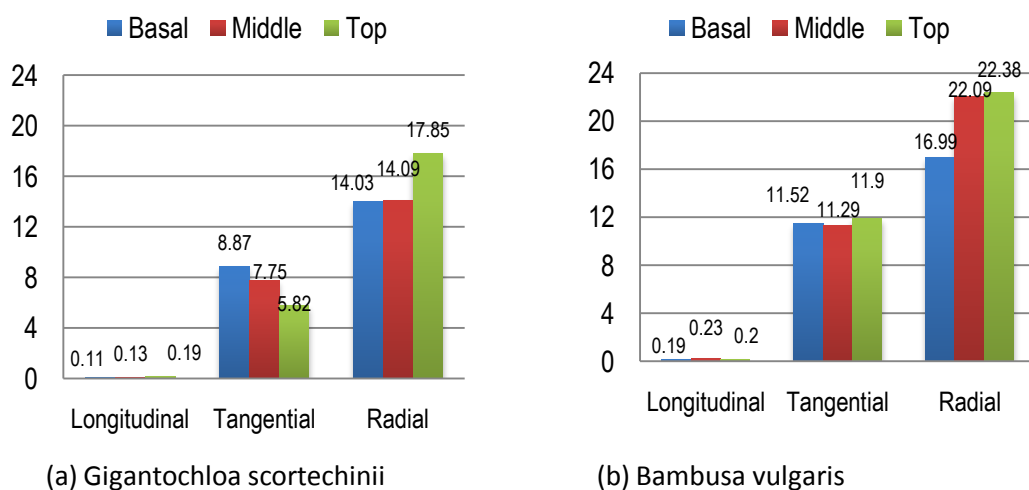


Figure 4. Mean shrinkage of strips for *G. scortechinii* and *B. vulgaris*

The shrinkage property of bamboo is also influenced by the anatomical structure of the bamboo. The dimensional changes shown by bamboo occur in timber as well. This behaviour occurs in timber because most of the microfibrils (S2 layer) are aligned parallel to the longitudinal axis. The explanation of this behaviour also applied to bamboo. According to Parameswaran & Liese (1975), there are two types of microfibril orientation in bamboo, the narrow lamellae showing fibrillar angle of 80-90° to the axis and the broader ones with fibrillar angle almost parallel to the axis. Although the fibres in bamboo demonstrated polylamellate nature (8 lamellae compare to 3 lamellae in wood (S1, S2, and S3)), the broad fibril layer which are parallel to the axis is greater when compared to the narrow lamellae.

CONCLUSIONS

The results of this study showed that the moisture content for both nodes and internodes for the two bamboo species decreases along the culm from basal to the top section. Nodes presents along the culm generally have lower moisture content compare to internodes. This was believed to have caused by the increasing vascular bundle proportion and decreasing proportion of parenchyma tissue from basal to the top. Bamboo has a similar anatomical structure of higher presence of vascular bundles to parenchyma cells that serve as site for water storage. It can be seen clearly from the dimensional changes or shrinkage on the strips tested, that the MC and the anatomical characteristics of bamboo influenced and affected the shrinkage behaviour of bamboo.

The shrinkage pattern of the two species of bamboo studied also revealed the radial section tending to shrink slightly higher compared to tangential directions with a ratio of 1.15 : 1. This minimal differential radial and tangential shrinkage contributes to the dimensional stability of bamboo.

RECOMMENDATIONS

The improvement to this study can be done in the future to get more detailed information on the physical properties of bamboo. The same study should be carried out on other local bamboo species as we still lack information on the physical properties of such local bamboo species.

This kind of study can give a good information for the local bamboo industry in the direction of plying or lamination of strips for laminated bamboo board or lumber to reduce the occurrence of dimensional instability. A highly maintained tools and apparatus should be used during the process of study to avoid error in the results and to conserve time and energy so that the study can be organized more systematically.

ACKNOWLEDGEMENTS

The work described in this paper is part of a project was fully supported by a grant from the Universiti Putra Malaysia (Putra Grant GP-IPB/2013/9413401). The autors also wish to express their gratitude to the staff of Faculty of forestry and FRIM for their support in this study.

REFERENCES

- Abd. Latif, M., & Mohd Tamizi, M., (1992). Variation of anatomical properties of three Malaysia bamboos from natural stand. *Journal of Tropical Forest Sciences*, 5 (1), 90-96.
- Abd. Latif, M., & Mohd. Zin, J., (1992). Trends of variation of some physical properties of *Gigantochloa scortechinii*. *BIC, India Bulletin*, 2, 7-12.
- Abd. Latif, M., Wan Tarmeze, W.A., & Fauzidah, A., (1990). Anatomical features and mechanical properties of three Malaysian bamboo. *Journal of Tropical Forest Science*, 2(3), 227- 234.
- Abd. Razak, O., Hashim M. N., Jamaludin H. M. (2007), Harvesting technique in natural stands of Buluh Semantan (*Gigantochloa scortechinii*), FRIM reports, 87.
- Anwar, U.M.K., Zaidon, A., Hamdan, H., Tamizi, M. M., (2005). Physical and mechanical properties of *Gigantochloa scortechinii*. *Journal of Tropical Forest Science*, 17: 413-418.
- Arce, O.A., (1993). *Fundamentals of the design of bamboo structures*. Doctoral dissertation, Technische Universiteit Eindhoven, p.281.
- Bakar, E.S., (2000). *Utilization of oil palm as housing and furniture material*. Unpublished doctoral dissertation, Bogor Agricultural University.
- Bakar, E.S., Sahri, M.H., & H'ng, P.S. (2008). Chapter 12: Anatomical characteristics and utilization of oil palm wood. T., Nobuchi, M.H., Sahri, (Eds.). *The formation of wood in tropical forest tress - A challenge from perspective of functional wood anatomy*, pp.161-178. Penerbit UPM.
- Chung, K. F., & Yu, W. K. (2002). Mechanical properties of structural bamboo for bamboo scaffoldings. *Engineering structures*, 24(4), 429-442.
- Florian, M. E., Kronkright, D. P., Norton, R. E., (1991), *The conservation of artefacts made from plant materials*, Getty Publications, Pg 348.

- González, M.E., Veblen, T.T., Donoso, C., & Valeria, L., (2002). Tree regeneration responses in a lowland Nothofagus-dominated forest after bamboo dieback in South-Central Chile. *Plant Ecology*, 161(1), 59-73.
- Grosser, D., & Liese, W., (1971). On the anatomy of Asian bamboo, with special reference to their vascular bundles. *Wood Science Technology*, 5, 290- 312.
- Janssen, J.J., (1995). *Building with Bamboo: A handbook*. Intermediate Technology Publications, London.
- Hamdan, H., Anwar, U.M.K., Zaidon, A., Tamizi, M. M., (2009). Mechanical properties and failure behaviour of *Gigantochloa scortechinii*. *Journal of Tropical Forest Science*, 21(4): 336-344
- Khabir, M.F., Bhattacharjee, D.K., Sattar, M.A (1995). Physical properties of node and internodes of culm and branch of *Dendrocalamus hamiltoni*. Pp 19-22 in Rao IVR and Sastry CB (Eds.) *Bamboo, People and the Environment. Proceedings of the IV International Bamboo Congress. Volume 3*. 19-22, June 1995, Bali
- Liese, W., (1980). Anatomy and properties of bamboo. The structure of bamboo in relation to its properties and utilization. In S., Zhu, W., Li, X., Zhang, & Z., Wang, (Eds.), *Bamboo and its uses. Proceedings of Bamboo Research in Asia*, 28-30 May 1980, Singapore.
- Liese, W., (1987). Research on bamboo. *Wood Science and Technology*, 21(3), 189-209.
- Liese, W., (1985), *Proceedings of the Anatomy and properties of bamboo, International Bamboo Workshop, China*, pp196-208.
- Nordahlia, A.S., Anwar, U.M.K., Hamdan, H., & Mahanim, M A.L.S., (2011). Anatomical, physical and strength properties of *Shizostachyum brachycladum* (Buluh leman). *Journal of Bamboo and Rattan*, 10(4), 111-122.
- Pande S.K. and Pandey S. (2008), Bamboo for the 21st century, *International Forestry Review*, Commonwealth Forestry Association 10(2):134-146.
- Parameswaran, N., Liese, W., (1975). On the polylamellate structure of parenchyma wall in *Phyllostachya edulis*. *IAWA Bulletin* 4, 57-58.
- Pliura, A., Yu, Q., Zhang, S. Y., MacKay, J., Périnet, P., Bousquet, J. (2005) Variation in Wood Density and Shrinkage and Their Relationship to Growth of Selected Young Poplar Hybrid Crosses; *Forest Science*, Society of American Foresters, 51(5):472–482.
- Razak, W., Mustapa, M., Sulaiman, O., Mohamed, A., Hassan, A., & Khalid, I., (2010). Anatomical and physical properties of cultivated two and four year old *Bambusa vulgaris*. *Sains Malaysiana*, 39(4), 571-579.
- Yu, Y., Jiang, Z., Fei, B., Wang, G., & Wang, H. (2011). An improved microtensile technique for mechanical characterization of short plant fibers: a case study on bamboo fibers. *Journal of Materials Science*, 46(3), 739-746

EFFECT OF HEATING TEMPERATURE ON THE PHYSICAL AND MECHANICAL PROPERTIES OF OKAN WOOD (*Cylicodiscus gabunensis*(Taub.) Harms)

Wahyu Hidayat^{1 2}, Jae-Hyuk Jang¹, Se-Hwi Park¹, Nam-Hun Kim¹

¹College of Forest and Environmental Sciences, Kangwon National University, Chuncheon, 200-701, Republic of Korea; awayrie@gmail.com

²Department of Forestry, Faculty of Agriculture, University of Lampung, Jl. Prof. Dr. Sumantri Brojonegoro No. 1 Bandar Lampung, 35145, Indonesia

ABSTRACT

The objective of this research was to evaluate the physical properties and mechanical properties of Okan wood (*Cylicodiscus gabunensis* (Taub.) Harms) after heat-treated at different temperatures. Sapwood and heartwood specimens of Okan wood grown in Africa tropical rainforest were prepared. The boards dimensions were 300 mm x 90 mm x 20 mm in length, width and thickness respectively. The boards were stacked using metal clamp to prevent the occurrence of drying defects. The boards were heat-treated at 160°C, 180°C, 200°C, and 220°C for 2 hours in an electric furnace (L-Series, JEIO TECH Ltd., Korea). The results revealed that increasing heating temperature reduced lightness (L^*) and yellow-blue chromaticity (b^*) of Okan wood. Color change in sapwood is more obvious than that in heartwood. Weight loss of sapwood and heartwood significantly increased with increasing temperature. Sapwood heat-treated at low temperature of 160°C seems to lose more weight than heartwood, but as the temperature increased to 220°C weight loss of heartwood increases reaching 11.26% against 10.39% for sapwood. Increasing heating temperature significantly reduced EMC and leads to an improvement of dimensional stability. Mechanical properties evaluation showed that the MOR and MOE values decreased with increasing heating temperature. MOR and MOE of heartwood decreased higher compared to sapwood, in contrary the compressive strength reduction for sapwood was higher compared heartwood. The results of this study showed that heat treatment at temperature ranging between 160 - 200°C was effective enough, while high decrease in the mechanical strength makes Okan wood heat-treated at 220°C not suitable for structural applications.

Keywords: Heat treatment, heating temperature, Okan wood, physical and mechanical properties.

INTRODUCTION

Okan (*Cylicodiscus gabunensis*(Taub.) Harms) or African greenheart, is a large tree native to tropical rain forests of West and Central Africa that grows up to 60 m tall with straight bole up to 24 m (Kadiriet al. 2005). Okan very durable and it is commonly used in heavy construction and harbour works such as lock gates, bridges and railway sleepers (Louppeet al. 2008). In Korea, Okan is increasingly used for wood decks and flooring. However, the colour between sapwood and heartwood of Okan wood are not uniform. The sapwood part of Okan is light-yellow, lighter than the heartwood which has brown color.

Heat treatment has been known to obtain darker wood color and improve dimensional stability of wood products including wood decks and flooring. Heat treatment of wood is invariably performed at temperature ranging between 160 - 260°C, with temperatures lower than 140°C resulting in only slight changes in material properties and higher temperatures resulting in unacceptable degradation to the substrate (Hill 2006). Heat-treated wood products can be used for a broad range of applications such as garden fences and channel linings or even cladding, decking and exterior joinery. The main effect gained by a heat treatment of wood is reduced wood hygroscopicity. Foremost advantages of wood treated in this manner are increased resistance to different types of biodegradation and improved dimensional stability. However, originally some undesired side effects, in particular loss of strength and increased brittleness of the treated wood were the main objections for overall commercial utilisation of heated timber.

Many factors including species, heat transfer medium, treatment temperature and time, steam pressure and oxygen concentration influence the degree and pattern of chemical reactions during heat treatment (Jiang

et al. 2014). As there is little information about heat treatment of Okan wood (Shi et al. 2011), this study intended to evaluate the effect of heat treatment on color, weight, EMC, water absorption, MOE, MOR, and compression strength of sapwood and heartwood of Okan.

MATERIALS AND METHODS

Flat-sawn boards from sapwood and heartwood part of Okan (*Cylicodiscus gabunensis* (Taub.) Harms) grown in Africa tropical rainforest were prepared for heat treatment. The boards dimension were 300 mm x 90 mm x 20 mm in length, width and thickness respectively. The air-dry densities of sapwood and heartwood boards were ranging between 0.77-0.89 g/cm³ and 1.16-1.23 g/cm³, respectively. The boards were stacked using metal clamp to prevent the occurrence of drying defects (Fig. 1). Each set of stack consists of three sapwood and heartwood boards. Each board was covered by flat metals on their edgewise and fastened by using bolts and nuts equipped with metal spring. Wood stickers having dimension of 80 mm x 20 mm x 20 mm were put between boards.

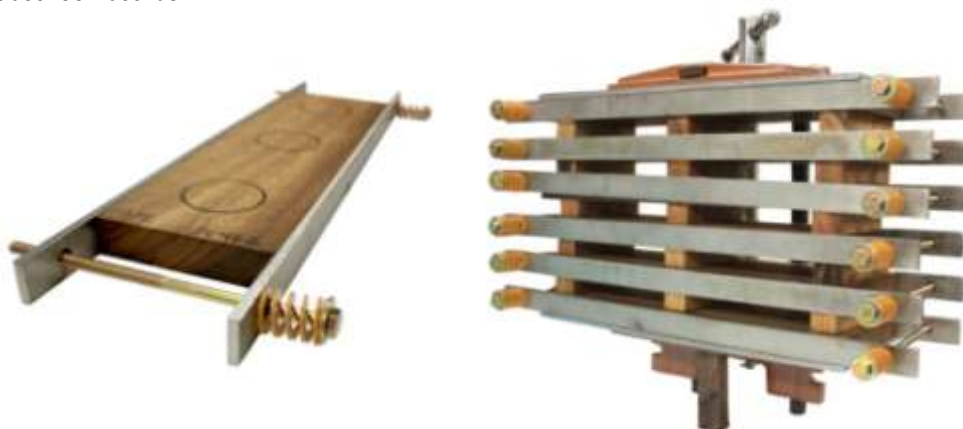


Figure 1. Samples stacking using metal clamp

Heat treatment was performed in an electric oven with programmable controller (L-Series, JEIO TECH Ltd., Korea). The heat treatment was started at initial temperature of 25°C - 30°C and then rising to target temperature of 160°C, 180°C, 200°C, and 220°C with a heating rate of 2°C /minute. The target temperature was maintained over a period of 2 hours. At the end of the heat treatment, the oven was turned off and the boards were taken out and kept in conditioning room under relative humidity of 65% and temperature of 25°C. The boards were allowed to cool naturally until they reached 30°C.

The colorimetric evaluation was performed by using CIE-*L*a*b** system as the method to determine wood color (Commission International de L'Éclairage). Three measurements of each sample before and after heat treatment were taken by MINOLTA CR-400 Chroma Meter to obtain *L**, *a** and *b** color values. The color change (ΔE^*) was calculated as follows:

$$\Delta E^* = (\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2})^{1/2}$$

Where ΔL^* , Δa^* , Δb^* , and ΔE^* represent changes in lightness, red/green chromaticity, yellow/blue chromaticity, and overall color, respectively.

Weight loss, moisture content, and water absorption of the samples were evaluated according to Korean Standards (KSA 2009a, KSA 2011a, KSA 2011b). Evaluation of modulus of rupture (MOR), modulus of elasticity (MOE) and compression strength were performed by using a mechanical testing machine (Model 4482, Instron, USA) in accordance to Korean Standards (KIS 2009b, KIS 2009c).

RESULTS AND DISCUSSION

Heat treatment affected the color parameters of Okan wood. The results showed that heat treatment mostly affected lightness (L^*) and yellow-blue chromaticity (b^*). Darkening as a result of heat treatment was clearly visible and it increased with increasing temperature. In overall, ΔE^* of sapwoods were higher than heartwoods. The highest ΔE^* was 33.80 for sapwood and 22.25 for heartwood after heat treated at 220°C for 2 hours. Results of this study are compatible with the other studies. Shi *et al.* (2011) stated that heat treatment resulted in a darkening of wood tissues and the color became dark with temperature increase. Their study also revealed that the effect of treatment temperature on color change in sapwood is more obvious than that in heartwood as the result in this study.

Table 1. Color of Okan wood before and after heat treatment

Temperature (°C)	L^*		a^*		b^*		Color change (ΔE^*)	
	SW	HW	SW	HW	SW	HW	SW	HW
Control	55.10 (2.57)	43.15 (2.70)	9.46 (1.55)	9.57 (1.52)	30.37 (1.73)	19.46 (3.15)	-	-
160	50.65 (2.48)	42.85 (3.06)	9.98 (0.51)	11.80 (0.64)	26.82 (2.32)	20.28 (2.52)	4.76 ^A (0.27)	4.39 ^A (0.51)
180	49.48 (4.16)	37.69 (2.56)	8.75 (1.25)	9.44 (0.85)	24.72 (4.34)	13.75 (2.91)	9.98 ^A (2.41)	6.69 ^A (2.07)
200	37.27 (1.67)	32.74 (1.57)	9.10 (3.44)	5.73 (0.99)	15.53 (3.81)	8.46 (2.14)	21.65 ^B (4.09)	12.07 ^B (2.40)
220	31.85 (1.52)	29.99 (0.43)	4.53 (1.23)	3.19 (0.81)	7.33 (2.30)	5.90 (1.60)	33.80 ^C (0.45)	20.00 ^C (1.84)

Notes: SW= sapwood; HW= heartwood; means within a column followed by same capital letter are not significantly different at 5% significance level using Tukey's HSD test. Numbers in parenthesis are standard deviations. Means are average of 3 replications.

Table 2 shows the physical properties of Okan sapwood and heartwood before and after heat treatment. The results showed that weight loss of sapwood and heartwood samples significantly increased with increasing temperature. Sapwood heat-treated at low temperature of 160°C seems to lose more weight than heartwood, but as the temperature increased to 220°C weight loss of heartwood increases reaching 11.26% against 10.39% for sapwood. Esteves and Pereira (2009) stated that during the heat treatment process, extractives, hemicelluloses and a part of cellulose molecules in the amorphous regions are degraded due to high temperature. This causes the chemical changes of the wood; or in other words, the basic components of the wood cell wall structure are changed in their number and dimension, leading to the reduction in dimension and weight of the wood after heat-treated.

Table 2. Physical properties of Okan wood before and after heat treatment

Temperature (°C)	Weight loss(%)		EMC(%)		Water Absorption (%)	
	SW	HW	SW	HW	SW	HW
Control	-	-	8.99 ^A (0.03)	9.68 ^A (0.14)	32.18 ^A (2.57)	13.74 ^A (1.00)
160	6.04 ^A (0.60)	5.59 ^A (2.20)	6.98 ^B (0.29)	7.05 ^B (0.59)	29.62 ^A (2.90)	10.61 ^B (1.01)
180	7.18 ^{AB} (0.83)	6.87 ^A (1.01)	6.74 ^B (0.11)	6.56 ^{BC} (0.17)	26.81 ^{AB} (1.90)	9.71 ^B (1.85)
200	8.28 ^B (0.56)	8.09 ^{AB} (1.13)	5.12 ^C (0.25)	5.61 ^C (0.44)	21.46 ^B (2.61)	7.84 ^C (1.01)
220	10.39 ^C (0.83)	11.26 ^B (0.65)	4.50 ^D (0.04)	4.11 ^D (0.21)	18.91 ^C (1.89)	6.58 ^C (0.89)

Notes: SW= sapwood; HW= heartwood; means within a column followed by same capital letter are not significantly different at 5% significance level using Tukey's HSD test. Numbers in parenthesis are standard deviations. Means are average of 3 replications.

Table 2 also shows that increasing heating temperature significantly reduced EMC. Jämsä and Viitaniemi (2001) stated that the reason for the decrease of the equilibrium moisture content is that less water absorbed by the cell walls after the heat treatment as a result of chemical change with a decrease of hydroxyl groups. The decrease of EMC of Okan wood due to heat treatment leads to an improvement of dimensional stability. The water absorption decreased from 32.18 to 18.91% for sapwood and from 13.74 to 6.58% for heartwood after heat treated at 220°C.

The mechanical properties Okan wood before and after heat treatment is shown in Table 3. The MOR and MOE values decreased slightly at temperature ranging between 160°C to 180°C and increased rapidly from 200°C to 220°C. Highest MOR decreases of sapwood and heartwood samples were occurred after heat treatment at 220°C reaching 29.17% and 37.50%, respectively. Highest MOE decreases of sapwood and heartwood samples were also occurred after heat treatment at 220°C reaching 12.45% and 22.19%, respectively. It can be seen that MOR and MOE of heartwood decreased higher compared to sapwood. The results were in line with the increase of weight loss values, in which heartwood loose more weight compared to sapwood. Compressive strength values were decreased with increasing temperatures. The results showed significant differences between sapwood and heartwood in which compressive strength value reduction for sapwood was higher compared heartwood. Esteves *et al.* (2013) stated that a decrease of strength properties of less than 30% for wood with about 3% weight loss is acceptable for most applications like cladding, sound barriers or decking. The results of this study showed that heat treatment at temperature ranging between 160 - 200°C was effective enough, while high decrease in the mechanical strength makes Okan wood heat-treated at 220°C not suitable for structural applications.

Table 3. Mechanical properties of Okan wood before and after heat treatment

Temperature (°C)	MOR (N/mm ²)		MOE (N/mm ²)		Compressive strength(N)	
	SW	HW	SW	HW	SW	HW
Control	120 ^A (7)	192 ^A (14)	10,740 ^A (441)	15,573 ^A (578)	20.15 ^A (1.48)	48.27 ^A (3.18)
160	118 ^A (8)	185 ^A (13)	10,476 ^{AB} (549)	15,015 ^A (834)	19.06 ^A (1.53)	46.73 ^A (3.86)
180	110 ^A (9)	169 ^{AB} (37)	9,963 ^{AB} (351)	15,301 ^A (686)	18.02 ^A (2.48)	46.02 ^{AB} (4.32)
200	102 ^{AB} (10)	156 ^{AB} (21)	9,837 ^{AB} (588)	13,811 ^{AB} (594)	16.66 ^A (2.67)	39.96 ^{AB} (3.41)
220	85 ^B (10)	120 ^B (6)	9,403 ^B (460)	12,117 ^B (636)	16.15 ^A (1.42)	35.75 ^B (4.88)

Notes: SW= sapwood; HW= heartwood; means within a column followed by same capital letter are not significantly different at 5% significance level using Tukey's HSD test. Numbers in parenthesis are standard deviations. Means are average of 3 replications.

CONCLUSIONS

This study investigated the effect of heat treatment on physical and mechanical properties of sapwood and heartwood part of Okan wood (*Cylicodiscusgabunensis*(Taub.) Harms). Based on the findings in this work, color changes were significantly affected by heat treatment, higher treatment temperatures resulted in darker wood color. Furthermore the effect of treatment temperature on color change in sapwood is more obvious than that in heartwood. Treatment temperature significantly affected physical properties of Okan wood including the weight, EMC, and water absorption. Heat treatment at lower temperature slightly reduced the mechanical properties of Okan wood including bending strength and compressive strength, while heat treatment at higher temperature rapidly decreased mechanical properties of Okan wood. Heat treatment at temperature ranging between 160 - 200°C was effective enough, while high decrease in the mechanical strength makes Okan wood heat-treated at 220°C unsuitable for structural applications.

ACKNOWLEDGEMENT

This work was supported by Business for Cooperative R&D between Industry, Academy, and Research Institute funded Korea Small and Medium Business Administration in 2013-2014 (Grants No. C0123198).

REFERENCES

- Esteves BM, Pereira H (2009) Wood modification by heat treatment: a review. *BioResources* 4(1):340–404.
- Esteves BM, Nunes L, Domingos I, Pereira H (2013) Comparison between heat treated sapwood and heartwood from *Pinus pinaster*. *Eur. J. Wood Prod.* 72(2014): 53-60.
- Hill, CAS (2006) Wood modification: chemical, thermal and other processes. Wiley Series in Renewable Resources. John Wiley & Sons, Ltd. England.
- Jämsä S, Viitaniemi P (2001) Heat treatment of wood-Better durability without chemicals. In: Proceedings of special seminar held in Antibes, France.
- Jiang JH, Lu JX, Zhou YD, Huang RF, Zaho TK, Jiang JL (2014) Optimization of processing variables during heat treatment of oak (*Quercus mongolica*) wood. *Wood Sci Technol* 48:253-267.
- Korean Standards Association (KSA) (2009a) KS F 2204: Method of test for water absorption of wood.
- KSA (2009b) KS F 2208: Method of bending test for wood.
- KSA (2009c) KS F 2206: Method of compression test for wood.
- KSA (2011a) KS F 2198: Determination of density and specific gravity of wood.
- KSA (2011b) KS F 2199: Determination of moisture content of wood.
- Kadiri AB, Olowokudejo JD, Ogundipe OT (2005) Some aspects of foliar epidermal morphology of *Cylicodiscus gabunensis* (Taub.) Harms (*Mimosaceae*). *J. Sci. Res. Dev.*, 10(2005): 33-38.
- Loupe D, Amoako AO, Brink M (2008) *Prota* 7(1): Timbers/Bois d'oeuvre 1. Plant Resources of Tropical Africa, Wageningen, Netherlands.
- Shi Q, Bao FC, Lu JX, Jiang JH (2011) Effect of heat treatment temperature on the colour of Okan wood. *Advanced Materials Research* 214: 531-534.

MECHANICAL PROPERTIES OF COMPOSITE BASED ON POLY (LACTIC ACID) AND KRAFT PULP OF OIL PALM EMPTY FRUIT BUNCH

Lisman Suryanegara, Yudhi Dwi Kurniawan*

Research Center for Biomaterials - Indonesian Institute of Sciences.
Cibinong Science Center, Cibinong-Bogor 16911, Indonesia

*Corresponding author: yudh003@lipi.go.id

ABSTRACT

The main disadvantage of low toughness of poly(lactic acid) (PLA) has been circumvented by the use of Kraft pulp of oil palm empty fruit bunch (OPEFB) as a reinforcing agent, providing a green composite. The composite was prepared by mixing the PLA with the pulp in various fiber loading, i.e., up to 20 wt%. The reinforcement effect was evaluated in the term of the mechanical properties. It was found that the tensile modulus was improved up to 25% at 20 wt% of loading filler. However, the tensile strength and the elongation at break were decreased to 19% (10 wt%) and 72% (20 wt%), respectively.

Key words: Kraft pulp, oil palm empty fruit bunch, poly(lactic acid) composite, mechanical properties

INTRODUCTION

Recently, environmental issues and requirement of waste management policies have been an attractive focus gaining much attention of many researchers to develop type of materials which are biocompatible and environmentally benign as a long term alternative to traditional fossil-based polymers (Espino-Pérez *et al.*, 2013; Frone *et al.*, 2011; Šumigin *et al.*, 2013; Wigner, 1965; Braun *et al.*, 2012). Utilization of biopolymers which are naturally occurred in many living organisms is now considered as an attractive approach to work in this area (Petersson *et al.*, 2007). The less harmless property of the biopolymers provides huge beneficial impacts for the environmental conservation efforts of its application compared to the use of fossil-based material as a raw substance for plastic production (Suryanegara *et al.*, 2009). Biopolymers can be found in many sources, for instance, agricultural biomass, marine fauna and as microbial metabolism product. Many researchers have now motivated to apply these biopolymers as a potential matrix for the fabrication of bio-based composites, such as starch-based polymers, polycaprolactone, polyhydroxy butyrate, polyamide and polylactic acid (PLA) (Suryanegara *et al.*, 2009; Haafiz *et al.*, 2013).

PLA is a polymer which can be degraded in a relatively short time under suitable condition and achieved its first large-scale production at 2001 through fermentation of sugar into lactic acid followed by distillation into dimer form and subsequent ring-opening polymerization using stannous octoate, Sn(Oct)₂, as a catalyst (Lunt, 1998; Jonoobi *et al.*, 2010; Vink *et al.*, 2003; Raquez *et al.*, 2013). This biopolymer is thought to have a good potential in replacing fossil-based materials regarding to its high mechanical properties (tensile strength of 50-70 MPa and modulus of 3 GPa) (Suryanegara *et al.*, 2009). However, the application of this material is still limited due to its inherent brittleness and lower impact resistance (Pei *et al.*, 2010). Therefore, efforts to improve its properties are highly necessary.

One of the approach to circumvent this drawback has been shown by many authors. To provide a fully bio-based material, reinforcing fillers isolated from natural sources are now incorporated to improve the mechanical properties of the resulting composite (Maria *et al.*, 2010). Reinforcement of PLA using lignocellulosic fibers has been studied intensively (Mohanty *et al.*, 2002; Samir *et al.*, 2005; Oksman *et al.*, 2003; Huda *et al.*, 2005) which involved the use of cellulose fiber from wood (Huda *et al.*, 2006), recycled newspaper (Huda *et al.*, 2005), kenaf (Maurizio *et al.*, 2008), rice straw (Qin *et al.*, 2011) and hemp (Song *et al.*, 2012). Cellulose is one of the most abundant biopolymer which acts as natural reinforcing agent in plant structure (Maddahy *et al.*, 2012).

In our study, we are interested to apply cellulosic Kraft pulp from oil palm empty fruit bunch as a reinforcing agent for PLA composites. The mechanical properties were evaluated as the tensile strength and modulus.

EXPERIMENTAL METHOD

Materials

As the matrix, an amorphous poly(lactic acid) biopolymer (NatureWork® Ingeo™ Biopolymer 4060D) with density of 1.24 g/cm³ and melting point of 140 °C was applied. The Kraft pulp of oil palm empty fruit bunch (OPEFB) was obtained from Biomass Conversion Laboratory in Research Center for Biomaterial – Indonesian Institute of Sciences, Indonesia.

Preparation of Composites

The pulp was placed into a beaker glass, added with distilled ethanol and stirred for 30 minutes to remove the water (1 g dry-base of pulp:70 mL of ethanol). This process was repeated four times to remove water completely. The pulp was then solvent-exchanged to acetone in the same manner with washing process and repeated four times. The suspension of the pulp in acetone was stirred and added with PLA pellet gradually. The stirring was continued at ~1000 rpm for another 1-1.5 hours until well-dispersed mixture was obtained. The mixture was then spreaded out into a teflon-layered tray and the solvent was evaporated in a fume hood at room temperature for 16 h followed by oven-dried at 60 °C for 24 h. The composition of the composites was listed in Table 1.

The composites after drying were cut into small pieces (1-2 cm) and kneaded by a twin rotary mixer (rheomix, HAAKE polydrive) at 140 °C, 40 rpm for 12 minutes. The resulting compound was then crushed and hot-pressed into sheets at 150 °C in two chronological steps, pre-heating for 8-9 minutes and 4 MPa for 30 seconds. The composites was allowed to room temperature for additional 20 minutes.

Table 1. Composition of the composites

Composites	PLA (g)	Pulp (g)
PLA	60	0
PLA/pulp 5 wt%	57	3
PLA/pulp 10 wt%	54	6
PLA/pulp 20 wt%	48	12

Tensile Test

The tensile test of the resulting composites were performed by using Shimadzu universal testing machine (UTM) with load cell of 1 kN. The specimens for measurement were rectangle in shape with the size about 6 cm x 0.5 cm x 0.1 cm and 2 cm upon gripping measured using caliper. The crosshead speed of 1 mm/min was applied. All the results obtained were summarized as the average value of five measurements.

RESULTS AND DISCUSSION

Tensile Properties

The tensile modulus, strength, and the elongation at break of the resulting composites and the neat PLA (control) were summarized in Table 2.

Table 2. Tensile properties of the composites

Composites	Tensile modulus ^a (GPa)	Tensile strength ^{a,b} (MPa)	Strain at break ^a (%)
PLA	1.18±0.07	47.9±2.1	15.6±4.3
PLA/pulp 5 wt%	1.30±0.07	44.2±3.1	6.5±0.7
PLA/pulp 10 wt%	1.28±0.04	38.8±0.7	6.1±0.7
PLA/pulp 20 wt%	1.47±0.07	39.1±1.1	4.3±0.5

^aaverage±SD; ^bmaximum stress

The effect of Kraft pulp addition on the mechanical properties of PLA/pulp composites is illustrated in Fig. 1-3. As shown in Figure 1, the addition of Kraft pulp of oil palm empty fruit bunch pulp into PLA improved the tensile modulus of the resulting composite from 1.18 GPa to 1.47 GPa, i.e. up to 25%, compared to the neat PLA at the fiber loading of 20 wt%. This enhancement in tensile modulus could be explained by the combination of the increase in the number of intermolecular hydrogen bonding, stiffening effect as well as the crystallinity of the fiber which is a customary properties of of fiber/polymer properties (Cheng *et al.*, 2009).

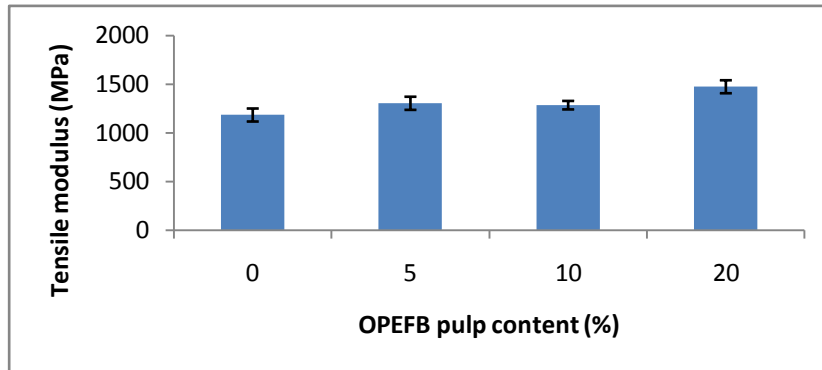


Figure 1 Tensile Modulus of PLA/OPEFB Composites

In the other hand, as shown in Figure 2-3, the incorporation of the pulp into PLA matrix did not result in any improvement in both their tensile strength and the elongation at break. The decrease in the tensile strength of the resulting composites as the filler content increased (Figure 2) could be addressed by agglomeration of the filler due to Van der Waal's forces (Yew *et al.*, 2005). This phenomenon was suggested to be responsible to the superiority of the filler-filler interaction rather than the filler-matrix one. As the consequence, plenty of voids at the filler-matrix interface are formed due to their poor interfacial adhesion. This factor accounts for the inefficient stress transfer to the corresponding filler affording a low strength properties. This observation was in agreement to the previous related studies (Yew *et al.*, 2005; Qu *et al.*, 2010).

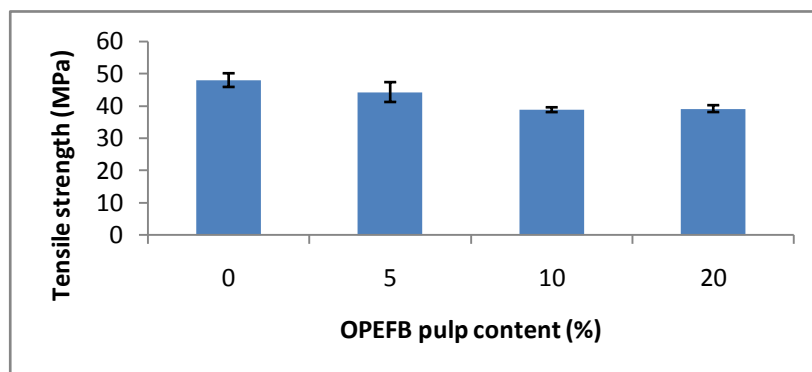


Figure 2 Tensile Strength of PLA/OPEFB Composites

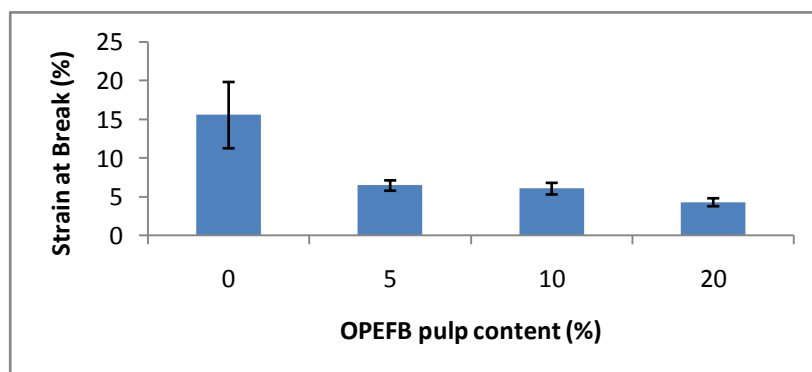


Figure 3 Strain at break of PLA/OPEFB Composites

The similar trend was also observed to the elongation at break of the resulting composites. Figure 3 clearly depicts the decrease in this property as the pulp content increased. This observation could be attributed to the stiffening effect of the filler by restriction in segmental chain motion of the PLA during the test progress. Some factors influencing the elongation at break property have been proposed by Pei *et al.* (2010), which are the volume fraction of the loaded reinforcing agent, the level of dispersion of the reinforcing agent in the matrix polymer, and the interaction between the reinforcing agent and the matrix. The formation of aggregation of the filler result in the significant local stress concentration which in turn alleviated the level of elongation at break (Cheng *et al.*, 2009).

We are interested to notice a significant lower figure for the tensile modulus of the neat PLA observed in our recent work compared to the references, i.e., 1.2 GPa compared to 3 GPa (Pei *et al.*, 2010; Wigner, 1965; Suryanegara *et al.*, 2009; Haafiz *et al.*, 2013; and Anderson *et al.*, 2008). In contrast, some other authors obtained the similar result to ours (Xu *et al.*, 2012; Syamani *et al.*, 2013; and Subyakto *et al.*, 2011).

CONCLUSION

In conclusion, the composites of PLA/Kraft pulp of oil palm empty fruit bunch was successfully prepared. The mechanical properties of the resulting composites was evaluated as their tensile modulus and strength. The tensile modulus of the composites showed an increase up to 25% at a loading filler of 20 wt%, due to the stiffening effect of the fiber. In contrast, the tensile strength and elongation at break of the composites decreased as the fiber content increased, i.e., to 19% (10 wt%) and 72% (20 wt%), respectively.

ACKNOWLEDGEMENT

This research was financially supported by LIPI through Competitive Program on Advance Material and SATREPS Program. We are very thankful to Mr Sudarmanto for his valuable technical assistance.

REFERENCES

- Anderson, K.S.; Schreck, K.M.; Hillmyer, M.A., Toughening polylactide, *Polymer Reviews* 2008; 48: 85–108.
- Braun, B.; Dorgan, J.R.; Hollingsworth, L.O., Supra-molecular ecobionanocomposites based on polilactide and cellulosic nanowhiskers: synthesis and properties, *Biomacromolecules* 2012, 13, 2013–2019, dx.doi.org/10.1021/bm300149w.
- Cheng, Q.; Wang, S.; Rials, T.G., Poly (vinyl alcohol) nanocomposites reinforced with cellulose fibrils isolated by high intensity ultrasonication, *Composites Part A Applied Science and Manufacturing*, 2009, 40, 218–224.
- Espino-Pérez, E.; Bras, J.; Ducruet, V.; Guinault, A.; Dufresne, A.; Domenek, S., Influence of chemical surface modification of cellulose nanowhiskers on thermal, mechanical, and barrier properties of poly(lactide) based bionanocomposites, *European Polymer Journal* 49 (2013) 3144–3154, <http://dx.doi.org/10.1016/j.eurpolymj.2013.07.017>.
- Frone, A.N.; Berlioz, S.; Chailan, J.-F.; Panaitescu, D.M.; Donescu, D., Cellulose Fiber-Reinforced Polylactic acid, *Polymer Composites-2011* 976-985.
- Haafiz, M.K.M.; Hassan, A.; Zakaria, Z.; Inuwa, I.M.; Islam, M.S.; Jawaid, M., Properties of polylactic acid composites reinforced with oil palm biomass microcrystalline cellulose, *Carbohydrate Polymers* 98 (2013) 139–145, <http://dx.doi.org/10.1016/j.carbpol.2013.05.069>
- Huda, M.S.; Drzal, L.T.; Misra, M.; Mohanty, A.K., Wood-fiber-reinforced poly(lactic acid) composites: evaluation of the physicomechanical and morphological properties. *J Appl Polym Sci* 2006; 102 (5): 4856–69.
- Huda, M.S.; Drzal, L.T.; Misra, M.; Mohanty, A.K.; Williams, K.; Mielewski, D.F., A study on biocomposites from recycled newspaper fiber and poly(lactic acid), *Ind Eng Chem Res* 2005; 44(15): 5593–601.
- Jonoobi, M.; Harun, J.; Mathew, A.P.; Oksman, K., Mechanical properties of cellulose nanofiber (CNF) reinforced polylactic acid (PLA) prepared by twin screw extrusion, *Composites Science and Technology* 70 (2010) 1742–1747, [doi:10.1016/j.compscitech.2010.07.005](http://dx.doi.org/10.1016/j.compscitech.2010.07.005)

- Lunt, J., Large-scale production, properties and commercial application of polylactic acid polymers, *Polym. Degrad. Stab.* 1998, 145–152.
- Maddahy, N.K.; Ramezany, O.; Kermanian, H., Production of nanocrystalline cellulose from sugarcane bagasse, *Proceedings of the 4th International Conference on Nanostructures (ICNS4)* 12-14 March, 2012, Kish Island, I.R. Iran
- Maria, D.; Garcia, S.; Lagaron, J.M., On the use of plant cellulose nanowhiskers to enhance the barrier properties of polylactic acid, *Cellulose* 17(5): 987-1004 (2010).
- Maurizio, A.; Gordana, B.-G.; Aleksandra, B.; Maria, E.E.; Gennaro, G.; Anita, G., Poly(lactic acid)-based biocomposites reinforced with kenaf fibers, *J Appl Polym Sci* 2008; 108 (6): 3542–51.
- Mohanty, A.K.; Misra, M.; Drzal, L.T., Sustainable bio-composites from renewable resources: opportunities and challenges in the green materials world, *J Polym Environ* 2002;9(2):19–26.
- Oksman, K.; Skrifvars, M.; Selin, J.F., Natural fibers as reinforcement in polylactic acid (PLA) composites, *Compos Sci Technol* 2003; 63(9): 1317–24.
- Pei, A.; Zhou, Q.; Berglund, L.A., Functionalized cellulose nanocrystals as biobased nucleation agents in poly(L-lactide) (PLLA) – crystallization and mechanical property effects, *Composites Science and Technology* 70 (2010) 815–821, doi:10.1016/j.compscitech.2010.01.018.
- Petersson, L.; Kvien, I.; Oksman, K., Structure and thermal properties of poly (lactic acid)/cellulose whiskers nanocomposite materials, *Composites Science and Technology*, 2007, 67, 2535–2544.
- Qin, L.; Qiu, J.; Liu, M.; Ding, S.; Shao, L.; Lü, S.; Zhang, G.; Zhao, Y.; Fu, X., Mechanical and thermal properties of poly(lactic acid) composites with rice straw fiber modified by poly(butyl acrylate), *Chemical Engineering Journal* 166: 772-778, 2011.
- Qu, P.; Goa, Y.; Wu, G.F.; Zhang, L.P., Nanocomposite of poly (lactic acid) reinforced with cellulose nanofibrils, *BioResources*, 2010, 5(3), 1811–1823.
- Raquez, J.-M.; Habibi, Y.; Murariu, M.; Dubois, P., Poly(lactide) (PLA)-based nanocomposites, *Progress in Polymer Science* 38 (2013) 1504–1542, <http://dx.doi.org/10.1016/j.progpolymsci.2013.05.014>.
- Samir, M.A.S.A.; Alloin, F.; Dufresne, A., Review of recent research into cellulosic whiskers, their properties and their application in nanocomposite field, *Biomacromolecules* 2005; 6: 612–26.
- Shibata, M.; Oyamada, S.; Kobayashi, S.; Yaginuma, D., Mechanical composites and biodegradability of green composites based on biodegradable polyesters and lyocell fabric, *J Appl Polym Sci* 2004; 92 (6): 3857–63.
- Song, Y.S.; Lee, J.T.; Ji, D.S.; Kim, M.W.; Lee, S.H.; Youn, J.R., Viscoelastic and thermal behaviour of woven hemp fiber reinforced poly(lactic acid) composites, *Composites: Part B* 43: 856-860, 2012.
- Subyakto; Hermiati, E.; Masruchin, N.; Ismadi; Prasetyo, K.W.; Kusumaningrum, W.B.; Subiyanto, B., Injection molded of bio-micro-composite from natural fibers and polylactic acid, *Wood Research Journal* Vol. 2 • No. 1 • 2011.
- Šumigin, D.; Tarasova, E.; Krumme, A.; Viikna, A., Influence of cellulose stearate (CS) content on thermal and rheological properties of poly(lactic acid)/CS composites, *Key Engineering Materials* Vol. 559 (2013) pp 99-104, [10.4028/www.scientific.net/KEM.559.99](http://www.scientific.net/KEM.559.99).
- Suryanegara, L.; Nakagaito, A.N.; Yano, H., The effect of crystallization of PLA on the thermal and mechanical properties of microfibrillated cellulose-reinforced PLA composites, *Composites Science and Technology* 69 (2009) 1187–1192, doi:10.1016/j.compscitech.2009.02.022.
- Syamani, F.A.; Susanthi, D.; Sudarmanto; Suryanegara, L., Production of green composites based on polylactic acid and cellulose fibers from oil palm fronds, *The 3rd International Symposium for Sustainable Humanosphere (ISSH) A Forum of Humanosphere Science School (HSS)* 2013.
- Vink, E.T.H.; Rabago, K.R.; Glassner, J.R.; Gruber, P.R., Application of life cycle assessment to natureworks polylactide (PLA) production, *Polym. Degrad. Stab.* 2003, 80, 403-419.
- Wigner, E.P., "Theory of traveling-wave optical laser," *Phys. Rev.*, vol. 134, pp. A635–A646, Dec. 1965.
- Xu, H.; Liu, C.-Y.; Chen, C.; Hsiao, B.S.; Zhong, G.-J.; Li, Z.-M., Easy alignment and effective nucleation activity of ramie fibers in injection-molded poly(lactic acid) biocomposites, *Biopolymers* (10) 97: 825–839, 2012.
- Yew, G.H.; Mohd Yusof, A.M.; Mohd Ishak, Z.A.; Ishiaku, U.S., Water absorption and enzymatic degradation of poly (lactic acid)/rice starch composites, *polymer Degradation and Stability*, 2005, 90, 488–500

FIBRILLATED OIL PALM FROND CELLULOSE FIBERS IN POLYLACTIC ACID-POLYPROPYLENE BLENDS COMPOSITE

Firda Aulya Syamani^{1*}, Subyakto¹, Sukardi², Ani Suryani²

¹Research Center for Biomaterials, Indonesian Institute of Sciences (LIPI)
Jl. Raya Bogor Km 46, West Java, 16911, INDONESIA

²Department of Agroindustrial Technology, Faculty of Agricultural Technology, Bogor Agricultural University
Jl. Raya Darmaga Kampus IPB Darmaga Bogor, West Java, 16680, INDONESIA

* Corresponding author : firda.syamani@biomaterial.lipi.go.id

ABSTRACT

Cellulose fiber has a great potential for polymer composite reinforcement due to its remarkable mechanical properties. Disintegration of oil palm frond cellulose fibers into fibrillated cellulose fiber by mechanical process, raised the aspect ratio. However, dispersion of cellulose fiber in polymer matrix dealt with difficulty because of entanglement potency which can create agglomeration. In this research, we produced soda pulp of oil palm frond, then bleached with hydrogen peroxide and purified with potassium hydroxide to obtain cellulose fibers. Oil palm frond cellulose fibers were fibrillated by high speed blender in varied agitation speed and time. Never-dried fibrillated cellulose fiber was dispersed into polylactic acid (PLA) solution, then dried to produce PLA/cellulose fibers sheets. Compounding PLA/cellulose fiber with polypropylene (PP) were done in rheomix with temperature of 175°C, for 8 minutes. The morphology and tensile properties of PLA/PP/cellulose fibers composite were analyzed.

Key words: oil palm frond cellulose fibers, mechanical fibrillation, cellulose fibers dispersion, microfibrillated cellulose composite.

INTRODUCTION

Indonesia has large area of oil palm plantation. In 2013, Indonesia oil palm plantation area was 10,465,020 hectare (Nuryati and Waryanto 2014). From this plantation there are many kind of by product such as oil palm trunk, empty fruit bunch, fruit shell and oil palm frond. Among of them, oil palm frond supply the largest number with about 95 million tons frond per year. Oil palm fronds are a potential fibers source due to its contain about 50% of fibers.

Lignocellulosic fibers can be processed further by mechanical or chemical disintegration to produce microfibrillated cellulose (MFC) or cellulose whisker. Due its remarkably mechanical properties, MFC or cellulose whisker can be utilized as reinforcing agent in polymer composite. One of chemical disintegration is acid hydrolysis, which by that process we can obtain crystal structure of cellulose that has a great mechanical properties. According to Zimmermann *et al.* (2004), crystal structure of cellulose exhibits tensile modulus of 130-250 GPa and tensile strength of 800-10,000 MPa. Mechanical fibrillation has been conducted by Turbak *et al.* (1983) using high-pressure homogenizer, or by Iwamoto *et al.* (2008) using Masuko Sangyo Grinder, or by Cheng *et al.* (2010) using ultrasonicator, or by Hrabalova *et al.* (2011) using Megatron Ultraturrax, to produce microfibrillated cellulose. According to Henriksson (2008) MFC film has tensile strength of 129 ~ 214 MPa and tensile modulus of 10.4 ~ 13.7 GPa, depend on cellulose degree of polymerization. The fibrillation process was conducted in order to obtain cellulose microfibril from macrofibril of cellulose, in other word to increase cellulose fibers aspect ratio. The diameter of microfibril and macrofibril of cellulose are less than 0.035 μm , and less than 1 μm , respectively (Chinga-Carrasco 2011). By the increasing of cellulose fiber aspect ratio (length per diameter), the cellulose reinforcing capacity in polymer composite was expected to be higher.

In this study we try to develop cellulose fibers from oil palm frond by chemical process. Further we proceed mechanical fibrillation to obtain fibrillated cellulose fibers. Our research objective is to characterize morphology and tensile properties of PP/PLA/OPF cellulose fibers composite.

MATERIALS AND METHODS

A. Materials

Oil palm fronds were obtained from oil palm plantation (PTPN VIII) in West Java, Indonesia. The sodium hydroxide at technical grade was used in pulping process. Bleaching process used technical grade of hydrogen peroxide. Potassium hydroxide were supplied by Merck. Two type of matrixs were used in composites production, which were Poly lactic acid (PLA) 4060D and Polypropylene (PP) HI10HO. PLA 4060D was produced by NatureWorks™, which was amorphous, with melting point of 210°C, glass transition temperature of 55-60°C, and density of 1.24 g/cm³. Polypropylene homopolymer HI10HO produced by PT Tri Polyta Indonesia. The melting point of PP was 157-170°C, density of 0.903 g/cm³, melt flow rate of 10 g/10min.

B. Cellulose Fibers Developments: Pulping, Bleaching and Purifying Processes

The oil palm frond (OPF) fibers were sun-dried and cut into ± 2 cm length. To produce soda pulp, OPF fibers were subjected to digester with ratios of liquor-to-materials were 8:1. Soda pulping was carried out at 45% alkali charge. NaOH solution which concentration of 490 g/L and water were added to digester by 410 mL and 3140 mL, respectively to cook 500g OPF fibers (10% moisture content). Pulping was conducted for 2h and 46min, at 176°C. After cooling of the digester, the pulp was collected and washed with water several times until neutralized.

For the bleaching process, as much of 20gram pulp (dry basis) and 300ml distilled water were added in 500ml erlenmeyer, then put in waterbath at 80°C. The technical grade solution of 50% hydrogen peroxide was used as bleaching agent. Every 60min, 8ml of 50% hydrogen hydroxide was added into erlenmeyer, for 3 times. After 4h bleaching process, bleached pulp was collected and washed with running water.

In order to eliminate hemicellulose content, bleached pulp were reacted with 5% (w/v) potassium hydroxide in waterbath at 80°C for 2 h, then washed with running water. The final stage to produce cellulose fibers was further bleaching process with 8 ml of 50% hydrogen peroxide for an hour at 80°C, then washed with running water to obtain cellulose fibers.

C. Charaterization of Fibrillated Cellulose Fibers by Scanning Electron Microscopy

The fibrillated oil palm frond cellulose fibers were analyzed by scanning electron microscope/energy dispersive X-Ray analysis (SEM/EDX) JEOL JSM-6510, operated at 10 kV. Samples were coated with gold using a vacuum sputter-coater to improve conductivity of the samples and thus the quality of the SEM images.

D. Production of PP-PLA-Fibrillated Cellulose Fibers Composites

For composite preparation, it was necessary to remove water from cellulose fibers before mixing with PLA. Water removal were conducted by adding ethanol and acetone into bleached pulp respectively. As much as 40 g wet bleached pulp of OPF was stirred in 500ml technical grade of 96% ethanol for 30 minutes, followed by vacuum filtration to remove the liquid phase (water and ethanol). The process was repeated three times in order to remove water. Next, 500ml acetone was used to completely remove water, by applying the same procedure. Water-free cellulose fibers in acetone were kept in sealed container. The solid content of cellulose-fibers-in-acetone was determined then its ready to fibrillation process.

In order to obtain fibrillated cellulose fibers, 6 g (dry base) of water-free cellulose fibers and 200 ml acetone were processed in high speed blender for 1, 2, 3, 6, and 12 minutes at agitation speed of level 10 (16,000 rpm). Meanwhile, 27 g of PLA was dissolve and stirred in 200ml acetone for about 3 hours. Fibrillated cellulose fibers was suspended gradually in dissolved PLA and stirred in a beaker until well mixed for 10 minutes at speed of 700 rpm. The OPF cellulose fibers-PLA-acetone mixture was spread in trays and the solvent was evaporated at room temperature for 12h followed by oven drying at 60°C for 24h to become a sheet.

Prior to kneading process, the sheets of PLA/OPF cellulose fibers were torn into small pieces. Kneading was done in a twin rotary mixer (rheomix, HAAKE polydrive) at 175°C, 60 rpm. As much as 24.75 g polypropylene was melting in rheomix for 5 min, then 30.25 g PLA/OPF cellulose fibers were added, and kneading process was continued for next 5 min. The compound of PP/PLA/OPF cellulose fibers was crushed into small pieces and hot pressed into sheets at 180°C in two steps: pre-heating for 4 min and 0.5 MPa for 3 min. Afterwards, sample was cooled at room temperature for another 8 min.

E. Mechanical Testing of PP-PLA-Fibrillated Cellulose Fibers Composites

Composite tensile properties were examined based on ASTM D-638 standard. The tensile properties were analyzed from four specimens of rectangular_shape_composites using an universal testing machine “Shimadzu” at a cross-head speed of 5 mm/min and a gauge length of 25 mm.

RESULT AND DISCUSSIONS

Cellulose fibers were developed from oil palm fronds strands in 4 stages; pulping, bleaching, purifying and further bleaching. We try to increase aspect ratio of cellulose fibers by fibrillation in high speed blender, then used it as reinforcing agent in PP/PLA composite. The mechanical properties of PP/PLA/OF cellulose composites were tested to analyze to the effect of cellulose fibers aspect ratio on composite mechanical properties.

A. Morphology characteristics of fibrillated cellulose fibers

Scanning electron microscope (SEM) images of fibrillated OPF cellulose fiber are demonstrated in Fig. 1. After undergo fibrillation in high speed blender for 3 min, the OPF cellulose fibers diameter (Figure 1a, 1b) were 5.2 ~ 7.3 μm . Whereas fibrillation for 12 min, resulted in fibrillated fibers with smaller diameter which 4.5 ~ 5.2 μm . It is noteworthy that fibrillation in high speed blender (agitation speed of 16,000 rpm) for 12 min, caused severe damage on cellulose fiber surface.

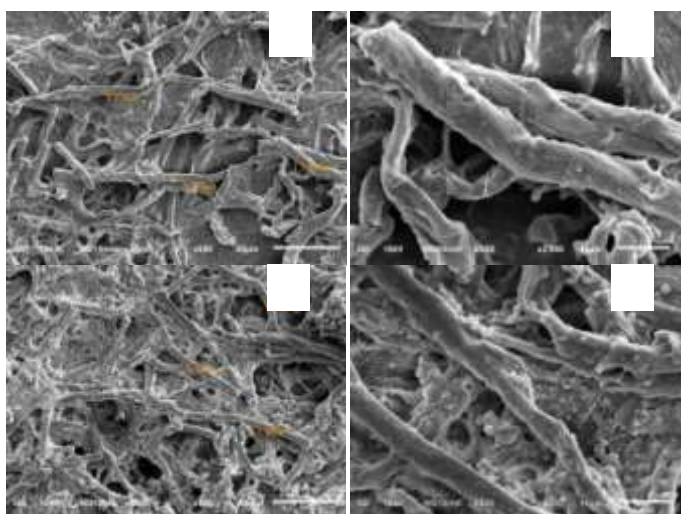


Fig 1. Fibrillated OPF cellulose fibers morphology: (a) 3min fibrillation, 500x mag, (b) 3min fibrillation, 2000x mag, (c) 12min fibrillation, 500x mag, (d) 12 min fibrillation, 2000x mag

In OPF soda pulping, OPF strand were reacted with sodium hydroxide to eliminate lignin (delignification process). However, soda pulp still contain hemicellulose and residual lignin, therefore the bleaching and purifying procedure were conducted to obtain OPF cellulose fibers. During pulping, OPF strands were subjected to high alkaline concentration and high temperature condition. And afterward, bleaching, purifying and further bleaching processes also conducted in high temperature. Those process successful to eliminate lignin and hemicellulose, however its affected in the cellulose structure stability, especially at 16,000 rpm agitation.

B. Mechanical Properties of PP-PLA-Fibrillated Cellulose Fibers Composites.

Tensile strength of PP/PLA composite filled with fibrillated OPF cellulose fibers which produced by various time of agitation and at constant agitation speed of 16,000 rpm are illustrated in Figure 2. Actually neat PP exhibited high tensile strength which was 31.76 N/mm². The lower tensile strength of PP/PLA composite (11.20 N/mm²), was indicating an immiscible PP/PLA blend. Afterward the addition of fibrillated OPF cellulose fibers could improved composite tensile strength.

PP is a hydrophobic material, whereas cellulose fibers is a hydrophilic material. The common procedure to incorporate cellulose fibers into PP matrix is by drying and reducing cellulose fibers size, as first step to obtain less hydrophilic cellulose fibers. Some procedures to prepare cellulose fibers prior to incorporate into PP matrix are by making pellet from bleached pulp fiber of softwood (Bengtsson *et al.* 2007), or milling freeze-dried rice straw fibril (Wu *et al.* 2012), or milling oven dried-oil palm empty fruit bunch fibers (Khalid *et al.* 2008). Those procedures required drying process which will result in cellulose aggregation due to fiber-fiber bonding and increase the average lateral fibril dimensions (Hult *et al.* 2001). In this study, we try to reduce cellulose diameter by fibrillation process then to incorporate never dried-fibrillated cellulose into PLA matrix to prevent cellulose fibers agglomeration prior to incorporate PLA/cellulose fibril compound into PP matrix.

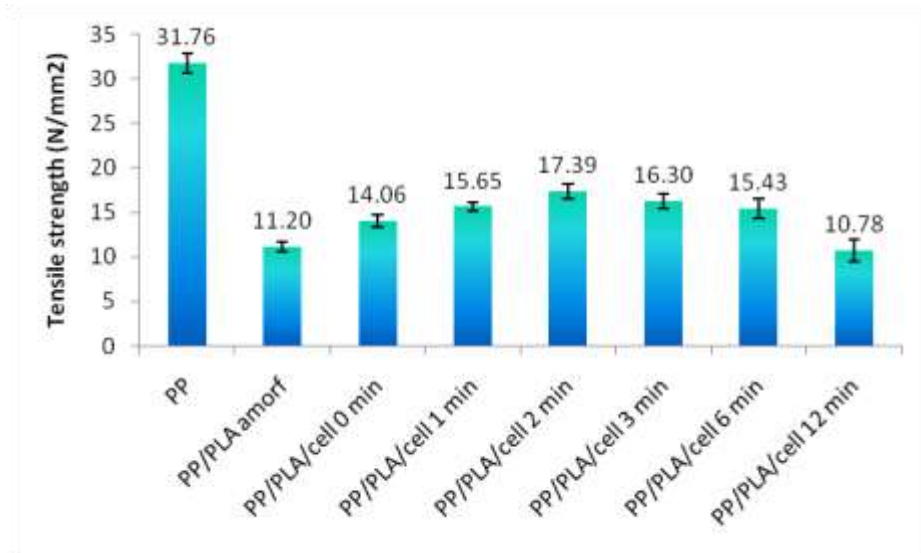


Fig 2. Tensile strength PP/PLA/OPF cellulose fibers composite's

The addition time of cellulose fibrillation until 2 minutes agitation at 16,000 rpm, gave an increment in composite tensile strength by 55.26% because of the reduction of cellulose fibers diameter. This improvement in tensile strength of the composites was due to the increment of fiber's aspect ratio (fiber length per fiber diameter) after fibrillation process. However, high speed agitation by 12 min, has a tendency to reduce fiber aspect ratio due to the reduction of fiber length were more intense than that of the reduction of fiber diameter, subsequently effected the lowering of composite tensile strength.

The mechanical properties of injection molded short fiber reinforced polymer (SFRP) depend critically on fiber length distribution (FLD) and fiber orientation distribution (FOD) (Fu and Lauke 1996). The critical fiber length was that the fiber length which was required for the fiber to develop it's fully stressed condition in the matrix. If the fiber length was much longer than the critical fiber length, it was difficult to maintain the shape of the original fiber due to the entanglement and overlapping of fiber during mixing process. Also, these problems led to an uneven distribution of fiber in the matrix. (Lee and Ryu 1999). The critical fiber length (L_c), is given by $L_c = r_f \sigma_{cu} / \tau_i$, where σ_{cu} is the ultimate strength of composite, τ_i and r_f are the interfacial shear stress between matrix and fiber and the fiber radius, respectively (Fu and Lauke 1996).

The tensile modulus of PP/PLA composite filled with fibrillated OPF cellulose fibers which produced by various time of agitation and at constant agitation speed of 16,000 rpm are presented in Figure 3. The blend of PP/PLA presented lower tensile modulus (959 N/mm²) than that of neat PP (1250 N/mm²). The addition of fibrillated OPF cellulose fiber which was agitated at 16,000 rpm by 3 min could improved composite tensile modulus (1060 N/mm²). However fibrillated OPF cellulose fibers which were agitated by longer time than 3 min, resulted in lower composite tensile modulus.

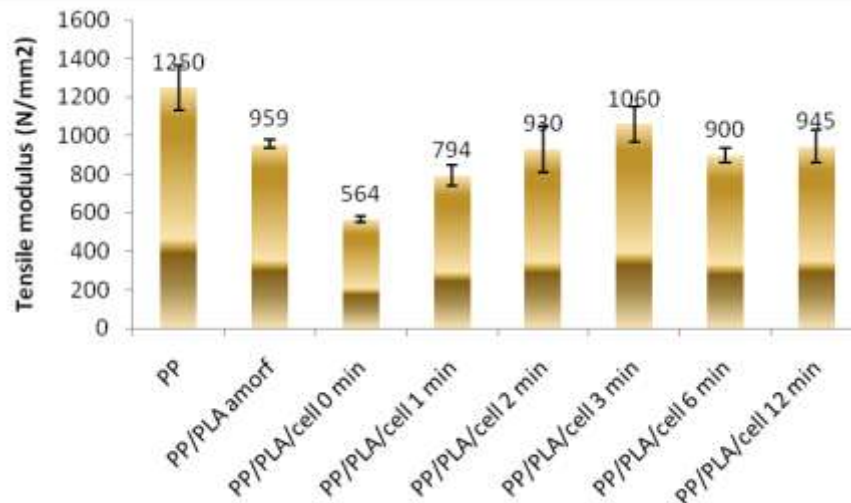


Fig 3. Tensile modulus of PP/PLA/OPF cellulose fibers composite's

Generally, the effect of short fiber reinforcement on the Young's modulus of thermoplastic matrix is governed by the following parameters: fiber dispersion, fiber concentration (fiber fraction), fiber orientation, fiber aspect ratio and fiber intrinsic rigidity (Lopez *et al.* 2012). The decrease of tensile modulus was probably caused by the poor condition of fiber dispersion due to incompatibility between PP (hydrophobic), PLA and OPF cellulose fibers (hydrophilic). Non-compatible polymer blend resulting some boundaries between the two polymeric phases, which the applied stress could not be efficiently transferred through the interface of blended component (Ploypetchara *et al.* 2014), then become the initial composite fracture. One of the solution to overcome that incompatibility blending is by employing a compatibilizer agent such as polypropylene-grafted-maleic anhydride (PP-g-MA). The compatibilization could achieve optimization of the interfacial tension, stabilize the morphology and enhance adhesion between the phases in the solid state (Ploypetchara *et al.* 2014).

To understand the effect of agitation time on the tensile properties of PP/PLA composite filled with fibrillated cellulose fibers, the fibrillation process were conducted at lower agitation speed that of 8,000 rpm. The tensile properties of PP/PLA/fibrillated OPF cellulose at various agitation speed were exposed in Figure 4.

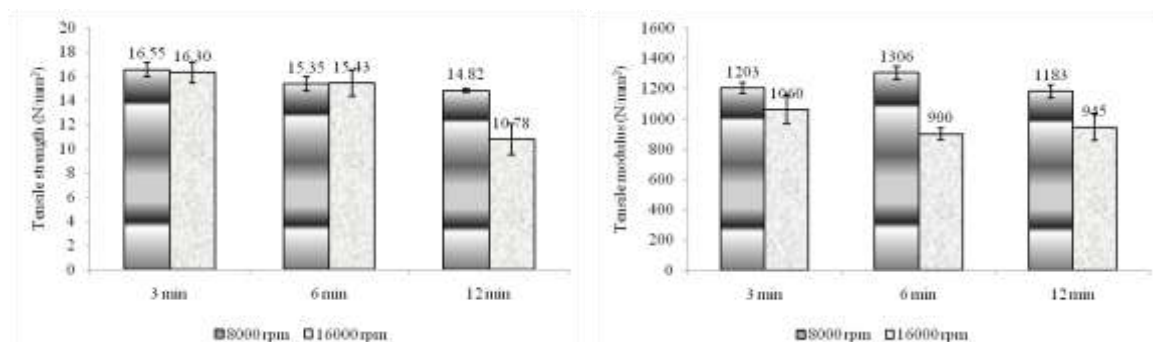


Fig 4. Tensile strength and modulus of PP/PLA composite filled with fibrillated OPF cellulose fibers by various agitation speed

The tensile strength and tensile modulus of composite PP/PLA filled with OPF cellulose fibers which were fibrillated at agitation speed of 16,000 rpm were lower than that of composite filled with fibrillated OPF cellulose fibers at agitation speed of 8,000 rpm. At agitation speed of 16,000 rpm, high centrifugal force from high speed blender agitation tend to reduce the length OPF cellulose fibers instead of disintegrate fiber along its diameter, so therefore produced OPF cellulose fibers with lower aspect ratio.

Actually, the technology of using high speed blender to produce cellulose nanofiber has been performed by Uetani and Yano. In 2011 they observed the process of nanofibrillation never-dried wood pulp using high speed blender. They clarified that the straw-like pulp was fibrillated in a very characteristic way, by

forming many "balloon-like structures". As the balloons extended to the edges, the fibrils were rapidly individualized. However, the pulp fragments with ripped cell walls were split into finer fragments and gradually disintegrated into nanofibers.

Fibrillation technique to produce cellulose fibers with high aspect ratio could be conducted by using high speed blender. However it should be noticed that agitation speed and pulp concentration influenced the success of fiber fibrillation.

CONCLUSION

Fibrillation at 16,000 rpm of agitation speed for 3 min produced OPF cellulose fibers with diameter of 5.2 ~ 7.3 μm . Whereas fibrillation for 12 min, resulted in fibrillated fibers with smaller diameter which were 4.5 ~ 5.2 μm . Cellulose fibrillation at agitation speed of 16,000 rpm produced shorter cellulose fibers than that of agitation speed of 8,000 rpm, subsequently generate composite with lower tensile properties. The composite tensile properties also influenced by interfacial adhesion between PLA and PP as hybrid matrix.

ACKNOWLEDGEMENTS

This work was supported by a Research Grant from the Education Fund Management Institution (LPDP) and LIPI Research Competitive Program. The first author thanks the Ministry of Science and Technology for awarding her a scholarship through-out her Ph.D programme.

REFERENCES

- Bengtsson M, Le Baillif M, Oksman K. 2007. Extrusion and mechanical properties of highly filled cellulose fibre–polypropylene composites. *Composites: Part A*, 38: 1922–1931.
- Cheng Q, Wang S, Han Q. 2010. Novel Process for Isolating Fibrils from Cellulose Fibers by High-Intensity Ultrasonication. II. Fibril Characterization. *Journal of Applied Polymer Science*, Vol. 115, 2756–2762.
- Chinga-Carrasco G. 2011. Cellulose fibres, nanofibrils and microfibrils: The morphological sequence of MFC components from a plant physiology and fibre technology point of view. *Nanoscale Research Letters* 2011, 6:417. Available online: <http://www.nanoscalereslett.com/content/6/1/417>.
- F. A. Syamani, L. Astari, Subyakto, Sukardi, A. Suryani. 2013. Characteristics of Strands and Pulp from Oil Palm Fronds and Vetiver Roots. Proceeding of the 2nd International Symposium for Sustainable Humanosphere, pp 1-7.
- Fu SY, Lauke B. 1996. Effect of fiber length and fiber orientation distribution on the tensile strenght of short-fiber-reinforced polymers. *Composite Sci and Technol*, 56:1179-1190.
- Henriksson M. 2008. Cellulose nanofibril networks and composite; Preparation, structure and properties. Thesis. KTH Chemical Science and Engineering. Available online: https://www.kth.se/polopoly_fs/1.111933!/Menu/general/column-content/attachment/henriksson%20phd.pdf.
- Hrabalova M, Schwanninger M, Wimmer R, Gregorova A, Zimmermann T, Mundigler N. 2011. Fibrillation of Flax and Wheat Straw Cellulose: Effect on Thermal, Morfological and Viscoelastic Properties of Poly(VinylAlcohol)/Fibre Composites. *BioResources*, 6(2), 1631-1647.
- Hult. E.L., Larsson. P.T., Iversen. T, 2001, Cellulose fibril aggregation-an inherent property of kraft pulps, *Polymer* 42: 3309-3314.
- Iwamoto S, Abe K, Yano H. 2008. The Effect of Hemicelluloses on Wood Pulp Nanofibrillation and Nanofiber Network Characteristics. *Biomacromolecules*, 9, 1022–1026
- Khalid M, Ratnam CT, Chuah TG, Ali S, Choong TSY. 2008. Comparative study of polypropylene composites reinforced with oil palm empty fruit bunch fiber and oil palm derived cellulose. *Materials and Design*, 29:173-178.
- Lee DJ, Ryu SR. 1999. The influence of fiber aspect ratio on the tensile and tear properties of short-fiber reinforced rubber. ICCM12 Conference Paris July 99th 1999, paper 226 , ISBN 2-9514526-2-4.
- Lopez JP, Mutje P, Pelach MA, El-Mansouri NE, Boufi S, Vilaseca F. 2012. Analysis of the tensile modulus of polypropylene composites reinforced with stone groundwood fibers. *BioResources*, 7(1):1310-1323.

- Nuryati L, Waryanto B. 2014. Statistik Pertanian 2014. Pusat Data dan Sistem Informasi Pertanian. Available online: http://pusdatin.setjen.pertanian.go.id/tinymcpuk/gambar/file/statistik_pertanian_2014.pdf
- P. Zugenmaier. 2001. Conformation and Packing of Various Crystalline Cellulose Fibers, *Prog. Polym. Sci.*, 26: 1341-1417.
- Ployetchara N, Suppakul P, Atong D, Pechyen C. 2014. Blend of polypropylene/poly(lactic acid) for medical packaging application: physicochemical, thermal, mechanical, and barrier properties. *Energy Procedia*, 56:201-210.
- Ruland, W. 1961. Determination of crystallinity and diffuse disorder scattering. *Acta Crystallogr*, 14:1180-1185.
- Terinte, N., R. Ibbett, K.C. Schuster. 2011. Overview on native cellulose and microcrystalline cellulose I structure studied by x-ray diffraction (WAXD): Comparison between measurement techniques. *Lenzinger Berichte* 89: 118-131.
- Turbak AF, Synder FW, Sandberg KR. 1983. Microfibrillated cellulose, a new cellulose product: properties, uses and commercial potential. *J. Appl. Polym. Sci.*; Appl. Polym. Symp; 37:815-827.
- Uetani K, Yano H. 2011. Nanofibrillation of wood pulp using a high-speed blender. *Biomacromolecules.*, 12(2):348-53. doi: 10.1021/bm101103p.
- Vonk, C.G. 1973. Computerization of Ruland's X-ray Method for Determination of the Crystallinity in Polymers. *J. Appl. Crystallogr.* 6: 148-152.
- Wu Y, Zhou D, Wang S, Zhang Y, Wu Z. 2012. Polypropylene Nanocomposite Reinforced with Rice Straw Fibril and Fibril Aggregates. Di dalam: Dr. Fatih Dogan (Ed.), *Polypropylene*, InTech. Tersedia pada: <http://www.intechopen.com/books/polypropylene/polypropylene-nanocomposite-reinforced-with-rice-straw-fibril-and-fibril-aggregates>.
- Zimmermann T, Pohler E, Geiger T. 2004. Cellulose fibrils for polymer reinforcement. *Advanced Engineering Materials* 6 (9): 754-761.

EFFECTS OF DENSITY AND RESIN LEVEL ON THE PERMEABILITY AND WATER ABSORPTION OF KENAF-RUBBERWOOD PARTICLEBOARD

Juliana Abdul Halip,^{1,*} Paridah Md Tahir,^{1,2,*} Adrian Choo Cheng Yong,¹
Alinaghi Karimi Mazraehshahi¹

¹Institute of Tropical Forestry and Forest Products, 43400 Universiti Putra Malaysia,
Serdang, Selangor Darul Ehsan, Malaysia

²Faculty of Forestry, 43400 Universiti Putra Malaysia, Serdang, Selangor Darul Ehsan, Malaysia

*Corresponding authors: parida.introp@gmail.com; julianahalip@gmail.com

ABSTRACT

The aim of this study was to evaluate the effect of board density and resin level on the permeability and water absorption of particleboard made from rubberwood-kenaf blends. Kenaf whole stem particles were mixed with rubberwood particles at a ratio of 50:50 (w/w) to produce particleboards with three different densities (300, 500, and 700 kg/m³) and urea formaldehyde (UF) resin levels (6, 8, and 10%). Results show that the density and resin levels had significant effects on the permeability and water absorption of the particleboards: increased densities and resin levels resulted in lower permeability and water absorption. A clear relationship between the permeability and physical properties of particleboard was also discovered, where the decrease of permeability in the boards also caused lower water absorption values. Boards with low density were observed to have more voids and less compactness that may facilitate the penetration of water.

Keywords: Density, Resin level, Permeability, Water absorption, Kenaf, Rubberwood

INTRODUCTION

Particleboard consumption worldwide represented 57% of the total volume of panel products consumed (Drake, 1997). As reported by Nirdosha et al., (2009), based on Australian forest statistics, particleboard consumption in Australia has increased by 7% during the year 2001. In Malaysia, rubberwood has been used in particleboard manufacture for decades. Traditionally, particleboards in Malaysia have been manufactured from rubberwood (*Hevea brasiliensis*) and other hardwood species. The demand for rubberwood for the panel and furniture industries is estimated to be 2,000,000 m³ annually and currently, rubber plantation areas have been decreasing year by year (NATIP 2009; Department of Statistics, 2010). One of the alternatives to overcome the shortage of raw material is to use other types of natural fibres such as kenaf (*Hibiscus cannabinus* L.).

The kenaf plant belongs to family of *Malvaceae*, and fibres can be extracted from the bast of stems of these plants (Rowell and Stout 2007). The kenaf stalk consists of two distinct parts, the core and the bast. The bast makes up 30 to 40% of the plant weight and is made up of long and coarse fibres, while the core makes up 60 to 70% of the plant weight and has short fibres. A study carried out by Voulgaridis et al. (2000) found that the microscopic appearance and cells of the bast are thick fibres, while the appearance of the kenaf core is similar to those observed in many diffuse-porous hardwoods. Kenaf caught the interest of many researchers due to its fast maturity and good fibre quality, and the main applications would be for fibre-based products such as particleboards.

Particleboard manufacture has been studied by numerous researchers (Seller et al., 1993; Grigoriou et al., 2000; Kalaycioglu & Nemli, 2006; Juliana et al., 2012). Nonetheless, most of the studies reported mainly on the bending strength, bonding strength, and swelling of particleboard, but few studies have been carried out on the permeability of particleboards. Dinwoodie (2000) stated that permeability is simply the quantitative expression of the bulk flow of fluids through a porous material. Several studies have found a positive relationship between particleboard properties and board density and resin level (Cai et al., 2004; Li et al., 2010; Loh et al., 2010). This study evaluated the effect of board density and resin level on the permeability and water absorption of particleboards made from rubberwood-kenaf blends.

MATERIALS AND METHODS

Panel Manufacture

Four to five month-old kenaf (*Hibiscus cannabinus* L.) stems were supplied by the National Kenaf and Tobacco Board (NKTB), located in Kelantan, Malaysia. After the kenaf whole stems were harvested, they were chipped using a laboratory Pallmann Mini Chipper and then flaked in a Pallmann Ring Knives Flaker to produce fine kenaf particles. The particles were then dried to 5% moisture content in an industrial oven. Afterwards, the dried particles were sieved through a vibrating screener and kenaf whole stem particles ranging in diameters from 0.5 to 2.0 mm were used in manufacturing particleboards. Rubberwood particles were obtained from the Institute of Tropical Forestry and Forest Products, Universiti Putra Malaysia. These particles were also screened and classified using a vibrator screen, and only particles with diameters in the range of 0.5 to 2.0 mm were used to produce the control panel samples.

A total of 27 boards of size 340 mm x 340 mm x 12 mm, comprising nine types of particleboards, were manufactured for the experiment. The particles were mixed with a weight ratio of 50% rubberwood particles and 50% kenaf whole stem particles with varying percentages (6%, 8%, and 10%) of urea formaldehyde (UF) in a rotating drum equipped with a pressurized resin spray gun. The furnish was placed in a 340 mm x 340 mm wood former and pre-pressed manually prior to hot pressing. Upon the removal the former, the mat was consolidated in a hot press set at a temperature of 160 °C for 6 min. The densities of all experimental particleboards were controlled at three values, which were 300, 500, and 700 kg/m³. The boards were then conditioned at a temperature of 20 °C and a relative humidity of 65% for one week before being cut into test specimens.

Evaluation of Panel

Physical tests were conducted according to the related standard methods of the Japanese Industrial Standard JIS A 5908 (2003), which specifies the board which are formed mainly from particles. These tests measures characteristics that include the water absorption (WA) of samples. Twelve specimens were taken from each type of particleboard (nine types), and the total for each test was 108 specimens. Gas permeability tests were carried out using the falling water displacement volume method (Siau 1995). The apparatus used to measure the gas permeability of the samples was similar to the apparatus used by Taghiyari and Samadi (2010) and Choo *et al.* (2013). The data were then analysed statistically using the Statistical Analysis System (SAS) software, using analysis of variance (ANOVA) and mean separation using the least significant difference (LSD) method. The level of significance (α) was set for all statistical tests at 0.05, such that a probability of less than 0.05 is taken as indicative of a statistically significant difference.

RESULTS AND DISCUSSION

Properties of Single-Layer Particleboards

Table 1 shows the physical properties, namely permeability, thickness swelling, and water absorption, of particleboards made from a mixture of kenaf and rubberwood. From Table 1, it can be seen that board density has a greater influence on the physical properties compared to resin level.

Table 1. Some Physical Properties of Kenaf-Rubberwood Particleboard (50:50 Ratio)

Density (kg/m ³)	Permeability (Darcy)			Water Absorption (%)		
	6%	8%	10%	6%	8%	10%
300	0.451	1.540	1.120	204	192	176
500	0.094	0.062	0.040	143	120	114
700	0.004	0.003	0.002	90	93	68

From Table 2, it can be seen that the density, the resin level, and the interaction between them all significantly affect the other physical properties of kenaf-rubberwood particleboards, such as the permeability and WA.

Table 2. ANOVA Summary Table for Significant Differences in Effects of Density and Resin Level on Permeability and Water Absorption Properties

Source	Df	Permeability	Water Absorption
Density	2	0.0001 ***	0.0001 ***
Resin level	2	0.0002 ***	0.0001 ***
Density*Resin level	4	0.0001 ***	0.0048 ***

Note:

ns Not significant

*** Significantly different at $p \leq 0.01$

Figure 1 shows the permeability values of kenaf-rubberwood particleboards at different densities and glue contents. It is clear that as the density of the particleboards increases, the permeability decreases; from Table 2, it can be observed that the difference is clearly significant between the densities and this finding was similar to study done by Saad and Izran (2012). Particleboards with higher densities have a lower amount of pores, and this accounts for the lower permeability values found in those boards. For the 500- and 700-kg/m³ samples, the permeability decreases as the resin level increases. The increase in the resin level results in fewer connections between pores in the particleboards. When the connections between pores are reduced, fluid flow is hampered and the permeability drops. However, this trend is not clear in the 300-kg/m³ particleboards.

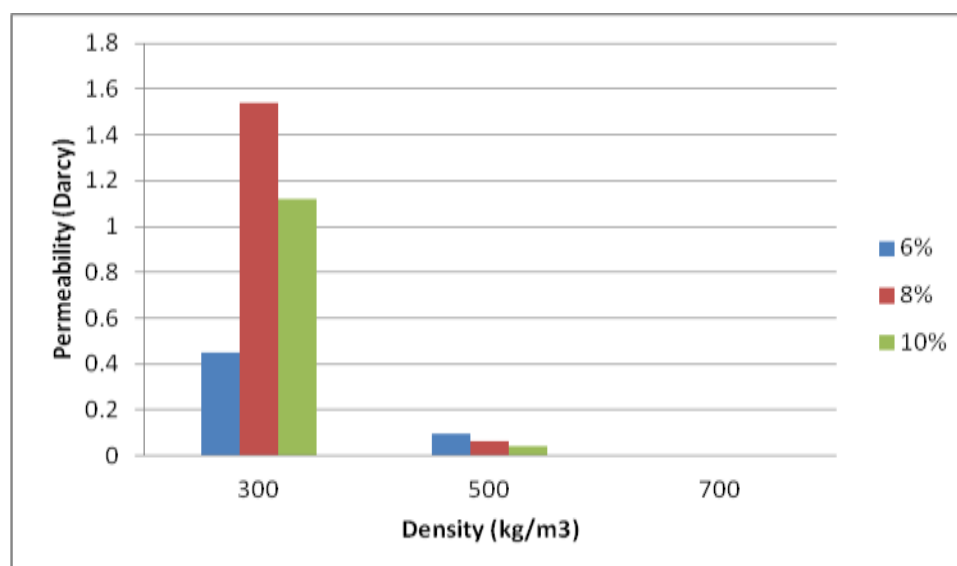


Fig. 1. Permeability values of kenaf-rubberwood particleboards at different densities and glue contents

The increase in density and resin level results in a decrease in water absorption as can be seen in Fig. 2. From the values in Fig. 2, the 6% resin content was inferior to the other ones for and consequently illustrated higher percentage of water absorption compared to 8% and 10%. Based on study carried out by Mendes *et al.* (2009), particleboard with higher adhesive contents were superior in term of physical properties compared to lower adhesive contents. The lowest permeability values were found in 700-kg/m³ boards with a 10% resin level, and the water absorption value was lowest here, at only 68%. The decreasing trend is in line with the decreasing trend of permeability. Particleboards with higher density have a lower amount of pores compared to particleboards with lower densities. Furthermore, a lower permeability value also indicates a lack of connection between the pores in the particleboard. These compounded facts result in lower water absorptions. When there is a higher UF content in the particleboards, the connection between pores is further blocked, which further reduces the amount of water absorbed.

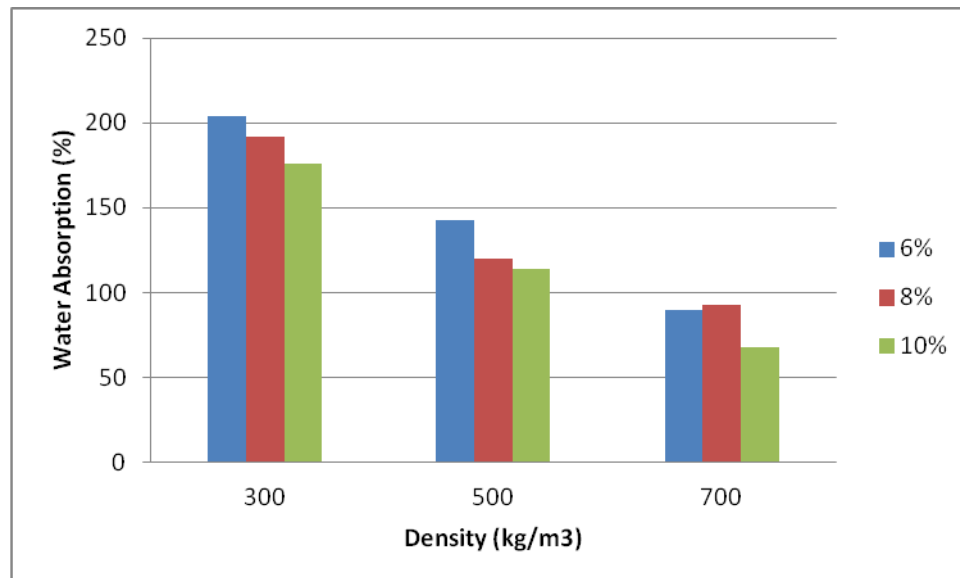


Fig. 2. Water absorption of kenaf-rubberwood particleboards at different densities and glue contents

From observation, less compaction and more voids were observed in panels with densities of 300 and 500 kg/m³. Therefore, more void spaces increases water uptake and swell the specimens. This is in agreement with a previous study (Saad and Izran 2011) that reported that lower-density panels, which consist of more voids, had higher TS and WA values.

CONCLUSIONS

The decrease of permeability in the boards also resulted in a lower water absorption rate. The density and the resin level also had significant effects on the permeability and water absorption of the particleboards. An increase in density and resin level results in lower permeability and water absorption values.

ACKNOWLEDGMENTS

The authors thank the EPU Kenaf scheme grant, Office of the Prime Minister of Malaysia, for their financial support. The authors also acknowledge the Institute of Tropical Forestry and Forest Products (INTROP) and Universiti Putra Malaysia for their contribution to this project.

REFERENCES

- Cai, Z., Wu, Q., Lee, J. N. and Hiziroglu, S. (2004). Influence of board density, mat construction, and chip type on performance of particleboard made from eastern red cedar, *Forest Product Journal* 54(12): 7.
- Choo, A. C. Y., Paridah, M. T., Karimi, A., Bakar, E. S., Khalina, A., Azmi, I., and Balkis, F. A. B. (2013). Study on the longitudinal permeability of oil palm wood, *Industrial & Engineering Chemistry and Research* 52(27), 9405-9410.
- Department of Statistics. 2010. *Getah*. Department of Statistic Malaysia: Kuala Lumpur. Retrieved on 1/04/2013 www.statistics.gov.my/portal/download_Economics/files/DATASERIES/2009/Bab9Getah.pdf
- Dinwoodie, J. M. (2000). *Timber: Its Nature and Behavior, Second Edition*, Taylor & Francis, New York.
- Drake, P.A. (1997). The composite panel industry: A global market assessment. In: Proceedings of 31st International particleboard/composite materials symposium, Washington State University, Pullman, Washington.
- Grigoriou, A., Passialis, C. and Voulgaridis, E. (2000). Kenaf core and bast fibre chips as raw material in production of one-layer experimental particleboard, *Holz als Roh- und Werkstoff Journal* 58: 290-291.

- Japanese Industrial Standard, JIS A 5908: 2003 (E).* (2003). Particleboards. Japanese Standards Association. Tokyo, Japan.
- Juliana, A. H., Paridah, M. T., Rahim, S., NorAzowa, I., and Anwar U. M. K. (2012). Properties of particleboard made from kenaf (*Hibiscus cannabinus* L.) as function of particle geometry. *Journal of Materials and Design*, 34: 406–411
- Kalaycioglu, H. and Nemli, G. (2006). Producing composite particleboard from kenaf (*Hibiscus cannabinus* L.) stalks, *Journal of Industrial Crops and Products* 24: 177-180.
- Li, X., Cai, Z., Winandy, J. E. and Basta, A. H. (2010). Selected properties of particleboard panels manufactured from rice straws of different geometries, *Bioresource Technology Journal* 101: 4662–4666.
- Loh, Y. W., H'ng, P. S., Lee, S. H., Lum, W. C. and Tan, C. K. (2010). Properties of particleboard produced from admixture of rubberwood and mahang species, *Asian Journal of Applied Science* 3: 310-316.
- Mendes, R. F., Mendes, L. M., Junior, J. B. G., Santos, R. C. D., and Bufalino, L. (2009). The adhesive effect on the properties of particleboards made from sugar cane baggase generated in the distiller, *Revista de Ciências Agrárias*, 209-210.
- NATIP: National Timber Industry Policy 2009-2020. (2009). Ministry of Plantation Industries and Commodities Malaysia, 1-128.
- Nirdosha, G., Setunge, S., Jollands, M., & Hague, J. (2009). Properties of hardwood saw mill residue-based particleboards as affected by processing parameters. *industrial crops and products*, 29(1), 248-254.
- Rowell, R. M. and Stout, H. P. (2007). Jute and kenaf. in: *Handbook of Fiber Chemistry*, M. Lewin (ed.), Taylor & Francis, New York.
- Saad, M. J. and Izran, K. (2012). Mechanical and physical properties of low density kenaf core particleboards bonded with different resins, *Journal of Science and Technology* 4(1), 17-32.
- Sellers, T. J., Miller, G. D. and Fuller, M. J. (1993). Kenaf core as a board raw material, *Forest Products Journal* 43: 69-71.
- Siau, J. F. (1995). *Wood: Influence of Moisture on Physical Properties*, Department of Wood Science and Forest Products: Virginian Polytechnic Institute and State University, Blacksburg.
- Taghiyari, H. R. and Samadi, Y. S. (2010). Ultimate length for reporting gas permeability of *Carpinus betulus* wood, *Special Topics & Reviews in Porous Media-An International Journal* 1(4), 345-351.
- Voulgaridis, E., Passialis, C., and Grigoriou, A. (2000). Anatomical characteristics and properties of kenaf stems (*Hibiscus cannabinus*), *IAWA Journal* 21(4), 435-442.

PERFORMANCE MEASUREMENTS OF OIL PALM STEM AS POTENTIAL RAW MATERIAL IN CERTIFIED PLYWOOD PRODUCTION

Aida Adnan¹, Paridah Md.Tahir¹, Rosli Saleh² and Khamuruddin Mohd. Nor³

¹ Institutes of Tropical Forestry and Forest Products, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, MALAYSIA

²Faculty of Entrepreneurship and Business, Universiti Malaysia Kelantan, Pengkalan Chepa, 16100 Kota Bahru, Kelantan, MALAYSIA

³Faculty of Forestry, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, MALAYSIA

ABSTRACT

Timber certification has becoming an important and growing phenomenon in forestry sector all over the world. It is generally regarded as a measurement stick for a company to show commitment towards the efforts of implementing well managed forest. Two certification schemes used in Malaysia, Forest Stewardship Council (FSC) and Programme for the Endorsement of Forest Certification (PEFC)¹. Oil Palm Stem (OPS), a non-wood material, including residues from oil palm plantations, was considered as an alternative raw material source for certified product with the fact that it is much cheaper than wood. In certification, OPS is categorised as “neutral material” under the PEFC and “non-forest base material” by FSC whereby it is not included in the calculation of certified wood content in certified product. The main objective of the study was to assess OPS plywood performance using “Property-Cost Index (PCI)” as a measurement tool. The study proven that the properties of OPS plywood produced can perform significantly better, provided that the OPS veneer undergone a resin pre-treatment after veneer drying. PCI result shows that the production of OPS plywood (with resin pre-treatment) is better (1.76) than plywood produced using 100% wood as raw material (1.57).

Keywords: *Certified wood, chain of custody, oil palm stem, oil palm plywood, property-cost index*

INTRODUCTION

Since year 2009, there are an increasing number of oil palm plantation areas in Malaysia. Every year the number of mature tree which ready to be harvested was also increase as shown in Table 1 below. Paridah and Loh (2009) in the 2009 Annual Timber Research and Industry Briefing reported that annually there are about 13.6 million of oil palm stems being harvested which turn into source of non-wood fibre materials that could be used as raw material for plywood production. Base on this information and the increasing hectare of mature oil palm tree every year, it is obvious that the supply and availability of oil palm stem in Malaysia is encouraging.

Table 1. Oil Palm Plantation area, mature tree area and estimated Oil Palm stem available in Malaysia

Year	Oil Palm Area (mil. Ha)	Mature Tree (mill. Ha)	Estimated Oil Palm Stem available (mill. logs)
2013	5.23	4.53	16.63
2012	5.08	4.35	15.96
2011	5.00	4.28	15.71
2009	4.20	3.70	13.60

Source: MPOB, 2013, 2012, 2011 and Paridah & Loh, 2009

¹PEFC endorses national timber scheme where in Malaysia know as the Malaysian Timber Certification Scheme (MTCS)

Performance measurement

Despite its availability, use of OPS as non-wood fibre material for plywood production arise questions on its performance in term of quality or property of OPS plywood produced and its production cost as well as its measurement issue. Performance measurement is the process of quantifying action, where measurement is the process of quantification and action leads to performance. It can be defined as the process of quantifying the efficiency which might reduce the cost incurred through decreased failure and effectiveness of action by achieving a higher level of product reliability (Neely, Gregory & Platts, 1995). It is in close relations with a new product development process. To ensure business survival through reduce time to market, increased quality and reduce cost, effectively managing and measuring the product development process is a vital process in performance measurement (Pawar & Driva, 1999). In timber industry, there is none or very limited evidence of work being conducted and availability of its related references in relations to performance measurement for new product development. Thus, in conducting this study a hybrid approach between *performance measurement* and *concept selection*, applied in product design development was used to derive a so called Property Cost Index (PCI) as a performance measurement for OPS plywood production. This study was conducted to introduce Oil Palm Stem (OPS) as an alternative raw material for plywood production particularly to certified plywood mill. In timber certification, the use of OPS is an advantage due to the fact that OPS is considered as 'Neutral material' under the MTCS (or PEFC) and 'Non-forest based material' under the FSC scheme. Thus, the use of OPS as raw material will not contribute to volume calculation of certified material content in certified product, and is also exempted from chain of custody (CoC) control requirements (FSC, 2011 & PEFC, 2013).

Objective

The main objective of the study was to assess OPS plywood performance using "Property-Cost Index (PCI)" as a measurement tool by evaluating the average production cost and mechanical properties of plywood produced using 100% certified wood and OPS mixed material.

METHODS

An experimental research design was employed in the study where a plywood mill which has the ability to produce plywood made of wood mixed with OPS as raw materials was chosen to conduct the production of plywood made from OPS. Raw material cost, production cost and other related costs as well as technical properties of plywood produced were recorded accordingly. A Plywood mill which has the ability to produce plywood made of wood mixed with OPS was selected. The Central Kedah Plywood Sdn. Bhd. was chosen for the study as it has the most systematic processing line for OPS plywood production. The study was divided into two stages. First stage was the production of plywood using MLHW (Figure 1) and OPS mixed plywood with MLHW veneer as face and back material (Figure 2) through conventional production method. The second stage was to establish a Property Cost Index (PCI) as performance measurement for the production of OPS plywood.

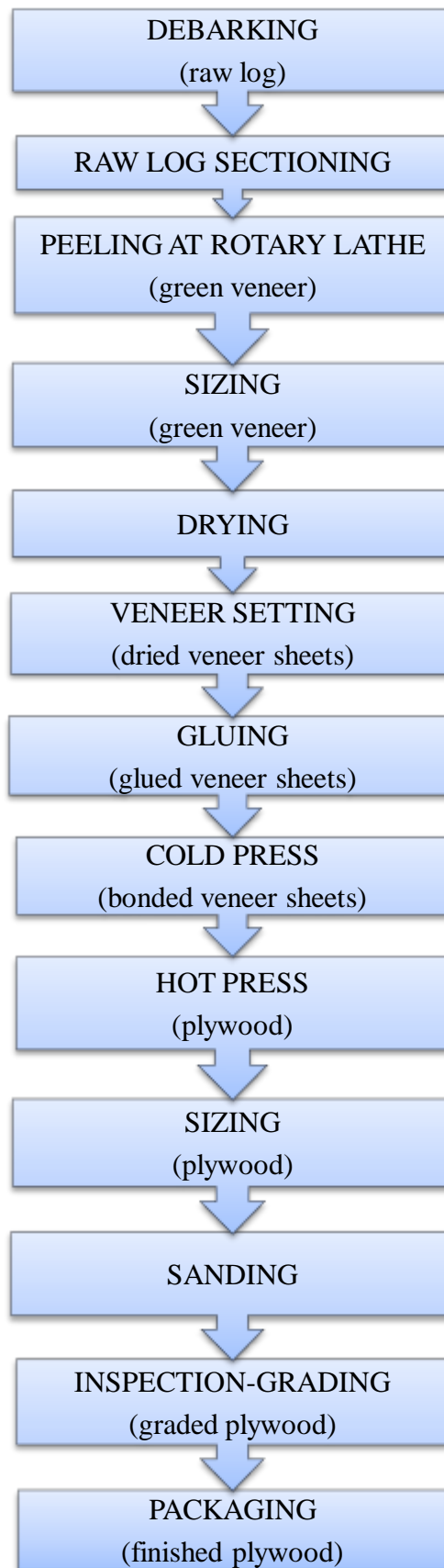


Figure 1. Typical process flow of conventional plywood production method using MLHW

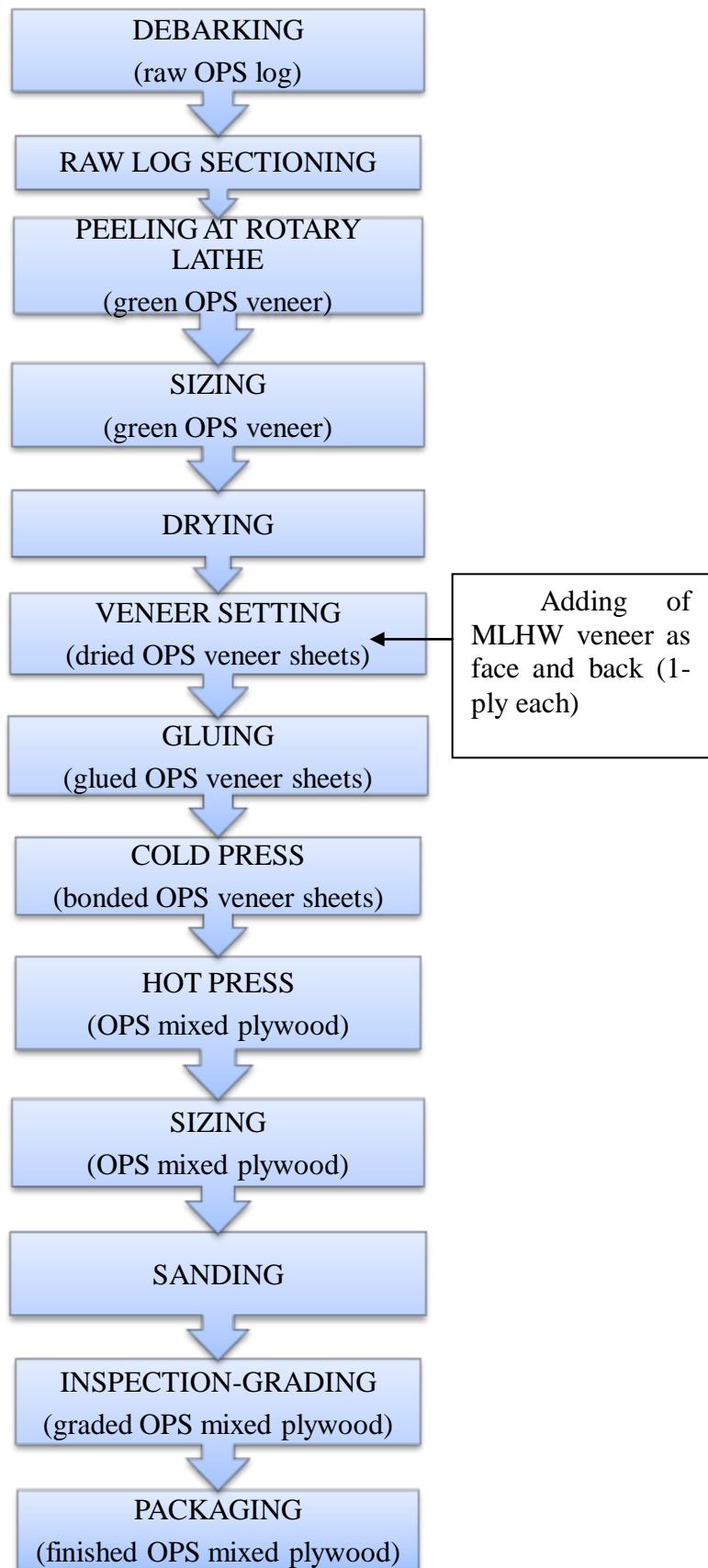


Figure 2. Process flow of OPS mixed plywood production using conventional production method.

Production cost analysis

Data on various components of production cost including investments, fixed and variable costs as well as sales was obtained by interviewing the mill manager and relevant key personnel. These include data on physical unit of fixed input acquired such as land, building, vehicles and equipment; variable input utilised including labour, materials and utilities; finished product which is OPS plywood, and data on price per unit of the fixed inputs, variable input and type of finished product produced. The average estimates of the fixed and variable production cost of OPS plywood was gained by computing the fixed and variable costs, sales and profit margin. The components of fixed and variable costs, and sales were obtained by multiplication of per unit price with number of units of fixed and variable inputs, and finished product. Whilst, profit margin was computed by deducting the fixed and variable costs of finished product from its sales figure. Finally the production cost was calculated according to the following production approach:

1. production of plywood produced using certified MLHW through conventional production method;
2. production of OPS mixed plywood (with MLHW as face and back veneer) through conventional production method.

Establishment of property cost index (PCI)

The process of establishing a Property Cost Index (PCI) was based on product design and development concept which is widely used in the engineering sector for concept selection purpose in new product development process. It is however was never been used in timber industry before thus, there are very limited references available with regards to the topic. A *normative model of conceptual design and evaluation* (Figure 3) approach was used as reference where concept evaluation is a predecessor to concept selection. The conceptual design phase is completed if a concept is selected base on it performance during the evaluation (Nikander, 2014).

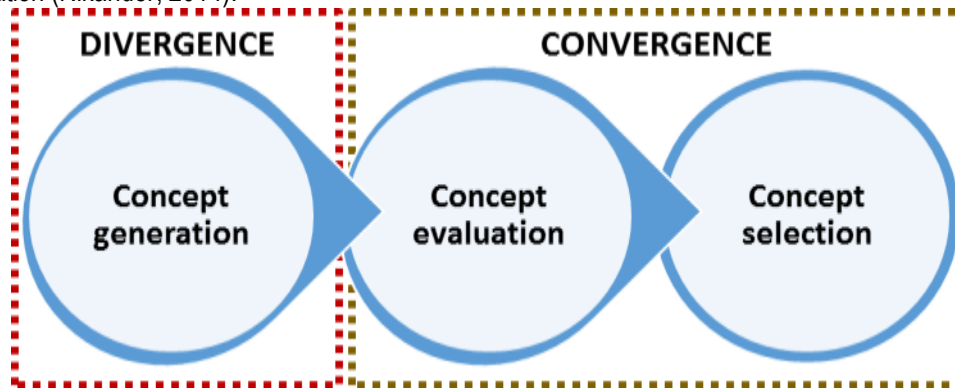


Figure 3. The normative model of conceptual design and evaluation
(Source: Nikander, 2014)

In this study the focus was concentrated on concept selection process where decision matrices method was selected since it is the most preferred method according to Ulrich and Eppinger (2008). It involves two-stage process which is concept screening and scoring.

Concept used for screening and scoring

"Weighting Scoring Method" is a process by which the units in a sample are assigned numeric values (weights), representing the contribution they will make to the population. In other word, the sample units in defines sense represent the population (Lynn, 2005). Industrial standards including British and Japanese standard together with 50 journals related to plywood strength test were reviewed to determine type of mechanical properties tested for structural plywood. It was found that Modulus of Rupture (MOR), Modulus of Elasticity (MOE), Weather Boil Proof (WBP) Shear, and Dry Shear test are the bonding and mechanical properties commonly used in plywood strength test. Each of these properties was assigned with a numerical value represent it priorities in determining plywood strength as shown in Table 2. Prior to that experts advise in plywood property was sought to confirm the right weight with the right value was assigned to each property as according to Delphi Method where opinion from group of experts was obtained through interrogative communications (Hsu and Sandford, 2007).

Table 2. Weighting factor assigned to each strength property of plywood according to priority

Mechanical testing property	Weightage
MOE	0.30
MOR	0.30
WBP Shear	0.30
Dry Shear	0.10

A matrix table was produced to incorporate data collected from the 2-types plywood production and raw material uses with their property weighted score as shown in Table 4. The total score for each production method and raw material used is the sum of the property weighted scores (Ulrich, 2000):

$$S_j = \sum_{i=1}^n r_{ij} w_{ij}$$

where;

r_{ij} = testing result of each property (j) for each production method

w_{ij} = weight for each property

i = 1

n = number of property tested

S_j = total weighted score for production method and raw material used

RESULTS AND DISCUSSION

Result of the study is described as according to data collection method which is divided into three sections: 1) Property of plywood produced; 2) Production cost, and 3) Property cost index (PCI).

Property of plywood produced

Property result recorded particularly for OPS mixed plywood and 100% OPS plywood achieved the minimum strength and bonding integrity stipulated in the BS EN standards as shown in Table 3.

Table 3. Strength and bonding property of plywood produced

Properties	OPS mixed plywood	MLHW Plywood
Modulus of Elasticity (MOE), MPa	5435	10200
Modulus of Rupture (MOR), MPa	35.40	63.10
Dry plywood Shear, MPa	1.04	1.60
WBP plywood Shear, MPa	Failed	0.78

Production cost

Following interview and research data on production, and after taking consideration on depreciation value of building, machinery and equipment assets, it was found that a production cost for certified MLHW plywood was RM1967.00 per m³ and OPS mixed plywood was RM934.56 per m³.

Property cost index (PCI)

Result of plywood property and production cost was incorporated into this section to establish a Property Cost Index (PCI) by developing a matrix and PCI table as tabulated in Table 4 and Table 5, respectively.

Table 4. Matrix created for each production method and raw material used

Production method and raw material used	Mechanical property ¹				Total weighted score ²
	MOE (MPa)	MOR (MPa)	WBP Shear (MPa)	Dry Shear (MPa)	
Weighted score ³	0.30	0.30	0.30	0.1	1
Conventional (certified MLHW) 100% wood	10200	63.10	0.78	1.60	
TOTAL	3060	18.93	0.23	0.16	3079.32
Conventional OPS (with Face/Back wood)	435	35.40	0	1.04	
TOTAL	1630.5	10.62	0	0.10	1641.22

Note: ² Total weighted score = a sum of (³ weighted score * ¹ mechanical property)

PCI is a division of total weighted score of property for each production method and raw material uses over production cost which was calculated as follows;

$$Property_i \text{ Cost Index (PCI)} = \frac{\text{Total Property}_i \text{ Weighted Score}}{\text{Production Cost}}$$

This equation was used as a performance measurement for OPS plywood production. This is in line with Leong's et.al. review on the manufacturing strategy literature (as cited in Neely, Gregory and Platts, 1995), who defined quality (property), cost, delivery speed, delivery reliability and flexibility are the key elements of manufacturing's performance. Preference for the best production method with raw material uses is given to the highest PCI results.

The property cost index, PCI, for both types of palm plywood is summarised in Table 5. The study shows that plywood production using OPS as core material and MLHW as face and back material (1.76) gives better PCI results compared to plywood produced uses 100% MLHW as raw material (1.57).

Table 5. Property Cost Index calculated for Conventional MLHW and Conventional OPS plywood

Production method and raw material used	Production cost (MYR/m ³)	Total weight score	PCI ¹
Conventional (certified MLHW) 100% wood	1967.00	3079.32	1.57
Conventional OPS (with Face/Back MLHW)	934.56	1641.22	1.76

Note: ¹Property Cost Index

In manufacturing activity, cost factor plays an importance role in decision making particularly when it involves changes in production system and/or production input. Plywood manufacturing is not exempted from the situation. Venturing into new production system or material requires thorough study and effort. Thus PCI could become a tool in helping plywood mill to focus on important factors which are cost and property, prior deciding any changes or new investment in the present system to proceed. PCI gives a better product's property and cost coordination whereby explicit evaluation of the plywood's property with respect to production cost helps to match the plywood's property with the manufacturing expenses of company. In addition, PCI reduce time to new production method or new product introduction. Its structured approach in decision making based on objective criteria helps decrease ambiguity, create faster communication and reduce false starts. It also minimise arbitrary or personal influence through effective group decision making. In addition, result of the decision process in obtaining the PCI can be documented. The production cost of OPS mixed plywood was found cheaper (MYR934.56 per m³) than production cost for certified MLHW plywood which was RM1967.00 per m³. In term of property values over cost (PCI), OPS mixed plywood also gives better PCI results than using MLHW alone for plywood production. Obviously, the study revealed that OPS is a potential and better alternative fibre material for plywood production. However, to use OPS alone in plywood production requires production system modification and new investment in order to get a good property results.

REFERENCES

- Ary, D., Jacobs, L.C., Razavieh, A. & Sorensen, C. (2006). *Introduction to research in education* (7th Edition). Canada: Thomson Wadsworth
- Baharuddin, H. G. (1995). Timber certification: an overview. *Unasyalva* 46, 18-24.
- Bartlett, J. E., Kotrlík, J. W., & Higgins, C. C. (2001). Organisational research: Determining appropriate sample size in survey research. *Information Technology, Learning and Performance Journal*, 19 (1), 43-50.
- European Tropical Forest Research Network (2007). *Models for Cost Effective Chain of Custody Certification*. Retrieved from <http://www.etfrn.org/ETFRN/workshop/certification/research2.html#up>
- Frank, G. (1998). *Cost of Production versus Cost of Production*. University of Wisconsin, Madison.
- Forest Stewardship Council (2011). *FSC Standard for Chain of Custody Certification (FSC-STD-40-004 V2-1 EN, 01 October 2011)*. FSC International Centre, Bonn, Germany
- Groves, M., Miller, F., & Donovan, R.Z. (1996). *Certification of Forest Products: Issues and Perspectives-Chain of Custody*. p.68. Island Press. Washington D.C
- Hansen, H., & Bratkovich, S. (2007). *Forest Certification in the Northeast and Midwest*. Retrieved from <http://na.fs.fed.us/spfo/pubs/forestprod/greencert/greencert.htm>
- Hurter, Robert W. (2007). *Non-Wood Fibre-2010 and Beyond Prospects for Non-wood Paper Production in Asia Pacific*. A keynote Address, Ontario, Canada.
- Hsu, Chia-Chen & Sandford, Brian A. (2007). The Delphi Technique: Making Sense of Consensus. *Practical Assessment Research & Evaluation*, 12(10). Retrieve from <http://pareonline.net/getvn.asp?v=12&n=10>
- Johnson, M., & Kirchain, R. (2009). Quantifying the effects of parts consolidation and development costs on material selection decision: A process-based costing approach. *International Journal of Production Economics*. 174-186
- Lloyd, Erwin H. and Seber, David (1996). *Bast Fibre Application for Composites*. Retrieved from <http://hempology.org/CURRENT%20HISTORY/1996%20HEMP%20COMPOSITES.html>
- Lynn, P.J. (2005). Weighting. *Encyclopedia of Social Measurement*. Volume 3, p967, Elsevier.
- Malaysian Investment Development Authority (2014). *Food Technology and Sustainable Resources*. Retrieved from <http://www.mida.gov.my/home/food-technology-and-sustainable-resources/posts/>
- Malaysian Palm Oil Board (2013). *Oil Palm Planted Area by States as at Dec 2013*. Malaysian Palm Oil Board. Retrieved from http://bepi.mpob.gov.my/images/area/2013/Area_summary.pdf
- Malaysian Palm Oil Board (2012). *Oil Palm Planted Area by States as at Dec 2012*. Malaysian Palm Oil Board. Retrieved from http://bepi.mpob.gov.my/images/area/2012/Area_summary.pdf
- Malaysian Palm Oil Board (2011). *Oil Palm Planted Area by States as at Dec 2011*. Malaysian Palm Oil Board. Retrieved from http://bepi.mpob.gov.my/images/area/2011/Area_state.pdf
- Malaysian Palm Oil Board (2013). *Minda Dr Choo Yuen May*. Berita SawitPage 2, 1 Jun 2013. Selangor, Malaysia
- Malaysian Timber Council (2007). *Development in Timber Certification in Malaysia*. Malaysian Timber Council. Retrieved from <http://www.mtc.com.my/publication/series/series2/development.htm>
- Neely, A., Gregory, M., & Platts, K. (1995). Performance measurement system design. *International Journal of Operations & Production Management*, 15(4), 80-116
- Nor Suryani, A.G., Mohd Shahwahid, H.O., Ahmad Fauzi, P., Alias, R., & Vlosky, R.P. (2011). Assessment of Chain of Custody Certification for Sawnwood Manufacturers in Peninsular Malaysia. *Journal of Tropical Forest Science*. 23(2). 159-165
- Paridah, M.T. & Loh Y.F. (2009). *Oil Palm Trunk Plywood-Have We Done Enough?* Annual Timber Research and Industry Briefing, 2009. Kuala Lumpur
- Pawar, K.S. & Driva, H. (1999). Performance measurement for product design and development in a manufacturing environment. *International Journal of Production Economics*, 60-68.
- PEFC International Standard (2013). *Requirements for PEFC Scheme Users, Chain of Custody of Forest Based Products-Requirements (PEFC ST 2002:2013, 2013-05-24)*. PEFC Council, Geneva, Switzerland
- The RIC Good Wood Guide (2007). *Wood-based Composite Building Materials*. Retrieved from http://www.rainforestinfo.org.au/good_wood/wb_compos.htm#anchor1204842
- Ulrich, K.T., & Eppinger, S.D. (2000). *Product design and development*. 4th Edition. Mc Graw-Hill
- Williams, T. (2007). *Certification Cost Analysis*<http://www.profor.info/pdf/March2.pdf>, 21-Nov-2007

EFFECT OF STEAMING AND COMPRESSION ON THE PHYSICO-MECHANICAL PROPERTIES OF COMPREG OPW TREATED WITH THE 6-STEP PROCESSING METHOD

Alhassan Y. Abare,¹ Edi S. Bakar,^{1,2,*} Zaidon Ashaari¹

¹) Department of Forest Production, Faculty of Forestry, Universiti Putra Malaysia

²) Laboratory of Bio-composite, Institute of Tropical Forest Products, Universiti Putra Malaysia

*) Contact address: edisuhaimi@upm.edu.my

ABSTRACT

The five-step processing method (sawing, drying, resin impregnation, heating, and hot-pressing) has been developed by Bakar *et al.*, 2004 to improve the quality of oil palm wood (OPW). The method is capable of solving the main imperfections of OPW (strength, dimensional stability, durability, and machining characteristic), but it takes a very long time in drying and heating and considered as difficult by industry. Therefore, a six-step processing method (sawing, steaming and compression, drying, resin soaking, heating, and hot-pressing) was developed and patented (Bakar *et al.*, 2014) which is more efficient. The effect of steaming and compression were evaluated. The highest density of 1065.25 kg/m³ was recorded at the steamed sample with 40% compression level. The MOE and MOR of the samples with pre-steaming were lower than those without steaming by 10.17% and 6.96%, respectively. The steaming pre-treatment did not give significant difference to the measured properties but Compression showed significant difference to both physical and mechanical properties measured. Therefore, steaming is optional, but it helps during densification by creating micro cracks in the OPW. Both physical and mechanical properties of compreg OPW were greatly enhanced. The drying time of OPW which normally takes longer time (3-4weeks) is basically reduce to 3 days after undergoing compression treatment. It was revealed that the properties of compreg OPW can be compare with the previous studies.

Keywords: Compreg OPW, compression, drying, heating, hot-pressing.

INTRODUCTION

Oil Palm tree is one of the most important trees in Malaysia and Indonesia because of the large area of land that is planted. The Malaysian Palm Oil Board (MPOB, 2010) stated that there are 5.0 million ha of oil palm plantation in Malaysia in 2010. Previously, oil production was the main purpose of oil Palm Plantation, this is used as cooking oil and other derivatives can also be obtain from it. It was also reported that biomass as 13.9 million tonnes based on dry weight of raw material including stems, fronds, and empty fruit bunches produced annually in Malaysia (Anis *et al.*, 2007). However, this oil only formed 10% of the total biomass of the whole OPT, the remaining biomass comes as a waste. These wastes can be seen as fronds, trunks, and empty fruit bunches. Oil Palm trunk, which is among the residues provide the best alternative as a substitute to wood because of its comparable properties. Bakar *et al.*, (2010) reported that there is 7 000 000 metric ton of oil palm trunks are cut down yearly for replanting exercise. OPT economic life span on an average is 25-26 years after these years it is considered not economical (Ismail & Mamat, 2001).

Wood industries in Malaysia find it difficult in securing enough raw materials for production. The availability of the Oil Palm Trunk (OPT) and it's a less expensive lignocellulosic materials compare to conventional wood. There will be increase in economic returns and the overall cost of production will drastically reduce by using this Oil Palm Trunk as raw materials.

Oil Palm Trunk has four main imperfection viz; very low in strength, poor dimensional stability, very low in durability, and very poor in machining characteristic (Bakar *et al.*, 2005). These imperfections must be addressed in order to make comparison with the properties of the solid wood. Ibach and Ellis (2005), revealed that impreg and compreg treatment with phenolic resin can increases the strength, dimensional

stability, and durability of many wood. All these setbacks in OPW has been solved by impregnating with low-molecular weight PF resins through modified compreg method (Bakar *et al.*, 2005).

However, this method that solved these OPW imperfections is considered very difficult and time consuming by practitioners, especially the polygon sawing and the longer two time dryings. This research has found an alternative to address this problem by adjusting and improving previous studies. Steaming and Compression was introduced in this studies in order to improve the physical and mechanical properties of Oil Palm Wood. Steaming was done in order to facilitate compression effectively. It was reported that softening the wood with high temperature or hot saturated steam during densification has improved the strength of densified wood (Haygreen and Daniels, 1969; Tabarsa and Chui, 1997). This will help save time, money and energy and thereby producing very strong, durable and dimensionally stable Oil palm Wood.

The main objective of this research is to find out the effect of steaming before compression on the physical and mechanical properties of compreg OPW treated with the 6-step processing method.

METHODS

Preparation of Materials

A number of oil palm trees that are matured (about 28-year) are selected from Taman Pertanian Universiti, UPM for this research. Only the bottom part of the matured Oil Palm was used for this research. The length of the bole used was 220cm from the bottom. The logs were taken to sawmill for further processing. The logs were debark using a Spindle-less Peeler and thereafter it was sawn using a new method of sawing known as "reverse cant sawing Pattern" to get samples with a measurement of 30cm long, 5cm thickness and 15cm width.

Steaming and Compressing Process

With the exception of samples that will not be steamed, all samples were steamed for 1 hour in a steamer set at $120 \pm 3^\circ\text{C}$. Steam helps in dissolving extractives and other chemical components of wood. This helps in softening the wood. The high-temperature steaming of wood, a hygrothermal method with more effective heat transfer than conventional heat treatment, is aimed at decreasing hygroscopicity and improving dimensional stability and durability and, hence, at improving the quality of wood (Yin *et al.*, 2011). The compression was carried out on all the samples using the cold press. The samples were compressed using different compression of the original thickness, i.e. 0%, 20%, 30% and 40%.

Impregnation Process Using

Phenol Formaldehyde resin (Lmw-PF) : Impregnation process was carried out using Phenol Formaldehyde after the OPW was dried to 15% weight target. The resin was diluted with distilled water to a solid content of 15% and impregnation was carried out at a tank pressure of 120 psi for 45 minutes. The samples that were impregnated were placed standing upright in order to drain away the excessive PF and thereafter dry to 60% and 70% in oven and Microwave wave respectively. The oven was set at 65°C until the samples reach target weight and followed by microwave (6 magnetron force) for 3-5 minutes which helps in heating up or makes the resins semi cured and bulks the OPW structure. The samples were finally subjected to hot-pressing densification to the pre-determined thickness of 2cm at the temperature of 150°C for 45 minutes.

Sample Preparations and Testing

Samples were conditioned for 1 day to ensure complete curing. The samples were further cut into sample size for physical and mechanical test.

Physical Properties Test

1. Density and Density Gain

The density was calculated using Equation 1. Density is the ratio of mass per unit volume of treated wood. Density Gain was evaluated based on increasing density before and after treatment. Density Gain was calculated by Equation 2 below.

$$\text{Density } (\rho) = \frac{W_t}{V_t} \dots\dots\dots \text{Equation 1}$$

Where:

W_t = Weight of treated OPW

V_t = Volume of treated OPW

$$\text{Density Gain (DG)} = \frac{\rho_t - \rho_i}{\rho_i} \dots\dots\dots \text{Equation 2}$$

Where:

DG = Density Gain

ρ_t = Density of treatment OPW

ρ_i = Density Before treatment of OPW.

2. Weight Percent Gain (WPG)

The formula below is used in determining the effectiveness of the resin impregnation :

$$\text{WPG}(\%) = \frac{W_2 - W_1}{W_2} \times 100$$

Where:

W₂ is the oven-dried weight of the treated Samples(Impregnated)

W₁ is the oven-dried weight of the untreated Samples(Samples before impregnation).

Mechanical Properties Test.

The mechanical properties testing were carried out according to British Standard BS 373 (BS 1957) using Intron Model 4204 Universal Testing Machine. The speed of 0.635 mm/min at crosshead was used in testing the samples. The ambient temperature (25±3°C) and humidity of 50% was used in conditioning the samples before undergoing testing. The mechanical properties that were tested are MOE and MOR (Static Bending). The samples were made into 20mm × 20mm × 300mm dimension was used for static bending.

RESULTS AND DISCUSSIONS

The overall effect of steaming and compression on the physical-mechanical properties are summarise on the Table 1. The ANOVA table showed that steaming before compression did not give significant effect on the tested properties. The compression level gave significant effects on the mean density, density gain, weight percent gain, and mechanical properties of the samples. The Detail discussions about the effect of steaming before compression on the physico-mechanical properties of compreg OPW are discussed below.

Table 2. ANOVA Of the Effect of Steaming and Compression Level on the Properties of High Grade Compreg OPW

Treatment	Df	Density (kg/m ³)	DG (%)	WPG (%)	Static Bending (MPa)	
					MOE	MOR
Steaming	1	0.34 ^{ns}	0.483 ^{ns}	0.125 ^{ns}	0.583 ^{ns}	0.528 ^{ns}
Compression Level	3	0.001 ^{**}	0.001 ^{**}	0.045 ^{**}	0.005 ^{**}	0.001 ^{**}
Steaming * Compression Level	3	0.748 ^{ns}	0.403 ^{ns}	0.327 ^{ns}	0.278 ^{ns}	0.018 ^{**}

** - Significant at P≤0.05

ns- Not significant

Table 1. Physical and Mechanical Properties of High grade Compreg OPW at Different Compression Level (%)

Steaming Status	CL	Density (kg/m ³)	Density Gain (%)	WPG (%)	MOE (MPa)	MOR (MPa)
Without Steaming	0	766.13±74.58	13.23 ± 7.15	23.05 ± 8.57	5687.34 ± 676.95	42.57 ± 3.02
	20	954.88±26.21	61.39±19.08	10.66 ± 14.00	10242.80 ± 5463.48	50.70 ± 5.27
	30	907.70 ± 96.09	44.10 ± 12.89	8.15 ± 3.62	12115.57 ± 3010.45	76.40 ± 43.34
	40	1038.77 ± 33.26	103.24 ± 17.38	16.23 ± 4.93	15046.53 ± 6454.61	78.15 ± 52.60
Steaming	0	795.02 ± 40.16	14.80 ± 5.30	25.15 ± 12.86	6680.11 ± 2307.64	48.30 ± 16.65
	20	1003.63 ± 110.43	64.86 ± 28.48	14.70 ± 10.48	11640.61 ± 3318.72	66.72 ± 17.29
	30	993.16 ± 64.78	63.38 ± 23.92	21.62 ± 9.42	11910.75 ± 2671.96	114.87 ± 7.66
	40	1065.23 ± 43.28	95.03± 16.76	14.90 ± 1.0	10041.49 ± 4995.82	39.04 ± 12.77

Note CL = Compression Level

Effect of Steaming and Compression on Density of Compreg OPW

In Table 1 above, steaming did not give significant effect on the density of Compreg OPW with different compression level, compreg OPW with 40% compression has the highest Density (1065.23 kg/m³) with the lowest density at 0% Compression level (766.13 kg/m³). The steamed 40% Compression level Compreg OPW has the higher density compare to the lowest density of unsteamed 0% Compression level Compreg OPW with 28%. Density is one of the important properties of wood. The increase in density is as a result of small micro cracks resulted from densification of the OPW after it has been steamed. This micro cracks will facilitates easy penetration of PF into the wood. This penetration of Pf and hot densification of OPW results into increment of density of OPW (Amarullah *et al.*, 2010)

Effect of Steaming and Compression on Weight Percent Gain

Table 2 shows that the steaming has no significant effect on WPG. The mean values of WPG among the steamed OPW are higher than the unsteamed OPW. The value of WPG of steamed compreg OPW and un-steam Compreg OPW range from 14.90-25.15% and 8.15% -23.06% respectively as shown in Table 1. This is higher than the result obtained in previous studies (Amarullah *et al.*, 2010). WPG is not affected by steaming even though the steamed Compreg OPW is higher than the un-steamed by 1.3 times. The compression of the OPW showed significant effect on the WPG. This is expected because there is also increase in density as a result of WPG.

Effect of Steaming and Compression Static Bending Strength

MOE is a variable that describes the relationship between stress and strain within a material's elastics region, while MOR of a treated wood is the maximum load it can support failure. Therefore a material with higher MOE will resist stress well and can keeps to their shape. The effect of steaming on both MOE and MOR are not significant ($p \leq 0.050$). But the compression Level showed significant difference ($P \leq 0.05$) for both MOE and MOR (as seen in Table 2). Table 1 above showed the mean Values of the MOE ranges from 5687.34 MPa -15046.53 MPa. I.e making the 0% compression Level unsteamed compreg OPW having the lowest MOE and 40% Compression Level steamed Compreg OPW having the highest MOE. Hsu *et al.* (1988) reported that the breakdowns of hemicellulose in the wood during steaming will not necessary cause the reduction in the strength of wood but will help in the compression of wood.

The mean values of MOR ranges from 42.57 MPa to 114.57. This shows that the 30% Compression level steamed Compreg OPW is more than the 0% Compression Level unsteamed compreg OPW with 2.7 times. It can be concluded that the resin has formed a cross-linked polymer, hence it has increased the strength and the stiffness.

CONCLUSION

The properties of Compreg OPW i.e physical and mechanical properties of OPW were greatly enhanced. The steaming pre-treatment, though it does not significantly affect the physical and mechanical properties of OPW, but it helps during densification which in turn create micro cracks for easy penetration of resins into the OPW. The compression significantly affects both the physical and mechanical of compreg OPW. The drying time of OPW which normally takes longer time (3-4 weeks) is basically reduce to 3 days after undergoing compression treatment. The compression Level that should be used should be used during treatment OPW should be between 30-40%.

REFERENCE

- Amarullah, M., Bakar, E.S, & Zaidon, A. (2010). Reduction of formaldehyde emission from phenol formaldehyde treated oil palm wood through improvement of resin curing state. I. *Trop. Wood Sci. Tech*, 8(1), 9–14.
- Anis, M., Kamarudin, H. and Hasamudin, W.H. (2007). Current status of oil palm biomass supply. In *Proceeding of 7th National Conference on Oil Palm Tree Utilization, Selangor, Malaysia, March, 2007. (Serdang: Institute of Tropical Forest and Forest Product, UPM)* (pp. 3–11.).
- Bakar, E.S., Hao, J., & Ashaari, Z. (2010). Durability of Low-Molecular Weight Phenol Formaldehyde Treated Oil Palm Wood against Termite *Coptotermes Curvignathus* and White-Rot Fungi *Pycnoporus Sanguineus*. In *Developing Wood Science and Technology to Support the Implementation of Climate Change Program* (pp. 182–190). Indonesian Wood Research Society(2011).
- Bakar, E.S; Tahir, P.M., and Sahri, M.H. (2005). Properties Enhancement of Oil Palm Lumber through the Compreg Method. *Proceedings of the International Symposium on Wood science and Technology (IAWPS 2005)*. Vol.2: p. 91-92.
- Bakar, E.S., Ashaari, Z., Choo, A.C.Y., & Abare, A. (2014). A new method of producing Compreg Oil Palm Wood. Malaysia.
- Haygreen, J.G., & Daniels, D.H. (1969). The simultaneous drying and densification of sapwood. *Wood and Fiber Science*, 1(1), 38–53.
- Hsu, W.E., Schwald, W., Schwald, M.J., & Shields, M.J. (1988). Chemical and physical changes required for producing dimensionally stable wood-based composites. *Wood Science and Technology*, 22(3), 281–289.
- Ismail, A., & Mamat, M.N. (2001). The Optimal Age of Oil Palm Replanting Azman Ismail and, *vol 2*(1), 11–18.
- Ibach, R.E. and Ellis, W.D. (2005). Lumen Modifications. In Roger M. Rowell (Ed.), *Handbook of Wood Chemistry and Wood Composites* (pp. 421–441). CRC Press.
- Tabarsa, T., & Chui, Y.H. (1997). Effects of hot-pressing on properties of white spruce. *Forest Products Journal*, 47(5), 71–76.
- Yin, Y., Berglund, L., & Salmén, L. (2011). Effect of steam treatment on the properties of wood cell walls. *Biomacromolecules*, 12(1), 194–202. doi:10.1021/bm101144m

APPLICATION OF NON-DESTRUCTIVE TEST FOR CHECKING AVAILABLE TIMBER FOR CONSTRUCTION MATERIALS IN THE MARKET

Ajun Hariono and Anita Firmanti

Research Institute of Human Settlement, Ministry of Public Work, Republic of Indonesia
Panyaungan Street, Cileunyi Wetan village, Cileunyi District, Bandung Regency 40393, Republic of Indonesia
Email: hariono_ajun@yahoo.co.id and anitafirman150660@gmail.com

ABSTRACT

One of the commonly used construction material is wood. Facts on the market, there are relatively large variations in the properties including strength aspect. The strength generally represented by the value of modulus of rupture (MOR_{real}). On the other hand the determination of the strength is relatively expensive through destructive laboratory test (flexural test parallel to the grain direction). Modulus of elasticity is one of reliable predictor parameter for non destructive test. In this study, the modulus of of elasticity of timbers were measured by using Stress Wave Timer Model 239A-Metriguard ($MOE_{SWTprediction}$) and Panter MPK-5 ($MOE_{PTRprediction}$). Thirty samples were randomized sampling from a lot of timber in the market. Moisture content and density of the timber were measured before the modulus of elasticity. For each sample, the real modulus of elasticity and modulus of rupture were tested with Universal Testing Machine. Data analysis showed that prediction of Stress Wave Timer Model 239A-Metriguard more accurate than Panter MPK-5 from the higher of coefficient of correlation. Based on the producted formula, 96 pieces of timber in the market were predicted. The data showed that the modulus of rupture ($MOR_{prediction}$) of available timber in the market is in the range of 33.613 to 99.162 N/mm².

Keywords: wood, strength, prediction, MOR_{real} , $MOR_{prediction}$, $MOE_{SWTprediction}$, $MOE_{PTRprediction}$

INTRODUCTION

Need of human facilities increasing due to human population increment. One of the commonly used construction material is wood. Facts on the market, there are relatively large variations in the properties including strength aspect. The strength generally represented by the value of modulus of fracture (MOR_{real}). On the other hand the determination of the strength is relatively expensive through destructive laboratory test (flexural test parallel to the grain direction). So, relatively cheap wood strength estimator with relatively accurate results was needed. If the strength can be understood well, the construction design will be more reliable. Based on the legal aspects, the study of strength aspect considered necessary to be done because directly related to the safety of the building. Safety aspect was one of the requirements in Indonesian Building Law No. 28-2002.

RESEARCH METHOD

Data collection was done by experimental testing (destructive and non-destructive testing). The tests were conducted to obtain an overview of the wood characteristics, particularly the strength aspects. To obtain the relationship (regression) of real strength to predicted strength, destructive testing laboratory (flexural test parallel to the grain direction) and non-destructive testing laboratory (by means of Stress Wave Timer Model 239A-Metriguard and Panter MPK-5) of 30 specimens was done. In this study, field non-destructive testing (by means of Stress Wave Timer Model 239A-Metriguard and Panter MPK-5) was done to 96 specimens. By applying the previous regression, tested field wood strength can be predicted. To complete the information characteristics, series of measurements have also been made, such as dimensional, weight and water content measurements.

Destructive testing laboratory (flexural test parallel to the grain direction)

This laboratory testing was conducted to obtain strength data that represented by MOR_{real} value. Details of tests can be described as follows. Use test sample appropriate to the real situation on the market / full scale (6/12 wood, span 4 m). This is done to obtain the value of the real strength of wood (including the effect of imperfection-sectional, the influence of knots, cross-sectional variation in moisture content, etc.). Provide multiple point loads to test sample (using a simple support), which equidistant to the support. The aim of this multiple point loads was to obtain pure bending behavior. Deflection measuring devices placed in the middle of the span relative to the position of the loading point. The specimen loaded until fracture. Illustration of the testing can be seen in Figure 1.



Figure 1. Illustration of flexural test parallel to the grain direction

Non-destructive testing laboratory by Stress Wave Timer Model 239A-Metriguard

This laboratory testing was conducted to obtain strength data that represented by $MOE_{SWTprediction}$ value. This instrument was measure the sonic propagation time of the specimen. This value correlates with the MOE. Illustration of measuring instruments and methods of data collection can be seen in Figure 2.



Figure 2. Stress Wave Timer Model 239A-Metriguard instrument and test illustration

Non-destructive testing laboratory by Panter MPK-5

This laboratory testing was conducted to obtain strength data that represented by $MOE_{PTRprediction}$ value. This instrument was measure MOE based on the value of the deflection caused by the load. The formula for determining the value of the $MOE_{prediction}$ derived from the formula of engineering mechanics. In this test, the test sample was supported on two sides (simple support) and the load was given on the middle span. The loads given to the specimens were relatively small (non-destructive). Because the deflection that occurred was relatively small, so to raise level of accuracy, the value of deflection was amplified by using a series of levers on the machine. Illustration of measuring instruments and methods of data collection can be seen in Figure 3.



Figure 3. Panter MPK-5 instrument and test illustration

RESULTS AND DISCUSSION

To obtain the relationship (regression) of real strength to predicted strength, destructive testing laboratory (flexural test parallel to the grain direction) and non-destructive testing laboratory (by means of Stress Wave Timer Model 239A-Metriguard and Panter MPK-5) of 30 specimens was done. In this study, field non-destructive testing (by means of Stress Wave Timer Model 239A-Metriguard and Panter MPK-5) was done to 96 specimens. Based on a series of destructive and non-destructive testing that has been done, the test data can be analyzed and the results obtained as described below.

Overview of the water content and density value of the test specimen

Water content of tested wood varied and diverse, it was influenced by the storage method, pretreatment (kiln dry or not), temperature and humidity of the warehouse. The density of tested wood varied and diverse as shown in Table 1.

Table 1. Water content and density of the test specimen overview

Test	Number of Specimen	Wood properties	Minimum	Maximum	Average	Standard deviation	Coefficient of variation
Laboratory	30 pieces	Water Content (%)	10,667	17,000	13,739	1,764	0,128
		Density (gr/cm ³)	0,445	1,124	0,778	0,171	0,219
Field	96 pieces	Water Content (%)	9,500	60,000	23,477	11,066	0,471
		Density (gr/cm ³)	0,475	1,185	0,797	0,157	0,197

Comparison of real strength (MOR_{real}) to Stress Wave Timer Model 239A-Metriguard predicted strength ($MOE_{SWTprediction}$)

From the laboratory testing results, comparison of MOR_{real} to $MOE_{SWTprediction}$ can be known as illustrated in Figure 4.

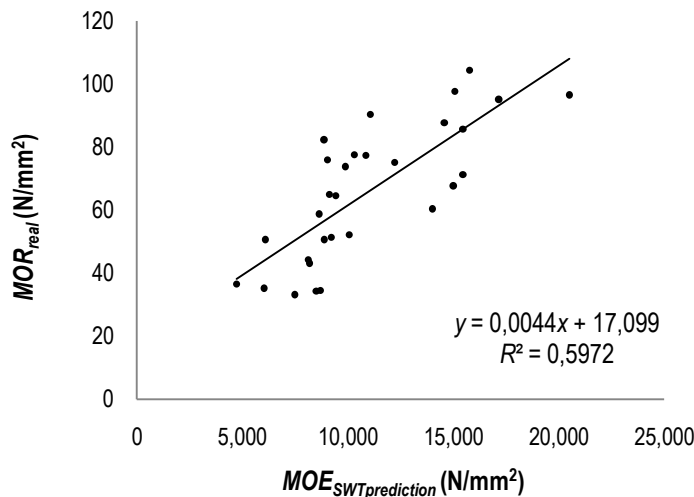


Figure 4. Linear regression of MOR_{real} to $MOE_{SWTprediction}$

Linear relation and its R^2 value can be written as follows:

$$MOR_{real} = 0,0044 MOE_{SWTprediction} + 17,099 \quad (R^2 = 0,5972).$$

Comparison of real strength (MOR_{real}) to Panter MPK-5 predicted strength (MOE_{PTRprediction})

From the laboratory testing results, comparison of MOR_{real} to MOE_{PTRprediction} can be known as illustrated in Figure 5.

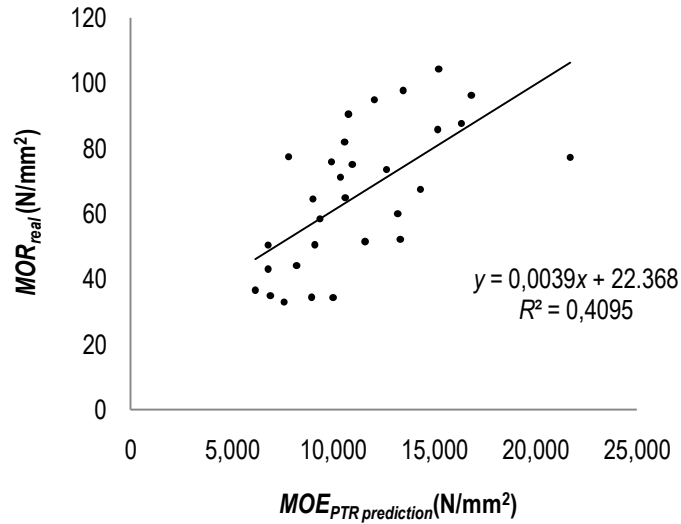


Figure 5. Linear regression of MOR_{real} to MOE_{PTRprediction}

Linear relation and its R² value can be written as follows:
 $MOR_{real} = 0,0039 MOE_{PTRprediction} + 22,368 \quad (R^2 = 0,4095).$

Stress Wave Timer Model 239A-Metriguard and Panter MPK-5 strength estimators accuracy

Recapitulation of the linear regression of real strength to predicted strength describes as follows:

1. $MOR_{real} = 0,0044 MOE_{SWTprediction} + 17,099 \quad (R^2 = 0,5972).$
2. $MOR_{real} = 0,0039 MOE_{PTRprediction} + 22,368 \quad (R^2 = 0,4095).$

Based on R² of test result value, it can be interpreted that strength estimator Model 239A Stress Wave Timer-Metriguard more accurate.

Relationship between MOR_{real} terhadap MOE_{real}

Value of flexural test parallel to the grain direction of full scale laboratory test varied and diverse as seen in Table 2.

Table 2. Flexural test parallel to the grain direction of full scale laboratory test result

Value	MOR _{real} (N/mm ²)	MOE _{real} (N/mm ²)
Minimum	13.566,219	32,997
Maximum	38.313,451	104,450
Average	24.894,464	65,707
Standard deviation	6.525,350	21,495
Coefficient of variation	0,262	0,327

Based on flexural test parallel to the grain direction of full scale laboratory test, the relationship between MOR_{real} against MOE_{real} can be described as illustrated in Figure 6.

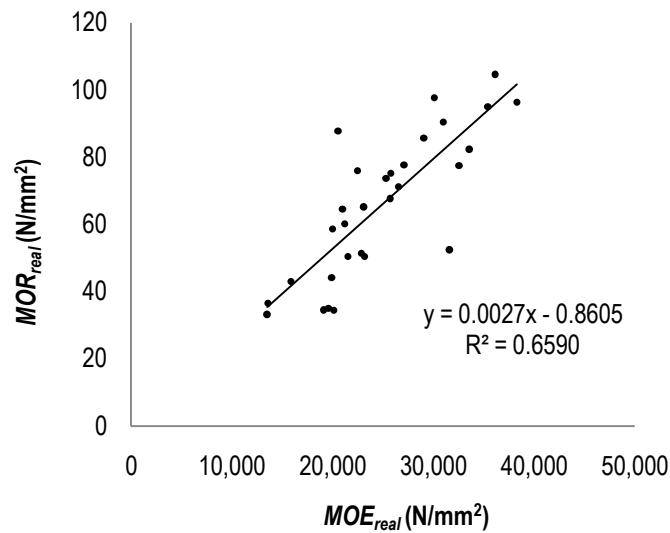


Figure 6. Linear regression of MOR_{real} to MOE_{real}

Linear relation and its R^2 value can be written as follows:

$$MOR_{real} = 0,0027 MOE_{real} + 0,8605 \quad (R^2 = 0,6590).$$

Predicted strength of tested field specimen ($MOR_{prediction}$) based on the value $MOE_{prediction}$ SWT

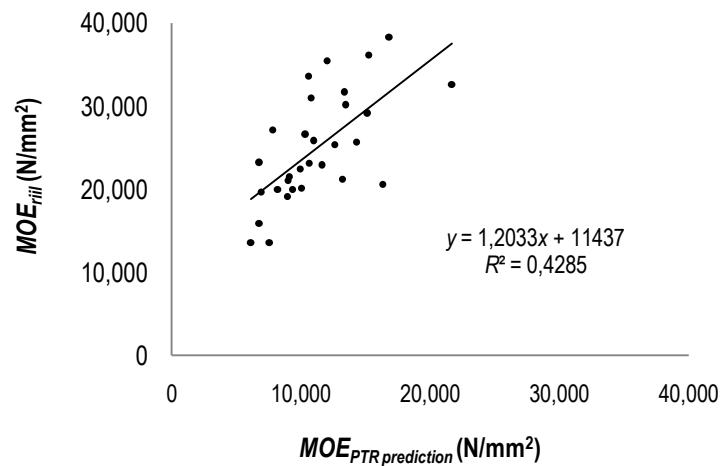
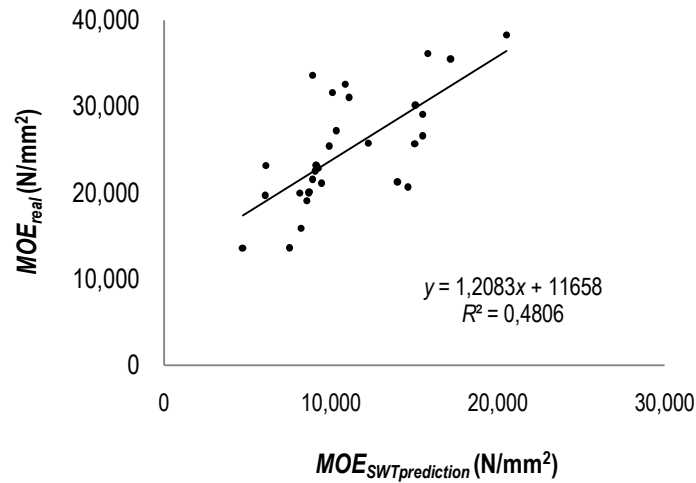
As described previously, strength estimator 239A Stress Wave Timer-Metriguard more accurate than Panter MPK-5. So to estimate the strength of tested field specimen (96 test objects) was used regression of $MOR_{real} = 0,0044 MOE_{SWTprediction} + 17,099$ ($R^2 = 0,5972$). By entering $MOE_{SWTprediction}$ value to the regression formula, results are obtained as in Table 3.

Table 3. Predicted MOR ($MOR_{prediction}$) of tested field specimen

$MOR_{prediction}$ value (N/mm^2)	
Minimum	33,613
Maximum	99,162
Average	59,465
Standard deviation	14,864
Coefficient of variation	0,250

Relationship of real strength (MOE_{real}) to predicted strength ($MOE_{SWTprediction}$ and $MOE_{PTRprediction}$)

For information, based on laboratory test results, relationship of real strength (MOE_{real}) to predicted strength ($MOE_{prediction}$) described as follows.



(a) strength estimator 239A Stress Wave Timer-Metriguard (b) strength estimator Panter MPK-5

Figure 7. Linear regression of MOE_{real} to $MOE_{prediction}$

Linear relation and its R^2 value can be written as follows:

$$MOE_{real} = 1,2083 MOE_{SWTprediction} + 11658 \quad (R^2 = 0,4806).$$

$$MOE_{real} = 1,2033 MOE_{PTRprediction} + 11437 \quad (R^2 = 0,4285).$$

CONCLUSION

The relationship of real strength and predicted strength from laboratory tested specimens (30 specimens) can be described by the following formula:

1. $MOR_{real} = 0,0044 MOE_{SWTprediction} + 17,099 \quad (R^2 = 0,5972).$

2. $MOR_{real} = 0,0039 MOE_{PTRprediction} + 22,368 \quad (R^2 = 0,4095).$

3. $MOR_{real} = 0,0027 MOE_{real} + 0,8605 \quad (R^2 = 0,6590).$

4. $MOE_{real} = 1,2083 MOE_{SWTprediction} + 11658 \quad (R^2 = 0,4806).$

5. $MOE_{real} = 1,2033 MOE_{PTRprediction} + 11437 \quad (R^2 = 0,4285).$

With real strength (MOR_{real}) range from 32,997 to 104,450 N/mm^2 .

From the results above, based on the value of R^2 can be seen that the prediction of real strength with test strength estimator Stress Wave Timer Metriguard more accurate than Panter MPK-5. If the regression was applied to the field test result (strength estimator 239A Stress Wave Timer Metriguard to 96 specimens), so the value of "real strength" ($MOR_{prediction}$) ranged from 33.613 to 99.162 N/mm².

REFERENCES

- BSN. 2013. SNI 7973:2013 tentang Spesifikasi Desain Untuk Kayu Konstruksi. Jakarta.
- Divos, Ferenc. et al. 2005. Relation Between Static and Dynamic Modulus of Elasticity of Wood. Acta Silv. Lign. Hung.
- Divos, Ferenc. 2008. Nondestructive techniques for characterisation of wood. University of West Hungary.
- Hansen, Christian P. 2000. Application of the Philodyn in the Forest Tree Improvement. Denmark. Stress Wave Timer 239A-Metriguard Manual
- Mäkipää, Raisa. et al. 2011. A Non-Destructive Field Method for Measuring Wood Density of Decaying Logs. The Finnish Society of Forest Science · The Finnish Forest Research Institute
- Ross, Robert J. et al. 1994. Nondestructive Testing for Assessing Wood Members in Structures. United States Department of Agriculture.
- Wang, Xiping. et al. 2000. Strength and Stiffness Assessment of Standing Trees Using A Nondestructive Stress Wave Technique. United States Department of Agriculture.
- Wang, Xiping. et al. 2000. Nondestructive Methods of Evaluating Quality of Wood in Preservative Treated Piles. United States Department of Agriculture.
- Wu, Shi-jun. et al. 2010. Use of the pilodyn for assessing wood properties in standing trees of Eucalyptus clones. Journal of Forestry Research. Northeast Forestry University and Springer-Verlag Berlin Heidelberg

DEVELOPMENT AND CHARACTERIZATION OF FINGER-JOINTED LAMINATED BAMBOO TIMBER FOR FURNITURE CONSTRUCTION

Rogerson Anokye^a, Edi Suhaimi Bakar^{a,b,*}, Jegatheswaran Ratnasingam^a,
Zaidon Ashaari^a, Khairul Awang^c

^a) Department of Forest Production, Faculty of Forestry, University Putra Malaysia, 43400, Serdang, Selangor Darul Ehsan, Malaysia

^b) Institute of Tropical Forestry and Forest Products, UPM, 43400, Serdang, Selangor Darul Ehsan, Malaysia

^c) Forest Research Institute of Malaysia, 52109, Kepong, Malaysia;

*) Corresponding author: edisuhaimi@upm.edu.my.

ABSTRACT

Laminated bamboo timber (LBT) are found to have a high tensile strength and modulus, good resistance to fatigue loadings, primarily due to its fiber properties. However, it is reported that LBT production is quit inefficient and are not well accepted due to the presence of nodes that disfigures the surface appearance of the board. Accordingly, V-grooving method was developed to counteract these inefficiencies but still with other problems requiring the lengthening of the short clear bamboo strips with finger-joints. The mechanical properties of the finger-jointed clear *Gigantochloa scortechini* bamboo species was therefore evaluated in static bending test using the bamboo strips selected for strip with finger joints specimens, with node and without node. Based on the distance between the joints, the best finger-jointed LBT strength was found to increase from 5 to 10cm and 5 to 15cm by 30.26% and 49.12% respectively. In the case is glue spread rate, there was an increase in MOR of 61.49% and 41.79% with phenol formaldehyde over the use of polyvinyl acetate at 250g/m² and 200g/m² respectively. The structural performance of finger-jointed LBT also showed a 31.87% higher in MOR than its counterpart with nodes.

Keywords: Laminated bamboo timber, tensile strength, with node, without node, finger-joint.

INTRODUCTION

Bamboo is one of the most common non-timber forest products in Ghana. It is estimated that the country has about 300,000 hectares of wild bamboo species. The most common species being *Bambusa vulgaris* (Anokye & Adu, 2014). Other local species include *B. multiplex*, *B. arundinacea*, *B. bambos*, *B. peruniabilis*, *B. vulgaris var vitata* (yellow bamboo) and *Oxythenanthera abyssinica*. Though *B. multiplex* is the only species regarded as indigenous, *B. vulgaris* (green bamboo) constitutes about 95% of the bamboo stands after it was introduced into the country in some several decades ago and has now been regarded as indigenous. Eighteen (18) exotic species has also been introduced from Hawaii of which many are striving.

Bamboo species has been used though not extensively, in the construction of furniture, rural housing and handicrafts and as temporal posts or props in the building construction industry. They are mostly used in the round culm form which does not require much complicated processing. As the forest products keep on decreasing with the ever increasing demand for wood and wood products in the country, there has been a need to innovatively develop bamboo as a substitute to low growing hardwoods for furniture manufacturing. The capability of bamboo to replenish itself after harvesting, fastest growing and other environmental friendliness, versatility of its use coupled with its low Eco-cost (Van der Lugt *et al.*, 2009) are the important considerations. Bamboo regarded as 'The Green Gold' of the 21st century played a significant role in human society since time immemorial and today contributes to the subsistence needs of over a billion people worldwide (Ogunjinmi *et al.*, 2009); and plays a vital role in the socio-economics of the rural population. Bamboo furniture has shown a lot of potentials and it continues to be a good potential for the future of the furniture industry. Experiences of Asian countries have shown that bamboo may prove beneficial as a valuable and sustainable natural resource (Dannenmann *et al.*, 2007). Its furniture has been accepted due the advancement of processing technology coupled with the increasing concerns about the environment, bamboo

furniture has become an imperative substitute or complement to conventional wood furniture in the world market.

In Ghana, the bamboo sector lacks substantive basic information on the problems and opportunities to enable implementation of appropriate interventions for efficient utilization of the resource to enhance the sector (Effah *et al.*, 2014). Ply-bamboo has been started developing in the country with difficulty of being accepted as a suitable furniture material due to its appearance of the nodes which are so obvious with the local species. A thorough understanding of the relations between structures, properties, behavior in processing and product qualities is therefore necessary for promoting the utilization of bamboo (Liese, 1987). The study is therefore to eliminate the unsightly node features from the bamboo and replaced with end-to-end finger-joints. Yeh & Lin (2011), examined the joint performance of laminated bamboo at different configurations.

Therefore the aim of this study was to verify the mechanical properties of Finger-jointed LBT panels produced from *Gigantochloa scortechinii* bamboo under different distances between the joints, adhesion and the rate of spread of the adhesive.

MATERIALS AND METHODS

Material preparation

One of the commercialized and commonest bamboo species, i.e., buluh samantan (*Gigantochloa scortechinii*) from the Kedah State of Malaysia were harvested at the matured stage estimated to be over 4 years. There were 12 bamboo culms used for the investigation. Bamboo strips were prepared from 9-m height from the bottom to the top. These were reduced into groups containing only internodes and ones with nodes of average height of 30cm. The selected culms were split into 30cm wide before preserved in a solution of Borax for 15 minutes. The samples were air-dried under a shed until a 10.5% MC was attained. The dried splits were planed to remove the outer skin (epidermal) and the inner cavity layer (pith peripheral) to obtain a thickness of 5 mm for the flat strips. The strips were then laminated edge-to-edge to obtain a mat. Polyvinyl acetate (PVAc) adhesive was applied during the bamboo strip lamination. The laminated members of 5 x 60 x 300 mm were finger-jointed end-to-end using a longitudinal finger-jointer (model: KMFJ-400s, Chuan Chier Industrial) in pairs with PVAc adhesive. The finger profile orientation during the cutting was made to conform to the work of Yeh and Lin (2011) and Ayarkwa *et al.* (2000). The finger lengths were 18mm with finger spacing of 4mm and tip width of 0.65mm with a slope of 1 in 12 or 4° (Fig. 1).

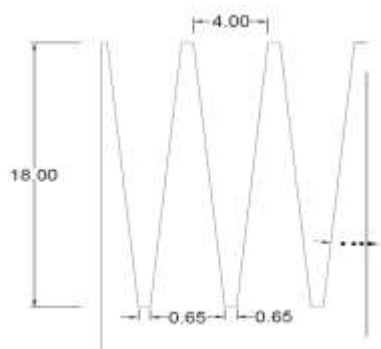


Figure 1. Finger profile

The finger-jointed mats were subsequently stacked or plied together with the surface of the epidermal layer facing one direction to ensure an optimum adhesive performance (Liu *et al.*, 1992; Hamdan *et al.*, 2009). The joints were aligned alternatively in successive lamina at different interval groups of 5cm, 10cm and 15cm to determine the best distance with higher performance. Two different glue types, Phenol formaldehyde (PF) and PVAc at spread rates of 200 and 250g/m² were used to establish the best glue type and spread rate for the board lamination (Aicher *et al.*, 2013). The pressing was done with the hot press for the samples with PF glue at 1.47 MPa for 30 min and cold press for the samples with PVAc at the same pressure for 4 h. The experimental codes of PV and PF for glue type, L and H for glue spread rate, and A, B and C for the distance between the finger joints in successive lamina. Similar strips were prepared and laminated from culms with nodes and those without node for comparison.

Table 1. Experimental design of the laminated bamboo timber with finger joint at different joint intervals.

Treatment ^{*)}	Glue Type	Glue Spread Rate (g/m ²)	Distance between joints (cm)
PF-L-A	PF	200	5
PF-L-B	PF	200	10
PF-L-C	PF	200	15
PF-H-A	PF	250	5
PF-H-B	PF	250	10
PF-H-C	PF	250	15
PV-L-A	PVAc	200	5
PV-L-B	PVAc	200	10
PV-L-C	PVAc	200	15
PV-H-A	PVAc	250	5
PV-H-B	PVAc	250	10
PV-H-C	PVAc	250	15

^{*)} PF Phenol formaldehyde; PV Polyvinyl acetate; L, H Spread rate of 200 and 250g/m²; A, B, C interval between joints of 5, 10 and 15 cm.

Property evaluation

The basic mechanical properties of bamboo for the selected species were evaluated in the static bending, compression and shear test. The LBT with finger-jointed and nodes underwent static bending to examine the effect of the nodes and joints on the strength properties while compression and shear tests were done on LBT without joint to determine the bonding strength of the glue types and spread rates. The size of LBT specimens were reduced to sizes of 20mm × 300mm × 20mm for the static bending test with 4 replicates with a total of 48 specimens each for the variables with nodes and finger-joints. The compressive and the shear tests were performed using a 20×20×40mm and 20mm³ specimens respectively. The standard ASTM 3043-00 (ASTM 2000) was referred for the static bending test, with a consideration of lamination orientation.

RESULTS AND DISCUSSION

Mechanical properties of the bamboo strips

The results on MOR, MOE and compressive strength of the bamboo strips along the culm are presented in this section. The results show the pattern of MOR, MOE and compressive strength along the height of the culm for each bamboo species.

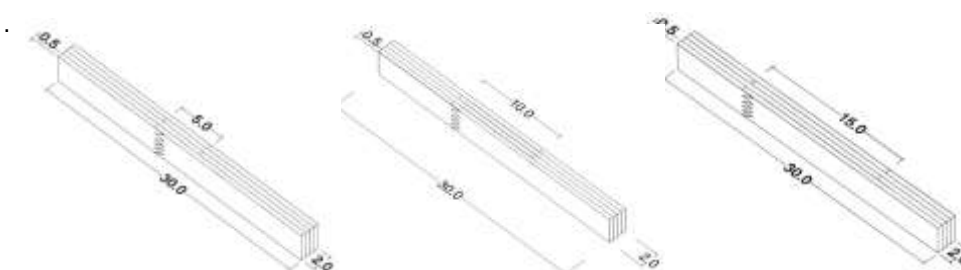


Figure 2. Finger jointed laminate bamboo timber at different joint intervals.

The overall results of the two different species of bamboo strips at different position (basal, middle, and top) and part (internodes = without node; node = with node) are shown in Table 2. The results of the modulus of rupture (MOR) of *G. scortechinii* bamboo strips were just 3.53% higher than that of *B. vulgaris* bamboo strips when combining the results for three different height levels with nodes and internodes. The bamboo density might have been a contributing factor to this minimal difference since the percentage difference in density was relatively 2.98%. Lin *et al.* (2006) supported the fact that, the density could influence the strength of the bamboo. In addition, the samples without nodes exhibited MOR of about 19.2% higher than samples with node in *G. scortechinii*. A similar trend was also found on the same bamboo species by Hamdan *et al.*

(2009), with about 17.3% higher. They observed anatomically the failure at the node further progressed laterally in shear which occurred along the weak fiber matrices.

Table 2. Properties of air dried *B. vulgaris* and *G. scortechinii* at different height portion with node and without node samples.

Treatment ^(*)	Density (g/cm ³)	MOR (MPa)	MOE (GPa)	Compressive strength (MPa)
S-B- Internode	0.68	122.7	9.29	68.9
S-B- Node	0.65	87.4	9.01	80.6
S-M-Internode	0.73	123.5	11.19	68.5
S-M- Node	0.66	102.4	8.39	65.7
S-T-Internode	0.70	126.8	12.93	71.0
S-T- Node	0.69	123.1	10.65	67.3
Mean	0.69	114.3	11.64	70.3
V-B- Internode	0.64	111.9	11.44	70.1
V-B- Node	0.63	102.5	10.84	68.2
V-M-Internode	0.73	112.7	13.16	72.3
V-M- Node	0.66	105.6	10.50	67.8
V-T- Internode	0.70	123.4	13.02	68.9
V-T- Node	0.68	106.4	11.67	68.4
Mean	0.67	110.4	11.77	69.3

^{*)} V = *B. vulgaris*; S = *G. scortechinii* (S); Node = = with node section; Internodes = without node section; B = Basal, M = Middle, T = Top

^{**)} n = 5; MOE = modulus of elasticity; MOR = modulus of rupture

Table 3. : ANOVA summary for effect of species, part and section for *B. vulgaris* and *G. scortechinii*

SOURCE	MOE		MOR	
	F values	P values	F values	P values
Species	191.213*	0.000	0.419 ^{ns}	0.546
Part	12.835*	0.011	3.949 ^{ns}	0.104
Section	85.151*	0.000	1.780 ^{ns}	0.261
Part * Section	22.328*	0.003	0.731 ^{ns}	0.527

ns = not significant, p > 0.05, * = significant up to 95%

n = 5: MOE = modulus of elasticity; MOR = modulus of rupture

Section = Node(with node) and internode(w/o nodes), Part = Basal, Middle, Top

While for the internode strips no such spontaneous fracture occurred as the crack became deflected in the direction of the weak matrix of the fiber bundle. The bamboo strips sampled from the middle and the top height levels of the culm displayed 7.5 and 18.9% higher MOR respectively than that of the bottom of the bamboo though the ANOVA showed no significant difference among the three sections (Table 3). For compressive strength property testing, the results yielded decreased MOR as compared to the bending strength. Moreover, there was no clear distinction in the compressive strength of *G. scortechinii* and *B. vulgaris* as well as between both the node and the internode. This implies that, to get the most out of both the node and the internode strips of bamboo during usage, the material must be orientated in compression as was noted by (Hamdan *et al.*, 2009). These strength behavior of the bamboo strips could be attributed to the anatomical structure especially, the vascular bundles which according to Janssen (2000), Widjaja *et al.* (1987) and Wahab (2013), have an important role in the mechanical properties development in bamboo.

Bending Properties of laminated bamboo timber (LBT) without finger joint

The bending properties of 20×20×300mm laminated bamboo members with only internode and those with nodes were performed for *Gigantochloa scortechinii* sampled from basal growth part for its wall thickness with horizontal lamination direction. The results indicated that most of the failures in the samples with node occurred at the node starting with node at the bottom. This is may be due to the low density of vascular bundles arrangements in the node site (Nahar and Hasan, 2013; Amada *et al.*, 1997). The results on the samples with nodes indicated that samples laminated with phenol formaldehyde (PF) were 27% higher than those laminated with polyvinyl acetate (PV) glue. Also, the overall results of the glue spread rate indicated that samples laminated with a glue weight of 200g/cm² in both glue types than the 250g/m². This was in the PF where the strength increase was about 79.6% higher. The PV also had an increase of 18.4% higher in the 200g/m² than 250g/m². On the intervals between the nodes, the laminated timber with 10cm interval joints were 10 and 22.2% higher than the 5cm and 15cm intervals respectively (Table 3). The best strength yield of laminated bamboo timber with nodes was found to have come from members laminated with 200g/cm² of PF jointed at an interval of 10 cm.

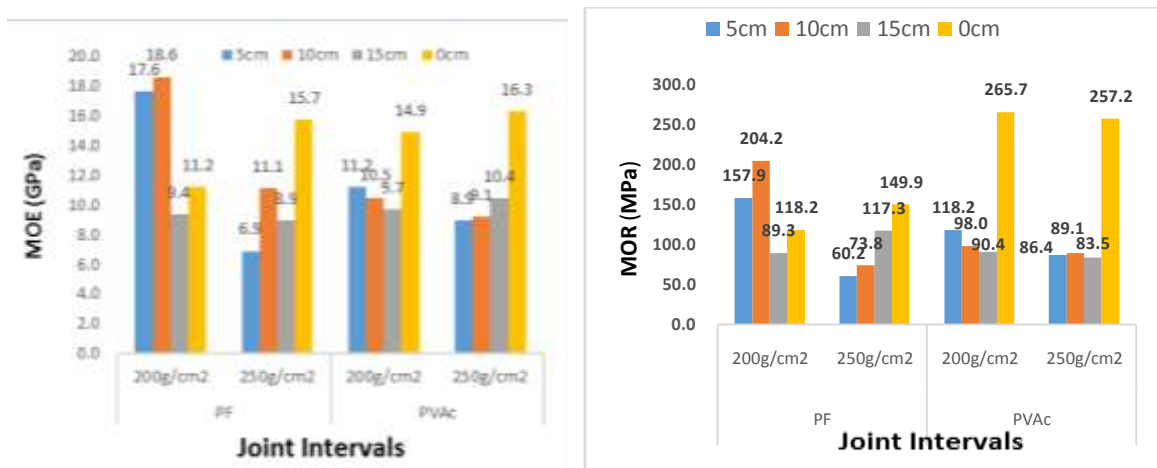


Figure 3. Comparison of the effects of joint interval on the MOE and MOR of LBT without finger joint.

Table 4. ANOVA on the effect of joint type, glue type, glue spread rate and the joint interval on the finger jointed bamboo laminated timber.

SOURCE	MOE		MOR	
	F values	P values	F values	P values
Joint Type	11.132**	0.001	8.876**	0.004
Glue type	16.467***	0.000	13.965***	0.000
Spread rate	2.631 ^{ns}	0.108	3.143 ^{ns}	0.080
Joint interval	1.690 ^{ns}	0.190	1.115 ^{ns}	0.332

ns = not significant, p > 0.05, * = significant up to 95%, *** = significant up to 99%

n = 5: MOE = modulus of elasticity: MOR = modulus of rupture

Effects of glue type and the glue spread rates

The bending tests of 20×20×300mm laminated bamboo timber laminated horizontally from only the basal section of the bamboo culm for the purpose of the culm thickness and low density and joined with a 12mm long finger joint formation were performed. Amoah *et al.* (2014) found that low density tropical hardwoods to be of higher strength than medium density ones. The MOR of the finger-jointed *G. scortechinii* as shown in (Table 4) revealed that samples laminated with PF glue exhibited a higher strength of about 51.51% than its counterpart PV. This conforms to the results of the laminated members with nodes. This may have been due to the polymeric materials reinforced with the synthetic resin (Liu *et al.* 2012). According to Yang *et al.* (2014), the change in press temperature can increase the MOE and MOR due to increase in plasticizing and adhesive curing. In the case of the glue spread rate, samples laminated with 250g/m² recorded a percentage increase of just 5.24 as compared to the samples laminated with 200g/m². Even

though this seems not to conform to that of the node samples, it is believed the adhesion of the finger-jointed samples with PV might have influenced the change.

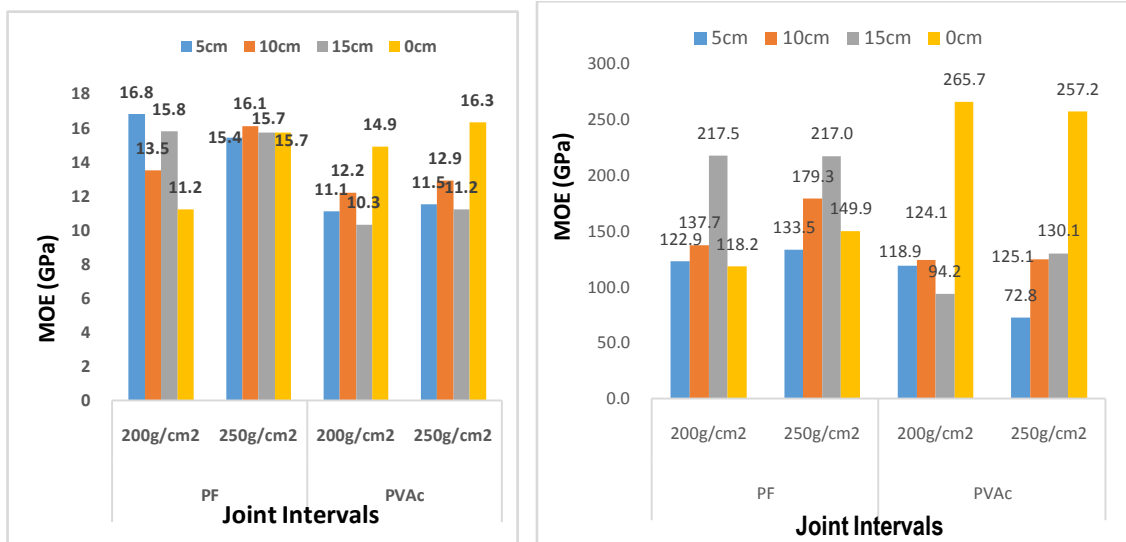


Figure 4: MOR and MOE of LBT containing finger-joints at different intervals and glue spread rate.

Table 5. Influence of joint interval and glue spread rate on the finger jointed laminated bamboo timber.

SOURCE	MOE		MOR	
	F values	P values	F values	P values
Joint Type	14.727**	0.000	10.909**	0.003
Glue type	20.732**	0.000	16.35**	0.000
Spread rate	3.787 ^{ns}	0.055	4.09*	0.311
Joint interval	2.438 ^{ns}	0.093	1.48 ^{ns}	0.233
Spread rate × Joint interval	3.478*	0.035	2.06 ^{ns}	0.133

ns = not significant; * = significant at 5%; ** = significant at 1%

Effects of finger-joint and joint intervals

MOR recorded for samples with different joint intervals showed a trend of increase in MOR with increase in intervals between the finger joints within the LBT. Ayarkwa *et al.* (2000) asserted that finger profile geometry has statistically significant influence on the MOR. Generally, there was an increase of 30.26% in the MOR between the joint interval of 5cm and 10cm. This further increased by 49.12% when the distance was increased to 15cm. Though, the ANOVA show no significant difference among the three joint intervals. In comparing the individual joint intervals with respect to the glue spread rates, there was an increase of 12% to 76% when the interval was increased from 5 to 10cm and 15cm respectively when laminated with PF at 200g/m² as shown in Table 6. In the same vein, there was an increase from 34.27 to 62.53% as the lamellae were glued with PF at 250g/m². Biswas *et al.* (2011), also found an increase in resin spread per unit area at a resin level to have resulted in increase in strength. On the part of the PV, there was rather a small increase of 4.38% from 5cm to 10cm and dropped by about 20.78% when a 200g/m² rate was used while there was an increase of 70 to 78% when 250g/m² was used.

For the MOE properties, the finger jointed samples laminated with PF at 200g/m² were 19.63 and 6.06% respectively less when the joint intervals were increased from 5 to 10cm and then from 10 to 15cm. On the other hand, the 250g/m² rate yielded an upward increase of 4.02 and 1.87 when the distance was increased from 5 to 10 and then to 15cm. However, the PV exhibited a higher increase of 26.74 and then dropped to 6.53% with the 200g/cm² rate while the 250g/cm² rate yielded an increase of 12.53 and dropped to 2.77% when the intervals were adjusted in the same manner.

CONCLUSION

1. Finger-jointed LBT containing no node was successfully developed and the strength performance with respect to joint type, glue type, glue spread rate and the interval between joints was examined
2. The mechanical properties examined on the bamboo revealed finger jointed bamboo laminated timber having higher MOE and MOR than members formed with nodes.
3. On the part of the glue type, finger jointed laminated timber bonded with PF showed a higher performance than PVAc on both MOE and MOR.
4. The flexural performance of the LBT with finger joint laminated increases with increase in joint intervals. The MOR of the members with finger joints showed higher performance when the joint interval is increased from 5cm to 10cm. However, the MOE did not revealed any significant difference

REFERENCES

- Aicher, S., Reinhardt, H.W., & Garrecht, H. (2013). *Materials and Joints in Timber Structures: Recent Developments of Technology* (p. 855). Springer Science & Business Media. doi:10.1007/978-94-007-7811-5_32
- Amada, S., Ichikawa, Y., Munekata, T., Nagase, Y. & Shimizu, H. (1997). Fiber texture and mechanical graded structure of bamboo. *Composites Part B: Engineering*, 28(1-2), 13–20. doi:10.1016/S1359-8368(96)00020-0
- Amoah, M., Kwarteng, F.O., & Dadzie, P.K. (2014). Bending properties and joint efficiency of some tropical hardwoods finger-jointed in green and dry states. *Journal of the Indian Academy of Wood Science*, 11(1), 57–64. doi:10.1007/s13196-014-0118-y
- Anokye, R. & Adu, G. (2014). The Status of Non-Timber Forest Products (NTFPs) Development in Ghana. *Journal of Environmental Science , Computer Science and Engineering & Technology (JECET)*, 3(1), 144–155.
- Ayarkwa, J., Hirashima, Y. & Sasaki, Y. (2000). Effect of finger geometry and end pressure on the flexural properties of finger-jointed tropical African hardwoods. *Forest Products Journal*, 50(11/12), 53–63.
- Biswas, D., Kanti B.S. & Mozaffar Hossain, M. (2011). Physical and mechanical properties of urea formaldehyde-bonded particleboard made from bamboo waste. *International Journal of Adhesion and Adhesives*, 31(2), 84–87. doi:10.1016/j.ijadhadh.2010.11.006
- Dannenmann, B.M.E., Choocharoen, C., Spreer, W., Nagle, M., Leis, H., Neef, A. & Mueller, J. (2007). Tropentag 2007 University of Kassel-Witzenhausen and University of Göttingen, October 9-11 , 2007.
- Effah, B., Boamong, E., Asibey, O., Pongo, N. A. & Nkrumah, A. (2014). Small and Medium Bamboo and Rattan Enterprises in Economic Empowerment in Kumasi : Perspectives of Producers, 1(1), 11–21.
- Hamdan, H., Zaidon, A. & Tamizi, M.M. (2009). Mechanical properties and failure behaviour of Gigantochloa scortechinii. *Journal of Tropical Forest Science*, 21(4), 336–344.
- Janssen, J.J.A. (2000). *Designing and Building with Bamboo, Technical report No.2, International Network for Bamboo and Rattan*.
- Liese, W. (1987). Research on Bamboo. *Journal of Wood Science and Technology*, 21, 189–209.
- Lin, C.J., Tsai, M.J., & Wang, S.Y. (2006). Nondestructive evaluation techniques for assessing dynamic modulus of elasticity of moso bamboo (*Phyllosachys edulis*) lamina. *Journal of Wood Science*, 52(4), 342–347. doi:10.1007/s10086-005-0772-1
- Liu, D., Song, J., Anderson, D.P., Chang, P.R. & Hua, Y. (2012). Bamboo fiber and its reinforced composites: structure and properties. *Cellulose*, 19(5), 1449–1480. doi:10.1007/s10570-012-9741-1
- Nahar, Shamsun and Hasan, M. (2013). Effect of Chemical Composition, Anatomy and Cell Wall Structure on Tensile Properties of Bamboo Fiber. *Engineering Journal*, 17(1), 61–68. doi:10.4186/ej.2013.17.1.61
- Ogunjinmi, A.A., Ijeomah, H.M. & Aiyeloja, A.A. (2009). Socio-Economic Importance of Bamboo (*Bambusa Vulgaris*) in Borgu Local Government Area of Niger State , Nigeria, 10(4), 284–298.
- Van der Lugt, P., Vogtländer, J. & Brezet, H. (2009). *Bamboo, a Sustainable Solution for Western Europe: Design Cases LCAs and Land-use* (Vol. 30). Retrieved from <http://www.bambooteam.com/pablo/200810INBAR TR 30 v2.7 incl figures SMALL.pdf>
- Wahab, R., Mustafa, M.T., Sukhairi, M. & Rasat, M. (2013). Anatomy and strength properties between tropical bamboo *Gigantochloa levis* and *G. scortechinii* 1. *2nd International Conference on Kenaf and Applied Fibres (ICKAF)*, (Ickaf 2013), 1–16.

- Widjaja, W. & Risyad, Z. (1987). Anatomical properties of some bamboos utilized Recent Research on Bamboos. in Rao, A.N., Dhanarajan, G. & Sastry, C.B. (Eds.) Recent Research on Bamboos. *Proceedings of the International Bamboo Workshop. October 6-14, 1985. Hangzhou, China.*, 244–246.
- Yang, X., Tian, G., Shang, L., Lv, H. & Yang, S. (2014). Variation in the Cell Wall Mechanical Properties of *Dendrocalamus farinosus* Bamboo by Nanoindentation, 9(2002), 2289–2298.
- Yeh, M.C., & Lin, Y.L. (2011). Finger joint performance of structural laminated bamboo member. *Journal of Wood Science*, 58(2), 120–127. doi:10.1007/s10086-011-1233-7

COMPARING THE POTENTIAL ABILITY OF FUNGI ISOLATED FROM TROPICAL AND TEMPERATE FOREST TO DECOLORIZE FOUR TYPES OF DYES

Asep Hidayat¹ & Sanro Tachibana²

¹ Forestry Research and Development Agency (FORDA), Ministry of Forestry – Republic of Indonesia, Mangala Wanabakti Building, Jl. Jend. Gatot Subroto, Jakarta – Indonesia, e-mail: ashephidayat@yahoo.com

² Department of Applied Bioscience, Faculty of Agriculture, Ehime University 3-5-7 Tarumi, Matsuyama, Ehime, 790-8566 Japan

ABSTRACT

Synthetic dyes are widely used in many industries in which 40% waste from 700.000 tons/year dyes resulted more colored wastewater. In water, dyes with only < 1 ppm impedes the growth of microorganism and adversely affect to food chain and water treatments processes. Dyes are also highly resistant to degradation, toxically, and potentially carcinogenic amine. The usages of lignin-degrading white-rot fungi to remove synthetic dyes have intensively increased, because it is a viable, relatively low cost technology and publicly acceptable. This study consisted of two steps experiments. First study was aimed to isolate potential white-rot fungi from tropical and temperate forest to decolorize Remazol Brilliant Blue R (RBBR). The results showed that AS03 and F0607 were able to grow (> 85%) and decolorize RRBR (> 40%). According to molecular analysis, AS03 and F0607 belong to *Trametes* sp. (99% similar with *Trametes hirsuta*) and *Cerrena* sp. (98% similar with *Cerrena unicolor*). Second study further evaluated the capability of both fungi to remove the color of four dyes, those were Remazol B. Violet (V5), Levafix Orange E3GA (Or64), Levafix B. Red E-6BA (R159), and Sumifix S. Scarlet 2GF (R222). AS03 showed the faster decolorization rate (0.78, 0.21, 0.12 and 0.31 d⁻¹) compared to F0607 (0.09, 0.12, 0.03, and 0.22 d⁻¹) in decolorizing V5, R159, Or64 and R222. The study indicated that tropical forest in home for various agents including decolonization. The study is also indicated that among the four dyes, V5 is the most degradable and nature friendly dyes.

Keywords: Synthetic dyes, decolorization, *Trametes* sp. AS03, *Cerrena* sp. F0607

INTRODUCTION

Synthetic dyes are used in many industries around the world. Synthetic dyes are used for paper printing, foods, color photography, textile dyes, pharmaceutical, painting and other. Among common classes of them, which referred on the chemical structure of chromophore groups, azo dyes have been widely used in textile processing and have dominated about 70% of dyestuffs in worldwide market. In the case of textile industry, it have been contributed the highly disposal of synthetic dyes in wastewater, about 40% waste from 700.000 tons/year dyes resulted more colored wastewater (Zongllinger, 1991; Jin *et al.* 2007). Dyes with only < 1 ppm in water will impede the growth of microorganism and adversely affect to food chain and water treatments processes (Ciullini *et al.* 2008). Dyes are also highly resistant to degradation, toxically, and potentially carcinogenic amine.

Recently, the wastewater of the dye industry has become a critical environmental concern not only because of its aesthetic reason but its levels of toxicity. Microbial decolorization has been claimed to be a viable, relatively low cost, low-technology technique and publicly acceptable to more traditional physical-chemical methods, which are highly cost, disposal problem and limited applicability (Verma and Madamwar, 2003; Ferreira *et al.* 2000) in solving the dyes industry problems. The uses of lignin-degrading white-rot fungi have intensively studied as the focus to degrade various recalcitrant organic pollutants (Verdin *et al.* 2004; Mastubara *et al.* 2006). The presences of a ligninolytic enzymes secreted by fungi, peroxidase and laccase enzymes, will catalyze both directly and un-directly of xenobiotic compounds (Cerniglia and Sutherland, 2001; Potin *et al.* 2004; Sing, 2006), including synthetic dyes (Asgher *et al.* 2006; Tavaker *et al.* 2006; Hamedani *et al.* 2007).

Although, white-rot fungi have been showed to have decolonization ability for dyes, it still remains a big challenge to compare tropical and temperate white-rot fungi origin that has the most powerful ability to decolorize azo dyes, and which of the enzyme, whether peroxidases or and laccases, that play the major rules in dyes removal. In this study, we isolated potential white-rot fungi to decolorize Remazol Brilliant Blue R (RBBR) from tropical and temperate forese. Therefore, we investigate the determined potential fungi, *Trametes* sp. AS03 and *Cerrena* sp. F0607 which have been isolated from tropical and temperate forest, to decolorize four types of dyes. The enzymatic activity involved during dyes removal was also investigated and analyzed.

METHODS

Chemicals

Remazol B. Violet (V5), Levafix Orange E3GA (Or64), Levafix B. Red E-6BA (R159), Sumifix S. Scarlet 2GF (R222) were obtained from Textile Company – Japan. Remazol Brilliant Blue R (RBBR) was purchased from Sigma (St. Louis, USA). All other chemicals were purchased from Wako Pure Chemical Industry (Osaka, Japan) at the highest purity available.

Fungi and culture condition

Fungi used in this study was isolated from decay wood pieces and fungal body collected from temperate mountain of Matsuyama, Japan and mangrove swamps of Sungai Pakning and Tanjung Buton – Riau Province, Indonesia. They were maintained on malt extract agar (MEA) medium containing malt extract (20 g L⁻¹), glucose (20 g L⁻¹), agar (20 g L⁻¹), and polypeptone (1 g L⁻¹) at 25 °C for several days and maintained at 4 °C.

Isolation and identification of fungi

The sample was screened for the ability to decolorize RBBR (100 mg L⁻¹) in the Czapek-Dox agar medium containing of glucose (10 g L⁻¹), sacharose (10 g L⁻¹), KH₂PO₄ (1 g L⁻¹), KCL (0.5 g L⁻¹), MgSO₄ 7H₂O (0.5 g L⁻¹), FeSO₄ 7H₂O (0.01 g L⁻¹), yeast extract (2 g L⁻¹), polypeptone (2 g L⁻¹) and agar (15 g L⁻¹). The potential fungi for each source (tropical and temperate forest origin) were selected for further study.

DNA was extracted from cultural mycelium using a modified CTAB method (Murray and Thompson 1980). The internal transcribed spacer ITS regions (Jellison and Jasalavich, 2000), primers ITS1-F (5'-CTTGGTCATTTAGAGGAAGTAA-3') and ITS4-B (5'-CAGGAGACTTGACAGGTCCAG-3'), was amplified by PCR. The PCR was performed in 20 µl of solution containing 10 ng of genomic DNA, 5pmol of each forward and backward primer, and 10 µl of Go Taq® Hot Start Colourless Master Mix (Promega, Wisconsin USA) prior to manufacturer's instruction. Initial denaturation was performed at 95°C for 2 min, followed by 30-35 cycles of denaturation at 95°C for 1 min, annealing 52-62°C and polymerization at 72°C for 2 min, and final extension at 72°C for 7 min. Prior to sequencing, the PCR products were purified using rAPid Alkaline Phosphatase™ (Roche, Germany) and exonuclease I (New England Biolabs, Massachusetts, USA). The purified PCR products were sequenced and BLAST searches for ITS region sequences in the GenBank database (<http://www.ncbi.nlm.nih.gov/>).

Decolorization of dyes in liquid fungus culture

The decolorization of dyes was also evaluated in malt extract liquid medium, containing malt extract (20 g L⁻¹), glucose (20 g L⁻¹), and polypeptone (1 g L⁻¹), with approximately pH 4.5. Each synthetic dye was contaminated after 7 days of fungi cultivation for each inoculum AS03 and F0607. The 6 ml samples were withdrawn by filtered at regular intervals, 1, 2 and 3 days. Using the remaining 6 ml, the supernatants were analyzed by a UV-visible spectrophotometer at the wavelength of maximum absorbance (λ_{max}) for each dyes solution used in these experiments. Decolorization percentage was calculated by following equation:

$$\% \text{ Decolorization} = ((A_o - A_t)/A_t) \times 100$$

A_o and A_t referes to initial and final absorbance units respectively.

MnP and laccases assay

The enzymatic activities were quantified directly after decolorization analysis (as mention in section above). Activities of manganese peroxidase (MnP) and laccase were assayed using spectrophotometric. Manganese peroxidase (MnP) activity was assayed using 50 mM malonate buffer and dimethoxyphenol in 20mM of manganese sulfate ($MnSO_4$) at 470 nm (Wariishi *et al.* 1992). Laccase activity was assayed by measuring the increase in absorbance at 525 nm using syringaldazine as a substrate in sodium acetate buffer (Leonowicz and Grzywnowics, 1981). All experiments were carried out at 25 °C. Activities were expressed as international units per liter of enzyme, where one unit of activity is defined as the amount of enzyme necessary to convert 1 μ mol of substrate in 1 min.

Data analysis

All results were presented as means of the standard deviation and analyzed using SPSS version 15 for windows. When necessary, results were also analyzed with pearson correlation coefficients (r), a two-tailed test of significance ($P < 0.05$). The azo dyes decolorization data was expressed with first-order kinetics (Ting *et al.* 2011) : $S = S_0 \exp(-k_1 t)$, $t_{1/2} = \ln 2/k_1$, where S_0 is the initial concentration, S is the substrate concentration at time t , t is the time period, and k_1 is the degradation rate constant. A *partial least square* analysis was used as an analysis to determined enzyme that having positive contribution on the decolorization of dyes, MnP or laccase.

RESULT AND DISCUSSIONS

Isolation and identification of fungi

There were 31 fruit body screened, 15 were collected from temperate forest in Matsuyama-Japan and 16 from Sungai Pakning and Tanjung Buton, Riau – Indonesia. From the total of 31 fruit body screened, nine strains fungi were selected for further study in this experiment. The isolation was conducted to their capacities to growth or decolorization RBBR dyes. Among all the strained screened, two strains fungi, F0607, and AS03, were capable to grow more than 85% and decolorize more than 40% of dyes in the end of 7 days incubation (Fig. 1). Both fungi, in which F0607 represented a temperate forest origin and AS03 represented a tropical forest origin, then further selected for their ability to decolorize four types of azo dyes.

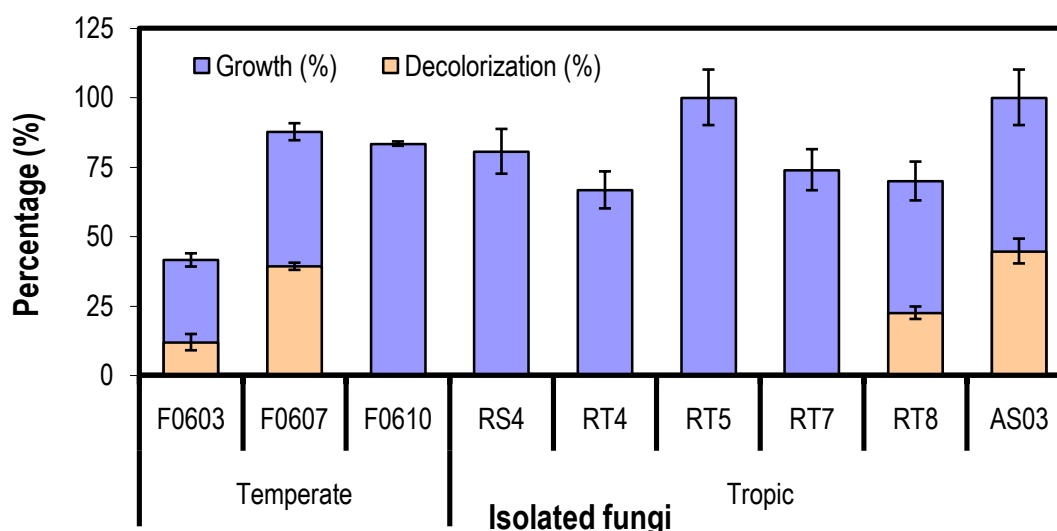


Figure 1. Growth percentages of the several isolated fungi in agar medium containing 100 mg L⁻¹ of RBBR at 25 °C

The genetic identification was also conducted to make sure of our finding. The 529-bp ITS sequence (ITS1/5.8S) of AS03 and F0607 was compared with similar sequences in the NCBI GenBank database using the BLAST online search program. Alignment of the strains, both manually and using Cluster W, showed that a partial sequence of AS03 had a maximum similarity index of 99% relative to *Trametes hirsuta* (Accession No. JN048768, JX861099, and FJ891292), named as *Trametes* sp. AS03 (Hidayat and Tachibana, 2014), and

F0607 belong to *Cerrena* sp. (98% similar to *Cerrena unicolor*, Accession No. JN182905 and FJ821535), named as *Cerrena* sp. F0607 (Hidayat and Tachibana, 2013). *Trametes hirsuta* species have been reported to have a broad ability to decolorize several of azo dyes (Couto, 2007 and Moilanen *et al.* 2010). Likewise, *Cerrena* sp. was also reported that will be responsible for the degradation of various dyes (Moilanen *et al.* 2010; Grassi *et al.* 2011).

Decolorization

Two isolate fungi, *Cerrena* sp F0607 and *Trametes* sp. AS03, were chosen for their capabilities to decolorize four types of selected dyes. Fig. 2 shows the decolorization of four types of azo dyes obtained by F0607 and AS03. Over all, decolorization rate was increased by addition on time of incubation, from 1 to 2 or 3 days, but the rate differed by fungi and type of dyes (chemical structural and properties). F0607 was able to decolorize: 24 %, 27 %, 11 % and 48 % of V5, R159, Or64 and R222, while AS03 showed higher decolorization rate, those were 91 %, 48 %, 31% and 60 % of V5, R159, Or64 and R222, respectively.

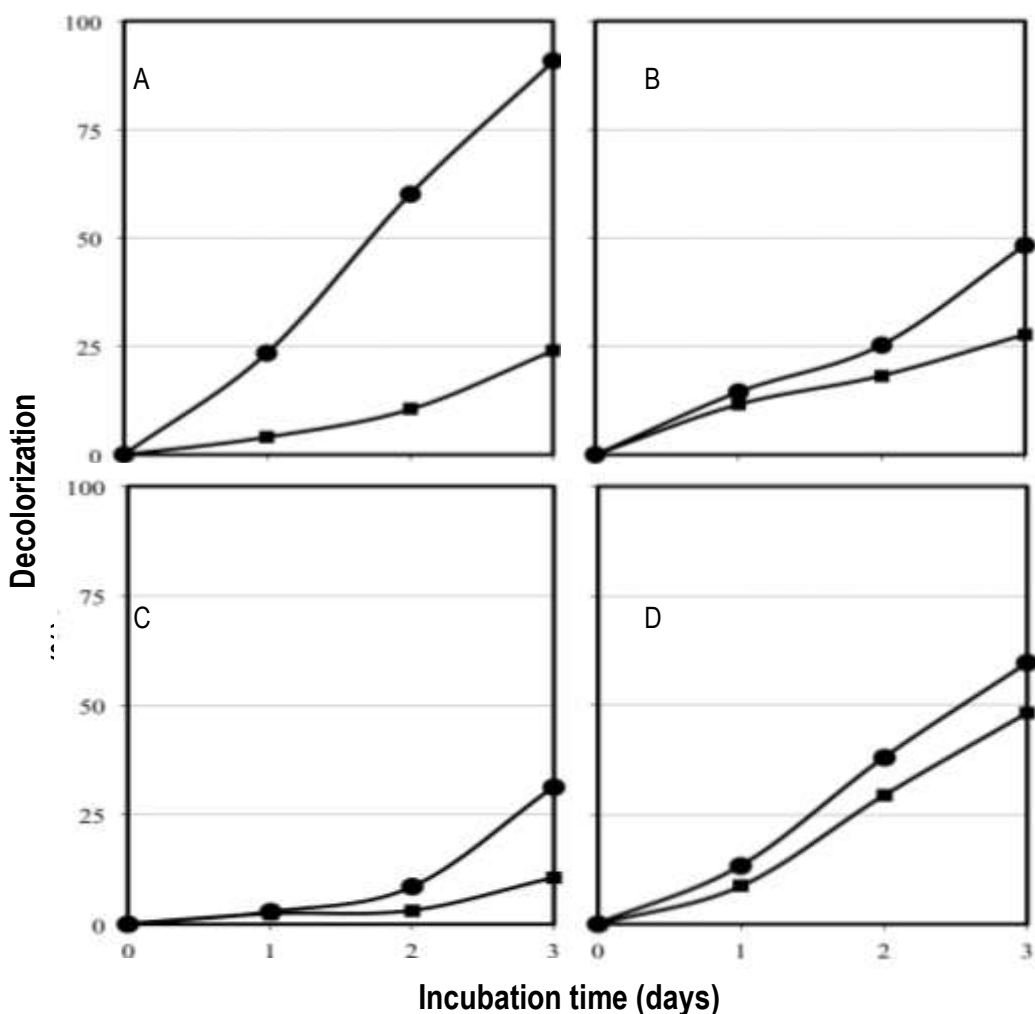


Figure 2. Decolorization of V5 (A), R159 (B), Or64 (C) and R222 (D) by AS03 (●) and F0607 (■), with initial concentration 100 mg L⁻¹.

According to equation described by Ting *et al.* 2011 (Table 1), the constant (k_1) azo dyes decolorization rate was faster observed in cultures of AS03 (0.78, 0.21, 0.12 and 0.31 d⁻¹) than F0607 (0.09, 0.12, 0.03, and 0.22 d⁻¹). The decolorization rate based on dyes types for both fungi were V5 > R222 > R159 > Or64, indicated that V5 was the most degradable dyes. Paszczyński *et al.* 1992 and Spadaro *et al.* 1992 reported that decolorization occurred because of the aromatic cleavage. While cleavage process itself depend on the ring substituents, such as phenolic, amino, acetamido, 2- methoxyphenol or other functional groups. The

complexities of the dyes structures have been reported to be not good indicator as difficulties of decoloration of a particular dye (Hadibarata *et al.* 2011). This study determined that that *Trametes* sp. AS03, a tropical forest - originated fungi, has been showing stronger ability to decolorize four types of dyes in malt extract liquid medium at specific pH 4.5 compare to *Cerrena* sp. F0607 , a temperate forest-originated fungi.

Enzymes activities

In this study, laccase and MnP was detected during decolorization of four types dyes in fungi liquid culture either for inoculum AS03 and F0607. Likewise lignin peroxidase (Lip), phenol oxidases (tyrosinases), and H₂O₂-producing enzymes, laccase and MnP are extra-cellular enzymes system (Haritash and Kaushik, 2009). Laccases are a multi copper enzyme that is distributed among fungal species, and capable to catalyze variety of phenol compounds, which involves the reduction of O₂ to H₂O. MnP oxidizes Mn (II) to form Mn (III) and then Mn (III) oxidizes a phenolic substrate to produce phenoxy radicals with hydrogen peroxide (H₂O₂). Laccase has potential applications in the mineralization of environmental pollutants, wine stabilization, paper processing, and the enzymatic conversion of chemical intermediates (Minussi *et al.* 2007). Although laccases exhibit relaxed substrate specificity, they may be less important than LiP and MnP in the oxidation of pollutants, including dyes (Harayama, 1997).

Table 1. The Constanta of decolorization rate MnP and Lac activities in liquid fungi culture of AS03 and F0607 supplemented with V5, R159, Or64, or R222

Fungi	Dyes ^a	K ₁ ^b	Enzyme Contribution ^c		Enzyme activities (U L ⁻¹)							
					MnP				Lac			
					Incubation Period			r ^d	Incubation period			r ^d
					MnP	Lac	1		2	3	1	
AS03	V5	0.78	2.12	1.55	5.06	4.52	15.44	0.81*	0.00	20.64	40.09	1.00**
	R159	0.21			2.79	4.52	7.25	1.00**	0.00	12.56	11.97	0.72 ^{tn}
	Or64	0.12			3.59	4.26	6.65	1.00**	3.89	2.99	8.97	0.95**
	R222	0.31			3.46	5.72	9.58	0.98**	9.87	14.36	21.54	0.99**
F0607	V5	0.09	0.01	0.03	90.75	31.07	148.10	0.66 ^{tn}	512.44	511.54	761.62	0.95**
	R159	0.11			48.10	43.11	59.08	0.74 ^{tn}	200.73	245.90	347.61	0.99**
	Or64	0.03			51.43	59.21	61.21	0.72 ^{tn}	215.68	220.17	277.01	1.00**
	R222	0.22			64.74	79.97	78.64	0.84*	284.19	340.43	517.52	0.95**

Decolorization rate constants were calculated as described by Ting *et al.*(2011).

Correlation coefficients were determined between decolorization dyes and enzymes activities (MnP or Lac)

* Correlation is significant at the 0.05 level

** Correlation is significant at the 0.01 level

^{tn} Correlation is not significant

^a Initial dyes concentration is 100 mg L⁻¹

^b Decolorization rate Constanta

^c Calculation by a *partial least square* analysis

^d Spearman's correlation coefficient

At specific time, in liquid culture containing V5, R159, Or64 or R222, the activity of laccase secreted by AS03 was higher than MnP (see Table 1). In each day of observation, positive correlation between decolorization of each dyes substrates (V5, R159, Or64 and R222) and MnP activities (0.81, 1, 1, 0.98) or laccase (1, 0.72, 0.95, 0.99) were found during the decolorization process by AS03. The maximum level of activity reached 15.44 U L⁻¹ for MnP and 40.09 U L⁻¹ for laccase during V5 decolorization at 3 days incubation.

The activity of MnP and laccase secreted by F0607 was higher than those enzymes secreted by AS03 (Tabel 1). In general, the activity of laccase was higher than MnP. In F0607 culture, the correlation between the decolorization and MnP (0.66, 0.74, 0.72, 0.84) or laccase (0.95, 0.99, 1, 0.95) was positive. The maximum level of activity reached 148.10 U L⁻¹ for MnP and 761.62 U L⁻¹ for laccase during decolorization V5 at 3 days incubation. The decolorization of V5 by F0607 was also highest among others dyes. Although the enzymes produced by F0607 was higher than AS03, but decolorization ability showed lower rate. Other our study also showed that decolorization of dyes by F0607 has higher rate compare to those of AS03, especially in Krik's liquid medium (Data no shown). It indicated that suitable medium would also affect decolorization rate in accordance to nitrogen and carbon sources availability (rich or poor) and pH (alkaline or acid) (Kaushi and Malik, 2009).

According to data showed in Tabel 1, MnP and Laccase had positive correlation to decolorization of dyes. However which enzyme had biggest contribute to decolorize of dyes is still remains unclear and requested further analysis to perform. Through *Partial Least Square* analysis, the possible contribution of MnP and laccase could be predicted. For decolorization by AS03, MnP determined to be more powerful (2.12) than laccase (1.55), but for F0607, laccases has been more adaptive (0.03) than Mnp (0.01). The lower contribution of MnP and laccase produced by F0607 on decolorization was caused by high enzyme activities but lower decolorization result. This study also revealed that high enzyme activity was not always closely related to decolorization ability. Other factors still give significant contribution on degradation, those are fungi strain, biochemical feature, and dyes types.

CONCLUSIONS

Trametes sp. AS03, a tropical forest origin fungi, and *Cerrena* sp. F0607, a temperate forest origin fungi, had capability to decolorize four dyes types. The study revealed that fungi from tropical forest have great potential benefit for various bioremediation agents, including decolorization of dyes. The data presented here show that V5 is the most degradable and nature friendly dyes.

REFERENCES

- Asgher, M., Shah, S.A.H., Ali, M., and Legge, R.L. 2006. Decolorization of some reactive dyes by white rot fungi isolated in Pakistan. *World Journal of Microbiology Biotechnology* 22: 89–93.
- Cerniglia, C.E., and Sutherland, J.B. 2001. Bioremediation of polycyclic aromatic hydrocarbons by ligninolytic and non-ligninolytic fungi. *In: Gadd GM (eds), Fungi in bioremediation*. Cambridge University Press, New York, pp. 136-187.
- Ciullini, I., Tilli, S., Scozzafava, A., and Briganti, F. 2008. Fungal laccase, cellobiose dehydrogenase, and chemical mediators: combined actions for the decolorization of different classes of textile dyes. *Bioresource Technology* 99: 7003-7010.
- Ferreira, V.S., Magalhaes, D.B., Kling, S.H., DaSilva, J.G., and Bon, E.P.S. 2000. N-Demethylation of methylene blue by lignin peroxidases from *Phanerochaete chrysosporium*. *Applied Biochemistry and Biotechnology* 84: 255–265.
- Grassi, E., Pablo, S., Nestor, F., Romina, C., and Laura, L. 2011. Potential of *Trametes trogii* culture fluids and its purified laccase for the decolorization of different types of recalcitrant dyes without the addition of redox mediators. *International Biodeterioration and Biodegradation* 65: 635-643.
- Hadibarata, T., Yusoff, A.R.M., Aris, M., Hidayat, T., and Kristanti, R.A., 2012. Decolorization of azo, triphenylmethane and anthraquinone dyes by laccase of a newly isolated *Armillaria* sp. F022. *Water Air Soil* 223: 1045-1054.
- Hamedaani, H.R., Sakurai, A., and Sakakibara, M. 2007. Decolorization of synthetic dyes by a new manganese peroxidase producing white rot fungus. *Dyes and Pigments* 72: 157–162.
- Harayama, S. 1997. Polycyclic aromatic hydrocarbon bioremediation design. *Current Opinion in Biotechnology* 8: 268-273.
- Haritash, A.K. and Kaushik, C.P. 2009. Bioremediation aspect of polycyclic aromatic Hydrocarbon (PAHs). *Review. Journal of Hazardous Material* 169: 1-15.
- Hidayat, A. and Tachibana, S. 2014. Decolorization of azo dyes and mineralization of phenanthrene by *Trametes* sp. AS03 isolated from Indonesian Mangrove Forest. *Indonesian Journal of Forestry Research* 1: 67-75.
- Hidayat, A. and Tachibana, S. 2013. Degradation of 2,4,8-trichlorodibenzofuran by a new isolate of *Cerrena* sp. F0607. *International Biodeterioration and Biodegradation* 77: 51-55.
- Jin, X., G. Liu, Z. Xu, and W. Yao. 2007. Decolorization of a dye industry effluent by *Aspergillus fumigatus* XC6. *Applied Microbiology and Biotechnology* 74: 239–243.
- Kaushi, P., and Malik, A. 2009. Fungal dye decolourization: recent advances and future potential. *Environmental International* 35: 127-141.
- Leonowicz, A., and K. Grzywnowicz 1981. Quantitative estimation of laccase forms in some white-rot fungi using syringaldazine as a substrate. *Enzyme and Microbial Technology* 3: 55-58.

- Matsubara, M., Lynch, J.M., and De Leij, F.A.A.M. 2006. A simple screening procedure for selecting fungi with potential for use in the bioremediation of contaminated land. *Enzyme and Microbial Technology* 39: 1365-1372.
- Minussi, R.C., Pastore, G.M., and Duran, N. 2007. Laccase induction in fungi and laccase/N-OH mediator systems applied in paper mill effluent. *Bioresource Technology* 98: 158-164.
- Moilanen, U., Oasma, J. F., Winquist, E., Leisola, M., and Couto, S.R. 2010. Decolorization of simulated textile dye baths by crude laccases from *Trametes hirsuta* and *Cerrena unicolor*. *Engineering in Life Sciences* 10: 242-247.
- Paszczynski, A., Pasti-Grigsby, M.B., Goszczynski, S., Crawford, R.L., and Crawford, D.L. 1992. Mineralization of sulfonated azo dyes and sulfanilic acid by *Phanerochaete chrysosporium* and *Streptomyces chromofuscus*. *Applied and Environmental Microbiology* 58: 3598-3604.
- Potin, O., Rafin, C., and E. Veignie. 2004. Bioremediation of an aged polycyclic aromatic hydrocarbons (PAHs)- contaminated soil by filamentous fungi isolated from soil. *International Biodeterioration and Biodegradation* 54: 45-52.
- Singh, H. 2006. *Mycoremediation: Fungal Bioremediation*. John Wiley & Sons, Inc. United State of America. pp. 115-148.
- Spadaro, J.T., Gold, M.H., and Ranganathan, V. 1992. Degradation of azo dyes by the lignin-degrading fungus *Phanerochaete chrysosporium*. *Applied and Environmental Microbiology* 58: 2397-2401.
- Tavaker, M., Svobodova, K., Kuplenk, J., Novotny, C., and Pavko, C. 2006. Biodegradation of Azo Dye RO16 in different reactors by immobilized *Irpex lacteus*. *Acta Chimica Slovenica* 53: 338-343.
- Ting, W.T.E., Yuan, S.Y., Wu, S.D., and Chang, B.V. 2011. Biodegradation of phenanthrene and pyrene by *Ganoderma lucidum*. *International Biodeterioration and Biodegradation* 65: 238-242.
- Verdin, A., Sahraoui, A.L.H., and Durand, R. 2004. Degradation of benzo[a]pyrene by mitosporic fungi and extracellular oxidative enzymes. *International Biodeterioration and Biodegradation* 53: 65-70.
- Verma, P., and Madamwar, D. 2003. Decolorization of synthetic dyes by a newly isolated strain of *Serratia marcescens*. *World Journal of Microbiology and Biotechnology* 19: 615-618.
- Wariishi, H., Valli, K., and Gold, M.H. 1992. Manganese (II) oxidation by manganese peroxidase from the basidiomycete *Phanerochaete chrysosporium* kinetic mechanism and role of chelators. *The Journal of Biological Chemistry* 267: 23688-23695.
- Zollinger, H. 1991. *Colour chemistry: synthesis, properties and applications of organic dyes and pigments*, 5th eds. VCH Publishers, Weinheim, pp 187-246

THE TREATABILITY ANGGRUNG WOOD (*Trema Orientalis*) BY COPPER SULFATE

Taman Alex

Samarinda Agricultural Polytechnic
Corresponding author : tamanalex2@gmail.com

ABSTRACT

Treatability studies on whether or easier absorption of copper sulfate preservative into the wood angrung (*Trema orientalis*) based on the actual value retention and penetration. And so measured of the Corrected Water Absorption High (CWAH). Anggrung preserve wood by immersion in preservative copper sulfate at a concentration of 2 %, 3 %, and 4 %, then the measured value of retention and penetration and absorption tested or calculated value Corrected Water Absorption High (CWAH). The result shows that Anggrung Wood are preserved the penetration of copper sulfate preservatives.. The fact was proved with actual retention value within 5.69 Kg/m³ for concentration 2 %, 5.7 Kg/m³ for concentration 3 % and 8.3 Kg/m³ for concentration 4 % Copper Sulfate. Whereas penetration value within 1.24 mm for 2 %, 1.25 mm for 3 % and 1.24 for 4 % concentration. The result shows that Corrected Water Absorption High (CWAH) value for 72 hour of plunged state resulting in CWAH of 62. That was the most important proof that Anggrung wood easier penetrated.

Keywords : Treatability, Copper Sulfat, *Trema orientalis*

INTRODUCTION

Wood is one of the ingredients that are important to human life various purposes such as for construction, energy and other industries materials. The choice of wood as a construction material requires knowledge of the wood properties. One is the use of timber as a construction material and the residential buildings. The Properties of wood is important the wood durability properties. Properties treatability is indicator easily preserved wood. Anggrung wood (*Trema orientalis*) is a pioneer plant of the family Ulmaceae that grows in Indonesia and is a fast growing timber species (Endert, 1976). If the have not been widely used as a construction material because the wood durable angrung included in class V (Seng, 1990). Based on the information needs to be improved the durable class by process of preservation the necessary information about the nature treatability. According to Hunt and Garrat (1986) and Duldjapar (1996), said that the activity of wood preservation the treatability know the nature of the wood is very important, because the success is influenced by the nature treatability preservation of wood, that is depend to the material, preservatives and preservation methods. The nature treatability angrung wood (*Trema orientalis*) by a chemical solution material is unknown. Higher treatability is a success of the preservation of wood which can be determined from the value of the timber porosity or power impregnating solution known as high water absorption value or Corrected water Absorption High (CWAH) (Siau, 1995). This study focuses on the nature of indicator treatability value and retention values by using copper sulfate preservatives.

RESEARCH METHODS

Material and Equipment.

1. Research materials : Copper sulfate, water and wood of angrung.
2. Equipment : buckets, basins, scales, measuring cups, soaking tub, stationery, gauges, caliper, pH meter, aerometer, chainsaw, cut saw, planner, chipper, glass pipes and oven dry etc.

Procedures for research.

1. Create a test example by means of: cutting, splitting and planing timber of anggrung to get wooden beam with size 2 cm x 2 cm x 20 cm for the soaking preserved and made of wood with samples size of 2 cm x 2 cm x 2 cm to test the specific gravity and moisture content.
2. Make to copper sulfate solution is put into water at a concentration of 2 %, 3 % and 4 %.
3. Make sawdust of wood anggrung a certain size, and then dried in a drying oven at a temperature of 70 degrees Celcius for 3 days. Then done sifting with 40 mesh size.
4. Measure the acidity and specific gravity of the preservative solution.
5. All pieces samples of wood have been soaked measured weighed to calculate the value of retention, which is one indicator of treatability. Indicator of treatability is value of Current Water Absorption High (CWAH).

Data Processing.

Data processing techniques to determine treatability based on the measured parameters, namely : the actual retention and CWAH value.

1. The actual retention (AR). Actual retention (AR) is the amount of preservatives is absorbed in the wood cell cavities. Actual retention was calculated by the formula of Siau (1995), are as follows:

$$AR = \left\{ \frac{A}{V} \times C \right\} \times \left\{ 1 - S \left(\frac{1}{1.53} + \frac{MC}{1.15} \right) \right\}$$

Remarks:

AR = Actual retention. A = Absorption. V = volume. C = concentration. S = specific gravity of wood. MC = moisture content. 1.53 = specific gravity of cell wall. 1.115 = specific gravity of bound water.

2. Corrected Water Absorption High (CWAH). Determining corrected water absorption high (CWAH) using the formula Siau (1995).

$$CWAH = H \left(\frac{D^2 \pi H_2}{4 W S} \right)$$

Remarks:

H = high of infiltration on the time. D² = diameter of pipes. H₂ = high of maximum infiltration. W = Weight of sample. S = specific gravity of solution/water. π = 3.14

RESULT AND DISCUSSION

1. Actual Retention.

The value of the actual retention are presented in table one below :

Table 1. Retention of the actual value of a portrait magnitude treatability anggrung wood (kg/m³)

Soaking Time	Solution Concentration		
	2 %	3 %	4 %
One week	3.15	3.08	3.62
Two week	5.69	5.70	8.31

Based on the actual retention of immersion results listed in Table 1, describing that anggrung timber is wood that is easy to absorb solution including the preservative and has a high treatability. Actual retention is retention that takes into account the percentage of the wood cell cavities, so the preservative will only occupy the empty spaces in the wood. Thus the actual retention which is a realistic retention preservative contained in the wood and is heavily influenced by the retention of wood properties.

2. Corrected Water Absorption High (CWAH).

CWAH value is manifest information about ease of solution impregnated wood. CWAH value calculation results are presented in Table 2 below :

Table 2. Correlation average value CWAH anggrung wood absorption time.

Period	Time (hours)	CWAH Value
1	0.5	15
2	2	24
3	4	29
4	24	42
5	48	57
6	72	62
7	96	62

Corrected water absorption high can be used to estimate or provide early information on whether a particular type of wood is preserved. CWAH high value means high wood porosity, high porosity means porous wood preservative solution. Wood anggrung CWAH value for 0.5 hours worth 15 and over 72 hours worth 62. According to Sushardi et al. 1997, that the value of a type of wood called CWAH higher if the absorption test for 30 minutes or 0.5 hours to obtain results CWAH value of up to 100. The higher the value CWAH means getting solid wood or wood grew thicker cell walls and smaller porosity. The smaller of CWAH value means the wood cell walls are thin and the greater porosity and mean more easily infused liquid or more easily preserved. In the studied wood anggrung turns in the first period of 30 minutes or 0.5 hours resulted in a value of 15, meaning anggrung wood thin cell walls and is infused preservative or high treatability.

CONCLUSION

1. Wood treatability anggrung based value retention test results with the actual process of immersion with preservative copper sulfate were included easily preserved wood.
2. Based on the Corrected Water Absorption High / CWAH value for preservative types of copper sulfate to timber was included wood porous or absorb easy water/solution.

REFERENCES

- Alex, 2001. Efek Pengawetan dengan Vakum-Tekan Terhadap Sifat Kekuatan Kayu Meranti. Buletin Loupe. Jurusan Pengolahan Hasil Hutan. Politeknik Pertanian Negeri Samarinda. No. 1 Tahun 2001.
- Budiarso, 2013. Pengeringan Kayu Gergajian. Mulawarman University Press. Samarinda.
- Brown, et al. 1952. Textbook Of Wood Technology. MC Graw Hill, Inc. Book Company New York.
- Boyce, 1961. Forest Pathology. McGraw Hill Book Company, Inc. New York
- Ender, 1976. Penuntun Kearah Keluarga Tumbuh tumbuhan di Indonesia. Yayasan Pembina Fakultas Kehutanan UGM. Yogyakarta.
- Hunt dan Garrat. 1986. Pengawetan Kayu. Akademika Pressindo. Jakarta.
- Nandika, D. 1994. Bahan Pengawet Kayu. PAU. IPB. Bogor.
- Seng, 1990. Berat Jenis Dari Jenis-Jenis Kayu Indonesia dan Pengertian Beratnya Kayu Untuk Keperluan Praktek. Pengumuman. Pusat Penelitian dan Pengembangan Hasil Hutan. Bogor.
- Sushardi, A.D. Yuniarti, T. Alex dan Sukadariyati, 1997. Sifat Penyerapan Kayu Balsa. Teknologi Hasil Hutan. Program Studi Ilmu Kehutanan. Pascasarjana Universitas Gajah Mada. Yogyakarta.
- Siau, JF. 1995. Wood Influence Of Moisture On Physical Properties. Departement of Wood Science and Forest Products. Virginia Polytechnic Institute and State University.

TERMITE RESISTANCE OF THREE LAYER PARTICLEBOARD *Shorea leprosula* Miq. FROM NATURAL AND PLANTATION FOREST

Yuliati Indrayani¹, Gusti Hardiansyah¹, Gustan Pari²

¹ Faculty of Forestry Tanjungpura University, Jl. Imam Bonjol, Pontianak, Indonesia

² Research and Development of Forest Engineering and Forest Products Processing, Bogor, Indonesia

E-mail: mandapermai@yahoo.com

ABSTRACT

The development of composite particle board made from red meranti (*Shorea leprosula* Miq.) and their resistance to termite attack has been investigated. This study was carried out to investigate the effect of density on three-layer resin-bonded particleboard under laboratory conditions. The wood species used were *Shorea leprosula* Miq. collected from both natural and plantation forest. Target densities of boards were 0.6 g/cm³, 0.7 g/cm³ and 0.8 g/cm³, respectively. Two size categories of particles, fine and coarse were applied for board manufactured with ratio of 40:60. Commercial urea formaldehyde (UF) resin was used as an adhesive (9% for middle layer and 11% for the surface layers based on the oven dry weight of the particle). The press condition was 160°C and 6 min. Wood specimens were then subjected to laboratory termite resistance tests using the subterranean termites, *Coptotermes formosanus* Shiraki according to the Ohmura et al (2000) method. Results indicated that particleboard with higher density resulting higher resistance to termite attack. However, *S. leprosula* from natural forest show slight higher resistant than *S. leprosula* from plantation forest against subterranean termites. Differences in the termite resistance between natural and plantation forest were caused by the presence of the chemical content.

Keywords: Three layer particle board, *Shorea leprosula* Miq., Natural and plantation forest, *Coptotermes curvignatus* Holmgren

INTRODUCTION

Red meranti (*Shorea* sp.) supplies from natural forests are being decreasing. Nowadays many plantation forests established. To fulfill the requirement of wood supply, red meranti has been planted as a species of plantation forest. This plantation forest was developed by intensive silviculture (SILIN).

Wood of red meranti from natural forest well has known use for construction materials or raw material for plywood manufacturing. However, the characteristic of timber produced from plantation forest were fast growing, short rotation, small diameter, has a low mechanical and physical properties. An effort is needed to increase the properties of red meranti from plantation forest. One of them is as raw material for wood-based composite. One of the most important wood-based composites is particleboard.

Particleboard is a panel product manufactured under pressure from particles of wood or other ligno-cellulosic materials and an adhesive (Nemli and Aydin, 2007). It has found typical applications as furniture, cabinets, flooring, table, office dividers, wall and ceiling, home constructions, sliding doors, kitchen worktops, interior designs, and other industrial products (Wang et al., 2008). The three-layer particleboard has been studied (Abdel & Nasser, 2012; Hrazsky & Kral, 2003; Nazerian et al., 2011; Geimer et al., 1975).

On the other hand, wood-based composite boards were susceptible to termite attack (Curling and Murphy 1999; Chung et al.1999). One of the most important termite species in the world is subterranean termite. Subterranean termites can cause extensive damage to wood and non-woody composites produced from non-durable material resources. Therefore, it is indispensable to investigate the termite resistance of particleboard of *Shorea* sp. as diversification product composite.

The aim of this study is to discuss the biological properties of the three-layer particleboards which were manufactured in the laboratory using *Shorea leprosula* collected from natural and plantation forest.

METHODS

Board Preparation

The red meranti (*Shorea* sp.) were collected from both natural and plantation forests in PT. Alas Kusuma, West Borneo. The diameter of both woods was approximately 30 cm. They were chipped using a hacker chipper before the chip were reduced into smaller particles using a knife ring flakers. The chips were dried to approximately 10% moisture content. Dried chips were classified into two size categories, namely fine and coarse. The ratios of the mixture of fine and coarse particles were 40:60, in the surface and middle layers (Ghalehno & Nazerian, 2011). Urea formaldehyde (UF) resin was used as an adhesive (for the middle layers 9% and for the surface layers 11% based on the oven dry weight of the chips) (Ghalehno & Nazerian, 2011). Mattresses were hand-formed and hot pressed at 160°C for 6 min using a pressure of 30 kgm². Boards were manufactured with varied target density of 0.6, 0.7, 0.8 gcm³, respectively and target board thickness was 1 cm. Three replicates panels were produced for each board type. After manufacture the boards were conditioned at temperature room for seven days before the test.

Termite bioassay

After conditioning, test samples measuring of 2 cm x 2 cm x 1 cm were cut from the particleboard panels and exposed to the subterranean termite *Coptotermes curvignathus* Holmgren in accordance Ohmura et al (2000) with modification. No-choice bioassay was conducted in this study. A test container was made of a plastic cup with upper diameter of 6 cm, bottom diameter of 5 cm and height 5 cm with a hard plaster bottom. The bottom of the container was covered with 10 g of sand (15-20 mesh) and moistened with 2 ml of distilled water. A test sample was placed on the centre of the test container. Fifty workers of the subterranean termite *Coptotermes curvignathus* Holmgren were introduced into the container. The plastic containers were then placed in the dark room with room temperature for 21 days. After 21 days the samples were taken out and dried to determine the weight loss of each sample. Termite mortality was also determined as well. Three replications were carried out for each test treatment. The effect of the variables on the properties of the boards was assessed by Variable Analysis in factorial design and Tukey's Analysis was used for comparison of the average values.

RESULTS AND DISCUSSION

The average of weight losses and percentage mortality of termites of board during the termite bioassays are shown in Tables 1 and 2. The laboratory test indicates that there was a significant effect of density on the susceptibility of the particleboard specimens. Habitat (location of collection) of *S. leprosula* had no significant effect on the termite resistance of the specimens against *C. curvignathus*. All termites were found almost moribund after 3-weeks termite exposure to particleboard for both *S. leprosula* from natural and plantation forest (Table 2).

Tabel 1. Weight loss in three layer particleboard *Shorea leprosula* Miq specimens after 3 weeks exposure to termite *Coptotermes curvignathus* Holmgren

Material	Density (gr/cm ³)		
	0.6	0.7	0.8
<i>S. leprosula</i> from natural forest	2.82a	2.65ab	2.38c
<i>S. leprosula</i> from plantation forest	3.82a	3.28b	1.99c

Means followed by the same letter are not significantly different (Tukeys's test: P<0.05)

Table 1 show that the highest average weight loss of the three layer particleboard was density of 0.6 gr/cm³ (2.82%) followed by density of 0.7 gr/cm³ (2.65%) and density of 0.8 gr/cm³ (2.38%), respectively. The average weight loss of the three layer particleboard made from *S. leprosula* from natural forest was obtained 2.617%, however the average weight loss of particleboard made from *S. leprosula* from plantation forest was 3.030%. It was noted that average weight loss of the three layer particleboard made from *S. leprosula* from plantation forest higher than three layer particleboard made from *S. leprosula* from natural forest. The results suggest that the density of board may have played an important role to termite attack. These results were

consistent with those of Nzokou et al, (2005) who stated that the increase in termite resistance of laminated veneer lumber products was attributed to the density. Moreover, this finding supported the previous observation by May, 1983; Kalaycioglu and Nemli, 2006, that increasing of fine particles in the face layers of three layer particleboard promotes better compact and adhesion.

The outcome as shown in Table 2 illustrates that average mortalities of termites of particleboard made from *S. leprosula* from natural forest was obtained 100%. It was found that all termite almost moribund after 3-weeks termite exposure to particleboard for both *S. leprosula* from natural and plantation forest (Table 2). This observation highlighted that three layer particleboard in all density of 0.6 gr/cm³, 0.7 gr/cm³, and 0.8 gr/cm³ gave higher worker termite mortalities without any consideration was made whether *S. leprosula* was from natural forest or plantation forest (Table 2).

However, the effect of the source of *S. leprosula* was not significantly observed. It can be said that *S. leprosula* from plantation forest can be used as substitution of *S. leprosula* from natural forest.

Tabel 2. Termite mortality during the-3 weeks exposure to three layer particleboard *Shorea leprosula* Miq specimens to termite *Coptotermes curvignathus* Holmgren

Material	Density (gr/cm ³)		
	0.6	0.7	0.8
<i>S. leprosula</i> from natural forest	100a	100a	100a
<i>S. leprosula</i> from plantation forest	98a	98,667a	100a

Means followed by the same letter are not significantly different (Tukeys's test: P<0.05)

CONCLUSIONS

The utilization of higher density of three layer particleboard is effective in prohibiting the degradation by termites. Termite resistance test revealed that three layer particleboard made from *S. leprosula* from plantation forest seem to be suitable for substitution *S. leprosula* from natural forest for building construction materials purposes and promising for the development of a durable construction material.

Further research is needed to investigate the resistance of three layer particleboard from decay attack. Indonesia is tropical country which high humidity and temperature which the optimum condition for decay growth.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge Directorate General of Higher Education of Indonesia for financial support in Fiscal Year 2012 under Program MP3EI.

REFERENCES

- Abdel, R., Nasser, S. 2012. Physical and mechanical properties of three-layer particleboard manufactured from the tree pruning of seven wood species. *World Applied Sciences Journal* 19(5):741-753.
- Chung, W.Y., Wi, S.G, Bae, H.J. 1999. Microscopic observation of wood-based composites exposed to fungal deterioration. *Journal of Wood Science* 45:64-68.
- Curling, S.F, Murphy, R.J. 1999. The effect of artificial ageing on the durability of wood-based boards materials against basidiomycetes decay fungi. *Journal of Wood Science and Technology* 33:245-257.
- Geimer, R.L., Montrey, H.M., Lehmann, W.F. 1975. Effect of layer characteristics on the properties of three-layer particleboards. *Forest Product Journal* 25(3):19-29.
- Ghalehno, M. D., and Nazerian, M. 2011. Producing roselle (*Hibiscus sabdarifa*) particleboard composites. *Ozean Journal of Applied Sciences* 4(1):1-5.
- Hrazsky, J., Kral, P. 2003. The influence of particle composition in a three-layer particleboard on its physical and mechanical properties. *Journal of Forest Science* 49(2):83-93.

- Kalaycioglu, H. and Nemli, G. 2006. Producing composite particleboard from kenaf (*Hibiscus cannabinus* L.) stalks. *Industrial Crops and Products* 24:177-180.
- May, A. 1983. Relations between properties, raw materials and the distribution of density in particleboard. Part 4. *Holz als roh und Werkstoff* 41:271–275.
- Nzokou, P., Zyskowski, J., Boury, S., Kamdem, D.P. 2005. Natural decay resistance of LVL made veneers from durable and non-durable wood species. *Holz Roh Werkst* 63:173-178.
- Nemli, G. and Aydin A. 2007. Evaluation of the physical and mechanical properties of particleboard made from the needle litter of *Pinus pinaster* Ait. *Industrial Crops and Products* 26(3):252–8.
- Nazerian, M., Ghalehno, M.D., Shojaiishad, M., Sharifpoor, H., Taftiyan, M.H. 2011. Properties of three-layer particleboard made from wood of Athel (*Tamarix aphylla*) and Pruning particles of Almon (*Amygdalus communis*) and Pistachio (*Pistacia vera*). *J.Basic.Appl.Sci.Res* 1(8):837-843.
- Ohmura, W., Suichi, D., Masakazu, A. 2000. Antifeedant activity of flavonoids and related compounds against the subterranean termite *Coptotermes formosanus* Shiraki. *Journal of wood science* 46:149-153.
- Wang, S.Y., Yang, T.H., Lin, L.T., Lin, C.J. and Tsai M.J. 2008. Fire retardant treated low formaldehyde emission particleboard made from recycled wood waste. *Bioresource Technology* 99:2072–7.

DAMAGE INTENSITY OF HOUSE BUILDING AND TERMITE DIVERSITY IN PERUMAHAN NASIONAL BUMI BEKASI BARU, RAWALUMBU, BEKASI

Arinana, Noor Farikhah Haneda, Dodi Nandika, Windi Ayu Prawitasari

Faculty of Forestry, Bogor Agricultural University, Darmaga-Bogor-West Java, Indonesia
Email: arinanaiskandaria@yahoo.co.id

ABSTRACT

Number's of residential increasing equal by the increasing of population in Bekasi. Residential is fragile ecosystem that easily attacked by termite. Buildings were damaged because of attacked by termite with high intensity. This damaged causing a number's of economics disadvantages and decreasing service life of the building. The objective of this research is to review building damage intensity, diversity of termite species and distribution of termite based on the place of this research. This research held at Perumahan Nasional Bumi Bekasi Baru, Rawalumbu, Bekasi with survey of damage buildings and spread 200 *Pinus merkusii* stakes (2 cm x 2 cm x 45.7 cm). Damage survey results majority of building status in medium criteria (79.33%). Biologist factor showed high percentage (39.96%) as the main cause of the damage of the buildings. Stakes attacked by 2 kind species of termite, *Schedorhinotermes* sp. and *Coptotermes* sp. *Schedorhinotermes* sp. were found in RW 005 and *Coptotermes* sp. were found in RW 028.

Keywords: Bekasi, damage of building, residential, subterranean termite

INTRODUCTION

Bekasi City is one of the city located in the West Java, Indonesia. This city belong as a megapolitan city. Today this city become a place to live for urban people and centre of industry. The existence of industrial area in this city increasing the economy growth by placing industrial processing as a main industry. The industrial activities affected the growth of civil population in Bekasi City. From Dinas Kependudukan dan Catatan Sipil Kota Bekasi (2013) data's, recorded that in 2008 this city have 1 793 924 population and increasing by the time in 2013 to 2 801 758 population. The population increasing affected the growth of residential area. Most of land in Bekasi City converted into residential area.

Residential area is fragile ecosystem that easily attacked by termite. Damage of residential buildings in big cities in Indonesia caused by termite attack reached more than 70%. This damage causing a number's of economics disadvantages and decreasing service life of the building. According Rakhmawati (1996) Disadvantages caused by termite attack in residential buildings in Indonesia reached Rp 1.67 trillion per year.

Termites are one of the main factors that cause damage to various ecosystem. Termites are insect that eating wood (*xylophagus*) or lignocelluloses material (Nandika *et al.* 2003). Building damage caused by termite attack is not limited on wood components, but on all components that made from organic or lignocelluloses materials. Termite life supported by conditions of climatic, soil, and many kinds of plants in Indonesia. In Indonesia is recorded approximately 200 species of termites and 20 of them are wood destroying pests. One of termite species that cause greatest economic disadvantages in Indonesia is *Coptotermes curvignathus* Holmgren.

Population and residential areas increased, allowing interaction between termite colonies with residential buildings will increase. Necessary to research in Perumahan Nasional Bumi Bekasi Baru, Rawalumbu, Bekasi. This research was aimed to review intensity of damage building, diversity of termite species, and distribution of termite in this residential.

MATERIAL AND METHODS

Materials

Materials used are alcohol 70%, termite specimens, soil samples, *Pinus merkusii* (2 cm x 2 cm x 45.7 cm), and red oil based paint.

Damage Building Intensity

Damage building intensity did with interview and building inspection on 150 houses in Perumahan Nasional Bumi Bekasi Baru. This inspection did on main parts of house building such as roof, foundation, frame of wall, ceiling, wall, sills, floor, drainage of home page, and utility. Table 1 shows the values of building damage level.

Table 1. Assessment criteria of building damage level

Building damage level	Score	Description
Good	5	Building components are still functioning and there are periodic maintenance
Medium	4	Building components are still functioning and no periodic maintenance
Minor damage	3	Building components are still functioning, but <10% the component parts have indications of damage (rotten, cracks, termite attack, discoloring, etc)
Medium damage	2	Building components are still functioning, but 10-40% have functional damage (rotten, cracks, termite attack, discoloring, etc)
Mayor damage	1	>40% building components have functional damage (rotten, cracks, termite attack, discoloring, etc)

Source: Suryadi (2005)

Required weighting value of work to calculate value of robustness building. Table 2 shows weighting technique on each group of work.

Table 2. Weighting technique on each group of work

No	The object research	Weight of activity (%)
1.	Roof	27
2.	Foundation	21
3.	Frame of wall	19
4.	Ceiling	10
5.	Wall	9
6.	Sills	6
7.	Floor	4
8.	Drainage system	3
9.	Utility	1
Total		100

Source: Suryadi (2005)

Values of building robustness were calculated according to the following formula:

$$VR (\%) = \frac{\text{Total WA x S inspection results}}{500} \times 100\%$$

Where,

VR = Value of robustness building (%)

WA = Weight of activity (%)

S = Score

From formula of robustness value, final percentage have obtained, then divided into 5 classes of building conditions. Table 3 shows class of the building conditions.

Table 3. Category value of building conditions

No	Value of building conditions (%)	Category
1.	81-100	Good
2.	61-80	Medium,
3.	41-60	Minor damage
4.	21-40	Medium damage
5.	0-20	Mayor damage

Source: Sulaeman (2003)

Identification of termite species in Perumahan Nasional Bumi Bekasi Baru, Rawalumbu, Bekasi

Stakes are made from pinus wood (*P. merkusii*) size 2 cm x 2 cm x 45.7 cm, one of end from this stake is painted, in order to it is not affected by environmental condition. Then stakes were conditioning. The stakes were used in this research refers to American Standard for Testing and Materials (ASTM-D 1758-08 2008)

This research used 200 stakes. Stakes were assembled in home page with vertical position. This stakes left for 3 months. Figure 1 shows sketch of stake and stake in research location.



Figure 1. Assembled stake, (a) Sketch of assembled stake, (b) Assembled stake in location

Termite specimens were taken from soldier caste about 3 specimens. Termite specimens have found, then included into collection bottle that containing alcohol 70%. Termite specimens were photographed with stereo microscope. Identification of termite specimens refers to key of determination Tho (1992).

Measurement of Abiotic Environmental Factors

The abiotic environmental factors were measured consist of temperature, humidity, and light intensity. In one day, measurement did 3 times (at 07.30 WIB, 12.30 WIB, and 16.30 WIB) for 7 days. Location of measurement on 4 quadrants and each quadrant divided into 3 plots. Figure 2 shows divided of quadrant.

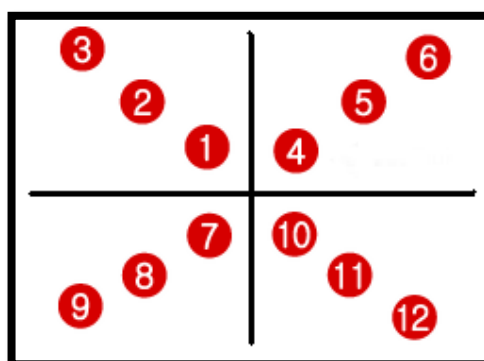


Figure 2. Plot 1-12 are locations of measurement from temperature, humidity, light intensity, and soil sampling.

Soil Sampling and Identification

Plot of soil sampling were adapted with Figure 2. Soil samples were taken at 0-20 cm and 21-40 cm depth with manual ground drill. Then soil sample at 0-20 cm depth from each plot were mixed, as well as with soil sample at 21-40 cm depth.

Data Analysis

Data processing of damage building intensity used Microsoft excel 2010. Data analysis to decide relationship between age, preservation, and renovation with building condition was Cross-tabulation Chi-square with software SPSS 16.0 for windows.

RESULTS AND DISCUSSION

General Conditions in Perumahan Nasional Bumi Bekasi Baru, Rawalumbu, Bekasi

Perumahan Nasional Bumi Bekasi Baru was established in 1992 in Kecamatan Rawalumbu, Bekasi City, West Java. This residential was founded in 3 steps, divided into Perumahan Nasional Bumi Bekasi Baru I (Kelurahan Pengasinan), Perumahan Nasional Bumi Bekasi Baru II (Kelurahan Bojong), dan Perumahan Nasional Bumi Bekasi Baru III (Kelurahan Bojongmenteng). Before the residential was founded, this region is rice fields area and swamps. The typical of residential is a river that cut it into west and east. In order to was founded 25 bridges. This residential has public facilities such as school, mosque, traditional market, park, and sport facilities. This research held in Rukun Warga (RW) 005 Kelurahan Pengasinan and RW 028 Kelurahan Bojong. Each RW have 300 house units. Interviews and inspections did in 150 houses in both of RW. Damage was found in location of research are many and varied.

Frequency of Damage House Building

House building conditions were determined by treatment and preservation into all of that building components. Simple building can be learned with observed parts of the building and the sanitation facilities. The parts are roof, foundations, frame of wall, ceiling, wall, sills, floor, drainage system, and utility. If the building conditions is not in the best performance that indicate of damage on it, accordingly this damage have to analyzed to be remedied (Puspantoro 1996).

Figure 3 shows that majority of house buildings in Perumahan Nasional Bumi Bekasi Baru in medium condition (79.33%). The other house buildings are in good condition (10.67%), medium damage (8.67%), and minor damage (1.33%). This shows that most of houses did not periodic treatments and preservations. The houses in good condition do treatment and preservations regularly, Meanwhile the houses in medium condition and minor damage only do treatments and preservations as needed. The houses in medium damage condition do not treatments and preservations at all. Preservations that usually did like painted with frequency twice in year. Building treatments that usually did on roof structure and sills that attacked by termites or the other of destroyed organism.

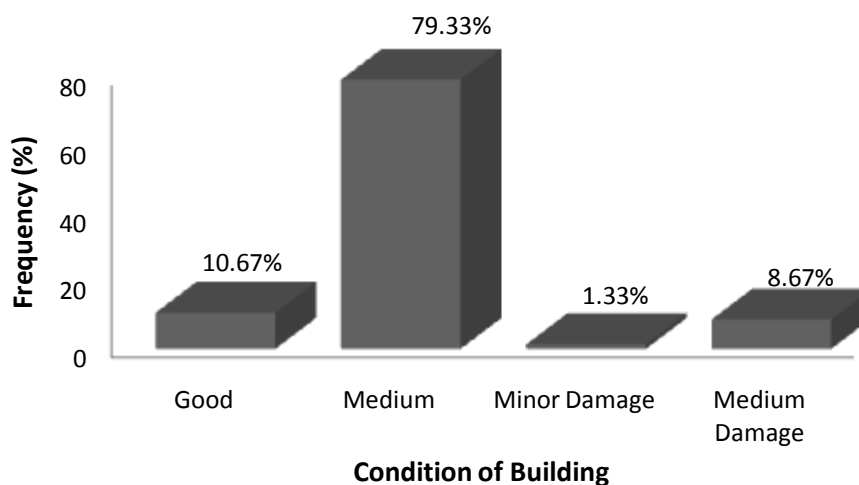


Figure 3. Frequency of house building conditions in Perumahan Nasional Bumi Bekasi Baru, Rawalumbu, Bekasi.

Type and Form of House Building Damage

Factors that causing damage of house building are biotic factors and abiotic factors. Mechanism process of damage on wood building or other materials divided into 5 steps, they're process of mechanical damage (cracks,broken) that causing of force both static and dynamic, process of physical damage that causing of climate factor, process of chemical that causing of water both capiler water and rain water. Process of biological damage that causing of fungi or moss and process of damage by human factor (Watt 1999). Wood as building material can be broke and decay because of attack from wood destroying organism such as insects and fungi (Hariyanto *et al.* 2000). Figure 4 shows that damaged causing of biological factor is factor with highest intensity (39.96%). Damaged causing of chemical factor is factor with lowest intensity (2.53%).

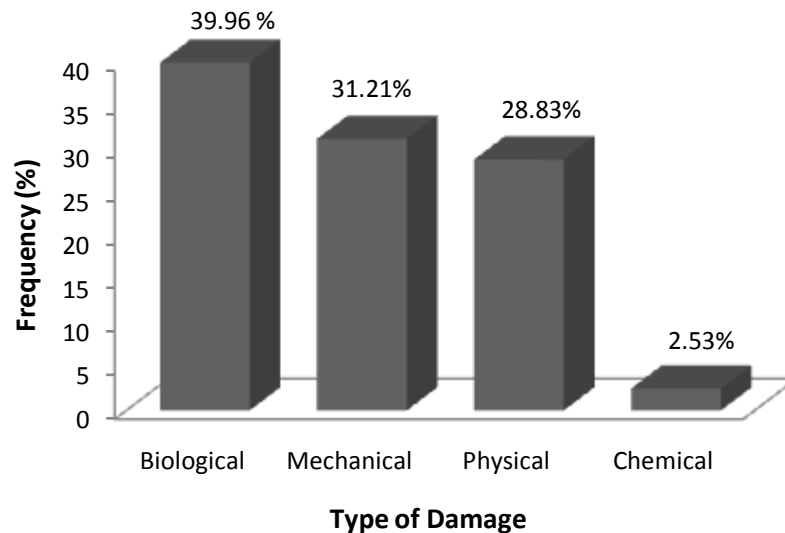


Figure 4. Factors causes damage of house building in Perumahan Nasional Bumi Bekasi Baru,Rawalumbu, Bekasi

According Watt (1999) Biological phenomena that affected for building are interaction between building with its biotic environmental such as plant and animal. Biological factor that highly causing of building damage are termites, beetle, and moss. Mechanical factors are damage type that causing of force both static and dynamic. The form of damage such as cracks and broke. Physical factors are damage causing of climate such as temperature and humidity. The form of damage are discoloring of wood, fading paint, and flaking of paint layers. Chemical factors are damage that causing of water, both capiler water and rain water. The damage are such as wood decay that causing of rain water from leak tile. Damage by human factors are not inspected.

Termite attack happened with direct contact between soil and wood, cracks, hole in the wall, they're affected for beam structure and building construction, moreover termites can make canals and close roads on wood surface, concrete, pipe, and etc (Nandika *et al.* 1991). Figure 5 shows that damage causing of termites (18.84%) have lower frequency than damage that causing of not termites (81.16%). Damage from termites causing of subterranean termite and dry wood termite that found on component of house building. Damage that not causing of termites such as rotten, cracks, flaking paint, beetle attack, moss, leak, and discoloring.

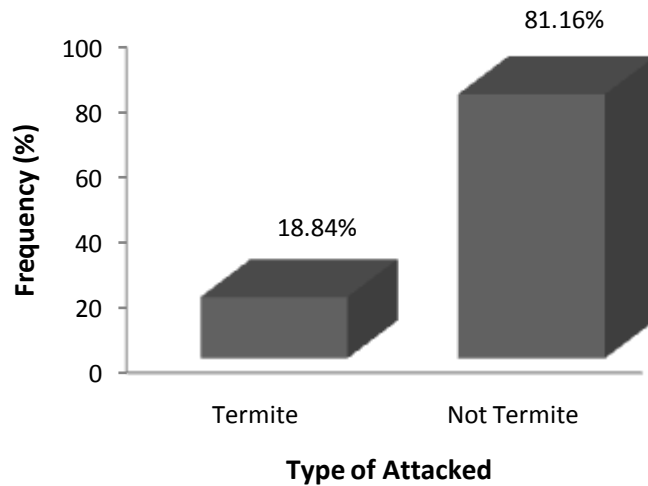


Figure 5. Frequency of damage causing of termites and not termites

Diversity and Distribution of Subterranean Termites

Termites feeding do in both of RW in Perumahan Nasional Bumi Bekasi Baru, Rawalumbu, Bekasi with 200 stakes that buried and left for 3 months. From 200 stakes spread, there are 30 stakes attacked by termites, but only 8 stakes were found termites specimen. Stakes attacked by 2 kind species of termite, *Schedorhinotermes* sp. and *Coptotermes* sp. Species of *Schedorhinotermes* sp. were found in RW 005 and *Coptotermes* sp. were found in RW 028. Both are attacking building species. In addition it was found that damage caused by dry wood termites, but did not found the physical form of the dry wood termites. Figure 6 and 7 show the sketch of stakes distribution in research location.

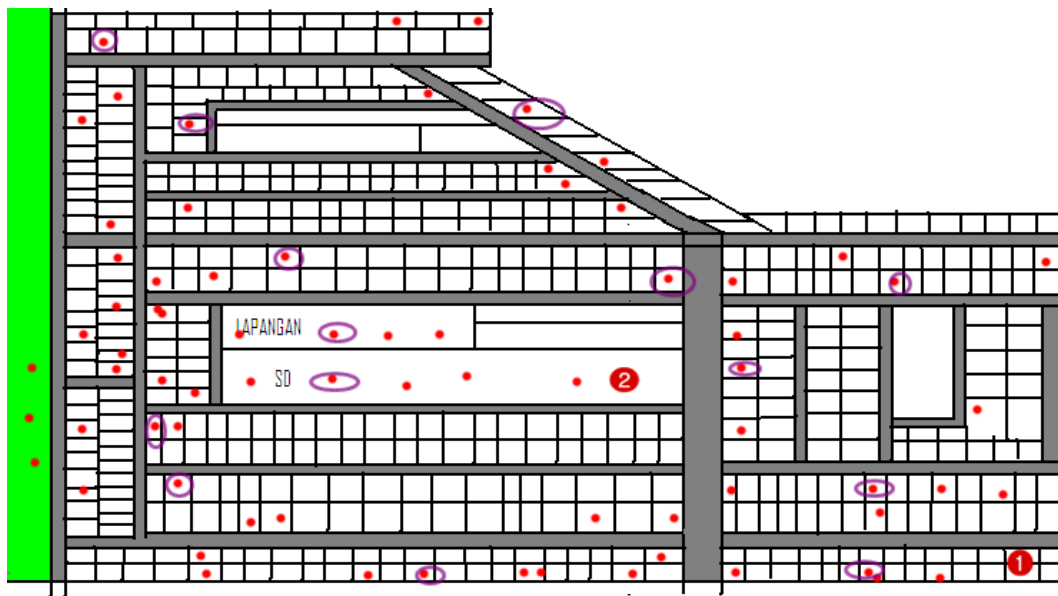


Figure 6. Sketch of stake distribution in RW 005

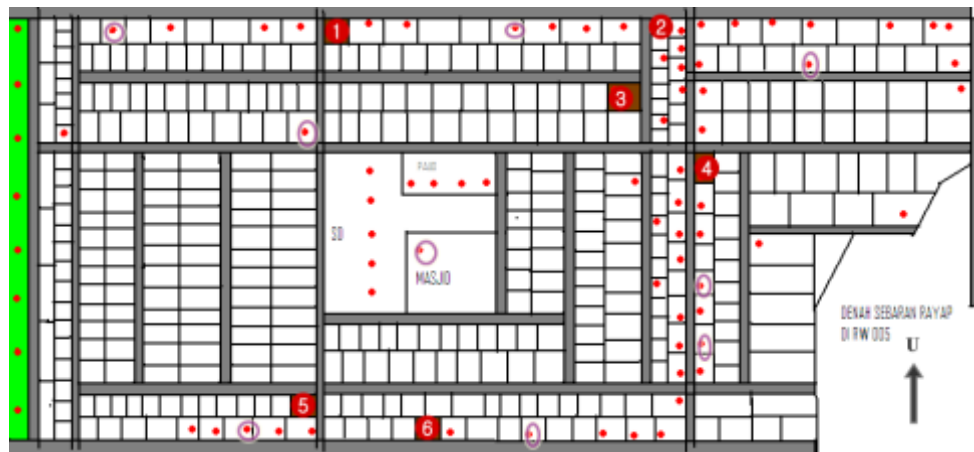


Figure 7. Sketch of stake distribution in RW 028

Termite species that attacked stake in point 3 RW 005 was *Schedorhinotermes* sp. Termite species that was found in RW 005 were worker caste that can't identifications. *Schedorhinotermes* sp. included in subfamily Rhinotermitinae and family Rhinotermitidae. This termites have two type of soldier caste, they're major soldier caste that large sized and minor soldier caste that small sized. According Khrishna *et al.* 1970 This termites can be found almost in all regions of java island especially on elevation below 1000 meters above sea level. Figure 8 shows minor soldier caste in location of research.



Figure 8. Soldier caste of *Schedorhinotermes* sp. magnification 30 times

Termite species have found in RW 028 was on 2 point. This termites were *Coptotermes* sp. This termite included in subfamily Coptotermitinae and family Rhinotermitidae. This termites have yellow head and mandible shape like a sickle and curved in the ends. *Coptotermes* sp. termites are vicious termites and very common in Indonesia. The existence of *Coptotermes* sp. should be warn because this species can attack high building by creating its secondary nest. Figure 9 shows *Coptotermes* sp. termite that found in research location.



Figure 9. Soldier caste of *Coptotermes* sp. magnification 30 times

Effect of Age, Frequency of Preservation, and House Building Renovation

Result of Cross-tabulation and Chi-square analyze show there are relationship between age, preservations, and renovations with building conditions(P-value<0.05). From results of building damage survey show that in the old house building has heavier damage than the new house building. This building damage on structural component and non-structural component that causing a decrease of building function. House building with preservation and renovation regularly have smaller damage than house building with preservation and renovation as needed or not at all. Painting is one way of preventing wood from fungi attack. Painting on wood surface can reduce absorption capacity of water, in order to the wood is not too moist (Allsop *et al.* 2003).

Chemical and Physical of Soil in Perumahan Nasional Bumi Bekasi Baru, Rawalumbu, Bekasi

Soil with high organic content is preferred by termites. The chemical analysis results show that soil in the residential has an C-organic content very low. Soil pH in this residential is neutral, it is indicating that the soil has a high fertility. Subterranean termites like soil with high clay content. The insects do not like sandy soil because it has low organic content (Nandika *et al.* 2003). The physical analysis result show that soil texture in residential is different between 0-20 cm depth and 21-40 cm depth. Soil texture in 0-20 cm is fine argillaceous and in 21-40 cm is dusty clay loam. Setiawati (2013) states on the soil with a neutral pH, very low C-organic content, and sandy loam texture can be found 6 termites species from two families that spread in 27 points. Meanwhile Lestari (2013) states on the soil with a neutral pH, very low C-organic content, and clay loam texture can found 5 termites species from 2 families that spread in 16 points. In this research is only found 2 termites species from the same family that spread in 3 points. It is show that soil texture can determine the existence of termites activity, but its too early to declare that the soil texture is an indicator of existence from termite activity. Table 4 show results of chemical and physical soil analysis.

Table 4. Result of chemical and physical soil in Perumahan Nasional Bumi Bekasi Baru, Rawalumbu, Bekasi

Chemical and Physical Soil		0-20 cm Depth	Criteria	21-40 cm Depth	Criteria
pH	H ₂ O	7	Neutral	6	Neutral
C-organik	(%)	0.64	Very low	0.32	Very low
Texsture	Sand (%)	47.47	Fine Argillaceous	7.72	Dusty clay loam
	Dusty (%)	31.59		52.19	
	Clay(%)	20.94		40.09	

Factor of Abiotic Environmental

Temperature is very affected for insects life. Temperature affect for insects divide of 3 class, the first is maximum and minimum temperature, the lowest or highest temperature range that can cause death in insects. Sencondly, estivasi or hibernation temperature that its temperature range above or below the optimum temperature which can reduce of insect activity or in dorman state, and the third is the range of optimum temperature (15-38 °C) (Nandika *et al.* 2003). In this research temperature in Perumahan Nasional Bumi Bekasi Baru, Rawalumbu, Bekasi is according to optimum temperature termites. The average temperature in the morning (07.30 WIB) was 29.66 °C, at noon (12.30 WIB) is 32.78°C, and in the afternoon (16.30 WIB) was 31.06 °C.

Termite activity is affected by humidity change. At low humidity, termite move into area with lower temperatue. Termite have ability to keep humidty in their nest, so it remains possible for termites to move into drier area. Subterarnaen termites requires high humidity. Optimum humidity for termites reach their activity is 75-90%. The research results show that average humidity in Perumahan Nasional Bumi Bekasi Baru, Rawalumbu, Bekasi quite suitable for termite activity. The average humidity in the morning is 79.11%. at noon is 61.06%, and in the afternoon is 75.23%.

Light intensity does not directly affect the termite activity, but affect the temperature and humidity of the environmental that affect the termites. Light intensity in the morning is 4 288 lux, at noon is 49 458 lux and in the afternoon is 4 613 lux.

CONCLUSION

Damage survey results majority of building status in medium criteria (79.33%). Biologist factor showed high percentage (39.96%) as the main cause of the damage of the buildings. Stakes attacked by 2 kind species of termite, *Schedorhinotermes* sp. and *Coptotermes* sp. *Schedorhinotermes* sp. were found in RW 005 and *Coptotermes* sp. were found in RW 028. In addition it was found that damage caused by dry wood termites, but did not found the physical form of the dry wood termites.

REFERENCE

- [ASTM] American Society for Testing and Materials. 2008. *Standard Test Method of Evaluating Wood Preservatives by Field Test with Stakes*. American Society for Testing and Material. United States: ASTM D 1758-08.
- Allsopp D, Kenneth JS, Christine C, Gaylarde. 2003. *Introduction to Biodeterioration (Second edition)*. Inggris (GB): Cambridge University Press
- Effendi R. 2013. Laporan Keterangan Pertanggung Jawaban Kepala Daerah Kota Bekasi. Bekasi (ID): Pemerintah Kota Bekasi 2013
- Hariyanto Y, Purba K, Hediana C. 2000. *Manfaat Pengawetan Kayu Perumahan Kayu dan Gedung*. Bogor (ID): Badan Penelitian dan Pengembangan Kehutanan dan Perkebunan.
- Lestari S. 2013. Keragaman Jenis Rayap dan Intensitas Kerusakan Bangunan di Perumahan Taman Darmaga Permai I, Ciampen, Bogor [Skripsi]. Bogor (ID): Institut Pertanian Bogor, Fakultas Kehutanan
- Nandika D, Raffiudin R, Husaeni EA. 1991. *Biologi rayap perusak kayu*. Pusat Antar Universitas Ilmu Hayati IPB. Bogor (ID)
- Nandika D, Rismayadi Y, Diba F. 2003. *Rayap: Biologi dan Pengendaliannya*. Surakarta(ID): Muhammadiyah University Press.
- Puspantoro B. 1996. *Konstruksi Bangunan Tidak Bertingkat*. Yogyakarta(ID): Universitas Atmajaya Yogyakarta.
- Rakhmawati D. 1996. *Prakiraan kerugian ekonomis akibat serangan rayap pada bangunan perumahan di Indonesia* [skripsi]. Bogor (ID): Institut Pertanian Bogor, Fakultas Kehutanan.
- Setiawati C. 2013. Keragaman Jenis Rayap dan Intensitas Kerusakan Bangunan di Perumahan Alam Sinarsari, Cibeureum, Darmaga, Bogor [Skripsi]. Bogor (ID): Institut Pertanian Bogor, Fakultas Kehutanan.
- Sulaiman. 2005. *Keterandalan konstruksi bangunan pendidikan (studi kasus pada gedung Sekolah Dasar)* [Tesis]. Departemen Hasil Hutan, Fakultas Kehutanan Institut Pertanian Bogor(ID). Tidak dipublikasikan.
- Suryadi D. 2005. *Kekokohan konstruksi bangunan Sekolah Dasar Negeri (studi kasus: Kec. Cibusah Kab. Bekasi)* [skripsi]. Bogor: Universitas Pakuan.
- Tho YP.1992. *Termites of Peninsular Malaysia*. Kualalumpur: Forest Research Institute Malaysia, Kepong.
- Watt DS.1999. *Building Pathology: Principle and Practice*. Inggris (GB): Cambridge University Press.

QUALITY TRAITS OF LEAF BLEACHED KRAFT PULP (LBKP) OF LOCAL WOOD SPECIES, TERENTANG DAN BINUANG

Eka Novriyanti, Dodi Frianto, Ahmad Rojidin

Research Institute of Fiber Technology of Forest Plants
Ministry of Forestry – Republic of Indonesia
Jl. Raya Bangkinang-Kuok km 9, KotakPos 4/BKN, Bangkinang, Riau, 28401

ABSTRACT

As a potential raw material for pulp and paper industry, yet lack information are available about pulping process and pulp quality of Sumatran local wood species, such as terentang and binuang. This study examined quality traits of leaf bleached Kraft pulp (LBKP) made of those two local wood species. Wood chips of those woods were pulped by Kraft process in condition as follow, active alkali 22%, sulfidity 30%, ratio of chips to white liquor was 1:4, maximum cooking temperature was 170°C within 2+2 h of cooking time. The resulted pulp was bleached in four stages D0D1ED2. The results showed that LBKP of those woods were met the requirement in SNI 6107-2009, except for brightness and tear index. Further, terentang showed slightly better performance than binuang for LBKP production due to its lower kappa number and extractive content.

Keywords: local wood species, Kraft process, LBKP, pulp quality traits

INTRODUCTION

Until 2011, 14 pulp industries and 79 paper industries had been established in Indonesia with total installed capacity of 7.9 ton of pulp and 12.2 ton of paper annually. Those industries would require large amount of fibers as material of the production (Kusumaputra 2011). This increase pulpwood consumption trend will require ample wood supply as main raw material of pulp industry. In the meantime, Industrial Plantation Program (HTI) which has been running for some time could not maximize wood supply for pulp industry, only 23.5% had been planted out of the allocated 7.8 million ha (FWI/GFW, 2001). In addition, some has noted that exotic species such as acacia and eucalypts which have been largely planted in HTI showed a decreasing productivity after planted for several rotations.

Those previously mention condition have drawn consideration to exploit local wood species for pulpwood raw material. This will heighten the availability of raw material and enrich the diversity of material resources. However, although these local wood species has potency for pulpwood material, yet lack data and information on processing condition and pulp quality is available for them. Therefore, local wood species still less popular to be planted in HTI.

All woody trees, including local wood species, contain fibers which can be processed into pulp (Pasaribu and Tampubolon 2007). However, recognizing suitable local wood species will need deep examination and intense researches. Previous study on basic characteristics of the wood had revealed that there were at least 9 local wood species in Riau which might possess suitability for pulpwood. Binuang and terentang are among those potential local wood species (Suhartati et al. 2012). While both exotic and local wood species are fast growing, local wood is more beneficial than exotic in easiness to adapt with environmental changes (climate, pest and disease) because those indigenous woods are part of the local ecosystem. In addition, local wood species are very ecologically valuable for conservation of indigenous flora and fauna (Suhartati et al. 2012).

Based on basic wood characteristics, binuang's fibers are classified as quality I for pulpwood (Aprianis et al. 2007). In the meantime, terentang also owns potency for pulpwood. In accordance with results of previous studies, thus those two local woods were assigned in this present study. This research was aimed to gather scientific information on pulping process and quality of hardwood bleached kraft pulp (LBKP) of terentang (*Camposperma auriculatum* (Bl.) Hook.f.) and binuang (*Octomeles sumatrana* Miq.).

METHODS

Pulping process

Two native wood species were used in this study, terentang (*Campnosperma auriculatum* (Bl.) Hook.f.) and binuang (*Octomeles sumatrana* Miq.). Terentang woods were from Kuantan Singingi (Kuansing) District in Riau and Dharmasraya District in West Sumatra, while Binuang were originated from Kampar District and Indragiri Hulu (Inhu) District of Riau. Wood of terentang and binuang were chipped into $\pm 2.5 \times 2.5 \times 0.5$ cm chips, air dried, and the moisture content was determined for those chips prior pulping process. Kraft process was deployed with condition as follow, 22% active alkali, 30% sulfidity, chips and liquor ratio was 1:4, maximum cooking temperature was 170°C, and cooking time was 2+2 hours. The resulted brown-pulp was defiberated, washed, and dried in centrifuge drier.

Yield of the brown-pulp was determined based on oven dry weight of the pulp divided by oven dry weight of chip. Kappa number was determined based on SNI 0494-2008. Cellulose, lignin, and extractive content were determined based on SNI 0444-2009, SNI 0492-2008, and SNI 12-7197-2006, respectively.

Bleaching Process

Brown-pulp of terentang and binuang were bleached in 4 steps of bleaching process, D0D1ED2 (Table 1). The chemicals used in bleaching process were ClO_2 and NaOH.

Table 1. The 4 steps of bleaching condition for brown-pulp of terentang and binuang wood

	D0	E	D1	D2
Consistency (%)	10%	10%	10%	10%
Temperature (°C)	60	70	75	75
Duration (minute)	60	60	180	180
ClO_2 (%)	KF x K#	-	1	0.5
NaOH	-	1.5	-	-

Remark: KF is kappa number factor which is 0.22, K# is kappa number, and consistency is the percentage of oven dry pulp divided by weight of suspension (pulp + water + chemicals).

The bleached pulp was refined in Niagara beater to 300 CSF. Handsheet with a basis weight 70-80 g/m² were prepared by using sheet former. The handsheets were conditioned at laboratory condition at 23°C, RH 65% for 24 hours prior physical traits testing.

Chemical and physical traits of hardwood Kraft bleached pulp (LBKP)

The hardwood Kraft bleached pulp (LBKP) and the handsheet of this LBKP of terentang and binuang were examined for chemical and physical quality. Chemical traits analysis covered yield, cellulose, lignin, and extractive content of the LBKP. Basis weight, degree of freeness, brightness, moisture content, bursting index, tensile index, and tearing index were determined based on SNI 6107-2009.

RESULTS AND DISCUSSION

Wood traits

Chemical components of wood from different origin were dissimilar (Table 2). Terentang Dharmasraya showed higher pentosan and cellulose content than one of Kuansing. In contrast, lignin, extractive (dissolved in water, alcohol-benzene, and NaOH 1%), ash, and silica content were lower in terentang Dharmasraya than those in terentang Kuansing. Similarly, binuang showed different chemical traits with the different of wood origin. Binuang Kampar had higher lignin, cellulose, and ash content than those of binuang Inhu, while binuang from Inhu showed higher pentosan, extractive, and silica content than binuang Kampar (Table 2).

Wood trait is important parameter to describe phenomena in wood processing into pulp. Chemical components of wood would define type and amount of chemicals used in the processing. It probably also affect product quality.

Table 2. Chemical traits of the local wood species

Sample code and origin		Lignin	Pentose	Cellulose	Extractive content, dissolve in :				MC	Ash content	Silica content	Crystallinity
					Cold water	Hot Water	Alcohol-benzene	NaOH 1 %				
		(%)			(%)				(%)			
T	K	26.64	12.73	53.03	1.08	4.55	4.65	14.25	6.24	0.53	0.08	21.16
	D	26.31	18.09	54.74	0.77	3.84	4.04	11.40	6.54	0.28	0.05	28.27
B	I	33.62	11.95	52.16	3.30	5.55	3.25	9.87	9.43	1.48	0.19	33.38
	Ku	34.44	11.45	52.35	3.44	4.89	2.69	9.75	9.80	1.68	0.06	32.69

Remarks: T = terentang, B = binuang, k = Kuansing, d = Dharmasraya, i = Inhu, ku = Kampar.

In general, terentang had higher wood density than binuang, while moisture content was relatively similar among the species or different origin (Fig. 1). While had relatively similar moisture content, terentang from Kuansing showed slightly higher density than wood from Dharmasraya. Meanwhile, binuang Inhu had relatively higher density than binuang Kampar (Fig. 1). In order to be used as pulpwood, it is preferable for a particular species to have density less than 0.5 (Syafii et al. 2005), therefore those both local woods met density reference for pulpwood.

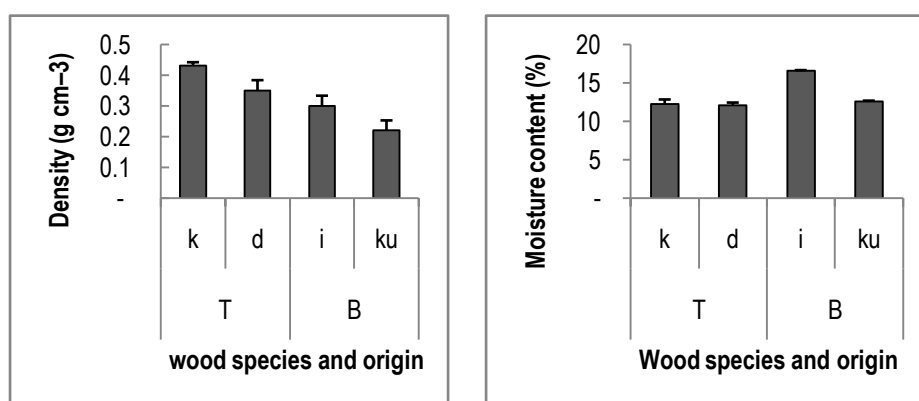


Figure 1. Density and moisture content of terentang's and binuang's wood
Remarks: T = terentang, B = binuang, k = Kuansing, d = Dharmasraya, i = Inhu, ku = Kampar

Fiber dimension is important to determine suitability of particular wood for pulpwood. Terentang and binuang of same origin showed similarity in fiber dimension (Table 3). The fibers of binuang were longer than terentang (Table 3), although both woods are classified as quality II for pulpwood. Syafii (2005) stated that quality II of pulpwood has fiber's length of 1000-2000 μm . Fiber of binuang in this study actually had equal length fibers to binuang in Aprianis et al. (2007) in which stated binuang had fiber of quality I for pulpwood. The difference probably caused by age of the trees or growing site condition (place of origin). Growth environment would alter by irrigation and fertilization which add nutrition input and prompt growth acceleration which could trigger elongation of fiber length, cellulose and lignin content, also volume or early wood portion (Daniel et al. 1979 in Sudomo et al. 2007).

Table 3. Fibers quality of terentang and binuang

Code Sample	Fiber dimension				Vessel dimension	
	Length	Diameter	\emptyset Lumen	Cell wall thickness	Length	Diameter
Tk	1,378.96	30.92	24.11	3.41	855.73	140.97
Td	1,306.06	28.67	21.95	3.36	757.35	143.45
Bk	1,703.53	42.23	35.68	3.27	566.27	291.10
Bi	1,899.63	35.53	29.07	3.23	509.20	267.38

Remarks: Tk = terentang Kuansing, Td = terentang Dharmasraya, Bk = binuang Kampar, Bi = binuang Inhu,

Yield and brown-pulp's traits

Terentang Dharmasraya showed slightly higher yield of brown Kraft pulp than terentang Kuansing, although the difference was not statistically significant, 47.06% and 45.26% for terentang Dharmasraya and Kuansing, respectively (Fig. 2). This resulted yield was presumably due to slightly higher cellulose content of terentang Dharmasraya than one of Kuansing, which are 54.7% and 53.0% for respectable terentang woods (Table 2). In contrast, kappa number of brown-pulp of terentang Kuansing slightly higher than that of terentang Dharmasraya that probably due to the higher lignin content of terentang Kuansing than one of Dharmasraya (Fig. 2 and Table 2).

Binuang Kampar had significantly higher yield of brown-pulp than that of binuang Inhu, 39.15% and 31.78%, respectively. In similar trend with terentang, in contrast with yield, kappa number was in fact relatively higher in brown-pulp of Binuang Inhu than that of binuang Kampar. However, cellulose and lignin content were not significantly different between binuang of different origin.

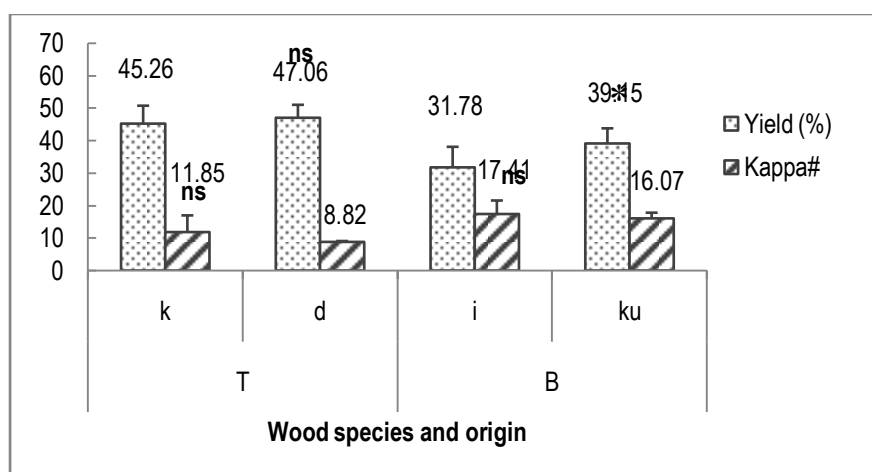


Figure 2. Yield and kappa number of brown Kraft pulp from terentang and binuang

Remarks: T = terentang, B = binuang, k = Kuansing, d = Dharmasraya, i = Inhu, ku = Kampar, * = significantly different, ns = not significant

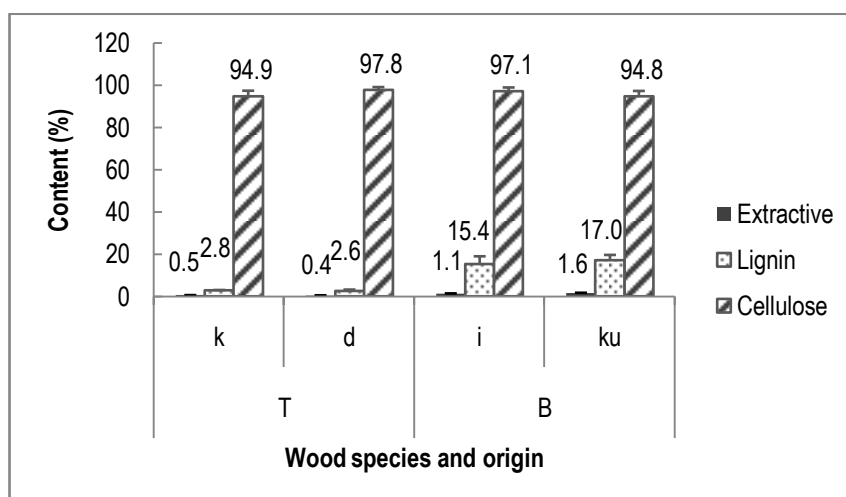


Figure 3. Chemical components of brown Kraft pulp of terentang and binuang

Remarks: T = terentang, B = binuang, k = Kuansing, d = Dharmasraya, i = Inhu, ku = Kampar, * = significantly different, ns = not significant

In general, terentang presented higher yield and better kappa number of brown Kraft pulp than binuang (Fig. 2) that perhaps caused by higher cellulose and lower lignin content of terentang than those of binuang (Table 2). Therefore, brown-pulp of terentang presumably is better than that of binuang to be further processes into hardwood bleached Kraft pulp (LBKP). Lower kappa number indicates advance digested pulp or delignification process perfectly takes place. Lower kappa number also designates smaller amount of

chemicals requirement in bleaching process to produce LBKP. Brown stock with kappa number more than 20 is suggested not to be produced into LBKP because it will require enormous bleaching chemicals (Siagian et al. 2004).

Brown pulp of terentang and binuang had similar cellulose content, but terentang showed lower content of lignin and extractive (Fig. 3). Chemical traits of the brown stock of those local woods indicated their suitability to be further processed into LBKP.

Quality traits of LBKP

Bleaching process was considerably effective as lignin have not detected anymore in LBKP of terentang and binuang (Fig. 4). Bleaching effectiveness could be reflected by decrease kappa number (Addleman and Archibal 1993). Yield of LBKP terentang Kuansing and Dharmasraya were comparable, but cellulose and hemicellulose were higher in LBKP terentang Kuansing (Fig. 4). Binuang Kampar showed higher yield of LBKP than that of binuang Inhu, even though the cellulose content in LBKP of binuang Kampar was lower than that of binuang Inhu (Fig. 4).

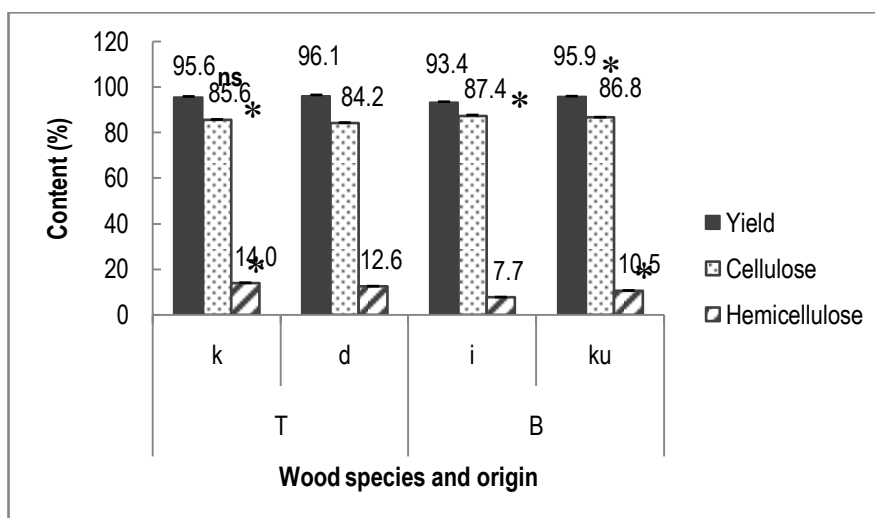


Figure 4. Chemical traits of form terentang and binuang

Remarks: T = terentang, B = binuang, k = Kuansing, d = Dharmasraya, i = Inhu, ku = Kampar, * = significantly different, ns = not significant

Basis weight of LBKP handsheet of terentang Dharmasraya was significantly higher than one of Kuansing, as well as degree of freeness. However, brightness, bursting, tensile, and tearing indices were significantly higher on LBKP of terentang Kuansing. Meanwhile, the LBKP handsheet of binuang Inhu showed higher degree of freeness, extractive content, and tensile index than binuang Kampar. In contrast, brightness and tearing indices were higher on LBKP binuang Kampar (Table 4).

Table 4. Physical traits of LBKP of terentang and binuang

Code sample	Basis weight (g/m ²)	Degree of freeness (ml CSF)	Brightness (% ISO)	Extractive content (dichloromethane) (%)	Moisture content (%)	Bursting index mN m ² /g	Tensile index kPa m ² /g	Tearing index Nm/g
T k	71.51 ± 1.48	607.00 ± 4.83	69.18* ± 0.48	0.12ns ± 0.01	6.73* ± 0.02	6.27* ± 0.78	81.49* ± 3.99	4.79* ± 0.30
T d	79.42* ± 0.81	664.00* ± 6.99	67.16 ± 0.43	0.12 ± 0.01	6.65 ± 0.07	4.91 ± 0.60	71.31 ± 1.46	4.26 ± 0.22
B i	70.54 ± 0.65	543.33* ± 5.00	55.10 ± 0.56	1.54* ± 0.01	6.24 ± 0.15	3.02 ± 0.30	87.05* ± 2.59	4.95 ± 0.90
B ku	70.86ns ± 2.92	510.00 ± 0.00	66.62* ± 0.53	0.86 ± 0.01	6.289ns ± 0.16	4.51* ± 0.64	81.77 ± 2.34	5.08ns ± 0.33

Remarks: T = terentang, B = binuang, k = Kuansing, d = Dharmasraya, i = Inhu, ku = Kampar, * = significantly different, ns = not significant

Terentang produced LBKP handsheet with significantly higher basis weight, degree of freeness, brightness, and bursting index than those of binuang (Table 4). In the meantime, LBKP binuang showed higher tearing and tensile index. Referring SNI 6107-2009, degree of freeness, tensile and tearing indices of all samples met the requirement of the standard. However, brightness and bursting index of all LBKP's

samples were below the requirement of SNI. LBKP terentang had advantages over those of binuang for having lower extractive content that met SNI's requirement. Furthermore, in accordance with SNI 6107-2009, LBKP terentang showed better performance than LBKP binuang.

Brightness of pulp or paper is highly affected by lignin and extractive contained in the pulp or paper. In this recent study, lignin was not detected any more in the LBKP that reflected an effective bleaching process. The extractive content in the LBKPs was also found to be low and met the requirement of SNI. Yet, brightness of all LBKP's samples was not meet SNI 6107-2009. Thus, it is assumed that it was not only the level of lignin and extractive but perhaps the type of compounds contained in the extractives that also affected the brightness of LBKPs. Certain compound of the extractive may influenced color or brightness of the pulp. Pretreatment to remove extractive or addition of particular additives may necessary to enhance brightness of LBKP of terentang and binuang.

Furthermore, brightness enhancement to meet SNI 6107-2009 is also possible by conditioning pulping process to lower the obtained kappa number. The use of oxygen in bleaching is also an alternative since oxygen could reduce kappa number by 30%.

Table 5.Characteristics of wood, fiber, and pulp of *Acacia mangium*

Parameter	<i>A. mangium</i>	<i>C. auriculatum</i>	<i>O. sumatrana</i>
Wood physical and fiber traits			
1. Basic density (g/cm ³)	0.43	0.43	0.35
2. Fiber length (µm)	650-900	1379	1899
Wood chemical traits			
1. Lignin (%)	25.6-27.1	26.3-26.4	33.6-34.4
2. a-cellulose (%)	46.5-50.8	53.0-54.7 (total)	52 (total)
3. Pentose (%)	13.3-17.4	12.7-18.0	11.4-11.9
4. Extractive dissolve in 1% NaOH (%)	16.4	11.4-14.3	9.8
5. Extractive dissolve in hot water (%)	4.8	3.8-4.5	4.9-5.6
6. Extractive dissolve in cold water (%)	3.9	0.8-1.0	3.3-3.4
7. Ash content (%)	0.5	0.3-0.5	1.5-1.7
Pulping characteristics (AA 20.5%, sulfidity 30%)			
1. Kappa number	17.4	8.8-11.8	16.0-17.4
2. Yield (%)	43.5	45-47	31.8-39.1
Pulp physical traits (AA 20.5%, sulfidity 30%)			
1. Tensile index (Nm/g)	46.0	71.3-81.5	81.2-87.0
2. Bursting index (kPa.m ² /g)	1.8	4.9-6.3	3.0-4.5
3. Tearing index (mN.M ² /g)	4.9	4.3-4.8	4.9-5.1

Sources: *A. mangium*: Ragauskas (2014), Rosli et al. (2009), Pinto et al. (2005), Siregar (2001); *C. auriculatum* and *O. sumatrana*: present research data

Wood of *A. mangium* had higher density than binuang but equal to that of terentang. Kraft process on *A. mangium* wood could yield over 50% of pulp and it could be up to 75% if the process is neutral sulfite (Ragauskas 2014). *A. mangium* contains high lignin and extractive, thus require particular pulping process to obtain equal kappa number and brightness to those of *Gmelina* and *Eucalypts* (Ragauskas 2014).

Rosli et al. (2009) pulped *A. mangium* in several conditions (various levels of active alkali and sulfidity) of Kraft process. Condition process of 20.5% AA and 30% sulfidity in study of Rosli et al (2009) was quite close with pulping condition in this present study, thus it was being used as comparison to this present study on terentang and binuang. In general, brown Kraft pulp of terentang and binuang were comparable to that of Advanced-pulpwood, in this case to *A. mangium*.

In similar condition of pulping process, brown Kraft pulp of both local wood species showed comparable physical traits to those of Kraft pulp of mangium, even better because bursting and tensile indices of the local woods were higher than those of *A. mangium* (Table 5). Moreover, similar with *A. mangium*, due to low brightness level of those local woods, it should require particular pulping process to obtain the desire brightness (Ragauskas 2014).

CONCLUSION

Local wood species, terentang and binuang showed potency to be used for pulpwood. Physical and chemical traits of those wood revealed suitability to be further processed into pulp. Kraft process with 22% AA and 30% sulfidity resulted brown pulp with kappa number suitable to be further processed into hardwood bleached Kraft pulp (LBKP). Brown pulp yield of terentang and binuang were 31.8-39.1% and 45.0-47.0% which is comparable to that of advance pulpwood species, *A. mangium*.

Lignin was not detected in LBKP of terentang and binuang and extractive content fulfil the requirement of SNI 6107-2009, yet the brightness of the LBKPs was below the standard. Presumably, not only level of extractive but also type of compounds in the extractive affects the brightness. Pretreatment to further remove extractive is required to enhance brightness of LBKP from those two local woods. However, in general, LBKPs of terentang and binuang met the requirements in SNI 6107-2009. Those two local woods were also comparable with an advance-pulpwood species, *A. mangium*, in yield and physical traits of brown pulp. LBKP of terentang showed better performance than that of binuang.

REFERENCES

- Addleman, K., Archibald, F. 1993. Kraft pulp bleaching and delignification by dikaryons and monokaryons of *Trametes versicolor*. *Applied and Environmental Microbiology* 59: 266-273.
- Aprianis, Y., Frianto, D., Aminin, M., Rojidin, A., Novriyanti, E., 2013. Rekayasa proses pembuatan corrugated paper dari kayu alternatif. Laporan Hasil Penelitian. Balai Penelitian Teknologi Serat Tanaman Hutan. Bangkinang. (Tidak dipublikasikan).
- Aprianis, Y., Wahyudi, A., Hidayat, A., Nurrohman, E. Sasmita, T., Kosasih. 2007. Analisa kualitas serat dan sifat pengolahan pulp jenis alternative baru penghasil serat. Laporan Hasil Penelitian. Balai Penelitian Hutan Penghasil Serat, Kuok. (Tidak dipublikasikan).
- Badan Standardisasi Nasional. 2009. SNI 6107-2009 LBKP. BSN. Jakarta.
- FWI/GFW.2001. Potret Keadaan Hutan Indonesia. Bogor, Indonesia: Forest Watch Indonesia and Washington D. C. Global Forest Watch.
- Kusumaputra, R.A. 2011. Indonesia ke-9 penghasil pulp dunia. Kompas.com, Kamis 1 Nopember 2011, <http://bisniskeuangan.kompas.com/read/2011/12/15/17463654/Indonesia.ke9.Penghasil.Pulp.Dunia>
- Pasaribu, R.A dan A.P.Tampubolon. 2007. Status Teknologi Pemanfaatan Serat Kayu untuk Bahan Baku Pulp. Workshop Sosialisasi Program dan Kegiatan BPHPS Guna Mendukung Kebutuhan Riset Hutan Tanaman Kayu Pulp dan Jejaring Kerja. (Tidak dipublikasikan).
- Pinto, P.C., Evtuguin, D.V., Neto, C.P. 2005. Chemical composition and structural features of the macromolecular components of plantation *Acacia mangium* wood. *J. Agric. Food. Chem* 53 (20): 7856-7862.
- Ragauskas, A. 2014. Short review: The chemistry and pulping of acacia. http://www.ipst.gatech.edu/faculty/ragauskas_art/technical_reviews/acacia.pdf. [diunduh 18 Februari 2014]
- Rahman, A.N., R.M. Siagian. 1976. Dimensi serat jenis kayu Indoensia. Laporan No. 75. Lembaga Penelitian Hasil Hutan. Bogor.
- Rosli, W.D.W., Mazlan, I., Law, K.N. 2009. Effect of kraft pulping variables on pulp and paper properties of *Acacia mangium* kraft pulp. *Cellulose Chem. Technol.* 43 (1-3): 9-15.
- Siagian, R.M., Lestari, S.B., Yoswita. 2004. Sifat pulp sulfat kayukurangdikenalasal Jawa Barat. *Jurnal Penelitian Hasil Hutan* 22 (2): 75-86.
- Siregar, D. M. 2001. *Acacia mangium* characteristics of various age,height point and branches for kraft pulping raw material. M. Sc. Thesis, AIT, Bangkok, Thailand.
- Sudomo, A., Permadi P., Rachman C. 2007. Kajian control silvikultur hutan tanaman terhadap kualitas kayu pulp. *Info Teknis Balai Besar Penelitian Bioteknologi dan Pemuliaan Tanaman Hutan* 5 (2): 1-10.
- Syafii, W dan Iskandar dan Z. Siregar.2005. Sifat Kimia dan Dimensi Serat Kayu Mangium (*A. mangium*) dari Tiga Provenans. *Tropical Wood Sciences dan Technology*.
- Suhartati, Rahmayanti, S., Junaedi, A., Nurrohman, E. 2012. Sebaran dan persyaratan tumbuh jenis alternative penghasil pulp di wilayah Riau. Badan Penelitian dan Pengembangan Kehutanan. Jakarta.

GROWTH EVALUATION OF EBONY (*Diospyros ebenum* Koenig.) FOR 22nd MONTH AGE IN ARBORETUM OF MANADO FORESTRY RESEARCH INSTITUTE

Julianus Kinho^{1,2)}

¹⁾ Manado Forestry Research Institute

Jl. Adipura Kima Atas Mapanget, Manado, North Sulawesi, Indonesia. Phone: +62431 3666683;

²⁾Post Graduate Student on Faculty of Forestry, Gadjah Mada University, Indonesia

email : ragilkinho@gmail.com

ABSTRACT

One of commercial tropical species in North Sulawesi is ebony (*Diospyros ebenum* Koenig.). This species was reported as native in India and Sri Lanka, which it was traded as commercial timber as called Indian ebony, Ceylon ebony, ebony Mauritius and ebony persimmon. This species was reported have high economic value and it has traded in units of kilograms (kg). Most of them were exports to China as raw material for furniture and to Europe as luxury goods. This species are member of minor commercial timber group in Indonesia. This species is one of lowland forests compound in North Sulawesi. Data and information about its growth outside their natural habitat is very limited. This study aims to determine the growth of ebony (*D. ebenum*) aged 22 months after planting in Arboretum of Manado Forestry Research Institute. This study was used randomized block design. 50 individuals are used as sample in this research. Planting spacing is 3 m x 3 m. The treatments were tested using dose of Nitrogen Phosphate and Potassium (NPP). Fertilizer with 5 replications. Replicate 1 (A0=10 gr/plant), replicate 2 (A1=20 gr/plant), replicate 3 (A2=30 g/plant), replicate 4 (A3=40 gr/plant) and replicate 5 (A4=50 g/plant). Parameters measured were growth of height (m) and diameter (cm). Data analyzed by statistic using SPSS. The results showed that the percentage of live of ebony (*D. ebenum*) until 22 months age was 98.00%. The high number of live percentage indicates that these plants can adaptation and growth well outside of their natural habitat. Results of statistical analysis on 95% confidence interval level indicates that the best height and diameter growth is shown by treatment A3 (40 gr/plant) with the average height is 2.92 m (*Mean Annual Increment*/MAI=1.46 m/year) and the average diameter is 4.40 cm (MAI=2.20 cm/year). The lowest response of growth were shown by treatment A0 (10 gr/plant) with average height is 1.93 m (MAI=0.96 m/year) and the average diameter is 2.86 (MAI=1.43 cm/year). These results indicate that treatment of doses fertilizer affect to the growth of height and diameter of young plants ebony (*D. ebenum*). Fertilizer using low dose of NPP (10 gr/plant) and high dose (50 gr/plant) showed the lower growth response than, moderate doses of NPP i.e 20 gr/plant, 30 gr/plant and 40 gr/plant. Optimal growth response by treatment shown that fertilizer using NPP 30 gr/plant is the best. It can be indicated that, optimal fertilizer dose using NPP 30 gr/plant are remained to fill of the macro nutrients i.e Nitrogen, Phosphate and Potassium for the growth of young plants ebony.

Keywords: North Sulawesi, ebony, commercial timber, growth, fertilization

INTRODUCTION

One of commercial tropical species in North Sulawesi is ebony (*Diospyros ebenum* Koenig.). This species was reported as native in India and Sri Lanka, which it was traded as commercial timber as called Indian ebony, Ceylon ebony, ebony Mauritius and ebony persimmon (Orwa *et al.* 2009). This species was reported have high economic value and traded in units of kilograms (kg). Most of them were exports to China as raw material for furniture and to Europe as luxury goods. This species is one of lowland forests compound in North Sulawesi. It is known as Zwart ebben in Germany (Orwa *et al.*, 2009). This species are member of minor commercial timber group in Indonesia (Soerianegara *et al.* 1995; Kartasujana *et al.* 1973). Ebony trees (*D. ebenum*) have other benefits as medicine. Extract of ebony leaves contains antioxidants and antibacteria. Baravalia *et al.* 2009, reported that the methanol extract of ebony leaves (*D. ebenum*) contain high of phenol as function for free radical and anti-bacteria of *Pseudomonas aeruginosa* and *Salmonella typhimurium*.

Rashed (2013), reported that extract of stems eboni (*D. ebenum*) 70% was showed significant antioxidant activity due to the presence of bioactive compounds as flavonoids, tannins, triterpenes and carbohydrates. Eboni (*D. ebenum*) species is not listed in the CITES Appendices, but is reported by the IUCN as being of data deficient (DD). Exporting of this species is restricted in India and Sri Lanka, due to decreasing of their population by exploitation (<http://www.wood-database.com>).

Species of ebony (*D. ebenum*) is one of the compilers of lowland forest in North Sulawesi. This species can be found in Batuputih Nature Park (BNP) and Tangkoko Nature Reserve (TNR), Bitung, North Sulawesi. This eboni belongs to less known species in Indonesia, because it has not much research done on it. Data deficient about their potency, distribution and utilization in Indonesia. This species has the potential to be utilized, but unfortunately not widely known so that the management and utilization is not maximized. This study aims to determine the early growth of ebony (*D. ebenum*) cultivation on exitu conservation 22 months age after planting in Arboretum of Manado Forestry Research Institute.

METHODS

This study was conducted in Arboretum of Manado Forestry Research Institute. The study was conducted using randomized block design in five replicates. Each replication consisted of 10 individuals. Total samples used in this study were 50 individuals. Spacing used 3 m x 3 m. Treatments used Nitrogen Phosphate and Potassium (NPP) fertilizer with 5 replications. Replicates 1 (A0 = 10 gr/plant, replicate 2 (A1 = 20 gr/plant), replicates 3 (A2 = 30 gr /plant), replicates 4 (A3 = 40 gr/plant), groups of 5 replicates (A4 = 50 gr/plant).

RESULT AND DISCUSSION

Percentage of Life

Observations of live plants percentage was done by counting the number of dead plants in each treatment by block planting. The percentage of live plants ebony (*D. ebenum*) until the age of 22 months generally is 98.00%. The percentage of live plants in all treatments until the age of 22 months at 100%, except the A3 treatment at the age of 12 months was reduced to 90% (Figure 1)

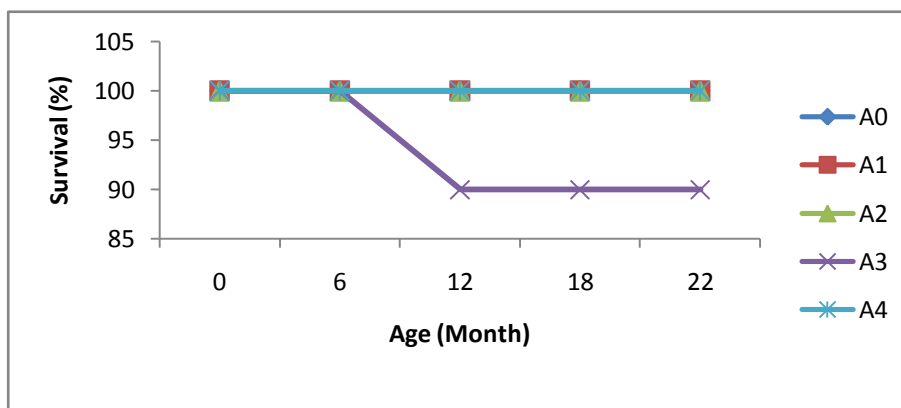


Figure 1. Percentage of live ebony (*D. ebenum*) until the age of 22 months

The percentage of live plants ebony (*D. ebenum*) on outside their natural habitats, especially in Arboretum of Manado Forestry Research Institute on ultisol soil type until 22 months age is high (98.00%). It is indicate that plants of ebony (*D. ebenum*) have a good adaptability on outside their natural habitats. The members of Diospyros in generally were semitoleran species. They requiring adequate shade during the early growth of the field, then the intensity of shade required to decrease follow their growth age. Kinho (2013), reported that some of Diospyros members were planted in Arboretum of Manado Forestry Research Institute have success rate above 75% until the age of 7 months after planting such as; *D. ebenum* (100%), *D. rumphii* (100%), *D. pilosanthera* (95%), *D. malabarica* (97.5%), *D. korthalsiana* (95%), *D. minahassae* (90%), *D. celebica* (90%) and *D. cauliflora* (88.75%). The lowest of survival rate is *D. hebecarpa* (60%). According to Evans (1986), mentioned that the percentage growth in short space planting (1250 trees/ha) could be lower around 80% (20% mortality), but for plants with wide spacing, the percentage of acceptable growing at least

90% (mortality 10%). According to Plant Assessment Guidelines for Forest and Land Rehabilitation in East Kalimantan (Anonymous, 2003), noted that the growing percentage of plants were divided into several categories i.e (1) very successful (> 85%), (2) success (75% - 85%), (3) has been successful (65% s / d <75%), (4) less successful (55% -65%), (5) failure (<55%). In plantation of teak (*Tectona grandis*), when the live percentage less than 50%, it should be replantation in the next year (Effendi, 2012). Hadiyan (2010), reported that average percentage live of plantation of Sengon (*Paraserianthes falcataria*) in four months of age in Forest Area Special Purpose/KHDTK Cikampek were 86.83% (82.47% - 93.38%). Mindawati and Heryati (2006), reported that the percentage of live for *Shorea stenoptera* and *S. mecystopterix* were 68.89% in KHDTK Haurbentes. Effendi (2012), reported about growth percentage of Nyawai (*Ficus variegata*) at 2 years age in KHDTK Cikampek above 83%, even up to 100% in 5 lines of 10 lines of planting using 120 samples.

Height and diameter growth

Test results using analysis of variance (ANOVA), indicating that the treatment accorded significantly different at 95% confidence interval level (0.05) (Table 1).

Table 1. ANOVA height and diameter growth response of ebony (*D. ebenum*) aged 22 months based on the treatment dose of NPP fertilizer

		Sum of Squares	Df	Mean Square	F	Sig.
High	Between Groups	60962.696	4	15240.674	3.936*	0.008
	Within Groups	170371.222	44	3872.073		
	Total	231333.918	48			
DBH	Between Groups	12.595	4	3.149	1.730*	0.160
	Within Groups	80.065	44	1.820		
	Total	92.660	48			

*) The mean differences is significant at the 0,05 level

The best high growth of ebony (*D. ebenum*) until the age of 22 months shown by treatment A2 with average 2.92 m (*Mean Annual Increment/MAI* = 1.46 m/year) (Figure 2), and the lowest shown by treatment A0 with average 1.93 m (*MAI* = 0.96 m/year). The best diameter growth is shown by treatment A2 with average 4.40 cm (*MAI* = 2.20 cm/year), and the lowest shown by treatment A0 with average 2.86 cm (*MAI* = 1.43 cm /year) (Figure 4).

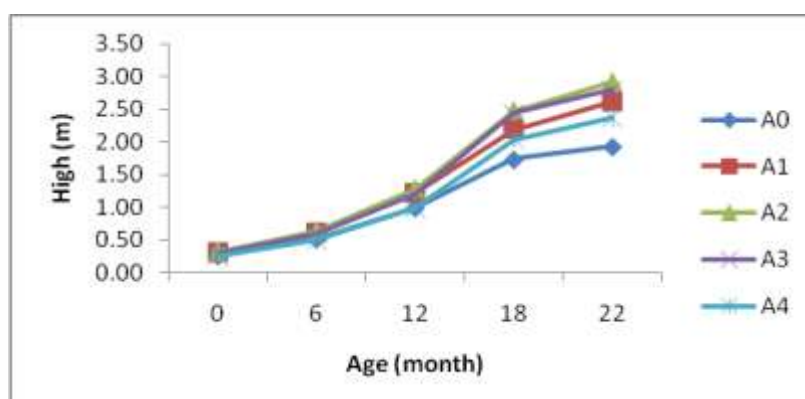


Figure 2. The growth high of ebony (*D. ebenum*) age 22 months

Plants growth indicates that increase of tree dimensions or forest stand during a certain period of time (Vanclay, 1994). He also mentioned that amount of growth or standing stock can be determined from the parameters of height, diameter or volume. Height growth of trees, both total tree height and bole height on the species of trees planted is one of the critical success factors of planting primarily for commercial timber species.

The relationship of tree growth with age is sigmoid pattern where at young age will grow up being, then quickly and after a little old growth or constant (Evans, 1986). Diameter increment growth chart of plants ebony (*D. ebenum*) age 22 months is shown in Figure 3. This research showed that fertilization given real effect on height and diameter growth. Fertilization with a low dose (A0 = 10 gr/plant) and the large dose (A4 = 50 gr/plant), shown the lower response of growth than medium dose of fertilization (A1, A2, A3). Growth response based on the treatment given at age 22 months is shown in Figure 4.

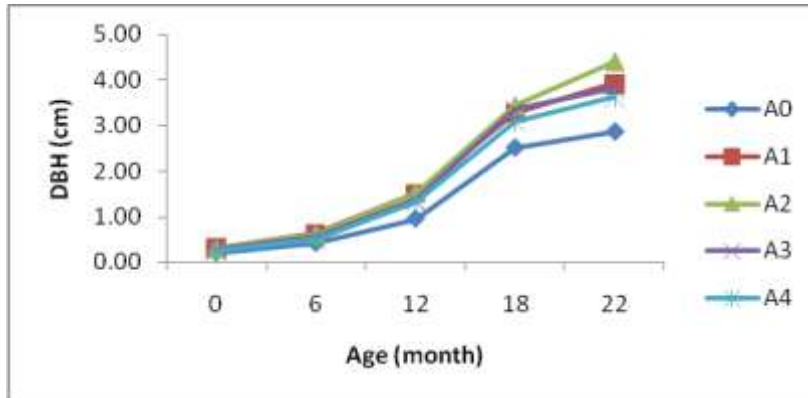


Figure 3. Diameter growth of ebony (*D. ebenum*) age 22 months

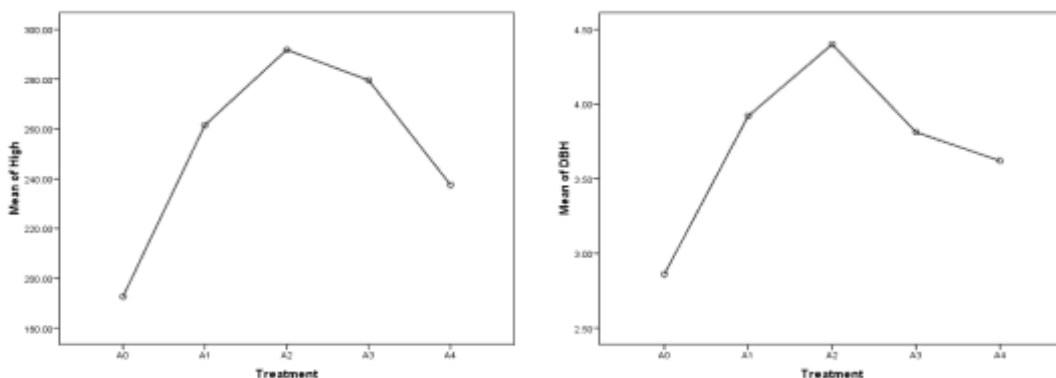


Figure 4. Growth of height and diameter response of ebony (*D. ebenum*) aged 22 months based on fertilizer treatment.

The charts of height and diameter growth of ebony (*D. ebenum*) aged 22 months at the Arboretum of Manado Forestry Research Institute (Figure 2 and 3) continues shown variation of growth from time to time, and it is seen from the results of 5 times measurements after planting until the age of 22 months in field. Variation of high and diameter growth that occurs is thought be influenced by three factors i.e genetic factors, environmental factors and the interaction between genetic factors and environmental factors (Wright, 1976). The difference between the geographical conditions of the natural habitat and outside natural habitat of a species can affect the growth of a plant species. The difference of geography site influence on the growth of a species (Zobel and Talbert, 1984). Soerianegara (1970), mentions that ebony if planted at different places will shown different growth responses. High growth is one indicator of the results of mineral nutrient uptake and photosynthesis (Rahman et al, 2002). The growth rate of a species can be an indicator of the adaptability of a species outside their natural habitat. The faster growth of a species outside their natural habitat reflects their ability of adaptation to different environments, as examples in ebony that occur on plants of a different species (*D. celebica*) were planted in two different locations, namely under monoculture teak stands and in the Cikampek experiment garden (West Java), which has the same climatic conditions, plant height growth turns ebony (*D. celebica*) under teak stands slower than Cikampek experiment garden. Growth inhibition is reported because of the stress by received direct sunlight during the crop ebony teak trees shed their leaves (Alrasyid, 1985). High growth on average total plants of ebony in this study was 2.53 m (MAI=1.26 m/year) is greater when compared with reported by Alrasyid (1985), which reported that average height growth of plants ebony

(*D. celebica*) on age 8 years planted under teak stands on climate C has average height ranges from 7-55 cm/year.

Diameter growth is more affected by competition than the height of the tree (Soeseno, 1985). The results of this study indicate that the plant ebony (*D. ebenum*) in Arboretum of Manado Forestry Research Institute has not shown significant differences under the age of 6 months after planting, but after the age of 6-22 months after planting, their looks different as shown in Figure 2 and 3. These was indicates that before the age of 6 months, there is no competition to gotten the nutrients and sunlight because they have similar growth increment of height and diameter between treatment groups. Diameter growth of plants ebony (*D. ebenum*) in this study at the age of 22 months with total of average 3.72 cm (MAI=1.86 cm/year) is faster than the growth of plants ebony (*D. celebica*) reported by Seran *et al.* (1991) with average diameter growth 2.44 mm/year. Santoso *et al.* (2002), reported that there is a variation in diameter growth of young plants ebony (*D. celebica*) at 36 months age (3 years) from 7 provenance were planted in Malili research station (South Sulawesi), where the best growth were shown by provenance Barru (MAI=4.45 mm/year) and followed by provenance Malili (MAI=4.21 mm/year), compared to 5 other provenance. Soerianegara (1967), states that diameter increment of plants ebony (*D. celebica*) until the age of 20 years ranged from 1.5 to 1.6 cm/year. After that the growth diameter increment will be reduced to 0.5 cm/year.

CONCLUSION

Specie of ebony (*D. ebenum*) have high adaptability in Arboretum of Manado Forestry Research Institute until the age of 22 months. There were shown by average value of live percentage on overall treatment 98.00%. Treatments of dose fertilization using NPP in this study provide a real influence on the growth of height and diameter of ebony (*D. ebenum*). Fertilization using low dose (10 gr/plant) and too large dose (50 gr/plant) shown lower response than moderate doses (20 gr/plant, 30 gr/plant and 40 gr/plant). The optimal growth response were shown by treatment using dose of fertilizer 30 gr/plant.

ACKNOWLEDGEMENT

I would like to thanks to Mr. Mahfudz, Ph.D as the Head of Manado Forestry Research Institute for supporting and funded. I am also appreciate and thanks for technical support provided by Sumarno Patandi, Yermias Kafiar, Jafred Halawane, Melkianus Diwi and Yohanes Muru for their help on fieldwork, especially in carrying out this research for maintaning and measurment during this research.

REFERENCES

- Alrasyid, H. 1985. Experimental Planting Wood Ebony (*Diospyros celebica*) Under Standing Teak in Java. Forest Research Bulletin 464: 23-37. Bogor.
- Anonymous, 2003. Crop Assessment Guidelines for Forest and Land Rehabilitation in East Kalimantan. East Kalimantan Forest Service. Samarinda.
- Bravalia, Y., Kaneria, M., Vaghasiya, Parekh, J., and Chanda, S. 2009. Antioxidant and Antibacterial of *Diospyros ebenum* Roxb. Leaf Extracts. Journal of Biology 33: 158-164.
- Effendi, R. 2012. Study of Success Growth Plant of Nyawai (*Ficus variegata* Blume.) In KHDTK Cikampek, West Java. Journal of Forest Research Plantation. 9 (2): 95-104. Research and Development Center of Forest Plantations, Bogor.
- Evans, J. 1986. *Plantation Forestry in The Tropics*. Clarendon Press Oxford, UK.
- Hadiyan, Y. 2010. Evaluation of Early Growth Nursery Garden Seeds Test Sengon Descendants (*Falcataria moluccana* Synonyms *Paraserianthes falcataria*) Age 4 Months In Cikampek West Java. Journal of Forest Plantation. 7(2):85-91. Center for Research and Development of Forest Plantations. Bogor.
- <http://www.wood-database.com/lumber-identification/hardwoods/ceylon-ebony/> download on September 28th 2014.
- Kartasujana, I., and Martawijaya, A. 1973. Commercial Wood of Indonesia, Their Properties and Uses. Announcement No. 3 In 1973, Forest Products Research Institute, Bogor.

- Kinho J. 2013. *The Ability of Adaptation and Early Growth of Nine Types of Diospyros in Exitu Conservation in North Sulawesi*. in: Langi, M., Tasirin, J.S., Walangitan H.J., dan Masson, G. (eds). *Proceeding of International Conference on Forest and Biodiversity*. Indonesia: Manado Forestry Research Institute; 2013, p.81-92.
- Mindawati, N., and Y. Heryati. 2006. The Effect of Plant Maintenance Frequency on Growth of Young Meranti in Field. *Journal of Plantation Forest Research* 3(2). Center for Research and Development of Forest Plantations. Bogor.
- Orwa, C., Mutua, A., Kindt, R., Jamnadass, R., Simons, A. 2009. *Agroforestry Database: A Tree Reference And Selection Guide Version 4.0* (<http://www.worldagroforestry.org/af/treedb/>)
- Rahman, W., and Abdullah, M.N. 2002. Effects of Shade and Origin Ebony Chicks Against Growth (*Diospyros celebica* Bakh.). *News Biology* 6(2):297-301: Special Edition Management Ebony. Research Center for Biology LIPI. Bogor.
- Rashed, K.N. 2013. Antioxidant Activity from *Diospyros ebenum* Stems Extracts and Phytochemical Profile. *Journal of Applied and Industrial Sciences*. 1(2):70-72.
- Santoso, B. 2002. The Status and Strategy of Tree Breeding Ebony (*Diospyros celebica* Bakh.). *News Biology* 6 (2):315-319: Special Edition Management Ebony. Research Center for Biology LIPI. Bogor.
- Santoso, B., Anwar, C. 2002. Growth of Exitu Conservation Plant Ebony (*Diospyros celebica* Bakh.). *Bulletin of Forestry Research* 8 (1). Forestry Research Institute, Ujung Pandang.
- Seran, D., Santoso, B., and Ginoga, B. 1991. Growth of Ebony in Kalaena Nature Reserve, Luwu Regency in South Sulawesi. *Journal of Forestry Research* 4(12). Forestry Research Institute, Ujung Pandang.
- Soerianegara, I. 1970. Forest Tree Breeding. Forest Research Institute. Report No. 104. Bogor.
- Soerianegara I. et al. 1995. *Diospyros* L. In Lemmens, R.H.M.J., Soerianegara, I. & Wong, W.C. (eds): *Plant Resources of South-East Asia No 5(2). Timber Trees: Minor Commercial Timbers*. Prosea Foundation, Bogor, Indonesia. p 185-205
- Soeseno, O.H. 1985. *Tree Breeding*. Foundation Trustees Faculty of Forestry Research, Gadjah Mada University, Yogyakarta.
- Vanclay, J.K. 1994. *Modelling Forest Growth and Yield. Application to Mixed Tropical Forest*. CAB International. Guildford.
- Wright, I.W. 1976. *Introduction to Forest Genetics*. Academic Press. New York, San Fransisco, London.
- Zobel, B., and J.Talbert. 1984. *Applied Forest Tree Improvement*. John Willey & Sons. New York, Chichester, Brisbane, Toronto, Singapore.

THE POTENCY OF INDIGENOUS SPECIES AS A MERCURY PHYTOREMEDIATOR ON ILLEGAL EX-GOLD MINING RECLAMATION

Wiwik Ekyastuti, Emi Roslinda

Faculty of Forestry Tanjungpura University
Jl. A. Yani Pontianak
e-mail: wieky_serdam@yahoo.co.id

ABSTRACT

Illegal gold mining at Menjalin district caused some environmental destruction. Surrounding the illegal ex-gold mining areas, there are forests that provide some plants which are potential as mercury phytoremediators. The purpose of this study was to determine the potential of indigenous species for mercury phytoremediator uses. The results found 8 indigenous species that were able to grow in the marginal illegal ex-gold mining areas. Further investigation indicated that from the 8 species of plants there were only 4 plant's species that potential as mercury phytoremediator e.g., simpur (*Dillenia suffruticosa*), medang (*Cinnamomum porrectum*), laban (*Vitex pinnata*) and pulai (*Alstonia pneumatophora*). Secondary forest were located surrounding the ex-gold mining area in Menjalin subdistricts, has excellent potential in providing the mercury phytoremediator seedlings. Therefore, utilization of indigenous species specifically simpur, medang, laban and pulai highly recommended to use in illegal ex-gold mining reclamation in Menjalin subdistricts, Landak district, West Kalimantan.

Keywords: ex-gold mining area, mercury phytoremediator.

INTRODUCTION

In the last twenty years, many gold mining activities conducted in West Kalimantan, including in Menjalin subdistrict. Gold mining is generally done by the community, and usually illegal. The negative impact of gold mining activities is changing the landscape and damage to the environment. Worse, because it is illegal then there is no attempt to rehabilitate the land. Ex-gold mining area called tailings that are materials in the form of both small and large rocks were barren, arid, nutrient-poor, there tends to be acidic and heavy metal content of mercury (Ekyastuti, 2013). Gold mining activities undertaken by community in Menjalin subdistrict, generally performed in a wooded area. Therefore, techniques for the rehabilitation of mined land reclamation of gold mining in these locations are to use the method of restoration. Restoration efforts to repair or restore the damaged land conditions by forming the structure and function close to the original condition (Project RECA, 2014). Thus, previous forested land would revert to forest.

The success of restoration activities is determined by the success of these plants growing in the mined land (replanting). The key to the success of replanting is the suitability of selected plant species to land. Therefore, the selection of appropriate indigenous species is a top priority. Moreover, by using indigenous species (native plants), restoration goal that is establish the structure and function of the forest close to the original or initially be more assured. In addition, plant species selected must have the ability to remediate mercury which is a pollutant material in the ex-gold mining area. The plants are called mercury phytoremediation (Wang, 2004; Prabha et al., 2007). Planting mercury phytoremediator, besides being able to improve the micro-climate conditions will also reduce the levels of mercury in the tailings.

During this time, the potential of indigenous species as reclamation plant as well as mercury phytoremediator, just discourse and theory. Especially in Menjalin subdistricts, Landak district, this potential has not been explored at all. Views of urgency, for the selection of indigenous species in reclamation of ex-gold mining areas, this data is indispensable. Therefore, studies that focusing on extracting the potential of indigenous species as mercury phytoremediator for ex-gold mining area reclamation is important to do. The purpose of this study was to determine the potential of indigenous species (tree structure) as mercury

phytoremediation for reclamation of ex-gold mining areas in Menjalin subdistricts, Landak district of West Kalimantan.

MATERIAL AND METHODS

The study was conducted over three months, from May to July 2014 in two locations, namely: (1) in the area of ex-gold mining in Menjalin subdistrict, Landak district West Kalimantan and (2) in secondary forest near the ex-gold mining area. Census methods used to explore the indigenous species (trees structure) were indicated as mercury phytoremediator in the tailings ex-gold mining area who have abandoned more than 5 years. In the area divided in 2 locations (plots) of each area of 0.5 hectares. The census data will be used as a base for seeing the potential of indigenous species in secondary forest area. To see the potential of indigenous species in the secondary forest, use quadrat sampling technique by double plot method. Plots were made systematically on 4 sides (east, west, south and north) and in the middle of the forest area, 2 plots each, bringing the total plot are 10. Sample plot size of 20m x 20m were used to collect the data type of tree, size of 10m x 10m plots were used to collect the data type of the pole, size of 5m x 5m sample used to collect the data types of saplings, and a plot size of 2m x 2m sample used to collect the data types of seedlings. Furthermore, the data were analyzed by calculating the basal area, density, relative density, frequency, relative frequency, dominance, relative dominance, and importance value index (IVI) (Kusmana, 1997).



Figure 1. Location of the study (a) the tailings area of the ex-gold mining and (b) secondary forest

RESULTS AND DISCUSSION

Inventory of indigenous species in the tailings area of the ex-gold mining

The census results in the tailings area of ex-gold mining in Menjalin subdistrict that had been abandoned for more than 5 years, only obtained 8 indigenous species (trees structure) with the number of individuals 132. These plants were found only on seedlings and saplings. Population was dominated by ground storey and shrubs such as grasses (*Cyperus* spp.), blady grass (*Imperata cylindrica*), cengkodok (*Melastoma malabatricum*) and several kinds of ferns. This indicates that the succession is happening very slowly in the ex-gold mining areas (Densmore, 2005). In addition to the indigenous species of plants are found also that the exotic acacia (*Acacia mangium*). Based on the investigation and the search turns near the tailings site, have been planted acacia as greening plants. Acacia has properties allelopathy, the ability to inhibit the growth of other plants, so it is suspected the existence of this acacia plants also inhibit the growth of indigenous plant species (Prawoto et al., 2011).

Table 1. Indigenous species (trees structure) found in the tailings area of the illegal ex-gold mining in Menjalin subdistrict

No.	Local name	Latin name	Family	Amount of individuals
1.	Simpur	<i>Dillenia suffruticosa</i>	Dilleniaceae	51
2.	Medang	<i>Cinnamomum porrectum</i>	Lauraceae	10
3.	Pulai	<i>Alstonia pneumatophora</i>	Apocynaceae	18
4.	Cempedak	<i>Artocarpus heterophyllus</i>	Moraceae	3
5.	Bingir	<i>Ploiarium alternifolium</i>	Theaceae	19
6.	Mahang merah	<i>Macaranga triloba</i>	Euphorbiaceae	9
7.	Laban	<i>Vitex pinnata</i>	Verbenaceae	17
8.	Ubah	<i>Syzygium zeylanicum</i>	Myrtaceae	5
Total				132

Regardless of the small number of species found in the tailings area of the ex-gold mining, these indigenous species are pioneer plant species that have relatively fast growth. Visually, healthy plant growth did not show depressed growth. This suggests that the types of plants have a good adaptability to marginal conditions, including the ability to regulate the presence of heavy metals mercury in tailings media. This condition indicates that the types of plants that have the ability to remediate mercury, as the basic categories of plants which belong to the group of mercury phytoremediator. Some plant species are presented in Figure 2.

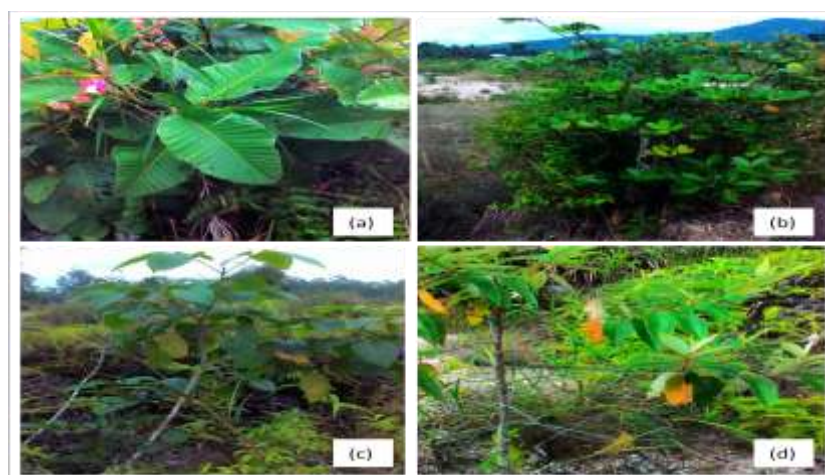


Figure 2. Some indigenous species that were found in the tailings area of the ex-gold mining (a) simpur (b) pulai (c) laban (d) medang

The ability of plants in mercury remediation

The plants ability to absorb mercury is the basic capabilities that must be owned by a group of plants of mercury phytoremediator. To ensure the success of reclamation in the tailings area of the ex-gold mining that is contaminated with mercury, the planting of mercury phytoremediator highly recommended. The results of the mercury analysis in indigenous plant species tissues showed diverse values (Figure 3). This illustrates the ability of plants to absorb mercury vary.

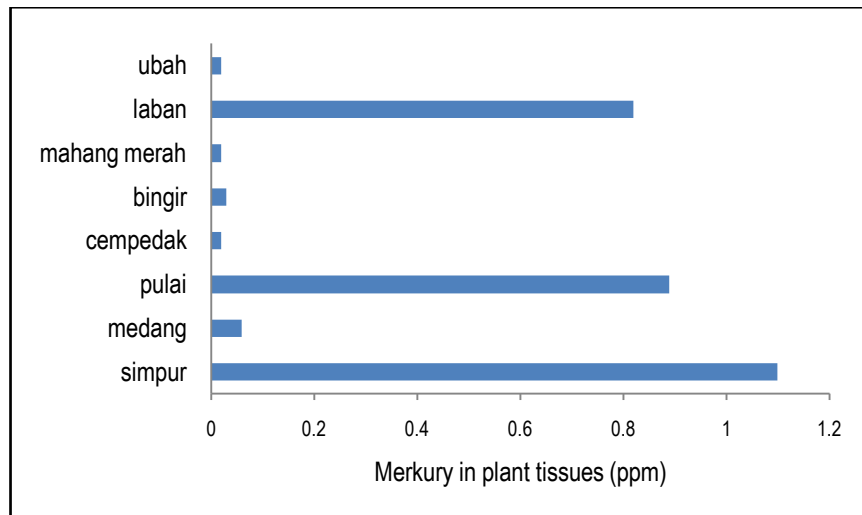


Figure 3. Content of total mercury in plant tissues

In addition to the data content of total mercury in plant tissues, total mercury content in the tailings were also measured of 0.05 ppm. Subsequently measured bioconcentration factor (BF), the mercury in the plant tissue divided mercury in the media (Rabie, 2005). If the value of $BF > 1$ means that the plants have a tendency as phyto-remediator, in this case mercury phyto-remediator. Based on these data it is known that simpur, pulai, laban and medang has a value of $BF > 1$ while cempedak, bingir, mahang merah and ubah the value $BF < 1$. This suggests that the indigenous species belonging to the group of mercury phyto-remediator only four plants i.e. simpur, pulai, laban and medang. The fourth type of other just be tolerant of mercury. The difference in response of plants to mercury due to the specific nature of plants to heavy metals (Ward & Singh, 2004), meaning that the plants remediator of Pb not necessarily remediator of Hg as well. Further described by Wang (2004) and Ghosh & Singh (2005), the mechanism of remediation by plants (phyto-remediation) can occur either through the process of evaporation (phyto-volatilisation) or absorption into the plant tissue through a process phyto-extraction or phyto-stabilisation. But in this study was not conducted in-depth investigation of the mechanisms of remediation by simpur, medang, laban and pulai.

The potential of secondary forests as a source of indigenous species seedlings for reclamation

Based on the data that has been previously described, illustrated that the process of succession in the tailings area of illegal ex-gold mining going very slowly, because after lasting more than 5 years is still dominated by ground storey and shrubs. The succession process can be accelerated with the reclamation and revegetation of the land, so that once can mitigate mercury contamination in the tailings. The key to the success of revegetation is to select the correct species, which are easy to grow, intolerant and pollutants phyto-remediator (Setiadi, 2003; Mansur, 2010; Sarma, 2011). From the previous data has been known to four indigenous species that can be used for the reclamation of ex-gold mining area in Menjalin subdistrict, which were simpur, medang, pulai and laban. The results of the vegetation analysis in secondary forests surrounding the illegal ex-gold mining area showed that all four species of plants were found, with varying density (Table 2).

Judging from the distribution of density, decrease successively for all types of plant density for seedlings to saplings, pole up to the level of the tree. This condition suggests that plant population was dominated by seedlings and saplings, so as to ensure continuity of stands in the future. Due to the location of the secondary forest (research site) not far from the illegal ex-gold mining area, then this condition is also at the same time guarantee the availability of seedlings for reclamation in the tailings area of illegal ex-gold mining in Menjalin subdistrict.

Table 2. Summary of density (individuals/ha) and IVI (%) of vegetation in secondary forest

No	Local Name	Latin Name	Seedlings		Saplings		Poles		Trees	
			Density (ind/ha)	IVI (%)	Density (ind/ha)	IVI (%)	Density (ind/ha)	IVI (%)	Density (ind/ha)	IVI (%)
1	Merkubung	<i>Macaranga gigantean</i>	12291,7	48,0404	466,67	29,3967	328,58	36,5855	77,33	84,2073
2	Simpur	<i>Dillenia suffruticosa</i>	11250,0	45,8181	200,00	20,2376	628,60	81,9518	12,00	9,3323
3	Bingir	<i>Ploiarium alternifolium</i>	9375,0	25,4545			114,30	12,9059	20,00	25,1899
4	Pakeng	<i>Ficus sp.</i>	2291,7	12,1616	333,33	26,3094			4,00	5,1889
5	Porang	<i>Amorphophallus oncophyllus</i>	2291,7	12,1616	266,67	22,4681				
6	Pulai	<i>Alstonia pneumatophora</i>	2083,3	11,717	166,67	11,1465	57,14	8,7933	8,00	10,2799
7	Ubah	<i>Syzygium zeylanicum</i>	1250,0	8,1212	633,33	44,181	328,58	36,5855	16,00	13,7434
8	Kamayo		1041,7	7,6768						
9	Laban	<i>Vitex pinnata</i>	1041,7	7,6768	500,00	23,6865	328,58	36,5855	92,00	87,5278
10	Medang	<i>Cinnamomum porrectum</i>	1875,0	7,6364	233,33	16,0938	57,14	8,7933	38,67	42,1037
11	Ubah besi	<i>Memecylon edule</i>	833,3	5,4141	733,33	43,8213	328,58	36,5855	8,00	10,3779
12	Mayam	<i>Cratoxylon glaucum</i>	625,0	3,1515	733,33	30,8341			12,00	12,0491
13	Cempedak	<i>Artocarpus heterophyllus</i>	416,7	2,7071						
14	Pudu	<i>Artocarpus kemando</i>	208,3	2,2626	133,33	15,5156				
15	Sabarubu	<i>Gaertnera vaginans</i>			266,67	10,4773				
16	Janang	<i>Adina minutiflora</i>			66,67	5,8315				
17	Gerunggang	<i>Cratoxylon arborescens</i>					228,60	30,6517		
18	Karimunting	<i>Melastoma sp</i>					57,14	10,5617		

In connection with the potential of secondary forests as a seedlings source, the seedling availability becomes very important. For seedlings, except simpur three others indigenous species i.e.: medang, laban and pulai in the secondary forest were not dominated the population. This can be seen from the value of IVI only 7.64%, 7.67% and 11.72% is much lower than the more dominating simpur with IVI 45.81%. However, because of the availability of seedlings is high enough then use simpur, medang, laban and pulai for illegal ex-gold mining reclamation is possible. According to Wyatt & Smith (1963) as quoted Syahri (2013) ecological regeneration adequacy requirement for the seedling rate of at least 1000, while the number of seedlings in the study sites are available for simpur was 11.250, pulai was 2.083, laban was 1.041 and medang was 1.875. So it can be concluded that the secondary forest (study site) has good potential as a seedlings source for reclamation on tailings area of illegal ex-gold mining in Menjalin subdistrict.

CONCLUSION

The conclusion that can be derived from this study is found four indigenous plant species belonging to mercury phytoremediator namely: simpur (*Dillenia suffruticosa*), medang (*Cinnamomum porrectum*), laban (*Vitex pinnata*) and pulai (*Alstonia pneumatophora*). Secondary forests are located surrounding the tailings area of ex-gold mining in Menjalin subdistricts, has excellent potential in providing indigenous species seedlings of mercury phytoremediator. Therefore, the use of indigenous species, especially simpur, medang, laban and pulai highly recommended for use in reclaiming illegal ex-gold mining area in Menjalin subdistrict, Landak district, West Kalimantan.

ACKNOWLEDGEMENTS

Our thanks go to the Directorate General of Higher Education (DIKTI) on the funding for this research through research scheme MP3EI.

REFERENCES

- Densmore RV. 2005. Succession on Subalpine Placer Mine Spoil: Effect of Revegetation With *Alnus viridis* Alaska, USA. *Arctic, Antarctic and Alpine Research* 37(1): 297-303.
- Ekyastuti W. 2013. Akselerasi suksesti vegetasi untuk mitigasi cemaran merkuri akibat penambangan emas skala kecil. Disertasi Fakultas Kehutanan UGM, Yogyakarta.
- Ghosh M & SP Singh. 2005. A Review on Phytoremediation of Heavy Metals and Utilization of Its Byproducts. *Appl. Ecol. Environ. Res.* 3(1): 1-18.

- Kusmana C. 1997. Metode survey vegetasi. Institut Pertanian Bogor. Bogor.
- Mansur I. 2010. Teknik Silvikultur untuk Reklamasi Lahan Bekas Tambang. Seameo Biotrop. Bogor
- Prabha K, Padmavathiamma & LY Li. 2007. Phytoremediation Technology: Hyper-accumulation Metals in Plants. *Water Air Soil Pollut* 184:105–126.
- Prawoto A, AM Nur , SW Soebagiyo dan M Zaubin. 2006. Uji Alelopati Beberapa Spesies Tanaman Penangung Terhadap Bibit Kopi Arabika (*Coffea arabica* L.). *Jurnal Pelita Perkebunan* 22(1):1-12.
- Project RECA. 2014. Pedoman Tata Cara Restorasi di Kawasan Konservasi. Project on Capacity Building for Restoration of Ecosystems in Conservation Areas. JICA dan PHKA, Jakarta.
- Rabie GH. 2005. Contribution of Arbuscular Mychorrizal Fungus to Red Kidney and Wheat Plants Tolerance Grown in Heavy Metal-Polluted Soil. *African Journal of Biotechnology* 4(4): 332-345.
- Sarma H. 2011. Metal Hyperaccumulation in Plant : A Review Focusing on Phytoremediation Technology. *Journal of Environmental Science and Technology* 4(2) : 118-138.
- Setiadi Y. 2003. Mycorrhizal Inoculum Production Technique for Land Rehabilitation. *Jurnal Manajemen Hutan Tropika* 8(1): 52-64.
- Syahri K. 2013. Syarat Kecukupan Permudaan Secara Ekologis. <http://khaerlita.syahri10.student.ipb.ac.id/2013/10/10/syarat-kecukupan-permudaan-secara-ekologis/>
- Wang Y. 2004. Phytoremediation of mercury by terrestrial plants. A doctoral dissertation on Department of Botany Stockholm University, Sweden.
- Ward OP & A Singh. 2004. Soil bioremediation and phytoremediation-An overview. In: Singh A, Ward OP (eds) Springer, Berlin, *Applied Bioremediation and Phytoremediation* (1): 1-11.

TROPICAL PEATLAND FOREST DEGRADATION: EFFECTS ON FOREST-REGENERATION BIOMASS, GROWTH, MORTALITY, AND FOREST MICROCLIMATE CONDITIONS

Dwi Astiani*¹, Mujiman², Ruspita Salim², Muhammad Hatta², Deddy Dwi Firwanta²

¹ Fakultas Kehutanan Universitas Tanjungpura, Indonesia,

² Lembaga Living Landscape Indonesia.

Jl. Imam Bonjol Pontianak

*Email: astiani.dwi@gmail.com

ABSTRACT

Tropical peatlands have numerous hydrological and ecological functions ranging from regulation of water flow to providing refuge for endangered animal species. The increasing scarcity of available resources in mineral soils, advanced land conversion technology and continuously rising demand for forest and agricultural products have led to a rapid increase in peatland conversion and degradation. Escalating rates of logging, drainage, fires, conversion to plantations and expansion of small-holder not only increase carbon emissions but also disturb ecosystem functions invariably. The occurrence of various forms of peatland conversion and degradation is well known. However, the impacts of forest degradation on peatland forest in-situ condition such as micro climates and regeneration is not clear. A study had been conducted to measure how peatland forest response through their regeneration and microclimate conditions to forest degradation (i.e., canopy gaps >70%, 30-70%, and <30%). Seedling (diameter 1- <5 cm) and sapling (diameter 5-10 cm) growths and microclimate conditions (e.g., soil temperature, surface CO₂, water content, water vapor, and also ambient temperature, LAI, and amount of throughfall) were monitored for ~2 years. Results indicate that higher degraded forest (canopy gaps >70%) significantly enhance mean seedling dan sapling growth in peatland forest, although it reduced young tree density and biomass per unit area. Forest microclimate also altered by forest degradation levels. These results indicate that forest degradation significantly influence the peatland forest floors microclimate which affect growth of tree regeneration phase of the forest. Seedling and sapling growths was fortunated by the higher canopy gaps among the forest degradation levels.

Key words : *Logged-peatland forest, canopy gaps, seedling and sapling density, site factors, leaf area index.*

INTRODUCTION

Tropical land use changes by logging and clearing tropical forest for plantation development, conversion to small-holder agricultural areas, or expanding urban development, are often disturbing ecosystem functions and degrading environmental conditions (Achard 2002; Foley et al. 2005; Field et al, 2009; Miettinen et al. 2011) and, in turn, generates major contributions to global greenhouse gas emissions (Soares-Filho et al. 2006; Defries et al. 2007; Skutsch et al. 2007; van der Werf et al. 2009; Eva et al . 2010). Tropical deforestation released ~1.5 – 2.2 Gt C annually to the atmosphere throughout the 1990s (Gullison et al. 2007). Deforestation in 1995–2005 accounted for about 17– 29% of the total anthropogenic emissions greenhouse gas (GHG) primarily carbon (IPCC 2011; Stickler et al. 2009; Van Der Werf et al. 2010). Increased forest degradation, and forest land conversion to agricultural lands or urban areas accelerates this release of organic carbon to the atmosphere (Mitra et al. 2005). In addition, land use change will also impact effects and alter terrestrial ecosystem processes (Miettinen and Liew 2011). Thus, land conversion has and will likely continue to alter the emissions of greenhouse gases (IPCC 2007; Carlson et al. 2012, 2013). However, the impacts of forest degradation on peatland forest in-situ condition such as micro climates and regeneration is not stated clearly and how this condition affect the process within the forest changes matrix is interesting to be investigated.

There are numerous hydrological and ecological functions of tropical peatlands ranging from regulation of water flow to providing refuge for endangered animal species (Rieley & Page, 2005). The increasing scarcity of available resources in mineral soils, advanced land conversion technology and continuously rising demand for forest and agricultural products have led to a rapid increase in peatland conversion and degradation. Escalating rates of logging, drainage, fires, conversion to plantations and expansion of small-holder dominated mosaic landscape have occurred since the 1980s (Silvius and Diemont, 2007). These activities not only increase carbon emissions but also disturb ecosystem functions invariably, both directly because of reduction of living biomass and acceleration in peat oxidation (Hooijer et al., 2006, 2010; Couwenberg et al., 2010) and indirectly by making the ecosystems more vulnerable to yearly fire activity (Siegert et al., 2001; Page et al., 2002). Logging activities, changes in livelihood sources, drainage and microclimate conditions (e.g. Siegert et al., 2001). The occurrence of various forms of peatland conversion and degradation is well known, However, the impacts of forest degradation on peatland forest in-situ condition such as micro climates and regeneration dynamics is not clear.

Increasing canopy gap size has been shown to impart greater microclimate change on in the forest floor (Barton et al. 1989; Proe 2001; Asbjornsen et al. 2004). These results imply that in tropical peatlands, forest degradation and land cover change - with corresponding alterations of soil microclimate (e.g., temperature, CO₂, light, humidity) - will influence forest growth especially for young trees.

This research aims to investigate the impacts of peatland forests degradation (i.e., canopy gap levels) on their tree regeneration, growth, and mortality. We also reveal how the canopy gaps built microclimate conditions.

MATERIALS AND METHODS

Study Site

This study was conducted in an *ombrotrophic*, peatland in Kubu Raya district, West Kalimantan, Indonesia (0°13' S and 109° 26' E, ~ 4 m a.s.l.; ~3km from northern perimeter of Kuala Dua peatland; Figure 1). Mean annual rainfall was 3318 mm ± 82 mm with 195 ± 3.9 rain days per year (compiled from Pontianak airport Supadio weather station, West Kalimantan; ~8 km from the research site in 2007-2013). Forest regeneration and microclimate condition were measured in a contiguous 12 ha block of peatland forest. From our peat surveys and studies in West Kalimantan, we determined that this study area was highly representative of West Kalimantan coastal-peatland areas as the overwhelming majority of coastal peat areas had been selectively-logged. Moreover, such logged peat sites become highly vulnerable to wildfires and conversion to agriculture – either by smallholder farmers or industrial plantations. Our pre-survey classified this forest degradation by canopy gaps classes: low, intermediate, and high degraded (gaps < 30%, 30-70%, and >70% consecutively). Under this class, we measured seedling and sapling density, biomass, growth, and mortality annually and their monthly microclimate conditions.

Seedling and sapling growths

Even though understory trees (seedlings and saplings) typically comprise <3% of above ground biomass on mineral soils (Brown et al.1997), we attempted to assess two years of measurement within this peat ecosystem. Because this tropical peat swamp ecosystem may have more stems of less stature, we deemed these measurements necessary initially to assess the relative contributions of smaller size classes to peat forest biomass and to reveal how this tree regeneration growth responses to forest degradation and thus, microclimate condition.

Across 12 ha, trees 1-<10 cm dbh were sampled using Nested Sampling by registering all trees diameter 1-10 cm within 1 meter and 5 meter-width transects for seedling and sapling measurements consecutively, sistematically built within each 50 m plots. All young trees within the sampling line were mapped, tagged, identified to species or at least genus and monitored for diameter growth. Seedlings and saplings were measured with a calliper and given a permanent red paint mark at the point of measurement. Tree increment was calculated as the difference between its estimated biomass at the end of each interval.

Transforming diameter increment into accurate biomass increment estimates requires application of an appropriate allometric equation (Clark et al. 2001). We follow Paoli and Curran (2007) to estimate aboveground biomass using the moist forest equation of Chave et al. (2005) that also incorporates specific wood densities. Chave et al.'s equation was derived from a larger data set than used by Brown (1997), and estimates aboveground biomass as a function of diameter and wood specific density.

Microclimate and Soil Properties Measurements

Leaf Area Index (LAI) readings were taken from 6:00 – 8:00 with a LICOR LAI-2000 Plant Canopy Analyzer under 48 of the 50 m x 50 m plots at early seedling and sapling data collection. Beside assessing microclimate data, this measurement was useful in refining canopy gap data for classifying forest degradation level.

Microclimate (soil temperature, water content, CO₂ concentration, ambient temperature and amount of precipitation) were recorded in the three forest degradation classes in forested area and in open areas during the measurement. Hobo Event Data Loggers – connected to tipping bucket rain gauges – were programmed to record hourly measurements of temperature and precipitation with loggers downloaded monthly. Three hobos were distributed under each of the three canopy gap classes and one hobo was placed under clear fully open open peat area. However, the hobo placed under mid canopy was damaged or lost during monitoring. To back up climate data, we registered data from Supadio Airport weather station in Pontianak (~8 km from forest site), daily maximum/minimum temperature and rainfall records were also compiled to compare results with regional trends.

Soil bulk density and carbon content was measured using a standard Russian peat borer (Aquatic Research Instrument), 48 undisturbed soil depth core samples were taken in the representative nine plots for soil bulk density measurement. Soil samples were drained for 24 hour at ambient temperature, weighed for water holding capacity measurement, oven dried at 70°C for 2–3 days, and then weighed. Soil bulk density was calculated as oven dried mass per volume sample g cm⁻¹. Soil microclimate data was collected using Licor 8100 (Soil Automatic Respiration Measurement System) in conjunction with our other study on soil respiration on peatland. Using this tool we collected soil surface temperature, water vapor, water content, and CO₂ concentration.

Data analysis

Throughout the estimation of seedling and sapling growths, mortality, and biomass, data are presented as means and standard errors (SE) unless otherwise noted. To test for differences among peat degradation levels/canopy gap classes, Repeated Measures ANOVA analyses were used and then proper pairwise comparisons were applied (e.g., Tukey Procedures). This procedure was also used to test for differences among forest canopy classes with several environment factors (peat temperature (°C), peat water vapour (H₂O mmol mol⁻¹), peat CO₂ concentration (ppm), peat water content (%), ambient temperature (°C), amount of throughfall (mm), and Leaf Area Index measurement reading (m²/m²).

RESULTS AND DISCUSSION

Results

Peatland Forest Regeneration

This peatland ecosystem is presented here best reflect degraded or converted peat forest parcels and provide a realistic condition of general peatland forest in Indonesia at present. Seedling dan sapling distribution showed that that this forest is in normal stage of succession after disturbance (logged over area that was low impact harvesting in 2003-2004 for transmigrants housing near the forest). The seedling and sapling population under low, intermediate, and high degraded peatland forest are 26436, 25241, and 16467 seedlings/ha and 1173, 1094, and 667 saplings/ha consecutively. However, the data imply that forest degradation influence the young trees density. High level of forest degradation reduced their sapling population to 56% and seedling to almost similar percentage (55%) when the forest are highly degraded from relatively low degraded and better forest condition (Figure 1).

Peatland regeneration comprised of approximately 18 ton/ha biomass from sapling and ~ 5 ton/ha from seedling biomass/ha, which accumulated become 23 ton/ha for all young trees with diameter <10cm. Forest degradation reduced both saplings and seedlings biomass by 37 % and 46% when forest being degraded relatively low degraded forest into high level or when canopy gap is increase into larger than 70%.

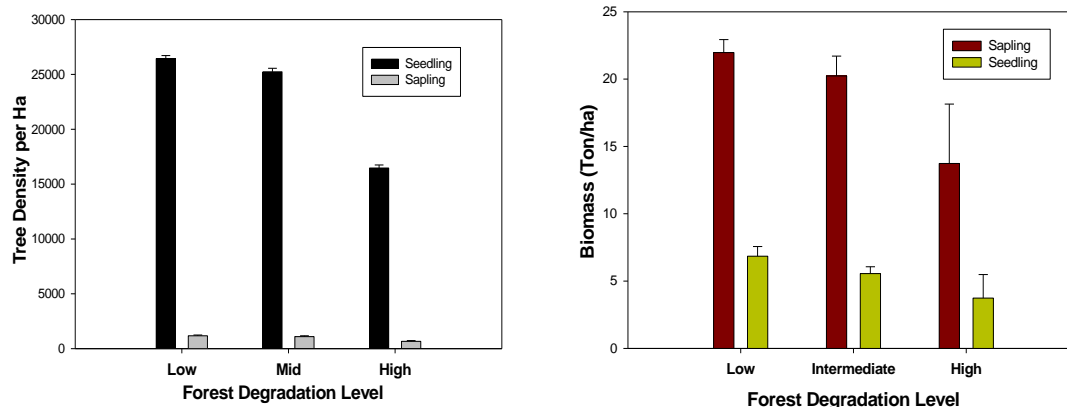


Figure 1. Seedling and sapling a) density; b) biomass; per hektar

Seedling and Sapling Growth and Mortality

Annual growth measurement demonstrated that forest degradation significantly affected diameter growth of both tree seedlings and saplings. High degraded forest (canopy gap >70%) induced growth of young trees under the canopy and significantly different from low and mid canopy gaps. Both seedling and sapling stages showed similar trend. The diameter growth among the 3 degradation levels (low, mid, and high) were 3,6cm, 3,9cm, and 5,5cm for sapling and 0,3cm, 0,4cm, and 0,8cm for seedling stages consecutively (Figure 2).

Peat Environmental Conditions

We collected data on peat temperature, peat surface water vapor, peat water content, soil surface CO₂ concentration, ambient temperatures, amount of precipitation and Leaf Area Index among under 3 canopy levels (forest degradation). Repeated Measures ANOVA showed that several microclimate conditions under forest degradation levels were invariably significantly different.

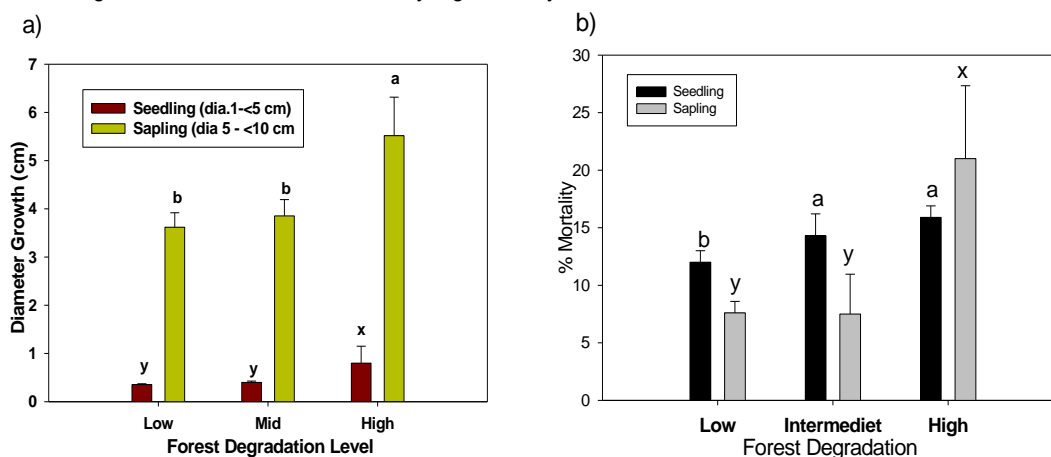


Figure 2. Peatland forest annual seedling and sapling a) diameter growths (mean and SE); b) Mortality (%); among peatland forest degradation level

- **Peat Temperature**
Mean peat temperatures fluctuated considerably during the 2 years of measurement, with the lowest and the highest daily soil temperature recorded from 27.2 °C to 41.1 °C and monthly mean from 28.2 °C to 37.9 °C. However, even though within this wide range, soil temperature did not impart a significantly different among forest degradation levels.
- **Peat Surface H₂O (Water Vapour)**
Forest degradation class also did not display any significant differences in the mean values of water vapor among the groups.

- Peat Surface CO₂ Concentration**
 Peat CO₂ concentration is fluctuated considerably both daily and monthly. Daily distribution of CO₂ concentration mean ranged from 363 ppm to 637 ppm with mean monthly range from 383 ppm to 485 ppm. The mean daily concentration among forest degradation level was significantly different. Data distribution indicate that CO₂ concentration under closed canopy tends to be higher than under open one (Figure 3a).
- Peat water content (%)**
 Mean daily distribution of water content (%) ranged from 33.4% to 100% with mean monthly distribution fluctuating from 41% to 100%. At these levels, water content was not found to significantly different among forest canopy gaps. Further data analyses indicate that in open canopy, peat water content was not significantly different among them.
- Rainfall**
 Hobo event data loggers recorded total monthly precipitation data across the sites. Note that because of incomplete rainfall measurements across all sites, the forest comparison can only be assessed among open area, open canopy and closed canopy sites. Mean monthly precipitation were found different between low vs high degraded, yet were not different across the three other sites, high degraded forest, open area and Supadio climate Station (RM ANOVA: $df = 47$; $F = 2.91$, $p = 0.05$; Figur 5b)
- Ambient Temperature**
 Monthly ambient temperature differed significantly across the three degradation levels ($df = 51$, $F = 16.5$, $p < 0.001$). The mean temperature indicated that the opened area and opened canopy were associated with higher ambient temperatures than both closed and intermediate sites. Closed canopy sites did not differ significantly from intermediate one. (Open Area: $27.6 \pm 0.2^{\circ}\text{C}$; low degraded: $25.5 \pm 0.4^{\circ}\text{C}$; intermediate : $26.6 \pm 0.3^{\circ}\text{C}$; and high degraded: $27.5 \pm 0.3^{\circ}\text{C}$; Fig 5c). As a comparison, ambient temperature records from the Supadio airport weather station indicate 32.5°C , 27.0°C , and 23.7°C for maximum, mean, and minimum temperatures, respectively.
- Leaf Area Index (LAI)**
 Mean LAI distribution among the three canopy classes are 4.22 ± 0.46 , 3.45 ± 0.15 , and $1.84 \pm 0.61 \text{ m}^2 \text{ m}^{-2}$ ($n = 3$) for low, intermediate and high forest degraded classes, respectively. One way ANOVA analysis indicated they are significantly different, and Tukey Tests show that the mean LAI values of low and high degraded sites were significantly different, while intermediate level was not different among others.

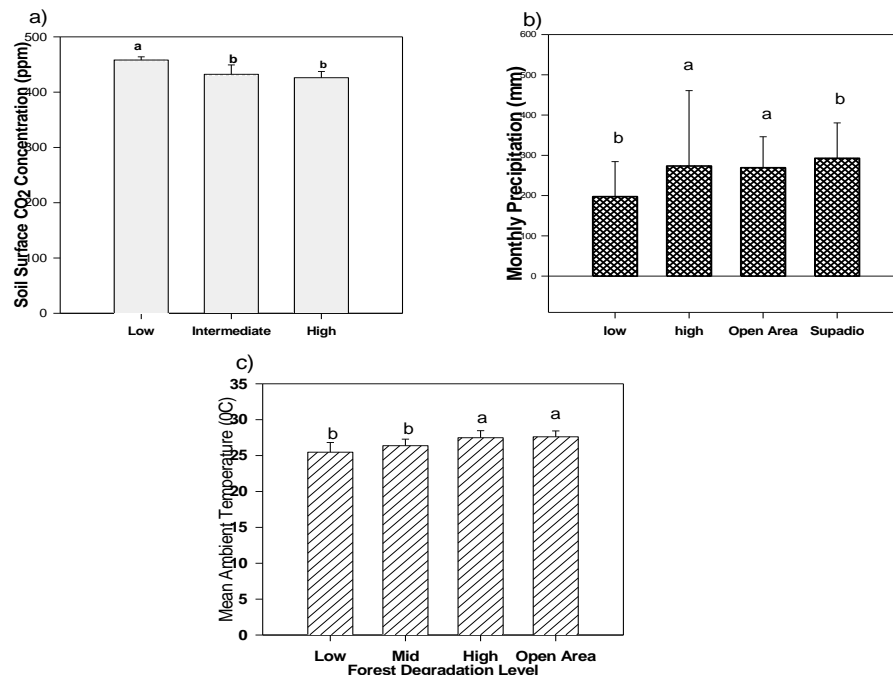


Figure 3. a) Mean daily CO₂ concentration; b) Mean monthly precipitation among low and high degraded forest, open area, and Supadio Climate Station; and c) Mean monthly ambient temperature among the three forest degradation levels

Discussion

Forest degradation effects on tree regeneration

Results show that forest degradation reduced seedling and sapling densities on forest floor. Fewer seed sources under high degraded forest because of lesser large trees could be one of the reasons why regeneration here was not as dense as under low or intermediate degraded forest. Surprisingly, seedling and sapling biomass was relatively high if compared to the density in mineral tropical forest (Brown et al. 1997). Our prior study demonstrated that this peatland forest total biomass was ~128ton/ha (Astiani, et al 2014, *inpress*). Thus, peatland forest young trees contribute to ~18% of total biomass, which are 14% from sapling plus 4% from seedling stages.

Our results indicate that larger gaps induced the seedling and sapling diameter growths. This result indicates that under high degraded forest is demonstrating potential recovery of this degraded peatland forest (Berenguer et al. 2014) and in general, this peatland forest has relatively adequate young tree to fulfill peatland forest regeneration. However, seedling and sapling mortalities is also increasing with higher level of degradation. This phenomenon need more attention in order to reduce the loss of higher biomass in the future time. Some seedling and sapling species might be favor to and some might be not tolerate to the alteration of site condition due to the canopy gaps changes.

What are site conditions altered by degradation?

Peatland degradation results predominantly in canopy cover loss. In undisturbed tropical rain forests, photosynthetic active radiation (PAR) is typically 1–2% (Brown 1993). Our measurement on LAI under the three degradation levels shows that there is a decrease on LAI index along higher degradation levels. This results imply that lesser leaves in canopy of higher degradation/ higher gap, and allow more opportunity to light radiation reach peatland forest floor. Any change in forest canopy structure may result in altering soil surface absorption of light, and then, in turn, changes soil and forest floor microclimates (Raich 1987, Becker 1988). Other consequences of increasing canopy gaps is escalating forest ambient temperature, peat surface CO₂ concentration, and different amount of precipitation reach forest floor. However, these changes of sites factor need further study to examine the effects of those factors on regeneration growth and mortality.

CONCLUSIONS

1. Forest degradation affect seedling and sapling density of tropical peatland logged-forest dan consequently their standing biomass.
2. Nevertheless, lowering forest quality and quantity through forest degradation and altering forest canopy gaps induced regeneration growth on tropical peatland forest floor. The increasing canopy gaps level allowed seedlings and saplings to enhance their growth due to the shifting of some site condition which favor to regeneration growth.
3. Beside the increased growth, however, the seedling and sapling survival were also increasing with increasing of degradation level. Some seedlings were not tolerate to grow under higher canopy gaps and thus, v_{cub} increase their mortality.
4. Several site factors responded to the alteration of canopy gaps due to forest degradation (i.e., ambient temperature, peat surface CO₂ concentration, amount of throughfalls, and forest Leaf Area Index), whereas other factors (i.e., soil temperature, water content, water vapor) were not affected.

ACKNOWLEDGEMENT

Our appreciation to people in Kubu Raya District of West Kalimantan peatland area, who allowed us to assess their community forest and assisted us with their works and times to help us to collect some data. We thanks to Yale University, that allowed us to have this study in between our other large goals in studying peatland carbon dynamics in West Kalimantan. We also thank to Universitas Tanjungpura students, Marshandi, Yuliani, S Yuliani, A Wibowo, F Fifian, Hanisah, I M Pattapa, NB Rusli, Doddy K, and M Hafidz. for all supports and hard works. Great thanks to D Ratnasari, N Lisnawati, WI Suci, A Rochman, D Firnata, Y Purwanto, E Nurdiansyah, R Hartono, M Anom, T Mardiantoro, E Supardi, Umar at Lembaga Living Landscape Indonesia for their supports and works. We thank you all other people who participated in this study.

REFERENCES

- Achard F, Eva HD, Stibig HJ, Mayaux P, Gallego J, Richards T, Malingreau JP (2002) Determination of deforestation rates of the world's humid tropical forests. *Science*, 297 (5583), 999–1002.
- Asbjornsen H, Ashton MS, Vogt DJ, Palacios S (2004) Effects of habitat fragmentation on the buffering capacity of edge environments in a seasonally dry tropical oak forest ecosystem in Oaxaca Mexico. *Agricultural Ecosystem and Environment*, 103 (2004), 481–495.
- Barton AM, Fetcher N, Redheads (1989) The relationship between treefall gap size and light flux in Neotropical rain forest in Costa Rica. *Journal of Tropical Ecology*, 5, 437–439.
- Berenguer E, Ferreira J, Gardner TA, Aragao LEOC, De Camargo PB, Cerri CE, Durigan M, De Oliveira Jr RC, Vieira ICG, Barlow J (2014) A large-scale field assessment of carbon stocks in human-modified tropical forest. *Global Change Biology*, doi:10.1111/gcb.12627
- Brown N (1993) The implications of climate and gaps microclimates for seedling growth condition in a Bornean lowland rain forest. *Journal of Tropical Ecology*, 9, 153–168.
- Carlson KM, Curran LM, Ratnasari D, Pittman AM, Soares-Filho BS, Asner GP, Trigg SN, Gaveau DA, Lawrence D, Rodrigues HO (2012) Committed carbon emissions, deforestation, and community land conversion from oilpalm plantation expansion in West Kalimantan, Indonesia. *PNAS* 109, 7559–7564.
- Carlson KM, Curran LM, Asner GP, Pittman AM, Trigg SN, Adeney JM (2013) Carbon emission from forest conversion by Kalimantan oilpalm plantation. *Nature Climate Change*. www.nature.com/natureclimatechange. DOI:10.1038/NCLIMATE1702.
- Chave J, Andalo C (2005). Tree allometry and improved estimation of carbon stocks and balance in tropical forests. *Oecologia*, 145(1), 87–99.
- Clark DA, Brown S, Kicklighter DW, Chambers JQ, Thomlinson JR, Ni J (2001) Measuring Net Primary Production in Forests: Concepts and Field Methods. *Ecological Applications*, 11, 356–370.
- Couwenberg J, Dommain R, Joosten H (2010) Greenhouse gas fluxes from tropical peatland in South-East Asia. *Global Change Biology*, 16, 1715-1732.
- DeFries R, Achard F, Brown S, Herold M, Murdiyarso D, Schlamadinger B, de Souza C Jr (2007) Earth observation for estimating global gas emissions from deforestation in developing countries. *Environmental Science and Policy*, 10, 385–394.
- Ernst C, Mayaux P, Verheggen A, Badart C, Christophe M, Defourny P (2013) National forest cover change in Congo Basin: deforestation, reforestation, and degradation for the years 1990, 2000, and 2005. *Global Change Biology*, 19: 1173-1187, doi:10.1111/gcb.12092
- Eva H, Carboni S, Achard F, Stach N, Durieux L, Faure J-F, Mollicone D (2010) Monitoring forest areas from continental to territorial levels using a sample of medium spatial resolution satellite imagery. *ISPRS Journal of Photogrammetry and Remote Sensing*, 65, 191–197.
- Field RD, van der Werf GR, Shen SSP (2009) Human amplification of drought-induced biomass burning in Indonesia since 1960. *Nature Geoscience Letters*. DOI:10.1038/NCEO433, Feb 22, 2009.
- Foley JA, DeFries R, Asner GP, Barford C, Bonan G, Carpenter SR, Chapin FS, Coe MT, Daily GC, Gibbs HK, Helkowski JH, Holloway T, Howard EA, Kucharik CJ, Monfreda C, Patz JA, Prentice C, Ramankutty N, Snyder PK (2005) Global consequences of land use. *Science*, 309, 570–574.
- Gullison RE, Frumhoff PC, Canadell JG, Field CB, Nepstad DC, Hayhoe K, Avissar R, Curran LM, Friedlingstein P, Jones CD, Nobre C (2007) Tropical forests and climate policy. *Science* 10.1126, 1–5.
- Hooijer A, Silvius A, Woosten M, Page S (2006) PEAT-CO₂, Assesment of CO₂ emissions from drained peatlands in SE Asia. *Delft Hydraulics report Q3943*.
- Hooijers A, Page S, Canadell G, Silvius M, Kwadijk J, Wosten H, Jauhiainen J (2010) Current and future CO₂ emissions from drained peatlands in Southeast Asia. *Biogeosciences*, 7, 1505 – 1514.
- IPCC (2007): The Physical Science Basis –Summary for Policymakers. <http://www.ipcc.ch/SPM2feb07>.
- IPCC (2011): Summary for Policymakers. In: Edenhofer O, Pichs-Madruga R, Sokona Y, Seyboth K, Matschoss P, Kadner S, Zwickel T, Eickemeier P, Hansen G, Schlomer S, von Stechow C, (eds). *IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation*. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.
- Miettinen J, Shi C, Liew SC (2011) Influence of peatland and land cover distribution on fire regimes in insular Southeast Asia. *Regional Environment Change* 11, 191–201.
- Miettinen J, Liew SC (2011) Deforestations rates in insular Southeast Asia between 2000 and 2010. *Global Change Biology*, 17, 2261–2270.

- Mitra S, Wassmann R, Vlek PLG (2005) An appraisal of global wetland area and its organic carbon stock. *Current Science*, 88, 25–35.
- Paoli GD, Curran LM (2007) Soil nutrients limit fine litter production and tree growth in mature lowland forest of Southwestern Borneo. *Ecosystems*, 10 (3), 503–518.
- Proe MF, Griffiths JH, McKay HM (2001) Effect of whole tree harvesting on microclimate during establishment of second rotation forestry. *Agricultural and Forest meteorology*, 110 (2001), 1410–154.
- Rieley JO, Page SE (eds) (2005) *Wise Use of Tropical Peatland: Focus of Southeast Asia*, ALTERRA-Wagenigen University and Research Center and the EU INCO-STRAPEAT and RESTORPEAT Partnership, Wagenigen
- Saatchi SS, Harris NL, Brown S (2011) Benchmark map of forest carbon stocks in tropical region across three continents. *Proceeding of the National Academy of Sciences*, 108: 9899-9904
- Saatchi SS, Harris NL, Brown S (2011) Benchmark map of forest carbon stocks in tropical region across three continents. *Proceeding of the National Academy of Sciences*, 108: 9899-9904
- Siegert F, Rueckee G, Hinrich A, Hoffman AA (2001) Increase damage from fires in logged forest during droughts cause by El Niño. *Nature*, 414, 437–440.
- Skutsch M, Bird N, Trines E, Dutchke M, Prumhoff P, de Jong BHJ, van Laake P, Masera O, Murdiyarso D (2007) Clearing the way of reducing emissions from tropical deforestation. *Environmental Science and Policy*, 10, 322–334.
- Soares-Filho BS, Nepstad DC, Curran LM, Cerqueira GC, Garcia RA, Ramos CA, Voll E, McDonald A, Lefebvre P, Schlesinger P (2006) Modelling conservation in the Amazon basin. *Nature*, 440, 220–223.
- Stickler CM, Nepstad DC, Coe MT, McGrath DG, Rodrigues HO, Walker WS, Soares-Filho BS, Davidson EA (2009) The potential ecological costs and cobenefits of REDD: a critical review and case study from the Amazon region. *Global Change Biology*, 15, 2803–2824
- van der Werf GR, Morton DC, DeFries R S et al. (2009) CO₂ emissions from forest loss. *Nature Geoscience*, 2, 737–738.
- van der Werf GR, Randerson JT, Giglio L, Collatz G.J, Mu M, Kasibhatla PS, Morton DC, DeFries RS, Jin Y, and van Leeuwen TT (2010) Global fire emissions and the contribution of deforestation, savanna, forest, agricultural, and peat fires (1997–2009). *Atmospheric Chemistry Physics Discussion*, 10, 16153–16230.

THE CONTENT OF HEAVY METAL LEAD (PB) IN THE DRAGON FRUIT AND CASSAVA ON COAL MINED LANDS IN THE VILLAGE OF PURWAJAYA TENGGARONG DISTRICT EAST KALIMANTAN

Budi Winarni, Nur Hidayat, Sri Ngapiyatun

Major of Crops Plantation, Samarinda Agricultural Polytechnic
E-mail: orcaella@yahoo.com

ABSTRACT

Coal mining conditions resulting in physical, chemical and biological soil becomes poor, as no soil layer profile, soil compaction occurs, reduced important nutrients, low pH, contamination by heavy metals, as well as a decrease in soil microbial populations. In the coal mined land planted dragon fruit and cassava. The purpose of this study is to analyze the content of heavy metal lead (Pb) in the soil, dragon fruit and cassava. This research is descriptive research that sampling point to the field with five soil sampling dragon fruit and cassava. The nutrient soil and Pb metal content test performed at the Soil Laboratory. The results showed that low nutrient content of the soil, pH 4.94 but the plant of dragon fruit and cassava can grow in the coal mined land. The heavy metal content of Pb in the former coal mining land under the maximum content, but the content of Pb in dragon fruit and cassava exceeds the maximum limit based on the SNI 7387: 2009, so the dragon fruit and cassava grown on coal mined lands in Purwajaya Village are not safe for consumption. Liming the soil may reduce the availability of lead (Pb) and uptake by plants.

Keywords: coal, dragon fruit, cassava

INTRODUCTION

Coal mining has the potential to cause damage to land. Mining activities can have an impact on the changes or the destruction of ecosystems. Damaged ecosystem is defined as an ecosystem that can no longer perform its functions optimally, such as soil protection, water management, climate control and other functions in regulating the protection of the natural environment. Consequences include the physical, chemical and biological soil to be bad, like a layer of soil is not profiled, soil compaction occurs, essential nutrient deficiencies, low pH, pollution by heavy metals in mined lands, as well as a decrease in soil microbial populations. The rock fragments are very hard/compact and impenetrable by roots. Whereas the potential for coal resources in East Kalimantan is the second largest after South Sumatera. Total resources of coal in East Kalimantan Province per 1 January 2010 was 37,904.97 million tons, while the total coal reserves of 5,903.83 million tons (Anonymous, 2011).

Mining causes changes in the landscape and the quality of the results of hoarding land after mining. Structures damaged overburden, topsoil mix or immersed in deep layers. Topsoil replaced soil of the bottom layer are less fertile, otherwise fertile topsoil is in the bottom layer. Likewise, soil biological populations in topsoil becomes immersed, so missing/dead and not working properly. Carrying capacity of the post-mining topsoil for plant growth to be low (Subowo, 2011).

Heavy metals can be easily generated surface enters the soil system, and are on an unstable form that is easily soluble and can be absorbed by plants. Plants can absorb Pb during times of fertility and low soil organic matter content. In this state of heavy metals Pb will loose from the ground and form free-moving ions in the soil solution. If other metals are not able to inhibit its existence, then it will happen Pb uptake by plant roots. The presence of heavy metals in agricultural soil can reduce agricultural productivity and quality of agricultural products, it can also harm human health through the consumption of food produced from heavy metal contaminated soil. In humans, lead entering through the respiratory tract or gastrointestinal tract into the circulatory system and then spread to various other tissues such as kidney, liver, brain, nerves and bones. Lead poisoning in adults is characterized by symptoms 3 P ie pallor, pain, and paralysis (Charlena, 2004 in Widaningrum *et al.*, 2007)

The coal mined land in the Purwajaya Village planted dragon fruit and cassava. The purpose of this study is to analyze the content of heavy metal lead (Pb) in the soil, dragon fruit and cassava.

METHODS

Research has been conducted at the Soil Laboratory. The material used is a composite soil taken at a depth of 0-30 cm, and dragon fruit and cassava from the former coal mining area in the Purwajaya Village, Tenggara District, East Kalimantan Province. The sampling point is determined randomly at five points. Samples were taken and mixed as homogeneous as possible, then the sub-samples were taken for laboratory analysis.

Data content of heavy metals (Pb) in the soil, dragon fruit and cassava were then compared with:

- 1) Heavy Metal Soil Contamination (U.S. EPA, 1993 in USDA NRCS, 2000)
- 2) The limit for heavy metal contamination in food (SNI 7387: 2009).

RESULTS AND DISCUSSION

Data analysis of the results of soil chemical properties, heavy metals lead (Pb) in the soil, dragon fruit and cassava shown in Table 1 and Table 2.

Table 1. Chemical Analysis of Soil

No.	Parameter	Method	Unit	Outcome	Criteria *)
1	C Organik	Walkley & Black	%	1,74	low
2	N Total	Kjedahl	%	0,11	low
3	Ratio C/N	Calculated	-	16,02	high
4	P ₂ O ₅ (Bray 1)	Spectronic	ppm	1,09	very low
5	K ₂ O (HCl 25%)	AAS	mg/100g	37,06	moderate
6	pH H ₂ O	Electrode	-	4,94	acid

Notes: *) Soil Chemical Properties Assessment Criteria (Land Research Center, 1983 in Hardjowogeno, 2010)

Table 2. Content of heavy metal lead (Pb) in the soil, dragon fruit and cassava

No.	Sample	Method	Unit	Outcome	Maximum Content
1	Soil	AAS	ppm	251,41	420 *)
2	Dragon fruit	AAS	ppm	0,87	0,5 **)
3	Cassava	AAS	ppm	1,03	0,5 **)

Notes: *) Heavy Metal Soil Contamination (U.S. EPA, 1993 in USDA NRCS, 2000)

***) The Limit for Heavy Metal Contamination in Food (SNI 7387:2009)

Acidity (pH) of the soil can affect soil nutrient availability, and may be a factor related to soil quality. The low pH of the soil in the remainder of this coal mine excavation occurs because the process of demolition and removal of the embankment soil parent material to the surface, resulting in a change into the oxidative reductive environment. Under reductive conditions, jarosite minerals formed from the pyrite (FeS₂), this mineral is stable but in this mineral oxidative conditions will change as:



The presence of SO₄²⁻ and H⁺ ions is what causes the soil becomes acid (Tala'ohu *et al.*, 1995). In this study, the pH of the soil is 4.94 including acid criteria.

The maximum content of Pb in soil is 420 ppm (USDA NRCS, 2000). The content of Pb in this study was 251.41 ppm. Thus the elements of Pb does not exceed the maximum limit. According to Angima (2010) if the soil tests for lead higher than 50 ppm, the following management practices will not remove the heavy metal contaminants, but will help to immobilize them in the soil and reduce the potential for adverse effects from the metals. These include:

1. Maintaining a neutral soil pH above 6.5. Lead up take by plants is reduced when pH is above 6.5.
2. Add phosphorus when soil tests indicate a need. Phosphorus reacts with lead to form insoluble compounds, therefore reducing toxicity.
3. Add organic matter which in turn binds lead and makes it less soluble in soil water. When adding OM, soil pH soil should be maintained above 6.5 to reduce uptake by plants.

Plants can absorb Pb during times of low soil fertility and organic matter content. In this state of heavy metals Pb will loose from the ground, in the form of free-moving ions in the soil solution. If other metals are not able to inhibit its existence, then it will happen Pb uptake by plant roots (Widaningrum *et al.*, 2007). Based on the SNI 7387: 2009 maximum limits of heavy metal contamination in food is at 0.5 ppm. In this study, the content of Pb in the dragon fruit was 0.87 ppm and 1.03 ppm in cassava. Thus the dragon fruit and cassava in the study of Pb contaminated elements.

CONCLUSIONS

1. The low soil nutrient content and the content of Pb in soil does not exceed the maximum limit.
2. Dragon fruit and cassava polluted Pb element, so it is not safe for consumption.

SUGGESTIONS

1. Need manure application to increase the nutrient content in the soil.
2. Soil liming to reduce the availability of lead (Pb) and reduce the uptake by plants.

REFERENCES

- Angima, S. 2010. Toxic Heavy Metals in Farm Soil. Publish Date: Summer 2010 Vol. V No. 3. <http://smallfarms.oregonstate.edu/sfn/su10toxicmetals>. Article updated 7/18/2013
- Anonymous. 2009. Batas Maksimum Cemar Logam Berat dalam Pangan. SNI 7387: 2009. Badan Standardisasi Nasional. Jakarta.
- Anonymous. 2011. 2011 Handbook of Energy & Economic Statistics of Indonesia. Center for Energy and Mineral Resources Data and Information, Ministry of Energi and Mineral Resources. Jakarta
- Hardjowigeno S. 2010. Ilmu Tanah. Akademika Pressindo. Jakarta.
- Subowo, G. 2011. Penambangan Sistem Terbuka Ramah Lingkungan dan Upaya Reklamasi Pasca Tambang Untuk Memperbaiki Kualitas Sumberdaya Lahan dan Hayati Tanah. Jurnal Sumberdaya Lahan. Vol. 5 No. 2. Desember 2011.
- Tala'ohu, S.H. Moersidi, S. Sukristiyorubowo, Gunawan. 1995. Sifat Fisiko Kimia Tanah Timbunan Tambang Batubara (PTBA) di Tanjung Enim, Sumatera Selatan. Dalam Prosiding Pertemuan Pembahasan dan Komunikasi Hasil Penelitian Tanah dan Agroklimat, Bidang Konservasi Tanah dan Air, serta Agroklimat. Pusat Penelitian Tanah dan Agroklimat. Bogor. Hal 39-47.
- USDA NRCS. 2000. Heavy Metal Soil Contamination. Urban Technical Note No. 3 September 2000.
- Widaningrum, Miskiyah and Suismono. 2007. Bahaya Kontaminasi Logam Berat Dalam Sayuran dan Alternatif Pencegahan Cemarannya. Buletin Teknologi Pascapanen Pertanian Vol. 3 2007.

BREADFRUIT (*Artocarpus communis* Forst) SEEDLING GROWTH RESPONSE TO SOME KIND OF WATERING TO SOIL DERIVED FROM THE CATCHMENT AREA OF LAKE TOBA

Budi Utomo^a, Afiffuddin Dalimunthe^a, Irma Y Sembiring^b

^a Lecturer of Forestry major, Agriculture Faculty, University of North Sumatera

^b Student of Forestry major, Agriculture Faculty, University of North Sumatera
email: affuddindalimunthe@yahoo.co.id

ABSTRACT

Physiologically, water is an important factor in supporting the growth of breadfruit plants. Lack of water will cause a decrease in the growth of seedlings of breadfruit. Lake Toba catchment area (CA) is very important to support water balance in the region, but the land tend to be less fertile because of its sandy soil texture, slope is steep and prone to erosion. For that a study had been conducted in the greenhouse of the Faculty of Agriculture USU on April to July 2014 using non-factorial completely randomized design with 9 treatments (Watering 2 times a day, 1 time a day, 1 time for 2 days, 1 time for 3 days, 1 times for 4 day, 1 time for 5 days, 1 time for 6 days, 1 time for 7 days and 1 time for 10 days) each consisting of 5 replicates. The parameters measured were height of plant, the increase in diameter and total leaf area. The results showed that the interval watering significant effect on all parameters. Breadfruit seeds were planted in soil that were derived from the Lake Toba CA produces the best growth on watering every day for up to four days. However, breadfruit seeds still capable to grew normally until the plants were not received water supply for up to 6 days for 12 weeks of observation.

Keywords: Lake Toba-CA, breadfruit, water, watering intervals

INTRODUCTION

Land in Lake Toba-CA is known as one of the critical area because it looks bare almost no trees growing in the hilly bertopografi. One of the CA region is the region in Sub district Silahisabungan which is one of the 15 districts in Dairi District located on the shoreline of Lake Toba. Several villages are located along the edge of Lake Toba in the district are: Village Silalahi I, Silalahi II, III Silalahi, Paropo, and the Paropo I. This is a residential area once agricultural area with plain overlooking the lake with a height of 600 ± meters. Most of its area consists of undulating mountains and only a small portion is flat. The type of soil in this sub district is dominated litosol type with a depth of solum only 15-20 centimeters off. The others characteristic are sandy loam soil texture, water absorption is very low, rolling hills with slopes over 60%, and shrub vegetation and secondary forest in some region. Such soil conditions resulted in less viable for agricultural cultivation despite abundant water resources in this area. In other words Silahisabungan soil layer is very shallow over host rock. The main result of this region is agriculture onions and rice are managed on a flat and sloping areas planted between rocks (Sidabutar, 2012).

In relation to afforestation, the region has several times been targeted reforestation program, which is implemented by both the government and private agencies spend billions of rupiahs. Nevertheless planting success rate seems to be still far from expectations.

Among the many types of plants that once planted in the Lake Toba-CA as crop planting, the plants have not been involved breadfruit (*Artocarpus communis* Forst). We selected the plants as regreening plants because it is own both ecology and economy values. This plant has many roots and is believed to be very effective to binding fragile soils in the sloping land. These plants are able to live up to 80 years and produce fruit that is expected to improve local economies. Research of Utomo (2013) stated in coastal areas of Nine Island, District of Langkat, fishermen who have 3-5 breadfruit trees 10-15 years old can pay for school needs for their children who were in elementary school up to high school.

However the climatic conditions in the region of Lake Toba DTA slightly different from the coastal areas of Langkat. Lake Toba-CA is a mountainous region with cooler temperatures, but has a low rainfall (<2000 mm yr⁻¹). Therefore, research on breadfruit plant resistance to drought stress needs to be further investigated. The study aims to measure the resistance to water stress breadfruit seeds through water watering interval difference.

MATERIALS AND METHODS

This research was conducted at the Faculty of Agricultural Greenhouses at University Sumatra Utara. The study lasted from March to June 2014. The materials used in this study is the breadfruit seeds, top soil media of Lake Toba-CA in the Village of Silalahi, Sub District Silahisabungan and Dairi District of North Sumatra Province, We used polybag size of 10 kg. For observation needs we used equipment such as calipers, hype, cutter knives, ovens, scales, scanners, software of image-J, cameras, etc.

This study used a completely randomized design consisting of non-factorial 9 treatments with 5 replications, namely: P₀: Watering 2 times a day; P₁: Watering 1 time a day; P₂: Watering 1 time in 2 days; P₃: Watering 1 time in 3 days; P₄: Watering 1 time in 4 days; P₅: Watering 1 time in 5 days; P₆: Watering 1 time in 6 days; P₇: Watering 1 time in 7 days; P₈: Watering 1 time in 10 days. Data were analyzed using non-factorial completely randomized design. The significance of the data was tested using DMRT (Duncan's Multiple Range Test).

Implementation of Research

The soil being used were top soil came from Lake Toba-CA which was from Silalahi Village, Sub District Silahisabungan, District of Dairi, North Sumatra Province. Soils taken by the zigzag of the few places that represent the catchment area of Lake Toba. Once collected, soil taken to the greenhouse to air dried and sieved using a 10 mesh sieve. Furthermore, soil mixed thoroughly to assume the condition of the soil is homogeneous. Breadfruit seeds that will be used is derived from the location of the nursery in the village Nogorejo, Sub District of Tg Morawa, located approximately 1 hour from capital of North Sumatra Province. Breadfruit seedlings were ± 5 months old. After 2 weeks acclimatization under the shade area, seedlings stored in green house in accordance with treatments. Watering is done in accordance with the watering interval that has been designed by the researchers. Observations began 1 week after being transferred to greenhouse. Parameters observed were plant height, stem diameter and total leaf area.

RESULTS AND DISCUSSION

1. Height of plants

One of the parameters used in observing the growth of breadfruit seedlings is increasing plant height. The results showed that from week 1 to week 12 breadfruit seeds having increasing plant height at each treatment. Results of analysis of variance showed that treatment of different watering intervals generated significant effect on plant height (Table 1).

Table 1. The increasing of breadfruit seedlings height for 12 weeks old in green house

Treatments of Watering Interval	Plant Height	
Watering 2 times a day (P ₀)	13,24	a
Watering 1 time a day (P ₁)	17,40	c
Watering 1 time in 2 days (P ₂)	21,28	d
Watering 1 time in 3 days (P ₃)	22,28	d
Watering 1 time in 4 days (P ₄)	23,44	d
Watering 1 time in 5 (P ₅)	17,48	c
Watering 1 time in 6 (P ₆)	17,38	c
Watering 1 time in 7 days (P ₇)	17,54	c
Watering 1 time in 10 days (P ₈)	15,10	b

Remarks: The value followed by the same letter in the same column are not significantly different according to DMRT at 5% level.

Based on the above table gives the average P4 was found that the highest compared with the other treatments, although after further tested by DMRT at 5% level test showed that treatment of P₂, P₃ and P₄ had no significant effect because it was followed by the same letter notation.

2. Stem diameter of breadfruit

The second parameter observed was increase in the diameter of breadfruit seedlings. Diameter measured breadfruit seedlings started week 1 to week 12. Breadfruit seedlings experiencing the increase in diameter each week as indicated by the increase in the average increase in diameter. Watering intervals significantly affected diameter growth of seedlings of breadfruit.

Table 2. The increasing of breadfruit stem diameters for 12 weeks old in green house

Treatments of Watering Interval	Stem Diameter	
Watering 2 times a day (P ₀)	0,299	a
Watering 1 time a day (P ₁)	0,318	a
Watering 1 time in 2 days (P ₂)	0,360	a
Watering 1 time in 3 days (P ₃)	0,395	a
Watering 1 time in 4 days (P ₄)	0,540	b
Watering 1 time in 5 (P ₅)	0,355	a
Watering 1 time in 6 (P ₆)	0,342	a
Watering 1 time in 7 days (P ₇)	0,274	a
Watering 1 time in 10 days (P ₈)	0,273	a

Remarks: The value followed by the same letter in the same column are not significantly different according to DMRT at 5% level.

Table 2 above showed that P₄ treatment resulted in the highest mean diameter compared with other treatments.

3. Total leaf area of breadfruit seedlings

Calculation of leaf area using image j software. From the data it appears that P₃ has the largest leaf area compared with other treatments. And most small leaf area owned by treatment P₀ and P₈. From the results of analysis of variance showed that watering intervals significantly affect the total leaf area. The average of the total leaf area of seedlings of breadfruit at week 12 are presented in Table 3 the highest leaf area was found in the P₃ treatment. However this treatment was not significantly different by treatment with P₂, P₄, P₅ and P₆.

Table 3. Total leaf area of breadfruit for 12 weeks old in green house

Treatments of Watering Interval	Total leaf area	
Watering 2 times a day (P ₀)	1,136.57	a
Watering 1 time a day (P ₁)	1,289.52	a
Watering 1 time in 2 days (P ₂)	1,541.02	c
Watering 1 time in 3 days (P ₃)	1,878.95	c
Watering 1 time in 4 days (P ₄)	1,793.13	c
Watering 1 time in 5 (P ₅)	1,747.86	c
Watering 1 time in 6 (P ₆)	1,491.70	c
Watering 1 time in 7 days (P ₇)	1,412.38	b
Watering 1 time in 10 days (P ₈)	1,148.75	a

Remarks: The value followed by the same letter in the same column are not significantly different according to DMRT at 5% level.

Discussion

The results showed that the different watering intervals significant effect on height increment, diameter, and leaf area. From the results of the study can also be seen that the longer the interval watering then growth tends to become smaller. Conditions were not favorable for the plant will slow the growth of plants. According Fitter and Hay (1991), water is a compound that plants need in large amounts. More than 80% of wet weight of the cells and tissues of plants consisting of water. The water content of the cells contained in the media for

many biochemical reactions. Therefore, the metabolic activity of the cells will be disturbed if crop plants suffer from drought. Plants that suffer from water stress (drought) generally have a smaller size compared with plants that grow normally. Water stress affects all aspects of plant growth, such as the physiology and biochemistry of plants and lead to the modification of plant anatomy and morphology.

The soil used was a regional land from catchment area of Lake Toba, precisely from Silalahi village tend has sandy texture. The sandy soil has macropores which low water holding capacity. Land area is classified as a type of soil that is formed litosol due to volcanic eruptions. Anneahira (2013) states litosol soil formed from igneous rocks of the volcanic eruptions and sediment harsh chemical weathering processes (with the help of organismke life) and physics (with the help of sunlight and rain) is not perfect for the parent structure of the original rock was still visible. Therefore also, land litosol often also referred to as the land of the youngest. Land of this type can be found on the slopes of mountains or hills that suffered severe erosion process. Large cross section and shaped gravel, sand or small rocks, because very little change from the structure or rock profile.

The results showed that nearly all the parameters was observed that treatment of watering 1 time 4 days belong to the highest growth indicated by the highest grades in plant height, stem diameter and leaf area. But looking at the above results it can be said the plant was still able to grow well until the conditions are not getting water supply for 6 days (treatment P₆). This is shown by the same notation in the parameters of plant height and leaf area. This means breadfruit resilience in field conditions in Lake Toba-CA that has a sandy texture and unstable, was still able to grow normally if it does not receive water supply for up to 6 days, either from rain or from watering down in this region. But the water supply is much longer will reduce growth (wilt). In the water supply in the soil because it caused a little bit of plant absorb water, so it is not able to meet their needs. If groundwater supplies become less then the plant will experience kelayuan. Kramer (1980) states that water is a major factor of plant defense. Another function of the water is important for maintaining turgiditas cell enlargement and growth, as well as forming herbaceous plants. Turgor important in opening and closing of stomata, leaf movement and movement korola flowers and plants, especially in structural variation. Water shortages in large numbers led to a lack of turgor pressure to support vegetative growth.

Fitter and Hay (1991) stated the importance of water as a solvent in the organism was evident, for example, the process of osmosis. In the leaves, the cell volume and the cell wall is limited by relatively little stream of water that can be accommodated by the elasticity of the cell wall. Consequences of hydrostatic pressure (turgor pressure) developed in the cytoplasmic vacuoles pressed against the surface of the cell wall and vacuole increases water potential. With the increase in turgor pressure, the adjacent cells press against each other, with the result that the first leaf will be in a state of increased fresh (turgid). In a balanced state, turgor pressure into or have a maximum value and the water here tends not to flow from the apoplast to the vacuole. This is evidenced by the wilted seedlings will come back refreshed after watering because the plant has not yet reached the permanent wilting point where if it reaches the permanent wilting point of plants that wilt not be refreshed and will experience death because of drought. Under the permanent wilting point of plants no longer able to absorb water because water adhesion to the soil grains are too powerful compared to absorption plants. Drought stress in plants caused by a shortage of water supply in the root zone and excessive demand for water by the leaves in a state of evapotranspiration rate exceeds the rate of water absorption by plant roots. Water uptake by plant roots is affected by the rate of transpiration, root system and soil water availability (Lakitan, 1996).

Sinaga (2008) states that the response of plants to water stress is determined by the level of stress experienced and plant growth phase when experiencing stress. When the plants exposed to dry conditions, there are two kinds of responses that can improve water status, namely (1) to change the distribution of assimilates new plant to support root growth at the expense of the canopy, thus increasing the capacity of the roots to absorb water and inhibit the expansion and to reduce transpiration; (2) the plant will adjust the degree of opening of stomata to prevent water loss through transpiration. In this study evidenced by the occurrence of autumn leaves on watering treatment 1 times for 7 days and 1 times for 8 days.

CONCLUSION AND SUGGESTIONS

Conclusion

The highest growth was obtained on treatment plant watering intervals once every 4 days (P₄). But the plant still showed normal growth on treatment for up to 6 days without watering. at intervals longer watering the plant growth to decline or even die.

Suggestions

In the future after the greenhouse research will be tried to plant in field and get recommendations of watering if rainfall does not occur in a long time, especially in catchment area of Lake Toba.

REFERENCES

- Anneahira. 2013. Tanah litosol benarkah tidak subur? <http://www.anneahira.com/tanah-litosol.htm> [tanggal akses 29 Maret 2014]
- Fitter , A. H dan Hay, R. K. M.. 1991. Fisiologi Lingkungan Tanaman. Diterjemahkan oleh Sri Andani dan E. D. Purbayanti. Gajah Mada University Press. Yogyakarta
- Kramer, P.J. 1980. Plant and soil water relationship a modern synthesis. Tata Mc Graw-Hill Publ. Co. Ltd., New York. 449 p.
- Lakitan, B. 1996. Fisiologi Pertumbuhan dan Perkembangan Tanaman. Rajawali Pers. Jakarta
- Sidabutar, Rina Mayawi. 2012. Studi Tentang Aktivitas Budidaya Ikan Keramba Di Desa Silalahi Kecamatan Silahisabungan Kabupaten Dairi. <http://digilib.unimed.ac.id/> [tanggal akses 10 Januari 2014]
- Sinaga, S. 2008. Asam Absisik Sebuah Mekanisme Adaptasi Tanaman Terhadap Cekaman Kekeringan. <http://research.mercubuana.ac.id> [tanggal akses 7 Januari 2014]
- Utomo, B. 2013. Manfaat Sukun dalam meningkatkan perekonomian masyarakat Desa Pulau Sembilan Kabupaten Langkat. *Vegetasi Jurnal* 3(2):78-83.

SPATIAL ANALYSIS FOR LAND CAPABILITY ASSESSMENT IN THE UPSTREAM OF WAMPU WATERSHED USING GEOGRAPHIC INFORMATION SYSTEM

Rahmawaty^a, Sari Adryana^a, Ahmad Sofyan^b, Abdul Rauf^c

^aForestry Study Program, Faculty of Agriculture, Sumatera Utara University,

^bBP DAS Wampu Sei Ular, Ministry of Forestry

^cAgroecotechnology Study Program, Faculty of Agriculture, Sumatera Utara University,
Medan, North Sumatra, Indonesia

Address: Jl. Tri Dharma Ujung No. 1 Kampus USU, Medan, 20155, North Sumatra, INDONESIA

email: rahmawaty@usu.ac.id

ABSTRACT

Land utilization in Wampu Hulu Sub Watershed should be based on its land capability. This research was conducted in March-September 2011 at Wampu Watershed, Langkat, North Sumatra, Indonesia. Land capability classification was conducted by spatial analysis for capability of land criteria using Geographic Information System (GIS) (overlay technique). The land criteria are slope, soil erodibility, level of erosion hazard, soil depth, soil texture, permeability and drainage. Soil analyze was done in order to obtain the data of soil texture, permeability, soil erodibility, while slope, soil depth, level of erosion hazard and drainage was obtain from land system map. The result showed that the land capability classification at Wampu Hulu Sub Watershed, divided by three classes, namely: Class III, V, and VI.

Keywords: Geographic Information System, Land Capability, Overlay, Wampu Watershed

INTRODUCTION

Land capability is defined as the inherent capacity of land to perform under a given use; thus, land capability classification (LCC) is the description of a landscape unit in terms of its inherent capacity to sustain a desirable combination of flora and fauna. It is the first approximation in the process of subdividing a land use planning unit into land use response units (Villanueva, 2005). The important factors in analyzing land capabilities are slope, elevation, climate, topographic, landform, vegetation, geology, soils and fauna (Oszaer, 1994).

The important event that has occurred in Wampu Watershed was a flash flood event on November 2, 2003. The flood that occurred in the upstream of Wampu Watershed was resulting land cover change on the physical conditions. After eight years of flooding, of course, there has been a lot of changes in land use. Incompatible land use will also worsen the condition of the Wampu Watershed which is a watershed in the category needs to be restored supportability. Therefore, it is necessary to do research on the capability of the land in Wampu Watershed using spatial analysis (overlay technique) that can be done with software of Geographic Information Systems (GIS).

Research on the classification of land capability especially after flash floods in Wampu watershed area using GIS has not been done before. Therefore, the data and information regarding the capability of the land needs to be studied further. This study aimed to map the land capability class in the upstream of Wampu Watershed.

METHODS

This research was conducted in March until September 2011, in the upstream of Wampu Watershed (Figure 1).

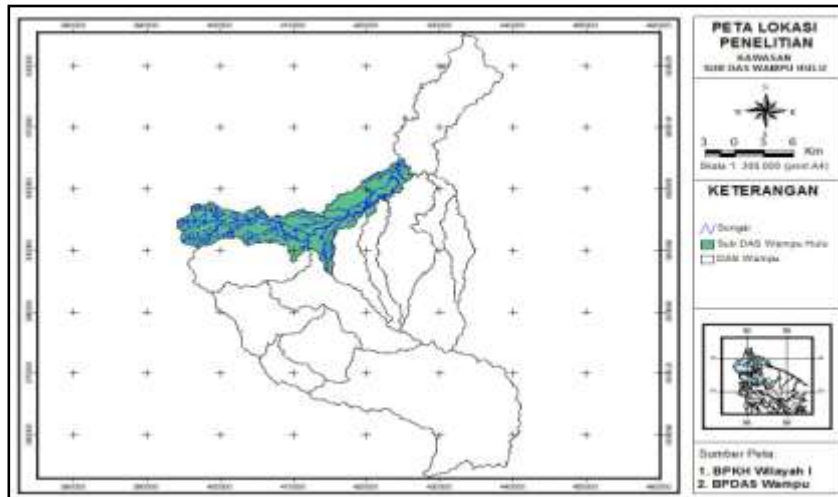


Figure 1. Map of study sites

Land capability classification (LCC) was evaluated based on FAO guidelines (FAO, 1976). Land capability classification was done is based on criteria in Arsyad (2006). According to Morgan (1986) cited by Oszaer (1994), the objective of the classification is to regionalize an area of land into units with similar kinds and degrees of limitations. The basic unit is the capability unit. This consists of a group of soil types of sufficiently similar conditions in terms of profile form, slope and degree of erosion as to make them suitable for similar crops and warrant the use of similar conservation measures. Furthermore, the capability units are combined into sub-classes according to the nature of the limiting factor and these, in turn, are grouped into classes based on the degree of limitation. The criteria and description of Land Capability Classes were based on FAO, 1976 and Arsyad, 2006. The GIS spatial analysis was used to overlay to all thematic maps.

RESULTS AND DISCUSSION

Based on Langkat Administration Map in 2010, the upstream of Wampu Wateeshed is located in 5 districts, namely: Bahorok Sub-District, Kutam Sub-District, Sirapi Sub-District, Wampu Sub-District, and Selesai Sub-District (Figure 2). The upstream of Wampu Watershed bordered with Batang Serangan Sub-District in Northern, Salapi Sub-District and Kuala Sub-District in Southern, Binjai Sub-District and Stabat Sub-District of the Eastern, and Aceh Tenggara District, Aceh Province in the west. There are 12 land systems in the upstream of Wampu Watershed, namely : Bakunan (BKN), Pakasi (PKS), Batuapung (BTG), Pandreh (PDH), Bukit Pandan (BPD), Lubuk Sikaping (LBS), Gunung Gadang (GGD), Maput (MPT), Taweh (TWH), Kalung (KLG), Kahayan (KHY), dan Bukit tinggi (BGT) (Figure 3). Based on the results, there are three land capability class in the upstream of Wampu Watershed, namely : land capability class III, V, and VI (Figure 4).

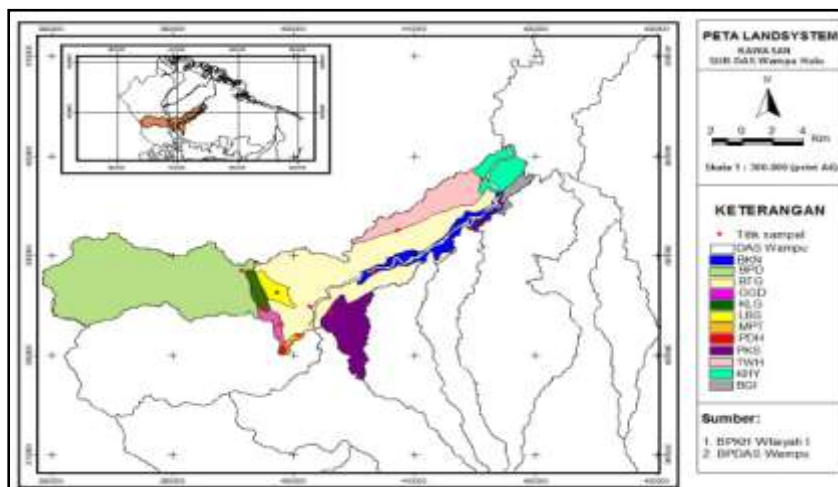


Figure 2. The location of the study on the Langkat administration

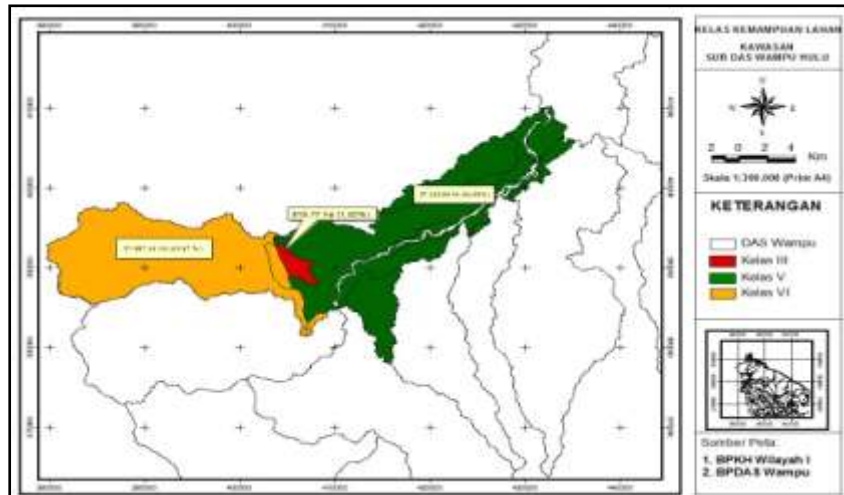


Figure 3. Map of the land system in the upstream of Wampu Watershed

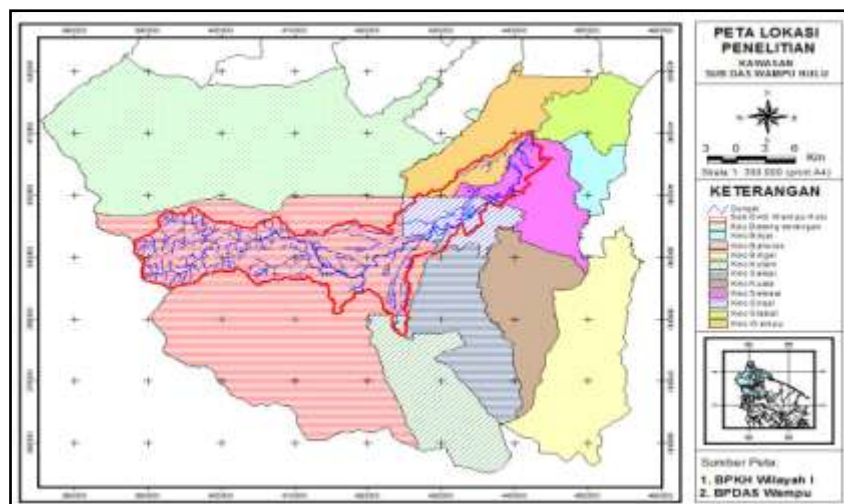


Figure 4. Map of land capability in the upstream of Wampu Watershed

The land with class III has a flat slope level, the land cover class III are in the wetland and dry farming with area 919.77 ha, land capability classification results were agree with the statement of Wirosuprojo (2005) which states that based on the landform and direction of land use, it can be explained that the area has a flat and gentle slopes with fertile soil and sufficient water available continuously an agricultural area of wetlands that can be established as a center for food crops. wetland and dry farming classified into class III was also agree with the statement of Arsyad (2006) which states that the land belonging to class III is a land that has a formidable barriers that reduce the choice of the use or require special conservation measures and both. The land with Class III can be used for crops and plants that require tillage, grass crops, pasture, forest production, forest and wildlife reserves. It is also supported by Fletcher and Gibb (1990) which states that the land capability class I-IV can be used for fields and intercropping.

The land with class V was covered by the dry agricultural land, fields, settlements, and the plantation. The area was about 27 442.93 ha. According to Fletcher and Gibb (1990) this was due to land fifth grade can only be used for intercropping with soil conservation measures, the statement also was supported by Arsyad (2006). In class V can only be used for grass, grazing meadow, forest production or protection forest and nature reserves. According to Arsyad (2006) soils in class V is not threatened land erosion but have other obstacles that are not to be removed, limiting its use choice, because the land is suitable for grass crops, pasture, and forest production or protection forest and nature reserves. Soils in class V have barriers that restrict the use of a wide selection of plants and inhibit tillage for crops. These soils located on flat or nearly

flat topography but stagnant water, frequently flooded or rocky or less appropriate climate or have a combination of these obstacles.

The land with class VI has a steep slope. The land was covered by the primary forest, secondary forest and shrub with area about 21.987.44 ha. This is agree with the statement of Wirosuprojo (2005) which states that the steep slope areas should be used for limited production forests, protected forests and nature reserves. Land cover belonging to the class VI is also consistent with the statement Arsyad (2006) which states that soils in class VI, the land is not suitable for agricultural use; its use was limited to grazing, production forests, protected forests, and nature reserves. Class VI soils located on moderate steep slope, if used for grazing and production forests should be managed properly to avoid erosion. Some soils in class VI and roots in the area but is located on moderate steep slope can be used for crops with severe conservation measures. It is also supported by Rahmawaty (2011) which conducted research in Besitang Watershed.

CONCLUSIONS

Land capability classification in the upstream of Wampu Watershed consists of three classes, namely: Class III, Class V and Class VI. Land capability classifications according to land cover were in Class III and Class VI in the upstream of Wampu Watershed. In class V, the suitable land covers were only on dry land agriculture and plantations.

REFERENCES

- Arsyad, S. 2006. Soil and Water Conservation (*Konservasi Tanah dan Air*). Penerbit IPB (IPB press), Bogor. 396p. [Bahasa Indonesia].
- Fletcher, J.R. and R.G. Gibb. 1991. *Land Resource Inventory Handbook for Soil Conservation Planning in Indonesia*. NZ DSIR Scientific Report No. 11. NZ DSIR Land Resources and Dir Gen RLR of Indonesia. 87 pp.
- Food and Agriculture Organization (FAO). 1976. A Framework for Land Evaluation. FAO Soils bulletin 32, Rome, Italy. <http://www.fao.org/docrep/X5310E/x5310e00.htm#Contents>
- Oszaer, R. 1994. Land Use Optimization in Waeriuapa Watershed, Kairatu, Seram, Maluku, Indonesia Using Geographical Information System and Linear Programming. Ph.D. Dissertation. University of the Philippines Los Banos.
- Rahmawaty, T.R. Villaneuva, M.G. Carandang. 2011. Participatory Land use Allocation, Case Study In Besitang watershed, Langkat, North Sumatera, Indonesia. Lambert Academic Publishing. German.
- Villanueva, T.R. 2005. Upland Ecosystem Management. Second Edition. University of the Philippines Open University, Los Banos, Laguna. 200pp.
- Wirosuprojo, S. 2005. Land Classification for land use planning in Sleman district Yogyakarta (*Klasifikasi lahan untuk perencanaan Penggunaan lahan di kabupaten sleman Daerah istimewa Yogyakarta*). Fakultas Geografi UGM. Yogyakarta. [Bahasa Indonesia].

LAND USE CHANGE AND IMPACT OF FOREST DISTURBANCES ON HUMAN WILDLIFE CONFLICT IN SUMATERA

Pindi Patana¹, Ma'rifatin Zahra²

¹) Forestry Department of Agriculture Faculty of The University of Sumatera Utara,
Email: pindipatana@gmail.com

²) Sekolah Tinggi Ilmu Kehutanan Pante Kulu Banda Aceh,
Email : titienmirza@yahoo.com

ABSTRACT

Development activities in Sumatera currently have derived changes on land use and forest disturbances as an impact of opening forest area without attentioning an ecological balance. One of the most attractive issues especially for environmentalists is human wildlife conflict which has threatened the existence of some umbrella species such as Sumatran elephant (*Elephas maximus sumatranus*), Sumatran tiger (*Panthera tigris sumatrae*) and Sumatran orangutan (*Pongo abelii*). This conflict doesn't only harm for human, but also sustainability of wildlife species. Further these species are categorized as critically endangered according to International Union for Conservation of Nature and Natural Resources (IUCN). One of the main factors causes wildlife threat is highly rate of deforestation and land degradation that affects decreasing of the carrying capacity of habitat. Forest disturbances by human activities such as illegal logging and encroachment of forest area could give direct impact to the changes of wildlife movements as the tendency of narrowing their home range and raising human wildlife conflicts frequently. It was usually occurred while they fulfilled their basic need such as foraging. In addition, less knowledge about wildlife behavior affected miss point of view of some land owners, i.e while wildlife entering community's fields, plantation even forest plantation that was assumed as intruder animal or pest. Another factor could make the conflict between human and wildlife become more seriously problem is disintegration of human wildlife conflict mitigation both policy aspect and operationally in the field. This paper aims to describe land use changes and impact of forest disturbances on human wildlife conflict in several wildlife habitat hotspots in Sumatera such as Aceh, North Sumatera, Riau and Bengkulu.

Keywords: Land use, disturbance, habitat, wildlife, conflict

INTRODUCTION

Sumatran forest is one of well known tropical rain forest with high biodiversity level, but recently it is being threatened by human activities. This forest occasionally is habitat for wildlife and forest loss or degradation become a main factor of wildlife habitat fragmentation. One of forest fragmentation impact is conflict of human and wildlife. This conflict is in a critical stage with much loss of material and non material either for human or wildlife. Some wildlife such as Sumatran elephant, Sumatran tiger, Sumatran rhino and orangutan are key species, but unfortunately it's categorized now in red list of IUCN (*International Union for Conservation of Nature and Natural Resources*).

Development activities in Sumatera which nearly neglected forest resources sustainability, is assumed as one of triggered factor of disharmony between human and environment. Human wildlife conflict is a strong evidence that habitat loss or degradation affected to carrying capacity of habitat. Big mammals such as elephant is the example of species which some of behavior changed due to this disturbance. Generally, home range of this species was narrower and conflict would be frequently occurred (Azmi, W. *et al.* 2008). Sumatran tiger and orangutan are in the same condition and this conflict will be ended commonly by the death of these species.

Most wild elephants are present in blocks of forest outside of conservation/protected areas, invariably creating a high potential for human-elephant conflict. This issues reflects the failure of the current land-use planning system to take into account elephant habitat requirements and the long-term benefits of forest

conservation. Ramono (2000) in Patana, P. et al (2010) stated that the conversion of primary forest into agricultural holdings has been one of the main causes of conservation problems in Sumatra and the elephant has been among the large mammals most seriously affected by it. Development program has led to the annual elimination of tens of thousands of hectares of wildlife habitat.

The government has declared the ministry decree No P.48/2008 about mitigation of human wildlife conflict to response this problem. Although it will be useless if there is no such a big effort to save forest as the main wildlife habitat. This paper aims to describe a forestland use change and impact of forest disturbances on human wildlife conflict around their habitat in Sumatera.

METHODS

The area of research is focused in Sumatera Island. Data is collected from primary and secondary data. Primary data is from the field, while secondary data is from any related sources such as government, non government and other publications. Data analysis is conducted by using qualitative and quantitative description.

RESULTS AND DISCUSSION

Land Use Change in Sumatera

In the last two decades, forestland use changes were occurred massively. Data of forest cover in Sumatera shows us clearly that the forest extent changes on forest area due to forest loss and forest degradation were supported by human activities. Many researches described a critical situation of decreasing forest coverage extent in Sumatera by using landsat imagery since the 80s, particularly in primary forest, either primary intact forest or primary degraded forest.

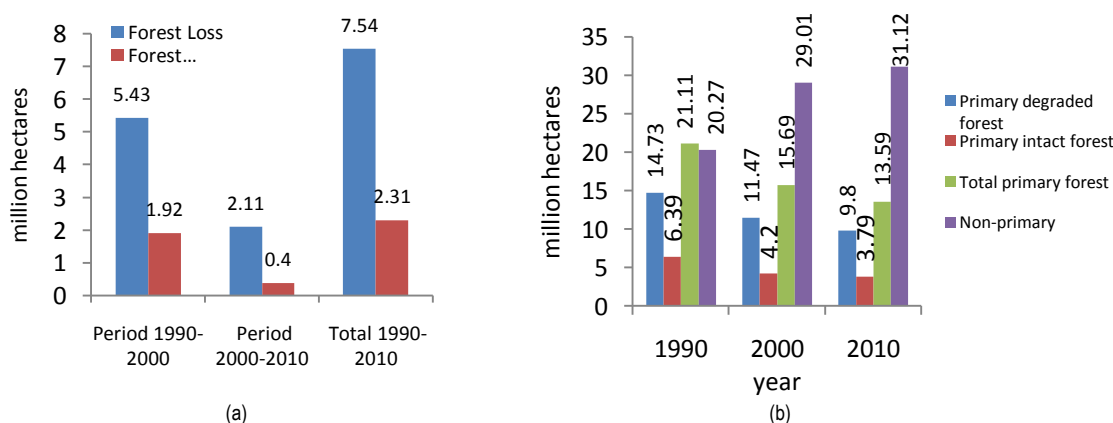


Figure 1. (a). Forest loss and degradation in Sumatera, (b). Primary forest and non-primary forest in Sumatera (Source: Graph modification from Margono, B et al 2012)

According to Margono, B *et al.* 2012, remaining total primary forest cover in 2010 was 30.4% of the total land area. Primary forest cover loss in Sumatera from 1990 to 2010 totaled 7.54 Mha. An additional 2.31 Mha of primary forest was degraded by 2010 (Figure 1). In total, nearly half (47%) of 1990 Sumatran primary forest was either cleared or degraded during the study period. Primary forest cover loss in the 1990s was far greater than in the 2000s. For the entire study period, the rate of forest loss was 0.38 Mha/yr, and the rate of forest degradation was 0.12 Mha/yr.

If we look the land use change in Sumatera, it's almost influenced by forest disturbances. According to Margono, B *et al.* (2012), each province in Sumatera has its own history of forest cover change. For example, forest fires played major role in forest clearing in South Sumatera (Tacconi, 2003 in Margono, B *et al.* 2012), while rubber plantations and 'jungle rubber' collection were the primary sources of forest degradation in Jambi (Tomich and Van Noorwijk 1995, Ketterings et al 1999 in Margono, B *et al.* 2012).

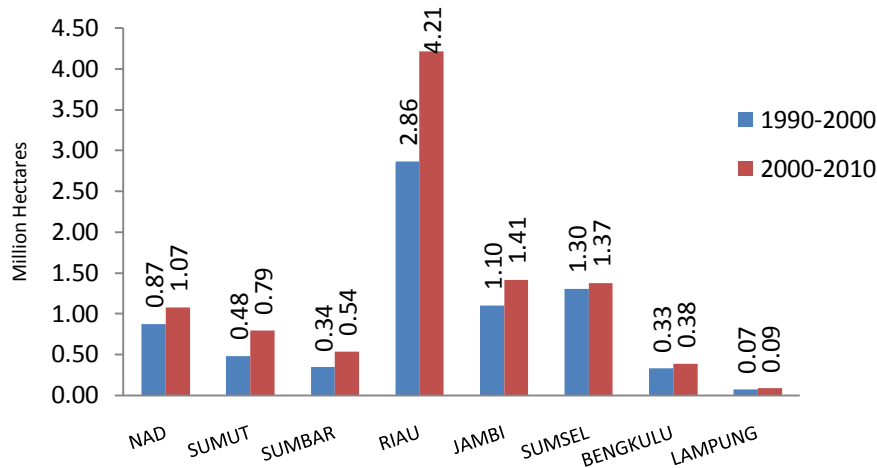


Figure 2. Forest loss and forest degradation of each province in Sumatera for two decades

(Source: Graph modification from Margono, B et al 2012)

NAD: Nangroe Aceh Darussalam, SUMUT: Sumatra Utara (North Sumatra), SUMBAR: Sumatra Barat (West Sumatra), SUMSEL: Sumatra Selatan (South Sumatra)

In the last two decades nearly the whole province in Sumatera experienced forest cover loss. It is summarized in Figure 2. Riau had a significant forest cover loss within primary intact forests. Margono, B et al. (2012) noted primary intact forest loss in Riau accounted for nearly 68% of all primary intact forest loss in Sumatera. Riau contributed 46% of total Sumatran forest degradation, followed by Nangroe Aceh Darussalam/Aceh (23%) and Jambi provinces (12%). For all provinces, there was a dramatic decline in primary intact forest loss between the 1990s and 2000s, reflecting the near exhaustion of intact lowland forests. Clearing of degraded forests also declined for all provinces, with Riau coming closest to a sustained inter-decadal rate; for Riau, primary degraded forest loss in the 2000s was 85% that of the 1990s. Remaining primary intact forest in 2010 was located largely in Aceh (40%), West Sumatra (15%), and Bengkulu (12%) provinces, which are all located along the Sumatra uplands. The primary forest cover for each province is showed in Figure 3.

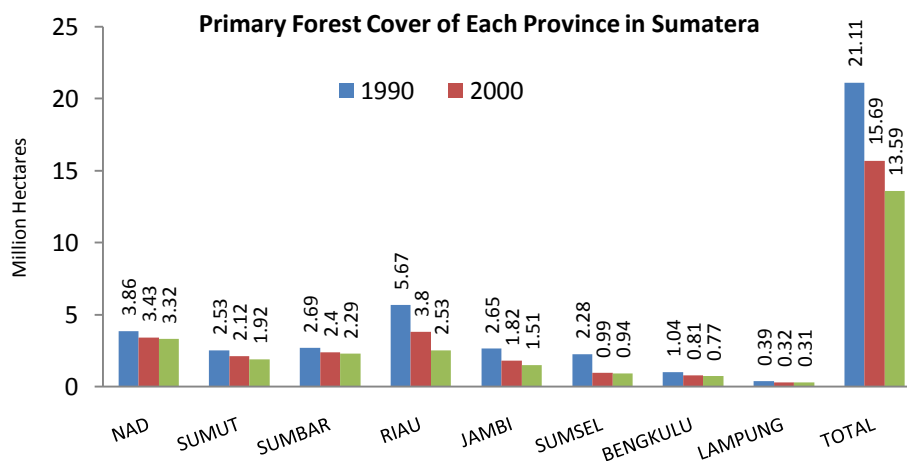


Figure 3. Primary forest cover of each province in Sumatera for two decades

(Source: Graph modification from Margono, B et al 2012)

NAD: Nangroe Aceh Darussalam, SUMUT: Sumatra Utara (North Sumatra), SUMBAR: Sumatra Barat (West Sumatra), SUMSEL: Sumatra Selatan (South Sumatra)

There is an explanation about a contrast phenomenon between Riau and Aceh forest cover that in 1990, Aceh's primary forest extent was second to Riau's but in 2010, the primary forest of Aceh was the greatest (24% of the island total). According to Tomich et al 2001 in Margono, B *et al.* (2012), Sumatra has always been a key area for oil palm production in the country, with Riau as the leading province. The very high rates of Riau primary forest loss over the study period were likely due to the intensive establishment of oil palm and forest timber and pulp plantations (Holmes 2000a, 2000b, Nawir *et al* 2007, Uryu *et al* 2008 in Margono, B *et al.* 2012). By the late 1990s, most of the Riau lowland forests had been converted, leaving mainly peat swamps as the remaining natural intact forest cover, which in the 2000s have been the location of forest clearing and conversion. These forests, in particular primary intact forest, have been preserved by the less accessible upland landforms and their conservation and protection land use status (Margono, B *et al.* 2012).

Regarding to Forestry Law No.41/1999, the forest land use zone is usually divided into several forest functions, those are regular production (HP), protection forests (HL) and conservation forests (HK). The other types of forest production are convertible production forest (HPK) and limited production forest (HPT). The primary forest change over the two decades for each forest land use zone in Sumatra is described in figure 4. Within the forest land uses, Margono *et al.* 2012, inferred that the highest rates of forest loss were in primary degraded forests of the regular production forest (HP), convertible production forest (HPK) and limited production forest (HPT) land uses. These land uses accounted for 32.5%, 17.1% and 15.8% of the total loss, respectively. For primary intact forest, about 50% of the loss occurred within the regular production forest land use (HP). Within the forest land uses, production forests as a whole (HP, HPT and HPK) accounted for 65.8% of the total forest cover loss, comparable to 5% of protection forests (HL), and 4% of conservation forests (HK).

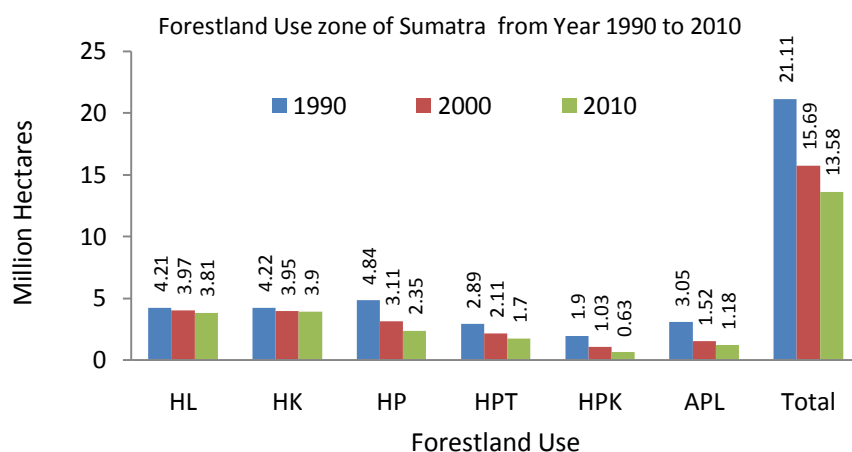


Figure 4. Forestland use zone of Sumatera for two decades
(Source: Graph modification from Margono, B *et al* 2012)

Forest Disturbances and Human Wildlife Conflict (HWC)

As a result of forest disturbances, habitat of wildlife can't support the basic needs of species or population to survive optimally. It means in ecological terminology the carrying capacity of habitat has decreased. Thus it will influence the quantity and quality of food provided by habitat, the space for mobility, cover for protection, reproduction process and other wildlife necessity. Forest disturbance can also make habitat fragmentation finally and overall forest disturbance will lead wildlife to look for other areas to survive itself. A crop riding is a good example to explain how big mammal such Sumatran elephant look for sufficient food and space for their life. In the other hand, human remarked it as activity of elephant outside of wildlife boundary. This conflict, as wellknown as human elephant conflict (HEC) will always arise when forest disturbances are still occurred. Illegal activities could be a trigger in many human wildlife conflict, such as showing in case of human elephant conflict around Elephant Conservation Center Seblat (Table1).

Table 1. Forest disturbances from 2006 to 2008 around Elephant Conservation Center Seblat , Bengkulu

No	Type of Disturbances	Frequency (times)		
		2006	2007	2008
1.	Forest fire	35	4	0
2.	Fish poisoning	8	1	0
3.	Illegal logging	11	23	2
4.	Forest encroachment	97	59	50
5.	Illegal hunting	4	2	1
6.	Illegal mining	4	0	0
7.	Illegal grazing	0	0	1
Total		159	89	54

(Source: FFI, 2009, in Patana, P., 2010)

Forest fire, illegal logging and forest encroachment were the main factor of HEC occurrence yearly. These factors contributed 89.9% (in 2006), 96.6% (in 2007) and 96.3% (in 2008) of HEC respectively. Although the number of HEC decreased but the threats to wildlife was still dangerously. In addition, there was a case of 5 elephants death in 2011 and suspected by poisoning at the oil palm estate. Since illegal activities such as forest fire, illegal logging, forest encroachment, illegal mining became part of forest disturbances surrounding wildlife habitat, HEC were occurred without being known until when it would be occurred (Figure 5). The conflicts usually were up and down following the elephant movement at the area. The elephant moved from one point to others just avoiding forest disturbances.

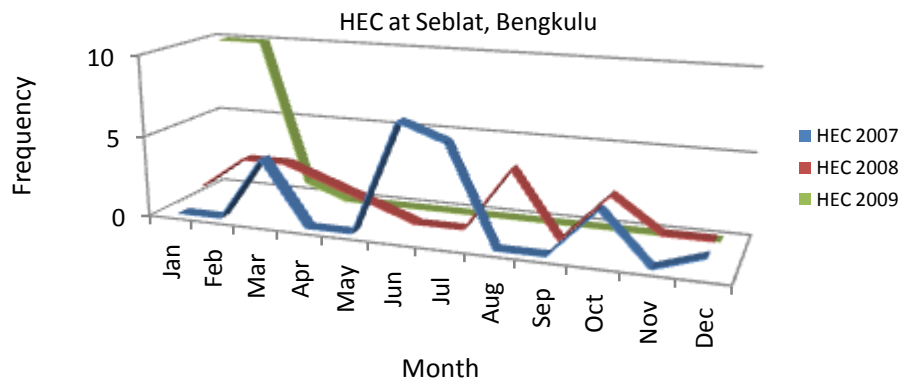


Figure 5. HEC in 2007,2008,2009 District of Mukomuko and North Bengkulu
(Source: FFI, 2009 modified by Patana,P et al. 2010)

Conflict can't be neglected as a consequence of forest disturbance. According to Santiapillai, C. and Ramono, W.S. 1993, the elephants, like other wildlife have lost so much of their former habitat that they are often forced to invade the communities that have displaced them. The Sumatran elephant (*Elephas maximus Sumatranus*) has an image problem. Almost all the reports that are published in the media refer to its proclivity to raiding crops and thereby causing economic ruin to the farmers trying to take out a precarious existence near areas inhabited by elephants. Elephant damage to oil palm and rubber plantations in South-east Asia can run into millions of dollars in economic loss to the county (Blair & Noor, 1981 in Santiapillai, C. and Ramono, W.S. 1993). Much of the crop depredations can be reduced if development planners and policy makers pause to understand why elephants raid crops. An illustration about crop raiding and forest disturbance is shown in Figure 6 which conflict was occurred surrounding Elephant Conservation Center Seblat, Bengkulu. It's shown that the elephant groups tried to move as far as possible from the disturbance sources. The area boundary was bordered with plantation estate and limited production forest. The case of HEC in this area currently is in the critical point since the elephants become the victim of HEC by poisoning.

a. Sumatran Elephant (*Elephas maximus Sumatranus*)

The number of wild elephants in Sumatera is estimated to be between 2,500 and 4,500 animals and distributed in 44 isolated population (Blouch & Haryanro, 1984; Blouch & Simbolon, 1985 in Forestry Ministry, 2007). Prior to about 1900, when agricultural settlements in Sumatera first led to a substantial degree of deforestation, most of the island was covered with primary forest. Presumably, up to that time, the elephant was more or less continuously distributed throughout. The conversion of primary forest into agricultural holdings, some of which have proved ephemeral and been abandoned, is a particularly serious cause of conservation problem in Sumatera, and the large mammals such as the elephant, rhinoceros and tiger are among the species most seriously affected by it (Santiapillai, C. and Ramono, W.S. 1993).

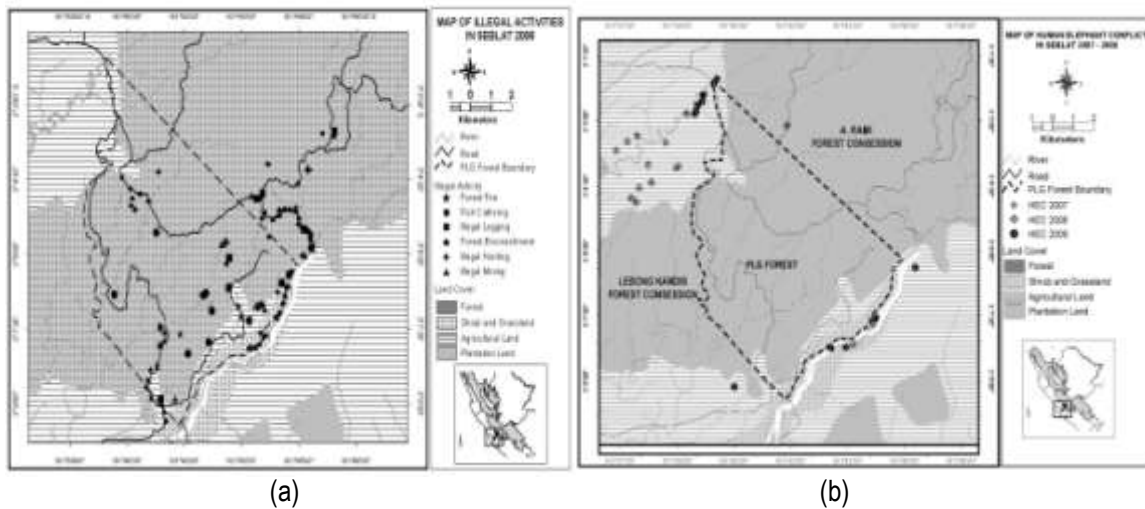


Figure 6. Forest disturbances within the elephant’s habitat (a), the distribution of HEC in Seblat (b)
(Source: FFI, 2009 in Patana, P., 2010)

Habitat loss is very potential to raise HEC frequency in the future. Further HEC was almost occurred yearly in the area of elephant habitat population and decreased the population number. Since 2011, Sumatran elephant was in the red list of IUCN as *critically endangered species*. Data of HEC in some provinces in Sumatera is summarized in Table 2.

Table 2. Data Compilation of Human Elephant Conflict in Sumatera

Year	Province	Landuse	Victim (Died)	
			Elephant	Human
2000-2008 ¹	Aceh	Plantation	11	
2011-2012 ²	Aceh	Settlement, Road	7	
2004-2012 ³	Riau	Plantation, Production forest	89	16
2012-2013 ⁴	Riau	Tesso Nilo National Park	19	1
2004-2011 ⁵	Bengkulu	Plantation, Elephant Conservation Center	17	

Source: Data Compilation from ^{1,2} FFI, WALHI, ^{3,4} WWF-Indonesia & BKSDA Riau (2013), ⁵ProFauna (2011)

Dealing with highly number of HEC in Riau (Table 2), according to the WWF report (2013), up until 2012 over 52,000 hectares of natural forest in Tesso Nilo Forest Complex (made up of a national park and two neighboring logging concessions) has already been converted to palm oil plantations, with over 15,000 ha of the converted area located inside the national park.

In the year 2000 *Wildlife Conservation Society* (WCS) was conducted a comprehensive research in Lampung Province and resulted 9 of 12 elephant isolated population in 1980 had lost (Hedges *et al.* 2005 in Forestry Ministry, 2007). A decreasing number of Sumatran elephant population is estimated 35% of 1992 which is very huge in a relative short time.

b. Sumatran Tiger (*Panthera tigris Sumatrae*)

Fewer than 500 wild Sumatran tigers are thought to persist in four main landscapes on the Indonesian island of Sumatra; the Leuser landscape in the north, the Kerinci-Seblat landscape in the center-west, the Bukit Tigah Puluhan landscape in the center-east, and the Bukit Barisan Selatan (BBS) landscape in the south. Since 1996 Sumatran tiger was classified as critically endangered species by IUCN (Cat Specialist Group 2002). There are three main direct threats to tigers in both the Leuser and BBS landscapes: habitat loss, direct killing of tigers by poachers, and killing of tiger prey by poachers. The severity of each of these threats, however, is different between the two landscapes. In Leuser habitat loss is a growing problem, particularly since the 2005 cease-fire between the GAM, an Acehese group that sought independence, and the Federal Government of Indonesia, which has enabled agricultural expansion (WCS, 2013).

According to WCS (2013), direct killing of tigers is a very strong threat in Leuser. Much of the direct killing of tigers in Leuser is done as a consequence of human-tiger conflict. The frontier of many parts of the Leuser landscape is a graded mixture of agricultural settlements mixed with secondary rainforest. This mixed habitat is a tremendous draw for wild pigs, whose plunder of agricultural crops has enabled a population boost in wild pigs. Following the wild pigs into this mixed habitat are tigers, who prey upon the pigs and upon domestic cattle. In response to the wild pigs, farmers place many snares, which end up also capturing many wild tigers. As a result of human tiger conflict, the victim of this is not only for tiger but also human and pasture such as shown in Table 3.

Table 3. Data Compilation of Human Tiger Conflict in Sumatera

Year	Area / Frequency of Conflict	Number of Victim			
		Tiger (Died)	Human		Pasture (Died)
			Injured	Died	
1978-1999 ¹	Aceh (34), Sumut (6), Riau (36), West Sumatera (48), Jambi (14), South Sumatera (1), Bengkulu (1), Lampung (6)	265	30	146	870
1998-2002 ²	Sumatera	35			
2000-2004 ³	Sumatera			40	
1997-2009 ⁴	Riau	8		27	

Source: Data Compilation from ¹Nyhus dan Tilson (2004); ²TRAFFIC (2002); ³PHKA, in Forestry Ministry (2007),

Riau was in the highest rank of human tiger conflict since the forest loss and forest degradation was the most extensive in the last decades. Another report noted human activities such as poaching and trading of part of tiger bodies, there would be 253 individuals of Sumatran tiger eliminated from their natural habitat from 1998-2002 (Shepherd, C. *et al*, 2004).

c. Sumatran Orangutan (*Pongo abelii*)

The biggest threat to orangutans is the destruction of their natural habitat by forest conversion for agriculture, plantations, mining sites and housing areas. These factors not only destroy habitat wholesale, they also affect the distribution of the species by fragmenting surviving orangutans into small, fragile populations scattered in equally small and vulnerable habitats (Rijksen & Meijaard, 1999; Robertson & van Schaik, 2001 in Yuwono, E. H *et al*. 2007). Population is distributed between Aceh and North Sumatera with total around 7,031 individuals (Forestry Ministry, 2007).

The loss and fragmentation of tropical rainforests (orangutan habitat) is the principal cause of conflict between humans and orangutan (HOC). One of the impacts of increasing HOC is an increase in orangutan killing and poaching for trade. The conversion of natural forests opens access to orangutan habitat, which often results in an increase in hunting activities. Moreover, such activities can push orangutans out of the forest, beyond their natural borders, in search for food. This often brings orangutans into cultivated areas managed by local communities. In extreme cases, forest conversion has even forced orangutans to enter residences and plantations, thus exacerbating negative perceptions of these animals by local people. For example, orangutans are increasingly regarded as crop raiding pests in several locations along the forest edges (especially in Sumatra), and are consequently illegally persecuted. Another impact of the human-orangutan conflict is the killing of orangutans by tree-felling activities, and starvation of these primates

because of lack of food resources. These factors contribute to decreases in orangutan populations and eventually lead to local extinction of the species (Yuwono, E. H *et al.* 2007)

Land Use Plan to Mitigate Human Wildlife Conflict (HWC)

Nowadays Sumatran's wildlife faces a continuous of conflict due to habitat loss and degradation through deforestation, logging, land conversion, encroachment, and forest fires. Therefore it is really urgently required to review land use planning in Sumatera cause it will be important factor for carrying capacity of habitat such as home range, food and water viability, coverage for protection and others habitat function. Elephant habitat at Jantho Nature Reserve (CA) and Seulawah Grand Forest Park (TAHURA) could be a good sample to describe about HWC. According to local community around Jantho Nature Reserve, they have never faced HWC and it's supposed that there is no significant forest disturbances in the area of nature reserve since there is no land cover change in this area. Contrary to this situation, people around Seulawah often interacted with the elephant and got the victim of human when land cover was changed and there was no more connectivity with forest surrounding area. Land cover change at Jantho Nature Reserve and Seulawah Grand Forest Park is shown in Table 4.

Table 4. Analysis of land cover change at Jantho Nature Reserve (CA) and Seulawah Grand Forest Park (TAHURA) from 2000 to 2011

Land Cover	CA JANTHO		Change (%)	TAHURA SEULAWAH		Change (%)
	2000 (ha)	2001 (ha)		2000 (ha)	2001 (ha)	
Primary forest	1,073.48	1,073.48	0	0	0	0
Secondary dry land forest	11,534.45	11,534.45	0	2,963.08	2,825.49	(-) 2.24
Plantation forest	0	0	0	117.68	117.68	0
Shrubs	444.47	444.47	0	2,673.78	2,809.38	(+) 2.21
Opened land	43.24	43.24	0	0	1,99	(+) 0.03
Savana	2,511.54	2,511.54	0	287.05	287.05	0
Water	10.52	10.52	0	0	0	0
Dry land agriculture	1,192.32	1,192.32	0	2.77	2.77	0

Note: (+) addition (-) reduction, Source: Land cover map (BAPLAN 2000 – 2011) in Zahra, M. 2014

From Table 4, we could see there was no change of land cover at Jantho, while at Seulawah there was a decreasing extent of secondary dry land forest (2.24%) and additional shrubs and opened land accounted for 2.21% and 0.03% respectively. Therefore, HWC incident at Seulawah was occurred due to land use cover change surrounding area and narrowed elephant habitat. It should be a warning for government to make a big effort to connect isolated population at Jantho Nature Reserve and Seulawah Grand Forest Park by a corridor. Current land cover of this proposed corridor is shrub and opened area which is suitable for elephant habitat. The status area as production forest need a political will from government to develop it as wildlife corridor. The proposed corridor is illustrated in Figure 7.

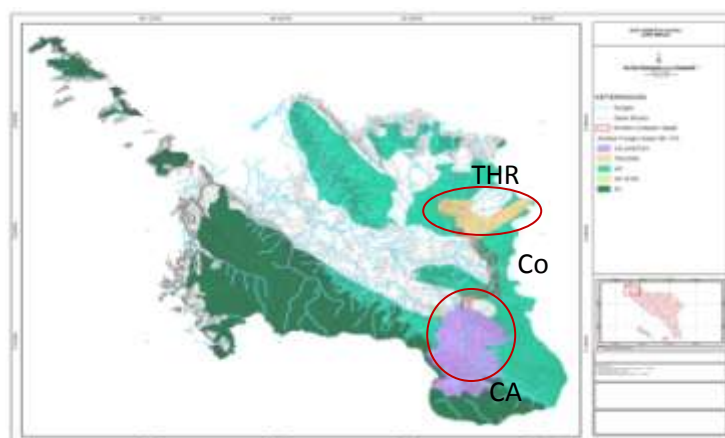


Figure 7. Map of corridor proposal to connect Seulawah and Jantho Nature Reserve (Source: Map is modified by Patana, P. from Zahra, M. 2014)

The existence of corridor is expected to be able to more space for elephants and others wildlife movement between these isolated population at Jantho and Seulawah, feeding area, coverage for protection, reproduction or genetic transformation, and other activities. Furthermore, the population density can be equitable with carrying capacity and finally reducing human wildlife conflict surrounding area.

CONCLUSIONS AND SUGGESTIONS

- (1) Land use change and forest disturbance were the main factors of human wildlife conflict in Sumatera in the last decades.
- (2) Reviewing land use plan by proposing corridor is one of alternative solution to mitigate human wildlife conflict for fragmented area of wildlife habitat.

REFERENCES

- Azmi, W., Patana, P. Subhan, M. Edy Sunardi, Harmita Desmerry, Diding M. Ichsan, A. Siddik Thoha, Ujang W. Barata. 2008. Conservation of Sumatran Elephants and Their Habitat Through Onservation Response Unit in The Buffer Zone Of Gunung Leuser National Park. Sumateran Elephant Conservation Program, Fauna and Flora International. Medan.
- Forestry Ministry. 2007. Strategy and Conservation Action Plan of Sumatran Elephant and Borneo Elephant 2007-2014. Direktorat General of Forest Protection and Nature Conservation. Jakarta
- Forestry Ministry. 2007. Strategy and Conservation Action Plan of Sumateran Tiger (*Panthera Tigris Sumatrae*) 2007-2014. Direktorat General of Forest Protection and Nature Conservation. Jakarta
- Forestry Ministry. 2007. Strategy and Conservation Action Plan of Indonesian Orangutan 2007-2014. Direktorat General of Forest Protection and Nature Conservation. Jakarta
- Margono, B. Arunarwati, Svetlana Turubanova, Ilona Zhuravleva, Peter Potapov, Alexandra Tyukavina, Alessandro Baccini, Scott Goetz and Matthew C Hansen. 2012. Mapping and monitoring deforestation and forest degradation in Sumatra (Indonesia) using Landsat time series data sets from 1990 to 2010. Environmental Research Letters. doi:10.1088/1748-9326/7/3/034010. 16pp. IOP Publishing Ltd, Printed in the UK.
- Patana, P., Azmi, W., and Bangun, A. 2010. The Role of Conservation Response Unit in Human Elephant Conflict Mitigation and Strengthening The Forest Status of ECC Seblat-Bengkulu. Fauna and Flora International-Sumatran Elephant Conservation Programme. Paper on SECP Meeting. Medan
- Santiapillai, C. and Ramono, W.S. 1993. Why do elephants raid crops in Sumatera. Gajah Vol.11. p.55-58.
- Shepherd, C. R. & Magnus, N. 2004. Nowhere to hide, the trade in Sumatran tiger. TRAFFIC South East Asia.
- WCS, 2013. Tiger Conservation in the greater Leuser landscape and the greater Bukit Baresan Selatan landscape of Sumatra.
- WWF-Indonesia, 2013. Palming Off a National Park, Tracking Illegal Oil Plm Fruit in Riau Sumatera. Riau
- Yuwono, E.H, Purwo S., Chairul S., Niviar A., Didik P., Sri S. U. Atmoko. 2007. Guidelines for The Better Management Practices on Avoidance, Mitigation and Management of Human-Orangutan Conflict an and Around Oil Palm Plantations. WWF-Indonesia.
- Zahra, M. 2014. *Analisis Kesesuaian Habitat untuk Konservasi Gajah Sumatera (Elephas maximus sumatranus) dengan Mengembangkan Indeks Habitat*. Dissertation. North Sumatera University. Medan

PRODUCTION AND PALATABILITY OF FEED PLANTS OF SUMATRAN ELEPHANT (*Elephas maximus Sumatranus*) IN JANTHO PINUS NATURE RESERVE, ACEH

Ma'rifatin Zahrah¹ and Retno Widhiastuti²

¹) Lecturing Staff at Sekolah Tinggi Ilmu Kehutanan Pante Kulu, Banda Aceh
Email : titenmirza@yahoo.com

²) Lecturing Staff at Environmental and Natural Resources Management Study Program, Graduate School, University of Sumatera Utara, Medan

ABSTRACT

This research was conducted to assess the potential source of the feed which is a major component in the habitat of Sumatran elephant. The purpose of this research was to obtain data about the types of feed plant of Sumatran elephant as well as measuring the production and its palatability. The study was carried out in the Pinus Nature Reserve Jantho, Aceh by conducting analysis of vegetation using the method of systematic sampling with random start on every different vegetation communities. Calculation of feed production by means of fresh biomass, whereas it is only done on ten species of plants commonly consumed feed elephants based on the former feed and the remaining feed left, assuming the types have the highest palatability. Results of the research there were recorded 75 feed plants from 269 plants were found, which means that 28% of plants in the study are a source of feed for the Sumatran elephant. Based on the palatability index, species of feed that is highly preferred kinds of rattan (*Callamus* spp.) with the highest level of palatability (IP = 0.75) and *Rubus moluccanus* (IP = 0.67). Other plant species that are preferred are *Nicolaia speciosa*, *Echinochloa stagnina*, *Digitaria ciliaris*, *Pandanus* sp., *Nephrolepis exaltata*, *Streblus elongatus*, *Mallotus paniculatus* and *Elasteriospermum tapos*. Total of fresh biomass of feed elephants on sample plots for ten species of feed is the most preferred of 1.714 kg/m².

Keywords: feed production, palatability, feed plants, Sumatran elephant

INTRODUCTION

One of the conservation efforts to the Sumatran elephants included in the category of endangered species according to the IUCN *Red List of Threatened Species* (IUCN, 2008) is to protect the natural habitat, which is commonly referred as *in situ* conservation. Jantho Pinus Nature Reserve is one of the elephant sanctuary areas in Aceh, which has a role to connect the populations of elephants in the Seulawah forest area with populations in other regions. The habitat condition of Jantho Pinus Nature Reserve as a provider of survival needs determines the future populations of wild elephants in Aceh.

Feed plant is a major component in a habitat to meet the needs of animals (Khanna *et al*, 2001). The availability of food is influenced by the physical factor of the habitat, such as climate and soil as a growth medium. The availability of adequate food influences the level of animal welfare so that the animals would have a high reproduction and disease resistance. In relation to reproduction, the availability of feed with sufficient quality and quantity affects the fertility and fecundity (Bailey, 1984).

The approach which needed to be conducted to determine the quantity of feed plant available in the habitat was to calculate the feed production; while its quality was through the palatability index that described the preference level of feed by elephants on certain plant species. It was assumed that the preferred feed that had better quality. Bailey (1984) and Alikodra (1990) suggests that herbivores requires a high protein content of feed and those which are easy to digest, so herbivores always prefer forage that has a high protein content.

METHODS

This research was conducted to assess potential sources of feed which is a major component in the habitat of Sumatran elephant. The objective of this study was to obtain data of species of elephant Sumatran feed plant and to measure the production and palatability. The study was conducted in Jantho Pinus Nature Reserve in Aceh Besar Regency by applying vegetation analysis through systematic sampling with random start method to each of different vegetation communities. The observation units in forms of sample plots in lines and by the number of lines were determined according to conditions of the field of each type of vegetation; each line vertically the contour line for about 500m -1km and width of 20 m; spacing between lines of 100 m.

The species of the elephant feed plant was known from wrench/bite/fracture, the residual feed plant which were already consumed and information from *pawang uteun* (forest handler). The data of kinds of feed plant was collected along with the vegetation analysis (in the sample plots of vegetation analysis) to determine the quantitative density and dominance in the structure and composition of vegetation in the habitat of elephants.

To quantify the production of elephant feed was conducted by cutting the feed plants for seedlings, saplings, ground cover (including grass), shrubs, lianas, epiphytes, palms and pandanus; then weighing them to obtain wet weight. The size of the observation sample plots for the types of grasses (including tall grasses) are 1m x 1m, whereas for seedlings, ground cover (other than grasses) eg. shrubs/herbs, ferns, with a sample size of 2m x 2m plots. For saplings, lianas, palms and pandanus (with 5 cm <DBH ≤ 10 cm); the sample of plot size is 5m x 5m (Solichin, 2009). The procedures for laying the sample plots were selected based on purposive observations of the location of food resources. The species of feed plant rate of growth poles (between 10-20 cm dbh) and growth rate of trees (dbh> 20 cm) that the leaves were consumed, feed productivity analysis can be approached through litter productivity by using litter container (*litter trap*) (Corbeels, 2001). Bark production was calculated by peeling bark in the sapling plants consumed by an elephant, and weighing them. Calculation of feed production was only performed on ten plant species that were often consumed by the elephant based on the former wrenches and residual feed left, assuming these species had the highest palatability.

Overall feed production can be calculated by equation (Kartono *et al.* 2008), as follows:

$$B_i = \frac{\sum_{i=1}^s x_i}{a_i}$$

Where: B_i = total of fresh biomass (kg) in the sample plots to i

x_i = fresh biomass (kg) of forage kinds to i

A_i = area of sample plots (m^2) to i

Not all parts of the feed plant species is consumed by elephants. Elephants prefer certain parts of certain plants. Parts of the plant which become the food for elephants include: leaves, stems, fruits, bark, roots and tubers. As for grass, almost all parts grow above ground are consumed by elephants. The calculation of elephant feed plant production in this study was limited to the 10 species of plants that have the highest level of palatability among feed plant found.

The palatability of feed was determined by noting and observing the former wrench, bite or fracture of all species of plants left in the whole sample plot observations. The palatability index was obtained by calculating the ratio between the numbers of sample plots with certain species of plant consumed by the elephant and the total number of sample plots where were such species. The calculation of palatability index (IP) applied the formula: $IP = X/Y$, where X = between the numbers of sample plots containing plant X which were consumed by the elephant, and Y = the total number of sample plots contained plant species X . The palatability index values range from 0-1, where the criteria for determining the level of preference were divided into 3 categories, namely highly preferred (0.67 to 1), preferred (0.34 to 0.66) and less preferred (0 to 0.33) (Masy'ud *et al.*, 2008).

RESULTS AND DISCUSSION

There were at least 75 species of feed plant on 269 species found, which meant that 28% of plants in the study area was a source for Sumatran elephants. The types of those feed plant were included into 25 families. Based on the residual feed plant found in the field, several types were: tall grasses: *Echinochloa crus-galli* and *Saccarum spontaneum*; short grasses: *Digitaria ciliaris* and *Echinochloa stagnina*; rattan: *Callamus* spp. and *Caryota mitis*; *Pandanus* sp., *Streblus elongatus*, *Arthocarpus* spp., *Nicolaia speciosa* and *Elasteriospermum tapos*. The trunks of *Macaranga* sp. and *Mallotus paniculatus* were seen broken and their skins were peeled. In terms of classification based on the families, Moraceae, Euphorbiaceae, Poaceae, Myrtaceae, Arecaceae and Fabaceae were the predominant species of feed. It turned out that those family were also important plant feed for the Asian elephants (Chen *et al.*, 2006; Campo-Arceiz *et al.* 2008) and African elephants (White *et al.* 1993). The percentage of plants based on the families was presented in Figure 1.

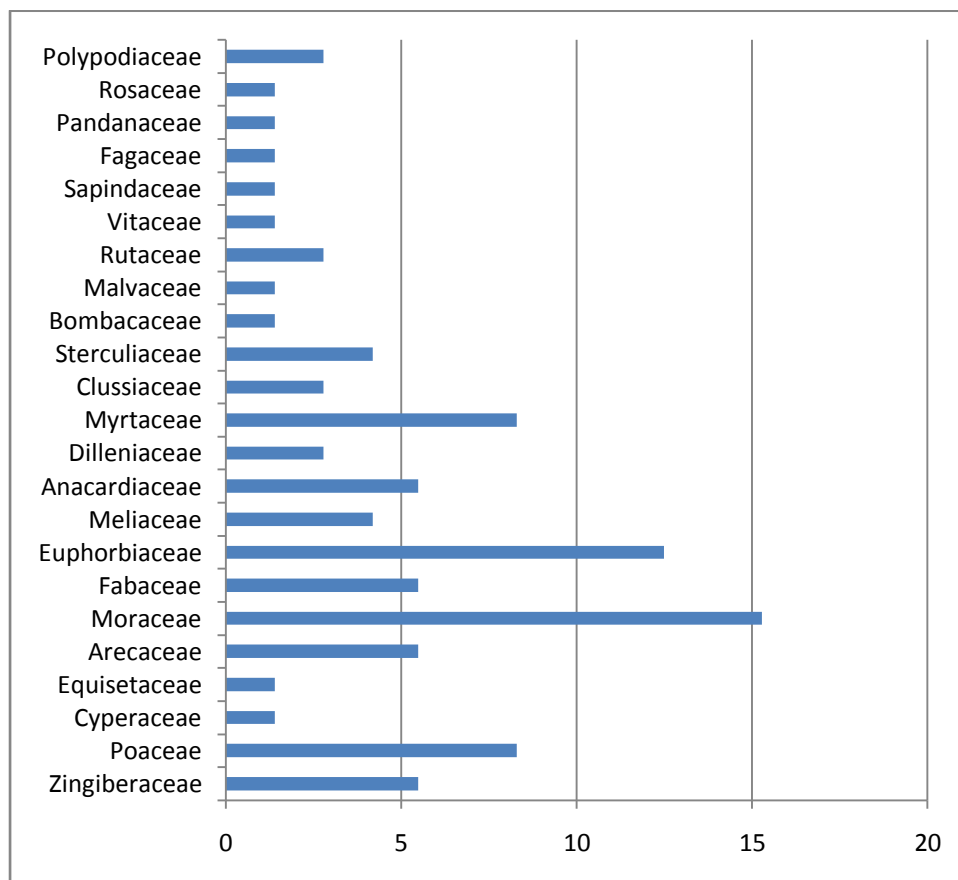


Figure 1. Percentage of feed plant based on the families

Sukumar (1985) recorded that the type of feed consumed by elephants were most often composed of several orders, namely: Malvales order (from the families of Malvaceae, Sterculiaceae, and Tilliaceae), families of Leguminosae, Palmae, Cyperaceae and Graminae; while Sitompul (2011) reported that the elephant feed in Seblat, Bengkulu were 273 species of plants from 69 families. The species of Moraceae, Arecaceae, Fabaceae, Poaceae and Euphorbiaceae families; were the types observed to be more often consumed by the elephants.

Given the many types of elephant feed found, the feed production calculation was only carried out onto 10 (ten) plant species that often consumed by the elephants based on former wrench and residual feed left, assuming these species have the highest palatability among plant species known. The determination for the kind was based on the presence in the sample plots, while the introduction of other types of plants were also carried out outside the sample plots; because the large amount of elephants feed plant, even those preferred, were outside the sample plots. Ten plant species with the palatability index for each type were shown in Table 1.

Analysis on palatability or preference level of elephants toward the feed plant were applied only to the species included in the sample plots, while those outside the sample plots were only recorded based on the frequency of those types consumed by an elephant. The highly preferred food species is rattan (*Callamus* sp.), one of the *Arecaceae* family, which is very popular species of feed plant, gaining a high level of palatability (IP = 0.75). The preferred parts were the thorny stems and umbut (shoots). Elephants had high preference to the leafy plant that were rough and had thorny stems, such as the types of rattan. This was seen from the extent of damage on the plant species as well as the residual feed plant left in the eating location. Ananthasubrahmaniam (1980) said, the elephant's favorite types of *Arecaceae* / *Palmae* families were caused by their high cobalt content.

Table 1. Palatability index of ten types of elephant feed plant

Scientific Name	X	Y	Palatability index
<i>Nicolaia speciosa</i>	4	7	0,57
<i>Echinochloa stagnina</i>	3	11	0,27
<i>Callamus</i> sp.	3	4	0,75
<i>Digitaria ciliaris</i>	4	12	0,33
<i>Pandanus</i> sp.	2	5	0,4
<i>Nephrolepis exaltata</i>	3	9	0,33
<i>Rubus moluccanus</i>	2	3	0,67
<i>Streblus elongatus</i>	1	3	0,33
<i>Mallotus paniculatus</i>	2	4	0,5
<i>Elasterospermum tapos</i>	5	12	0,42

The other type classified as highly preferred by the elephants was *Rubus moluccanus* (IP = 0.67). Of the three types of sample plots were found, this type was found to be consumed by the elephants in two sample plots. *Rubus moluccanus* is a type of shrub; the leaves and stems tend to be prickly coarse. Its fruits resemble those of red strawberries. All parts of this plant were consumed by elephants. The plant species preferred by elephants can be seen in Figure 2.

The types of feed plant preferred by elephants were *Nicolaia speciosa*, *Mallotus paniculatus*, *Elasterospermum tapos* and *Pandanus* sp. that had the palatability index from 0.34 to 0.66. *Nicolaia speciosa* and *Elasterospermum tapos*, stems and tubers were consumed by elephants; *pandanus* for its shoots; while *Mallotus paniculatus* for the bark. The rest, four species which were the least preferred type of feed, were *Digitaria ciliaris*, *Streblus elongatus*, *Nephrolepis exaltata* and *Echinochloa stagnina*.



A



B

Figure 2. Feed plants preferred by elephants (A). *Rubus moluccanus* and (B). *Callamus* sp.

Types of grasses in the sample plots were the elephant feed plant in types of short grasses namely: *Digitaria ciliaris* and *Echinochloa stagnina*. Outside of the sample plots, based on the residual feed plant and damage found, the type of *Saccharum spontaneum* and *Echinochloa crus-galli* were the highly preferred plant species. The distribution of the two types of grasses from the *Poaceae* family was only on grassland vegetation that was very broad and there were no other types that can grow. *Saccharum spontaneum* and

Echinochloa crus-galli are kinds of tall grasses, which can reach more than 1.5 meters. By this growth characteristic, such types were abundantly available at the study site.

During the study, the plant species that were mostly seen to be consumed by elephants were grasses from Poaceae family, lower plants of Polypodiaceae family. The groups of Zingiberaceae family, pandan, rattan and shrub were also seen to be consumed by the elephants. This was related to the abundant availability of these species in condition of high rainfall; although elephants were seen to consume the bark of woody plants.

Eltringham (1982) argued that the variation of feed usually depends on the season which affects the availability of food in its natural habitat. Besides grass, elephants also need other types of feed such as leaves of higher plants, shrubs, and trees. The types of grasses and shrubs are usually consumed in the rainy season, where the amount of these types are abundant; while in the dry season elephant prefers fresh leaves, when the grass is usually dry. Based on his research, Iswaran (1983) suggested that the elephant in the dry area of eastern Sri Lanka had more variety of feed from types of leaves of woody plants (*browse*).

In addition, Sukumar (1985) said that the elephants' preference toward the tall grasses is associated with their particular fondness for the stage of the growth of the grass. Elephants highly prefer the tall grass at the beginning of the rainy season where the new grasses spring (*fresh grass*) because they contain carbohydrates that are easily solved, and the low fiber content and silica; while the mature grass nutrient content applies instead. Furthermore it is said, the elephant has a strategy selection in determining consumption season between grass and leaves which are strongly associated with plant protein content. During the dry season the grass protein levels fall below 2.5%; otherwise the leaves have a high protein content in the dry season (8-10% in Malvales order and 10-20% in Leguminosae), so in the dry season elephant prefers leaves (*browse*).

The result of this study was similar with one conducted by Steinheim *et al* (2005), who noted that the proportion of feed elephants in Nepal during the dry season was 24% grasses and 65% *browse*, especially the type of *Bombax ceiba* tree bark and *Acacia* catechu and different from one by Sitompul (2011) who reported different conditions, that Seblat Elephant were *browsing* more during the rainy season, rather than *grazing*.

Analysis of feed production were performed only on ten types of plant food which had the highest palatability. The calculation of feed production was conducted by weighing the fresh biomass of each type of feed plant contained in the sample plots (Table 2). The feed production was the total fresh biomass of 10 species of elephant feed obtained from sample plots in the study area. In this study, the type of feed production was observed, excluding the productivity of elephant feed.

Table 2. Weight of fresh biomass of ten elephants feedplants

Scientific Name	Parts which are consumed	Fresh Biomass (kg/m ²)
<i>Nicolaia speciosa</i>	bulb and blade	0,061
<i>Echinochloa stagnina</i>	Leaves	0,56
<i>Callamus</i> sp.	Blade and tip of leaves	0,107
<i>Digitaria ciliaris</i>	Leaves	0,61
<i>Pandanus</i> sp.	Tip of leaves	0,05
<i>Nephrolepis exaltata</i>	Tip of leaves	0,1
<i>Rubus moluccanus</i>	All	0,175
<i>Streblus elongatus</i>	Bark of the stem	0,01
<i>Mallotus paniculatus</i>	Bark of the stem	0,011
<i>Elasteriospermum tapos</i>	bulb and blade	0,03
Total of fresh biomass		1,714

The results of calculations on the unit area of 26,800 m² sample obtained total fresh biomass of elephant feed for the 10 most preferred species of feed amounted to 1.714 kg /m². Thus it can be predicted that the production of total feed elephants in the area were more or less of 45935.2 kg/sample plot, whereas for the whole area of Jantho Pinus Nature Reserve is (totaling 16,640 ha) of 285.209.600 kg.

In addition to the type of feed, the elephant also preferred specific parts of a plant to be consumed. Based on field observations, for types of grasses and ferns, elephant picked the leaves; for rattans, the preferred parts were rods and tip of leaves; for the family Zingiberaceae, bulb and stem were preferred, while

for shrub, all of its partstend to be consumed. Certain species of woody plants in the growth rate of saplings, often seen to be consumed the bark of stem.

Regarding the reason of the consumption of elephants toward the bark of trees is not yet fully known, but the behavior is allegedly related to a deficiency of essential fatty acids on food intake (McCollough, 1973), as well as certain minerals such as manganese (Mn), iron (Fe) and copper (Cu) which are found in the bark of trees (Dougall *et al*, 1964), also sodium (Na) (Naomi, 1980) and calcium (Ca) (Croze, 1974).

Recent research on the nutritional content of the bark of African elephant woody vegetation feed was conducted by Wanderi (2007) in Kenya, which reported that the behavior of elephants consuming tree bark (*debarking*) was positively correlated with the levels of N, P, K, and Zn contained in the bark of trees. From these, a simple protein(N) has the biggest influence against *debarking* behavior.

In this study, the bark that was consumed (chipped) by elephant was kind of *Mallotus paniculatus*, *Streblus elongatus* (Figure 3).Bark consumed by elephants originated from vegetation level stake. Of these three species, *Mallotus paniculatus* was more frequently consumed. It was alleged that *M.paniculatus* contained higher nutrient content in the bark than the other two species.In general, the bark from the Euphorbiaceae family was more often consumed compared to other types.Sitompul research results (2011) mentioned that the Euphorbiaceae had *crude protein* content of 11.5%, 0.6% Ca and 0.22% P;but no further explanation was provided in what parts of the plants it was contained.Additionally Wanderi (2007) reported that, there was a positive correlation between the intensity of *debarking* with the mineral content of N, P, K and Zn in the stem bark of *Acacia elatior*, the type mostpreferred by *Loxodonta africana*, containing significantly higher nutrient. However,Douglas-Hamilton (1972) in Wanderi (2007) said that the selected species of plants that elephants was to eat the bark was for the reason that these types were more easily peeled.



Figure 3. Bark is consumed elephant (A) *Mallotus paniculatus* and (B) *Streblus elongatus*

CONCLUSION

The results of the study found that there were 75 species of feed plants on 269 plant species found, which concluded that 28% of plants in the study area was a source of feed for Sumatran elephants. Based on palatability index, the types of feed that were highly preferred were types of rattan (*Callamus* spp.) with the highest level of palatability (IP = 0.75) and *Rubus moluccanus* (IP = 0.67). Feed plant species in the preferred category (IP 0.34 to 0.66) were *Nicolaia speciosa*, *Mallotus paniculatus*, *Elasterospermum tapos* and *Pandanus* sp. In addition, *Echinochloa stagnina*, *Digitaria ciliaris*, *Nephrolepis exaltata* and *Streblus elongatus* were the kinds of the less preferred category. The total fresh biomass of elephant feed on sample plots for the 10 most preferred species of feed plants was 1.714 kg / m², or estimated for the entire area Jantho Pinus Nature Reserve covering 16,640 hectares, amount to 285.209.600 kg.

REFERENCES

- Alikodra, H.S. 1990. *Pengelolaan Satwaliar*. Jilid I. Pusat Antar Universitas Ilmu Hayat, Institut Pertanian Bogor. Bogor.
- Ananthasubrahmaniam, C.R. 1980. A Note on nutritional requirements of the Asian Elephant (*Elephas maximus indicus*). *Elephant (Suplement)*.1:72 – 73.
- Bailey, J.A. 1984. *Principles of Wildlife Management*. John Wiley & Sons. New York.
- Campoz-Arceiz, A., Lin, Z.T., Htun, W., Takatsuki, S. dan Leimgruber, P. 2008. Working with mahouts to explore the diet of work elephants in Myanmar (Burma). *Ecological Research* 23: 1057 – 1064.
- Chen, J., Deng, X.B., Zhang, L., dan Bai, Z.L. 2006. Diet composition and foraging ecology of Asian elephants in Shangyong, Xishuaangbanna, China. *Acta Ecologica Sinica* 26: 309 – 316.
- Corbeels, M. 2001. Plant Litter and Decomposition: General Concepts and Model Approaches. NEE Workshop Proceedings: 18 – 20 April 2001.
- Croze, H. 1974. The Seronera bull problem. *E. Afri. Wildl. J.* 12, 1-27.
- Dougall, H.W., Drysdale, V.M. dan P.E. Glover. 1964. A Chemical composition of Kenya browse and pasture herbage. *East Afr. Wildl. J.* 2: 86 – 121.
- Eltringham, S.K. 1982. *Elephants*. Blandford Press. Poole-Dorset.
- Iswaran, N. 1983. Conservation of the Sri Lanka Elephant planning and management of the Wasgomuwa-Maduru Oya Gal Oya Complex of Reserves. IUCN/WWF Project 1783. Final Report. University of Peradeniya.
- [IUCN] International Union for Conservation of Nature and Natural Resources. 2008. 2008 IUCN Red List of Threatened Species. www.iucnredlist.org. Diakses pada 24 November 2008.
- Khanna, V., Ravichandran, M.S., dan Kushwaha, P.S. 2001. Corridor analysis in Rajaji-Corbett Elephant Reserve – a Remote Sensing and GIS Approach. *Journal of the Indian Society of Remote Sensing* Vol 29 No.1 & 2.
- Mc Cullough, K.G. 1973. The african elephants deficient in essential fatty acids. *Nature*, 242: 267 – 268.
- Naomi, D.W. 1980. Environmental sodium as a factor in the behaviour and distribution of african elephant. *Elephant*, 1(4): 169 – 177.
- Sitompul, A.F. 2004. Human – Elephant Conflict Around Two National Parks in Indonesia, and Conservation Implication. M.S. Dissertation, University of Georgia, USA.
- Solichin. 2009. Panduan Inventarisasi Karbon di Ekosistem Hutan Rawa Gambut (Studi Kasus di Hutan Rawa Gambut Merang, Sumatera Selatan). Merang REDD Pilot Project.
- Sukumar, R. 1985. Ecology of the Asian Elephant (*Elephas maximus*) and Its Interaction with Man in South India. Ph D. Thesis. Indian Institute of Science. Bangalore.
- Steinheim, G., Wegge, P., Fjellstad, J.I., Jnawali, S.R. dan Weladji, B. 2005. Dry season diets and habitat use of sympatric Asian Elephants (*Elephas maximus*) and greater one-horned rhinoceros (*Rhinoceros unicornis*) in Nepal. *J. Zool., Lond* 265: 377 – 385.
- Wanderi, I.F. 2007. Forage Quality and Bark Utilisaton by The African Elephant (*Loxodonta africana*) in Samburu and Buffalo Springs National Reserve, Kenya. Thesis. School of Biological Science University of Nairobi.
- White, L.J.T., Tutin, C.E.G. dan Fernandez, M. 1993. Group composition and diet of forest elephant, *Loxodonta africana cyclotis* Matschie 1900, in Lope Reserve, Gabon. *African Journal of Ecology* 31: 181 – 199.

THE EFFECT OF SKIDDING TO SOIL POROSITY BY REDUCED IMPACT LOGGING AT NATURAL TROPICAL FOREST OF PT. INHUTANI II, EAST KALIMANTAN, INDONESIA

Muhdi

Lecturer of Faculty of Forestry, University of Sumatera Utara Medan
*) Jln. Nazir Alwi No. 4 Kampus USU Medan – Indonesia 20154
HP. 0811657101; email: muhdisyehamad@yahoo.com

ABSTRACT

The objective of this research was to know the degree of soil compaction caused by skidding on reduced impact logging in natural forest. This research examined the extent of soil compaction with crawler by mechanical skidding on skiddtrail in natural tropical forest, East Kalimantan. In area logged, using conventional, i.e. uncontrolled, harvesting technics. In contrast, in a 10 ha area experimental area where the reduced impact logging guidelines were implemented. The research showed that the soil porosity at conventional timber harvesting after skidding of deepness 0-5 cm, 10-15 cm and 25-30 cm was 52.90 %, 52.72 % and 53.77 % respectively. The soil porosity at reduced impact logging (RIL) after skidding of deepness 0-5 cm, 10-15 cm and 25-30 cm was 58.86 %, 59.09 % and 60.82 % respectively. This research indicated that the soil compaction at RIL was lower than conventional timber harvesting.

Key words : soil porosity, skidding, reduced impact logging, natural tropical forest

INTRODUCTION

Reducing the damage caused by timber harvesting is a prerequisite for achieving sustainable forest management. Reduced soil damage and stands can reduce cutting cycle as it ensures the regeneration and growth of commercial stands (Peña-Claros *et al.*, 2008; Rendon-Carmona *et al.* 2009). In the production forest in East Kalimantan, conventional timber harvesting is generally cause more damage than 50% in area harvested (Sist, *et al*, 2003). Timber harvesting is an activity in which the production of timber and other forest products as a result. Damage to vegetation and soil that may arise can not be avoided completely.

Skidding is one phase activities of harvesting timber to collect the log to landing. Skidder requires the range of motion that can result in damage to the soil. Likewise, the contact between the skidder to the ground may result in disclosure and damage to the soil structure.

Improved forest management in the form of improved harvesting techniques from conventional timber harvesting be environmentally friendly harvesting techniques (reduced impact logging) showed significant reduction of deforestation. Reduced impact logging techniques are harvesting intensively planned and controlled by workers trained so that in the process of harvesting the impact is minimal. Implementation of reduced impact logging techniques include planning timber collection points (landings), road network planning, planning of skid trails, directional felling and cutting determining lianas. The purpose of RIL practices including reducing the size and number of landings, reducing damage to the land and stands, reducing damage to trees and increase the increment, as well as reduce the openness of the land (Putz *et al*, 2008; Elias, 1998)

The purpose of this study was to know the soil porosity of soil compaction due to skidding with conventional timber harvesting and reduced impact logging in natural tropical forests.

METHODS

Soil porosity due to skidding of timber, made observations on major skid trails, branches and wood collection points which is on permanent plots measuring 100 mx 100 m. Observations on skid trails conducted

three replications, in which dots soil sampling systematically placed on both sides and the middle of the road skid.

Permanent plots / measurements are systematically placed on both the research plot in a way that represents the following places: (1) at the location where the collection timber (landing) (Plot I); (2) on the main skid trail locations (Plot II) and (3) at the location of skid trails branch (Plot III). Soil bulk density was measured by using irregular holes on each soil depth of 0-5 cm, 10-15 cm and 25-30 cm by taking a soil sample by inserting a cylinder of soil sampler into the ground.

Soil samples were also taken three replicates of undisturbed forest floor (virgin forest / VF) which is close to the skid trail to get an overview of the state of the mass density of the soil before skidding takes place. Examples were tested in the laboratory soil test Soil Mechanics and Physics, Faculty of Agricultural Technology, Bogor Agricultural University, Bogor.

Differences in the effect of conventional timber harvesting techniques on soil compaction vs RIL can be tested by t-test, that timber harvesting techniques is as treatments and plots is as replicates.

RESULTS AND DISCUSSIONS

Soil porosity is closely related to soil bulk density. Porosity of the soil in plots of conventional and RIL harvesting can be seen in Table 1.

Table 1. The Soil porosity (%) in plots of conventional timber harvesting and RIL

No Plot	Conventional			RIL		
	Soil Depth (cm)			Soil Depth (cm)		
	0-5	10-15	25-30	0-5	10-15	25-30
I	43.74	44.95	48.32	54.32	54.19	55.82
II	52.33	51.47	51.14	57.82	57.37	59.19
III	62.64	61.73	61.86	64.45	65.71	67.46
VF	75.64	72.43	68.61	76.88	71.47	68.12
Rataan	52.90	52.72	53.77	58.86	59.09	60.82

Table 1 showed that the presence of skidding cause soil compaction due to skidding on skid trails on both plots timber harvesting. This is indicated by a decrease in soil porosity value when compared with the porosity of the soil on land that is not traversed skidder (virgin forest). In conventional timber harvesting plot impaired soil porosity in the deeper soil layers, ie, at a depth of 0-5 cm, 10-15 cm and 25-30 cm, soil porosity of 75.64% to 52.90%, 72, 43% to 52.72% and 68.61% to 53.77%, respectively. At RIL harvesting plots the change is relatively smaller in the soil depth of 0-5 cm, 10-15 cm and 25-30 cm, respectively by 76.88% to 58.86%, 71.47% to 59, 09% and from 68.12% to 60.82%, respectively.

The average soil porosity in the plots of conventional timber harvesting timber skidding at a depth of 0-5 cm, 10-15 cm and 25-30 cm were 52.90%, 52.72% and 53.77%, respectively. Soil Porosity at RIL plots the change is relatively smaller in the soil depth of 0-5 cm, 10-15 cm and 25-30 cm were 58.86%, 59.09% and 60.82%, respectively. This was due to skidding on a patch of conventional timber harvesting, protection against soil compaction resulting in greater soil that causes the soil porosity to be lower when compared to the RIL plots timber harvesting. The effects of timber extraction on soil porosity in timber harvesting plots of conventional and RIL with different soil depths (0-5 cm, 10-15 cm and 25-30 cm) can be seen in Figure 1 and Figure 2.

Figure 1 showed that the change in porosity of the soil at the plot of conventional timber harvesting is larger than the porosity of the soil on the land that has not been disturbed (virgin forest), especially on the plot I and plot II. Porosity of the soil in all the plots show the value of soil porosity smaller than the porosity of the soil on forest land that has not been disturbed (virgin forest). The biggest change occurred at a depth of 0-5 cm in the first plot, where the soil porosity reaches its lowest point compared at all points of measurement. At a depth of 25-30 cm to the plot I and plot II still showed significant changes although tends to decrease. It is indicated that is very intensive soil compaction as a result of tractor traffic.

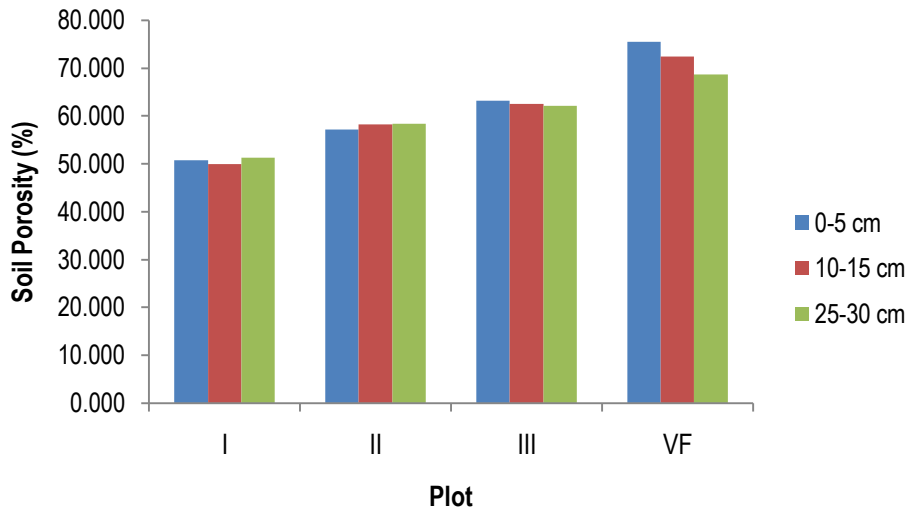


Figure 1. Relationship between soil depth on soil porosity (%) in plots of conventional timber harvesting.

There was a decrease in soil porosity skid RIL harvesting plots when compared to the weight of soil on land that is not traversed tool skid (virgin forest), especially on the first plot, plot II and III plot. However, changes in soil porosity value is relatively small. At a depth of 10-15 cm despite increased but decreased. At a depth of 25-30 cm for the first plot, the plot of the second and third plots showed no significant changes. This suggests that soil compaction on skid trails RIL plots intensive timber harvesting, because the tractor is not in direct contact with the soil surface but blocked by a wooden dock (Figure 1).

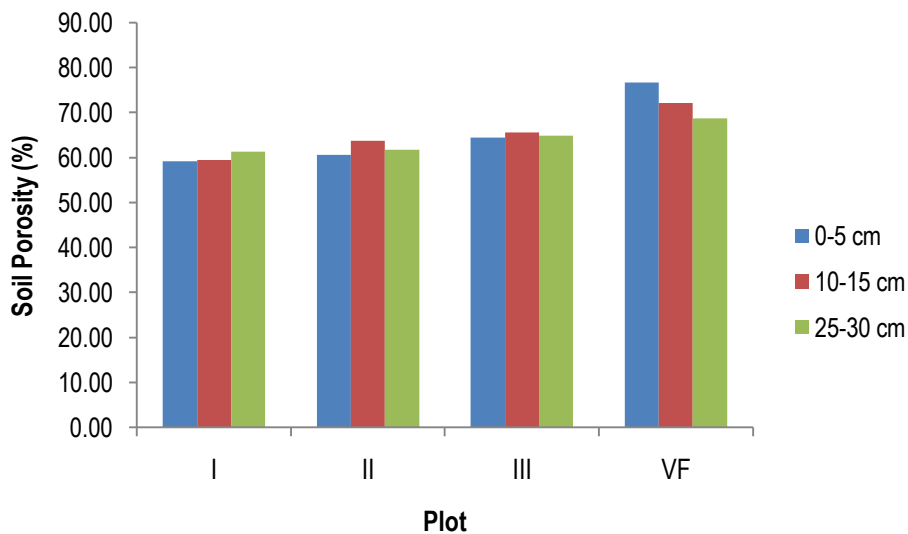


Figure 2. Relationship between soil depth on soil porosity (%) at RIL plots.

Figure 1 and Figure 2 show that due to the traffic of tractors has caused soil compaction resulting in lower porosity of the soil. Porosity of the soil in plots I, II plots and plot III is smaller than on the ground in soil is not disturbed (virgin forest). In conventional timber harvesting plots soil porosity biggest changes occurred at a depth of 0-5 cm and tends to decrease at a depth of 10-15 cm and 25-30 cm. At RIL harvesting plots soil porosity changes were relatively smaller.

In Figure 1 and Figure 2 shows that the porosity of the soil on skid trails traversed with a higher intensity causes the soil porosity was getting smaller. Average porosity of the soil on the plot I is less than the porosity of the soil in plots II and III plot. This is possible because the intensity of extraction tools (tractors) were higher in plots closer to the landing. The greater the intensity of traffic tractor then the greater the compaction process so that the porosity of the soil decreases. Based on the analyses t-test value, the average

soil porosity in the timber harvesting plots of conventional and RIL showed has different significant value to the depth of 0-5 cm and a depth of 10-15 cm and not significantly to a depth of 25-30 cm at the 95% confidence level.

In general, the amount of soil porosity decreases to a certain depth with increasing soil depth. The graph shows the porosity of the soil to a depth of 0-5 cm to 10-15 cm depth decreased. This is presumably because the soils are soil compaction of the soil surface due to traffic tools and on land that is under the surface of the experience accumulated in the upper soil compaction. Accumulated soil pematatan reached at a depth of 10-15 cm maksimum and tends to decrease at depths below (Idris, 1987; Matangaran, 1995). According to Hillel (1971) the minimum porosity of the soil for plant growth by 10%, then the effect of soil compaction caused by the skidding of timber harvesting on both plots is not yet a serious problem for forest regeneration. Furthermore, Putz *et al* (2008) suggested that improved forest management, timber extraction reduced impact logging can protect biodiversity levels higher and gives the ability of forests to recover more quickly than conventional harvesting.

CONCLUSION

Soil porosity caused by skidding in the conventional timber harvesting plots at a depth of 0-5 cm, 10-15 cm and 25-30 cm were 52.90%, 52.72% and 53.77%, respectively. However the effect of skidding to soil soil compaction in RIL plots is smaller than conventional plots that soil porosity in RIL plots in the soil depth of 0-5 cm, 10-15 cm and 25-30 cm were 58.86%, 59.09% and 60.82%, respectively.

REFERENCES

- Elias. 1998. Reduced impact wood harvesting in tropical natural forest in Indonesia. Forest-Case study 11. Food and Agriculture Organization of the United Nation. Rome.
- Hillel, D. 1971. Soil and Water. Physical Principles and Processes. Academic Press, New York and London.
- Idris, M.M. 1987. Pengaruh Penyaradan Kayu dengan Traktor Berban Ulat terhadap Kerusakan Tegakan Tinggi, Pergeseran Tanah serta Pematatan Tanah Hutan. Tesis Pascasarjana IPB Bogor. Bogor.
- Matangaran. 1995. Pengaruh Intensitas Penyaradan Kayu oleh Traktor Berban Ulat terhadap Pematatan Tanah dan Pertumbuhan Kecambah Sengon (*Paraserianthes falcataria*) dan Meranti (*Shorea sp.*). Tesis Pascasarjana IPB Bogor. Bogor.
- Peña-Claros M, Fredericksen TS, Alarcon A, Blate GM, Choque U, Leano C, Licona JC, Mostacedo B, Pariona W, Villegas Z, Putz FE. 2008. Beyond reduced impact logging: Silvicultural treatments to increase growth rates of tropical trees. *Forest Ecology and Management*, 256: 1458-1467.
- Putz FE, Sist P, Fredericksen T, Dykstra D. 2008. Reduced impact logging : challenges and opportunities. *Forest Ecology and Management*, 256: 1427-1433.
- Rendón-Carmona, Martínez-Yrizar A, Balvanera P, Pérez-Saliciup D. 2009. Selective cutting of woody species in an Mexican tropical dry forest: incompatibility between use and conservation. *Forest Ecology and Management*, 257 : 567-579.
- Sist P., Sheil D., Kartawinata K., dan Priyadi H. 2003. Reduced Impact Logging in Indonesian Borneo: Some results confirming the need for new silvicultural prescription. *Forest Ecology and Management* 179: 415-427.

THE DIVERSITY OF FORAGE PLANT AND HONEY YIELD OF *Apis cerana* AT SIMALUNGUN REGENCY

Dwi Endah Widyastuti¹, Darma Bakti Nasution², Sutarman³

¹Graduate School, Natural Resource Management And Environment Program
University of North Sumatra, dwiendah@usu.ac.id

² Faculty of Agriculture University of North Sumatra

³ Faculty of Mathematics and Natural Sciences University of North Sumatra

ABSTRACT

Apis cerana, honeybee species endemic to Asia, are farmed at Simalungun Regency North Sumatra. The objective of research to compare the diversity of forage plant and honey yield in different types of cover crops. Mixed garden, tea garden and the secondary forests is measured by the method of vegetation analysis turns a diversity of vegetation. Then the difference of location associated with the level of honey yield. The results showed the most diversity plant was on secondary forest, while the lowest diversity in the tea garden. While the highest level of honey yield is in the mixed garden and the lowest yield in secondary forests.

Key words: *Apis cerana*, forage plant, honey yield

INTRODUCTION

Apis cerana honeybee is a species of endemic to Asia. Compared to other types of another farm honeybees, it is relatively more aggressive types (Akratanakul, 1990). However due to the nature of the endemic then more adaptive to changes of the environment. At a suitable location would generate sufficient honey. The efforts of the bee farm (beekeeping/apiculture) is a worthy effort developed in an area that has a lot of good plant natural resources (agriculture, plantations and forestry). The benefits of special plantings do not need to as the requirement.

One important aspect in the beekeeping is the source of the forage, namely the types of plants that contain sufficient nectar and pollen (Estoque & Murayama, 2010). Without sufficient forage then bee colonies cannot thrive and produce honey. Not all types of flowering plants become the source of feeding bees. It depends on the existence of nectar and pollen as a food.

Plants not flowering throughout the year. Therefore the combination of the types of plants that were around the beekeeping need to be on notice. Because it required an assessment of the suitability of the location for the business beekeeping (Widyastuti, 2011). However if it does not meet, the beekeepers had to move the beehive to places that are has food.

Simalungun Regency group of beekeepers, put a beehive at various locations. This study aims to compare the diversity of the types of plants that bees feed on site as well as comparing results of the honey produced at that location.

METHODS

Sampling and Study Area

Research conducted in June 2014. The research was done at 3 location with different type of cover crop : (1) mixed garden at village of Nagari Bangun (2) tea garden at Bah Butong Tea Plantation, and (3) secondary forest at BPK Aek Nauli at Simalungun regency. Purposive sampling applied on the area, consist of 5 systematic double plots/location (totally 15), where beehive placed, with 20 x 20 m on size. Inventory of forage plant was done in that plot only for tree stage. Honey yield data obtained from interview with beekeeping farmer.

Data Analysis

The diversity of honeybee forage plants were analyzed by analysis of vegetation using Wiener Shannon Diversity Index. Analysis of description used to describe the forage plant at each location. Analysis of description is also used to describe the relationship between the type of land cover with honey yield.

RESULT AND DISCUSSION

Diversity of Forage Plant

Studies in three types of land cover shows the difference of diversity bee forage plants, as can be seen in table 1. The values of Shannon Wiener index illustrate the diversity within a community. According to Barbour et al. (1987) The Shannon Wiener Diversity Index can be grouped into four, namely: $H > 2$ (low), $2 < H < 3$ (moderate), $3 < H < 4$ (high), and $H > 4$ (very high).

Table 1. Cover crop type and diversity index

No	Cover crop type	Diversity index
1	Mixed garden	2.3
2	Tea garden	0.2
3	Secondary forest	2.6

The highest species diversity found in secondary forest. High diversity indicates that the ecosystem is a stable ecosystem. While the diversity of ecosystems with low levels tend to be unstable. Secondary forest has highest diversity at moderate category as mixed garden, and tea garden has lowest diversity at low category.

Species of Forage Plants

The different types of bee forage plants on mixed farms, tea plantations and secondary forests can be seen in Table 2, Table 3 and Table 4. Generally the types of flowering plants that are in the placement of bee hives are the types of forage plants bees. However, not all flowering plants can be food for bees. A type of plant can be called forage plants if the plants contains food bee, pollen and nectar which should meet the needs of the colony. Apis cerana cruising distance to fly as far as 2 km. The availability of adequate food in cruising radius is evidenced by the growing colony of bees and honey yield that can be harvested by humans.

Table 2. Species and Number of Individual in Mixed Garden

No	Local name	Scientific name	Number of Individual
1	Coklat	<i>Theobroma cacao L</i>	34
2	Alpukat	<i>Persea americana</i>	5
3	Kelapa	<i>Cocos nucifera</i>	14
4	Jengkol	<i>Archidendron pauciflorum</i>	2
5	Durian	<i>Durio zibenthinus</i>	6
6	Mindi	<i>Melia azendarach</i>	1
7	Torop	<i>Artocarpus elasticus</i>	2
8	Pinang	<i>Areca catechu</i>	18
9	Pisang	<i>Musa parasidica</i>	26
10	Kayu manis	<i>Cinnamommm burmanii</i>	4
11	Mahoni	<i>Sweitenia macrophylla</i>	7
12	Sawo	<i>Manilkara zapota</i>	1
13	Kaliandra	<i>Calliandra calothyrsus</i>	6
14	Suren	<i>Toona sinensis</i>	1
15	Sawit	<i>Elaeis oleifera</i>	5
16	Petai	<i>Parkia speciosa</i>	2
17	Gmelina	<i>Gmelina arborea</i>	2
TOTAL			134

Mixed garden owned by farmers, planted with other types of fruit trees forage plants such as avocados, coconuts and sapodilla. On mixed garden also found forage plants types of non edible fruit such as mahogany and caliandra. These plants if they have different flowering seasons, will ensure the sustainability of the results of honey throughout the year.

Table 3. Species and Number of Individual in Tea Garden

No	Local name	Scientific name	Number of Individual
1	Teh	<i>Nigella sativa</i>	225
2	Andulpak	<i>Omalathus populneus</i>	2
3	Kayu manis	<i>Cinnamomum burmanii</i>	4
4	Motung	<i>Ficus toxicaria</i>	1
5	Macaranga	<i>Macaranga sp</i>	2
Total			234

Tea garden as plantation business certainly has a tea as dominant plant species. It make senses has a low species diversity. Beehive placed in the tea garden where other types of plants usually pioneer plant found. Bee forage source in the tea garden Bah Butong also derived from eucalyptus forests which are not far from the location of beehive.

Table 4. Species and Number of Individual in Secondary Forest

No	Local name	Scientific name	Number of Individual
1	Kemenyan	<i>Styrax benzoin</i>	12
2	Ekaliptus	<i>Eucalyptus sp</i>	10
3	Tulasan	<i>Altingia excelsa</i>	7
4	Hoting	<i>Quercus sp</i>	2
5	Pirdot	<i>Cantela asitica</i>	6
6	Puspa	<i>Schima walichii</i>	4
7	Medang	<i>Lintsea sp</i>	10
8	Kopi	<i>Coffea arabica</i>	16
9	Meranti	<i>Shorea sp</i>	1
10	Sikam	<i>Biscofia javanica</i>	18
11	Pinus	<i>Pinus oocarpa</i>	19
12	Sampinur tali	<i>Dachrydium alatum</i>	8
13	Mohu	<i>Ptereumycbium tinctorium</i>	5
14	Motung	<i>Ficus toxicaria</i>	1
15	Aren	<i>Arenga pinata</i>	2
16	Antarasa	<i>Litsea cubiba</i>	1
17	Kaliandra	<i>Calliandra calotrycus</i>	7
Total			120

Secondary Forest Arboretum in BPK Aek Nauli, planted by the selection of wood tree species, which are usually not edible fruit trees. However, many forest plant species of flowering plants are forage plants, therefore the placement of bee hives at locations around the forest can be tested. The conditions are sufficient forage plants in sufficient quantities. From the examination of the condition of the bee colony can be seen, bees forage plants in the forest location sufficient or not .

Honey Yield

Based on interview with beekeeper, honey yield at three sites showed differences results as in Table 5. The mixed garden, produce honey with the highest result by an average of 60 kg/ month, while the tea gardens of 40 kg/month and secondary forests an average of 30 kg/ month.

Table 5. Cover crop type and Average Honey yield

No	Cover crop type	Honey yield
1	Mixed garden	60 kg/month
2	Tea garden	40 kg/month
3	Secondary forest	30 kg/month

Honey yield, more produce on mixed garden because of the type of bee forage plants are more widely available, especially species of fruit trees. Forage crop types of secondary forests less, so that the yield are not as much as in other locations . Tea garden despite having a low diversity of plant species, but the location is close to the tea gardens of eucalyptus plantation, which is a good type of forage plants.

CONCLUSIONS

High levels of the most diversity was on natural forests, while the lowest diversity in the tea garden. Then the level of honey yield the most is the mixed garden and the lowest yield in natural forests.

REFERENCES

- Akratanakul P. 1990. Beekeeping in Asia. FAO Agricultural Services Bulletin 68/4. FAO UN. Rome.
- Amiri F, Shariff ARBM, Arekhi S. 2011. An Approach for Rangeland Suitability Analysis to Apiculture Planning in Gharah Achach Region, Isfahan-Iran. *World Applied Sciences Journal* 12 (7) : 962-967. Idosi Publications.
- Estoque RC, Murayama Y. 2010. Suitability Analysis for Beekeeping Sites in La Union, Philippines, Using GIS and Multi-Criteria Evaluation Techniques. *Medwell Journals*.
- Mudzaky F. 2003. Usaha Lebah Madu dalam Pemberdayaan Ekonomi Masyarakat Pedesaan. Thesis. Program Pascasarjana UGM. Yogyakarta
- Noor NBM. 2007. Locating Suitable Zones for Beekeeping in Selangor, Malaysia. Thesis. School of Graduate Studies. University Putra Malaysia.
- Sarwono B. 2007. Lebah Madu. AgroMedia Pustaka. Jakarta.
- Widyastuti DE. 2011. Peningkatan Kemampuan Beternak Lebah pada Kelompok Petani di Desa Namorambe. *Jurnal Pengabdian USU*. Vol IV No. 1.

GALL RUST INFESTATION ON THE PRIVATE FOREST OF *Falcataria moluccana* IN KEPAHANG DISTRICT, BENGKULU PROVINCE, INDONESIA

Enggar Apriyanto, Deselina, Siswahyono, and Hemamalini Tagatorop

The Department of Forestry, The Faculty of Agriculture, Bengkulu University,
Jl. WR. Supratman No 1. Bengkulu,
Email : Enggavan@yahoo.com

ABSTRACT

Private forest of Sengon (*Falcataria moluccana*) has been developed since six year ago in Kepahiang district, Bengkulu Province. However the *sengon* stand has been infected by gall rust that could affect to the growth and wood quality. The aim of the study was to identify the incidence and severity of gall rust infestation on the *F. moluccana* stand. The experiment plot was pointed in the purposive manner on the *F. moluccana* stand about four year olds at 1000, 800, 600, and 300 m above sea level. Three experiment plots about 20 x 20 m² were set up to collect data on each altitudes. Observation was made to identify *F. moluccana* tree within those plots whether the tree was infected or healthy, damage, and severity. Result showed that damage and the severity of gall rust infestation was different at the four altitudes. The gall rust incidence on *F. moluccana* private forest at 1000, 800, 600, and 300 m above sea level was about 97,44, 99,14, 64,67, and 27,57% consecutively. The severity of gall rust infestation was about 60,92, 59,71; 29,11, and 15,58 % respectively.

Key words : *Falcataria moluccana*, Gall rust, Incidence, Severity

INTRODUCTION

Falcataria moluccana is as an important pioneer species that origin in Indonesia, Papua New Guinea, Solomon Island, Australia. It could grow up to 3300 m above sea level in region with a mean annual temperature and rainfall of 22 to 29^o C and 2000 to 4000 mm, respectively (Soerianegara and Lemmens, 1993 and Hidayat *et al.*, 2003). This species has been chosen as one of species that being develop to build private forest in the district of Kepahiang, Bengkulu province since six years ago. In the early plantation it is commonly planted in agroforestry systems. This species is used as panel, triplex, particle board, paper, construction wood, and musical equipment.

Falcataria moluccana plantation in Indonesia, especially in Java, has widely infected gall rust caused by *Uromycladium tepperanum* (Rahayu, 2008). *Uromycladium tepperanum* was identified as the cause of gall rust disease in *F. moluccana* (Brown, 1993 in Rahayu, 2008, PROSEA, 2003). Gall rust has infected *Falcataria moluccana* in private forest in Kepahiang District, Bengkulu Province (Apriyanto, 2012). Gall rust need for several year present on the plantation to caused severe damage (Rahayu, 2008). Formation of galls caused by gall rust can occur on foliage, twigs, branches, and bole. Severe damage occur when shoots and boles are affected. Several silviculture techniques have been applied to combat the gall rust in Java, Indonesia; however it was very difficult to eliminate (Anggraeni, 2008; Rahayu, 2008). This study was aimed to know the gall rust incidence and severity on *F. moluccana* at private forest.

MATERIALS AND METHODS

This study had been conducted since July up to August 2014 at Kepahiang District, Bengkulu Province, Indonesia. *Falcataria moluccana* stand (2 x 3 m) that used during observation was about 3–4 year olds. Three experiment plots about 20 x 20 m were set up in each private forests at 1000, 800, 600, and 300 m above sea level. Variables that being observed were healthy tree, infected tree and infected parts of infested trees. Environment factor measured was temperature, humidity, and light intensity.

The score of gall rust infestation on *Falcataria* trees was used based on Table 1. Qualitative and quantitative analyzes were used to analyze data (Rianse and Abdi, 2008). Diseases Incidence (DI) and

Disease severity were calculated according to the formula developed by Chester (1959) (Baskorowati and Santosa, 2010).

Table 1. Score of the infected *Falcataria moluccana* on the private forest

Score	Infestation level (%)	Description of Infected tree
0	0	Healthy tree (no infection)
1	1-19	Infected Twigs ($\geq 20\%$); or twig ($\geq 5\%$) and branch ($\geq 15\%$), or twig ($\geq 10\%$) and branch ($\geq 10\%$)
2	20-29	Infected Twig ($\geq 5\%$), branch ($\geq 5\%$), and bole ($\geq 5\%$); or twig ($\geq 30\%$); or branch ($\geq 25\%$) and twig ($\geq 5\%$), or or branch ($\geq 20\%$) and twig ($\geq 10\%$)
3	30-39	Branch ($\geq 20\%$) and twig ($\geq 5\%$), bole \geq ; or, twig ≥ 40 , branch $\geq 35\%$ and twig ≥ 5 , or branch ≥ 30 and twig $\geq 10\%$
4	40-49	Branch ($\geq 30\%$) and twig ($\geq 5\%$) and bole ($\geq 5\%$), or twigs ($\geq 50\%$); or twig ($\geq 45\%$) and twig ($\geq 5\%$); or branch ($\geq 40\%$) and twig ($\geq 10\%$)
5	50-59	Branch ($\geq 40\%$) and twig ($\geq 5\%$) and bole ($\geq 5\%$); or branch ($\geq 60\%$); or branch ($\geq 55\%$) and twig ($\geq 5\%$), or branch ≥ 50 and twig ($\geq 10\%$); or branch (≥ 50), twig ($\geq 5\%$) and bole ≥ 5
6	60-69	Branch ($\geq 50\%$) and twig ($\geq 5\%$) and bole ($\geq 5\%$); or twig ($\geq 70\%$), or branch ($\geq 65\%$) and twig ($\geq 5\%$); or branch ($\geq 60\%$) and twig ($\geq 10\%$)
7	70-79	Branch ($\geq 60\%$) and twig ($\geq 5\%$) and bole ($\geq 5\%$); or Twig ($\geq 80\%$); branch ($\geq 75\%$) and twig ($\geq 5\%$); or branch ($\geq 70\%$) and twig ($\geq 10\%$)
8	80-89	Branch ($\geq 70\%$) and twig ($\geq 5\%$) and bole ($\geq 5\%$); or twig ($\geq 90\%$); or branch ($\geq 80\%$) and twig ($\geq 5\%$) and bole ($\geq 5\%$); or branch ($\geq 80\%$) and twig ($\geq 10\%$)
9	90-99	Branch ($\geq 80\%$) and twig ($\geq 5\%$) and bole ($\geq 5\%$); or twig ($\geq 95\%$); or branch ($\geq 80\%$) and twig ($\geq 15\%$); or branch ($\geq 90\%$) and twig ($\geq 5\%$), or branch 95% .
10	100	Branch (96-100%) and twig (96-100%)

The value of gall rust disease incidence (DI) and disease severity (DS) on *Falcataria moluccana* stands were calculated based on the formula as follow:

$$DI = \frac{n}{N}$$

$$DS = \left\{ \frac{(n_1 \times z_1) + (n_2 \times z_2) + \dots + (n_9 \times z_9)}{1!} \right\} \times 100\%$$

N = number of infected trees

N₁, n₂, ..., n_x = number trees with index score 1, 2, 3, 4, ..., x

Z₁, z₂, ..., z_x = index score of gall rust presence 1, 2, 3, ... x

N = total number of trees in location

Z = the highest score

Table 2. Classification of incidence and severity of the gall rust on *F. moluccana*

Value of Disease Incidence	Incidence	Value of Disease Severity (%)	Severity Classes
< 10	Rare	0	Healthy/Uninfected
10 – 24	Occasional	1 – 29	Low
25 – 49	Common	30 – 59	Medium
50 – 74	Very common	60 – 79	Severe
75 up	Widespread	80 – 99	Very Severe

RESULTS AND DISCUSSION

Result showed that gall rust incidence on the *F moluccana* private forest was different according to altitude. The gall rust incidence was about 97.44 and 99.14 % on the *F moluccana* private forest at 1000, 800, 600, 300 m above sea level subsequently. The value of disease incidence showed that gall rust infestation was widespread on the *F moluccana* private forest at altitude of 1000 and 800 m above sea level (Table 3). Widespread of the gall rust infestation was mainly supported by ideal environmental factors, especially dew that often occur on those private forests. It also supported by humidity at those location that reached up to 90%. Humidity is an important factor that responsible to height infestation of gall rust (Wiryadiputra, 2007). The incidence of gall rust decreased markedly up to 64.67 and 27.57% on the *F moluccana* private forest at the latitude of 600 and 300 m above sea level. Based on the classification of gall rust incidence was found that gall rust incidence was very common and common on the *F moluccana* private forest.

Table 3. Gall rust incidence and distribution of gall rust on the *F moluccana* private forest at different altitude at Kepahiang District, Bengkulu Province.

Altitude (m sea above level)	Number trees	Number of Infected trees	Gall rust Incidence (%)	Gall rust Severity (%)
1000	117	114	97.44	60.92
800	116	115	99.14	59.71
600	150	97	64.67	29.11
300	214	59	27.57	15.58

Count of infected part of tree was separated according to infected bole, branch, and twig. Results showed that gall rust could infect all parts of tree. The incidence of gall rust on the branch of *F moluccana* was commonly higher than other parts (Table 4). Gall rust incidence and severity on each parts of tree decreased with decreasing the altitude. The ultra violet might be responsible to the condition.

Table 4. Disease incidence on the part of *F moluccana* tree in private forest at Kepahiang District, Bengkulu Province

Altitude (M SAL)	Number of			Number of Infected			Disease Incidence on		
	Twig	Branch	Bole	twig	Branch	bole	twig	branch	bole
1000	3290	1384	117	807	724	26	24.47	52.30	23.07
800	3186	1284	116	554	639	18	17.39	49.32	15.51
600	3180	1840	150	217	282	38	6.88	15.42	25.33
300	3415	1232	214	86	58	52	2.48	4.61	2.48

SAL : Sea Above Level

CONCLUSION

The gall rust incidence and severity increased relating with raising the altitude. The gall rust incidence has been occurred at widespread (97.44 and 99.14%) at the altitude of 1000 and 800 m and very common at 600 m (64.67%), and common at 300 m (27.57%) above sea level respectively. The severity of gall rust infestation reached at severe level (60.92 and 59.71%) in the private forest at 800-1000 m above sea level and low level at 600 and 300 m ((29.11, and 15.58%) above sea level.

REFERENCES

- Anggraeni, I. 2008. Pengendalian Karat Tumor Pada Sengon. Workshop Penyakit Karat Tumor pada Sengon, Balai Besar Penelitian Bioteknologi dan Pemuliaan Tanaman Hutan. Yogyakarta.
- Apriyanto, E. 2012. Kesehatan Tegakan Sengon (*Falcataria moluccana*) Di Kabupaten Kepahiang, Provinsi Bengkulu. Dalam Prosiding Seminar Nasional
- Baskorowati. L dan Santoso. B.H. 2010. Pengembangan Tanaman Sengon Untuk Ketahanan Terhadap Penyakit Karat Tumor. Balai Besar Pemuliaan dan Bioteknologi Tanaman Hutan, Yogyakarta dan Balai Penelitian Kehutanan Ciamis. Yogyakarta
- Hidayat, J., Irianto D. and Ochsner P. 2003. *Paraserianthes falcataria* (L.) Nielsen. Seed Leaflet No. 81 Indonesia Forest Seed Project. 15pp.
- PROSEA (Plant Resources of South East Asia) 5. 2003. *Paraserianthes* LC. Nielsen. In: Soerianegara, I. dan Lemmens, R.H.M.J. 1993 Plant resources of South-East Asia 5(1): Timber trees: major commercial timbers. Bogor. Indonesia 625pp.
- Rahayu. S. 2008. Penyakit Karat Tumor Pada Sengon. Makalah disampaikan pada Workshop Penanggulangan Serangan Karat Puru Pada Tanaman Sengon, Balai Besar Penelitian Bioteknologi dan Pemuliaan Tanaman Hutan. Yogyakarta.
- Rianse, U dan Abdi, E.M. 2008. Metodologi Penelitian Sosial dan Ekonomi Teori dan Aplikasi. Alfabeta. Bandung.
- Soerianegara, I. dan Lemmens, R.H.M.J. 1993. Plant resources of South-East Asia 5(1): Timber trees: major commercial timbers. Pudoc Scientific Publishers, Wageningen, Belanda.
- Wiryadiputra.S. 2007. Epidemi Penyakit Pada Sengon (*Paraserianthes falcataria*) Di Jawa Timur, Indonesia. Jurnal Penelitian Kehutanan, Vol.1. No.1.

POSTER

EFFECT OF AGE ON CHEMICAL COMPONENT OF PLATINUM TEAK WOOD – A FAST GROWING TEAK WOOD FROM LIPI

Dwi Ajjas Pramasari*, Ika Wahyuni, Danang Sudarwoko Adi, Yusup Amin,
Teguh Darmawan, Wahyu Dwianto

Research Center for Biomaterials - Indonesian Institute of Sciences,
Cibinong Science Center, Bogor 16911, Indonesia
*E-mail: dwia010@lipi.go.id, dwi.ajjas@gmail.com

ABSTRACT

Teak wood (*Tectona grandis* L. f.) is one of valuable timber species, which is also well-known for its strength and natural durability. This kind of high-quality teak wood is usually gain from an old-growth tree, and hence this become a problem in satisfying the increasing demand from the market. Recently, LIPI has developed Platinum Teak - a fast-growing teak wood - by tissue culture method. Unfortunately, it has the limited information of the basic properties as a new teak wood. Hence, the objective of the present study is to investigate the properties of Platinum Teak, particularly the effect of tree age (2 and 5 years of growth) on chemical composition of Platinum Teak wood, which was selected from Cibinong Science Center Nurseries. The samples were chemical analyzed by using Mokushitsu Kagaku Jiken Manual standard. The result showed that the alteration of chemical composition parallel with increasing age of Platinum Teak, especially extractive contents that soluble in Alcohol-Benzene and holocellulose component. Furthermore, the other conclusion has been suggest that 5 years old of Platinum Teak has not only similar chemical composition with the conventional teak wood, but also it has better than 2 years old of Platinum Teak.

Key words: *Platinum teak wood, chemical component, the tree age*

INTRODUCTION

Wood is a natural resources which have been useful for human being. The characteristic of wood such as sustainable, renewable, economical and low energy consumption process than other materials. Unfortunately, the high degradation and deforestation of natural forest cause the availability of those woods now days is decreasing. The one of major commercial species of Indonesia which is also well-known for its strength and natural durability is Teak wood (*Tectona grandis* L. f.) This kind of high-quality Teak wood is usually gain from an old-growth tree, and hence this become a problem in satisfying the increasing demand from the market. Therefore, some researcher has been investigated to increased the utilization of plant genetic engineering with tissue culture for fulfill the demands of Teak wood.

A fast growing teak wood by tissue culture method has expected will be grow three or four times faster than the conventional method with seed development (Krisdianto, 2006; Muslich & Hadjib, 2010), hence the teak wood can be harvested after 20-30 years of growth (Lukmandaru & Takahashi, 2008). Recently, Indonesian Institute of Sciences has developed Platinum Teak - a fast-growing teak wood - by tissue culture method. Platinum Teak Wood has been developed from Berlian Teak – a best variety of teak wood- by tissue culture and radition. Therefore, the teak can be produce the new plants will growth rapidly and large diameter. Other side, the result from DNA analysis showed discrepancies in genetical between a fast growing and conventional teak wood. The wood from a fast growing tree is generally considered to have inferior properties compare to the old growth. One of basic properties that affected by tree growth is chemical properties. The effect of age has shown considerable differences in the content of main wood chemical component as well as extractives (Lukmandaru & Takahashi, 2009; Nazri et al., 2009; Kasmani et al., 2011).

Hence, the objective of the present study is to investigate the properties of Platinum Teak, particularly the effect of tree age (2 and 5 years old) on chemical composition of Platinum Teak wood, which was selected from Cibinong Science Center Nurseries. Data on the chemical component of wood material, particularly tissue culture wood, are required for the many processes and application in wood industry.

METHODS

Materials

The raw material used in the experiment was stem of two and five years of growth – Platinum Teak obtained from Cibinong Science Center Nurseries. The stem was cut and divided into three parts of axial position, which is bottom (A), middle (B) and top (C) (Figure 1). After that only five years of growth for each axial position was divided into heartwood and sapwood, which is well-known the radial position. The two years growth was not divided into radial position due to the discrepancies between heartwood and sapwood not significantly. The specimens for determining the chemical composition of wood were collected by milling flakes of stem into sawdust that would be able to pass a No. 40 sieve and retained on a No.60 sieve. The chemical properties with respect to the relative amount of extractive percentage that soluble in alcohol-benzene solvent, holocellulose, α -cellulose, and lignin was analyzed by using Mokushitsu Kagaku Jiken Manual (2000).

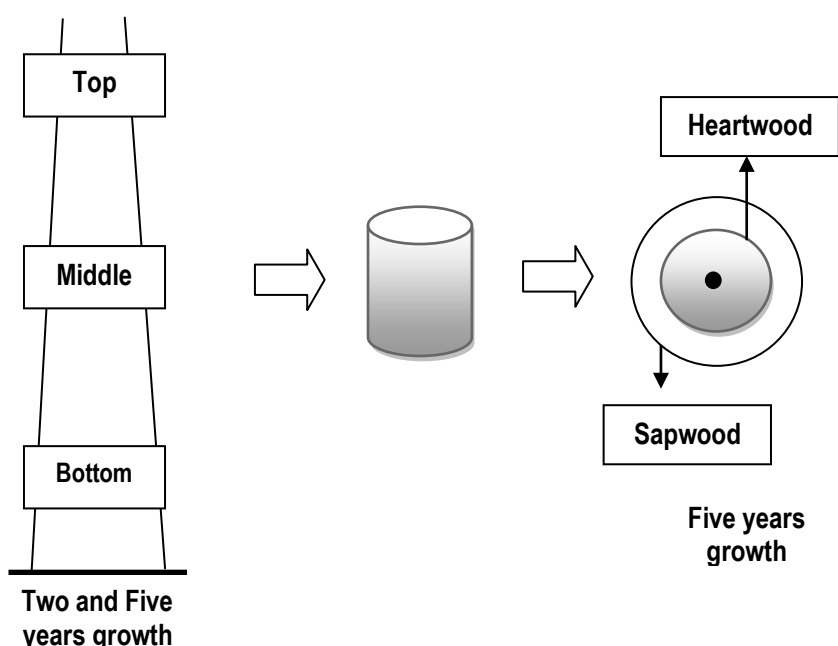


Figure 1. Wood sampel preparation

RESULTS AND DISCUSSION

The results of chemical components of Platinum teak wood describing as average value from extractive content that soluble in alcohol-benzene, lignin, holocellulose, and α -cellulose (Figure 2).

As shown in Figure 2, the alteration of chemical composition parallel with increasing age of Platinum Teak, especially extractive contents that soluble in Alcohol-Benzene and holocellulose component. The results similar with the research by Bedmansyah (2000) and Mauludi (2000). However, the alcohol-benzene extractives increase but the amount of holocellulose decrease. Meanwhile lignin and α -cellulose do not show a significant changes. These results suggested that α -cellulose hardly influenced by the age of wood (Santana et al., 2011).

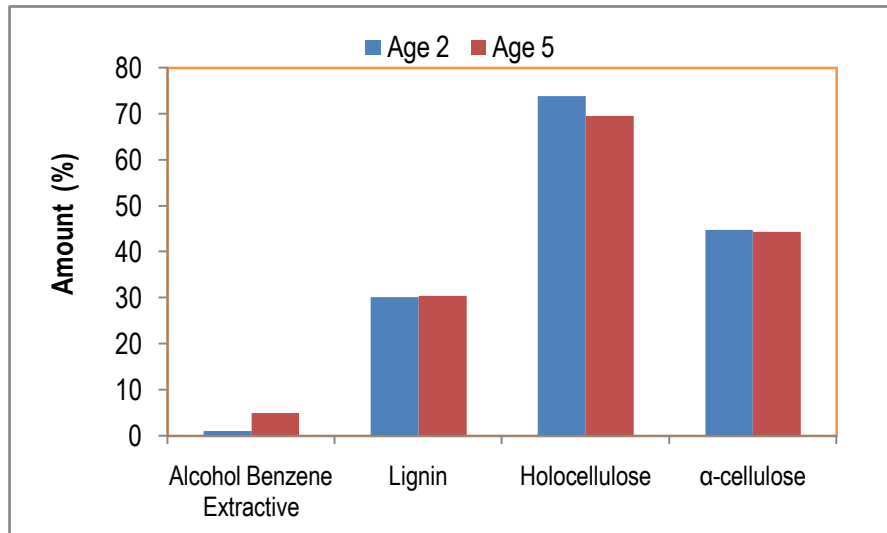


Figure 2. Chemical components of two and five years growth Platinum Teak wood

Extractive Content that Soluble in Alcohol-Benzene

Studying the effect of age of Platinum teak on chemical compounds changes shows that by the increasing the age from 2 to 5 years growth, the alcohol-benzene extractives increase. The average value from extractive content that soluble in alcohol-benzene in 2 and 5 years growth were 1,07% and 4,96%. The increasing of extractives content may related to heartwood formation (Santana et al., 2011). In addition percentage of parenchyma cells increase parallel with deposition of extractive contents, so that extractive contents will increasing (Hamidah et al., 2009; Kasmani et al., 2011).

Table 1. Classification of Indonesian hardwood species based on chemical component

Chemical component	Platinum Teak Wood (%)	Chemical Component Class		
		High	Moderate	Low
Extractive alcohol – benzene	1,07 – 4,96	>4	2 – 4	<2
Lignin	30,14 – 30,48	>24	21 – 24	<21
Holocellulose	69,54 – 73,91	>33	18 – 33	<18
α-Cellulose	44,37 – 44, 73	>45	40 – 45	<40

Source: Vadamecum Kehutanan Indonesia, 1967. Direktorat Jenderal Kehutanan Departemen Pertanian.

According the classification of Indonesian hardwood species based on chemical component (Table 1), extractive content that soluble in alcohol benzene for 2 year growth was low class while for 5 years growth was high class. The lower of extractive content for 2 years growth associated with sapwood formation which is an indication of juvenile wood without heartwood formation (Lukmandaru dan Sayudha, 2012). Certainly, this condition will be effect for the level of durability of two years growth Platinum Teak wood and application in wood industry.

The variety of distribution on chemical component depended on ecological condition of the environment, climate and formation of stem wood or branch wood (Achmadi, 1990; Dumanauw, 2001). The result of axial distribution showed that the highest of extractive content for 2 and 5 year growth on the top (1,19%) and the middle (5,86%). However the discrepancies of percentage in extractive content was not significantly. Contrast with the observation conducted by Prayitno (1992) that mentioned axial distribution on bottom of wood have the highest of extractive content cause more heartwood formation was found inside the bottom of wood.

Table 2. Axial distribution of chemical composition of 2 and 5 years growth Platinum Teak wood

Age (years)	Position	AB (%)	Lignin (%)	Holocellulose (%)	α -Cellulose (%)
2	Top	1.19	31.24	72.92	44.18
	Middle	1.11	30.17	73.87	43.04
	Bottom	0.92	29.01	74.94	46.98
	Average	1.07	30.14	73.91	44.73
5	Top	5.18	29.50	69.49	44.83
	Middle	5.86	30.22	68.26	43.29
	Bottom	3.85	31.73	70.86	44.99
	Average	4.96	30.48	69.54	44.37

The extractive content for 2 and 5 years growth increase parallel with the position of branchwood, which indicated the characteristic of teak wood by tissue culture method have slightly different compare to the old growth. Another possibility due to extractive content was influenced by many factors such as the size of sawdust, the moisture content, the type of solvent used and the frequency for mixing (Hamidah et al. 2009).

Lignin

In Figure 2, the result of lignin do not show a significant changes for 2 and 5 years growth of Platinum Teak wood. The average of lignin percentage were 30,14 % (2 years growth) and 30,48% (5 years growth). Furthermore, lignin content both of 2 year growth and 5 years growth was high class according the classification of Indonesian hardwood species based on chemical component (Table 1).

The result of axial distribution indicated that the lignin content of 2 years growth increasing tendency from bottom to the top position of wood (Table 2). Similar results were found by Zaki et al. (2012) while studying the chemical properties of juvenile rubber wood. They found the top position of wood has a high value compared to bottom portion because the top portion contains lots of new cells.

While the contrast pattern with lignin content of 5 years growth which is the highest lignin content found at the bottom of wood. Due to the cells on the bottom of wood have been lignified, so that the lignin is not only founded in the middle of lamela but also on primary and secondary wall of cells (Wardenaar et al.). Actually, the lignin content was influenced by tree growth (Haygreen & Bowyer, 1996). So that the difference patern of axial distribution in lignin content both of 2 and 5 years growth probably caused by more juvenile formation inside 2 years growth of Platinum Teak wood.

Holocellulose

According to Ritter and Kurth (1993) in Fengel and Wegener (1995) explain that holocellulose is a product from delignification process. Therefore, it is representing the amount of cellulose and hemicellulose (carbohydrates). In this research, the result shows that the holocellulose content decreasing in line with the increasing the age of wood. In addition, the holocellulose content of 5 years growth (69,54%) is lower than 2 years growth of Teak wood (73,91%). Bedmansyah (2000) explain that increasing the age of wood caused percentage of hemicellulose will be decrease. Hence, the percentage of holocellulose content will be decrease similar with hemicellulose content. Furthermore, holocellulose content both of 2 and 5 years growth was high class (upper 60%), according the classification of Indonesian hardwood species based on chemical component (Table 1).

The distribution of holocellulose content in 2 years growth decreasing tendency from bottom to the top position of wood, while the lowest of holocellulose content in 5 years growth is in the middle position (68,26%). Decreasing of holocellulose content from bottom to the top position cause the top position is still active to produce new cells (Zaki et al., 2012). In addition, the discrepancies pattern of 2 years growth in extractive and lignin content with holocellulose, which is the highest content in the bottom position of wood. According to Sunyata (2011), the bottom position of wood usually have the thicker cell wall in wood, thereby holocellulose as carbohydrate fractions constituent in the secondary cell wall will be higher. Moreover, holocellulose content in this research is lower than holocellulose component in classification of Indonesian hardwood species based (Pergamon, 1967 in Bedamansyah, 2000).

α -Cellulose

The result of α -cellulose shows that discrepancies between 2 and 5 years growth of Platinum Teak wood is not significantly (Picture 2). The average of α -cellulose percentage were 44,73 % (2 years growth) and 44,37 % (5 years growth). According the classification of Indonesian hardwood species based on chemical component (Table 1), α -cellulose content for 2 and 5 year growth was medium class.

The distribution of α -cellulose content in 2 and 5 years growth have similar pattern, which is the highest value in the bottom of wood, decreasing in the middle position and then increasing returns in the top of wood. Even though the discrepancies based on height position is not significantly. Decreasing of α -cellulose content from the bottom to middle position because the bottom position contains lots of mature cells (Zaki et al., 2012).

Comparison between Platinum Teak Wood and Other Teak Wood

In Table 3 shows comparison between Platinum Teak wood (2 and 5 years growth) with other Teak wood. The data for other Teak wood based on some literature.

Table 3. Comparison between Platinum Teak wood and other Teak wood

Variety of Teak Wood	Percentage (%)			
	Extractive alcohol – benzene	Lignin	Holocellulose	α -Cellulose
Platinum Teak Wood (2 years)	1,07	30,14	73,91	44,73
Platinum Teak Wood (5 years)	4,96	30,48	69,54	44,37
KU 1 Teak Wood from KPH Purwakarta *	3,16	24,73	70,65	37,41
Conventional **	4,60	29,90	-	-

Source :*)Bedmansyah, 2000;**) Martawijaya et al., 1981

The five years growth of Platinum Teak wood have extractive content that soluble in alcohol-benzene similar with Conventional Teak wood and higher than KU 1 Teak wood. These results indicated that the utilization of 5 years growth of Platinum Teak wood same with Conventional Teak wood due to heartwood formation which has not yet available in 2 years growth of Platinum. Moreover, lignin content for 2 and 5 years growth have value higher than KU 1 Teak wood and Conventional Teak wood.

Holocellulose content for 2 years growth of Platinum Teak wood is higher than KU 1 Teak wood, while 5 years growth is lower than KU 1 Teak wood. However, α -cellulose content both of them is higher than KU 1 Teak wood. The variety of chemical component in Platinum Teak wood compare with other Teak wood, indicated that condition due to the teak wood was produce by tissue culture and radition, theraby they found discrepancies in chemical component that affected to durability of wood.

CONCLUSIONS

The alteration of chemical composition for 2 and 5 years growth parallel with increasing age of Platinum Teak and height position of wood, especially extractive contents that soluble in Alcohol-Benzene and holocellulose component. Generally, 5 years growth of Teak wood is better than 2 years growth and almost similar with Conventional Teak wood. Furthermore, Platinum Teak wood was expected one of the prospect wood with fast growing. The further research still needed to see the comparison of chemical component and their effect of durability of other Teak wood of tissue culture and convention Teak wood with other variations of the age.

REFERENCES

- Achmadi, Suminar. 1990. Kimia Kayu. Departemen Pendidikan dan Kebudayaan. Direktorat Jenderal Pendidikan Tinggi. Pusat Antar Universitas. Ilmu Hayat. Institut Pertanian Bogor.
- Bedmansyah.2000. Komponen Kimia Kayu Jati (*Tectona grandis* L. f.) pada Berbagai Kelas Umur dari KPH Purwakarta. Skripsi Fakultas Kehutanan Institut Pertanian Bogor.

- Departemen Pertanian. 1967. *Vedemacum Kehutanan Indonesia*, Balai Penyelidikan Kehutanan, Jakarta.
- Dumanauw, J.F. 2001. *Mengenal Kayu*. Kanisius. Yogyakarta.
- Fengel, D. dan G. Wegener. 1995. *Kayu: Kimia, Ultrastruktur, Reaksi-Reaksi*. Terjemahan Harjono Sastrohamijoyo. Yogyakarta : Gajah mada University Press.
- Hamidah, S., Burhanudin, V., Istikowati, W.T. 2009. Kajian Sifat-Sifat Dasar Kayu Manis Sebagai Pertimbangan Pemanfaatan Limbah Pemanenan Kulit Kayu Manis (*Cinnamomum burmanii* Blume). *Jurnal Hutan Tropis Borneo* 10(26): 210-223.
- Haygreen, J. G. dan J. L. Bowyer. 1996. *Hasil Hutan dan Ilmu Kayu* (terj. Sutjipto, A. H.) Gajah Mada University Press. Yogyakarta
- Kasmani, J.E., Nemat, M., Samariha, A., Chitsazi, H., Mohammade, N.S., Nosrati, H. 2011. Studying The Effect of The Age in *Eucalyptus camaldulensis* Species on Wood Chemical Compounds Used in Pulping Process. *American-Eurasian J. Agric. & Environ. Sci.* 11(6): 854-856.
- Krisdianto dan Sumarni G. 2006. Perbandingan persentase volume teras kayu jati cepat tumbuh dan konvensional umur 7 tahun asal penajam, Kalimantan Timur. *Jurnal Penelitian Hasil Hutan* 24(5).
- Lukmandaru, G. dan Sayudha, I.G.N.D. 2012. Komposisi Ekstraktif pada Kayu Jati juvenil. Prosiding Seminar Nasional MAPEKI XIV, Yogyakarta.
- Lukmandaru, G. and Takahashi, K. 2008. Variation in the natural termite resistance of Teak (*Tectona grandis* Linn. fil) wood as a function of tree age. *Ann. For. Sci.* 65: 708.
- Lukmandaru, G. and Takahashi K. 2009. Radial distribution of quinones in plantation teak (*Tectona grandis* L.f.). *Ann.For.Sci.* 66 : 605p1-9.
- Martawijaya, A., Kartasujana, I., Kadir, K., Prawira, S. A. 1981. *Atlas Kayu Indonesia Jilid I*. Badan Penelitian dan Pengembangan Kehutanan. Departemen Kehutanan Bogor.
- Mauludi, A.S. 2000. *Komponen Kimia Kayu Jati(Tectona grandis L.f.) pada Berbagai Kelas Umur dari KPH Saradan*. Skripsi Fakultas Kehutanan Institut Pertanian Bogor.
- Mokushitsu Kagaku Jiken Manual, 2000, Japan Wood Research Society Publisher.
- Muslich, M. dan Hadjib, N. 2010. Peningkatan Pemanfaatan Jati Plus Perhutani (JPP) Untuk Kayu Lamina. Timur. *Jurnal Penelitian Hasil Hutan* 28(3).
- Nazri WM., Jamaludin K., Rudaini MN., Rahim S., Yuziah MYN. 2009. Effects of Chemical Components on Properties of Oriented Strand Board from *Leucaena leucocephala* Wood. *Journal of Tropical Forest Science.* 21 (4) : 353-360.
- Prayitno TA. 1992. Sifat Kimia Kayu Salam (*Zyzigium poliantha Wight*). Bulletin No: 22:53-65. Fakultas Kehutanan. Universitas Gajah Mada. Yogyakarta.
- Santana W.M., Calegario, N., Arantes, M.D.C., Trugilho, P.F. 2011. Effect of Age and Diameter Class On The Properties of Wood From Clonal *Eucalyptus*. *Cerne Lavras* 18 (1): 1-8.
- Sunyata A. 2011. Sifat Kimia Kayu Huru Kuning. Fakultas Kehutanan Institut Pertanian (INTAN) Yogyakarta.
- Wardenaar E., Mariani, Y., Husni, H., Diba, F., Yanti, H. *Distribusi Komponen Kimia Kayu Mahang (Macaranga hosei King)*. jurnal.untan.ac.id/index.php/tengkawang/article/view/4088/4102
- Zaki, J. A., Muhammed, S., Shafie, A., Daud, W.R.W. 2012. Chemical Properties Of Juvenile Latex Timber Clone Rubberwood Trees. *The Malaysian Journal of Analytical Sciences* 16 (3): 228-234.

MECHANICAL CHARACTERISTIC OF COCONUT AND OIL PALM EMPTY FRUIT BRUNCH FIBER BASED COMPOSITES WITH SOAKING TREATMENT IN VERTICAL GARDEN BOARD APPLICATION

M. Gopar and Ismadi

Research Center For Biomaterials-Indonesian Institute of Sciences
Jl. Raya Bogor KM 46, Cibinong, Bogor, Indonesia 16911

ABSTRACT

Urban population in the majority of city in the world has been increased every year. This case has caused the decrease of green space in the city settlement. One way to solve limitation of green space in the urban city settlement was by creating vertical garden at the wall of the urban house. For building the convenient vertical garden required specific characteristic of materials. Its materials have to strength enough, rigid, durable in differs of weather and also can be planted by more varies of plants. Materials candidate for vertical garden board were oil palm empty fruit bunch (OEFB) and coconut fiber (CF). The materials were very abundant in Indonesia and many of them not usage full yet. To examine the influence of soaking time on the physical and mechanics properties of fiber composites, it were made of composites with phenol formaldehyde adhesive. For seeking the best properties, OEFB and CF were soaked in the water for 2, 4, and 6 weeks. Then, the fibers dried in sun daylight until the moisture content of about 10-12%. The OEFB and CF then were tested with universal testing machine (UTM) for measuring the tensile strength. The fibers were dry blended with phenol formaldehyde (PF) concentration of 12% (based on oven dry weight fiber board). The fibers that had been given adhesive printed on mold size 25 x 25 x 0.8 cm and then compressed at a temperature of 145° C and pressured of about 10 kgf/cm² for 15 minutes. Target density is 0.3 g/cm³. Initial conditioning of the coconut fiber composites performed at room temperature in 2 weeks. Composite boards were tested for measuring mechanical properties and its physical characteristics. The characterization of the composites were MOE, MOR, screw withdrawal, internal bonding, water absorption, and thickness swelling.

Keywords : soaking treatment, coconut fiber, oil palm fruit bunch, composite, vertical board

INTRODUCTION

Indonesia has a great potency and diversity of natural fiber which has been used in the wide range of application. For the future, composite industry need green composites which more environmentally friendly, recyclable, light and strong. Urban population in the majority of city in the world has been increased every year. This case has caused the decrease of green space in the city settlement.

One way to solve limitation of green space in the urban city settlement was by creating vertical garden at the wall of the urban house. Settlements growing in the modern city were signed by sky-buildings expansion. All of the sky buildings were made from concrete, glass, steel and metals domination. The great settlements expansion reduces green free area. Therefore, increase the environment pollution such as air and sound pollution. The green area in the city settlements was something rare. For example, Jakarta City in 1983 has 32.185,9 hectares (50.2%) green area, and in 2002 decreased 159% to 9430.6 hectares (14.7%). The majority of field usage was to build huge sky-buildings^[1]. The concept of modern vertical park introduced by Patrick Blanc in 1994 which made park in limited area. The concept was always improving as long as modern people settlements. To build the convenient vertical garden required specific characteristic of materials. Its materials have to strength enough, rigid, durable in differs of weather and also can be planted by more varies of plants^[2,3]. Usage of natural fiber compare than synthetic fiber were renewable, biodegradable, recyclable, environment friendly, better mechanic characteristic and cheaper ^[4,5,6, 7]. Materials candidate for vertical garden board were oil palm empty fruit bunch (EFB-OP) and coconut fiber (CF). The materials were very abundant in Indonesia and many of them not usage full yet. More treatment was required to make natural fiber applicable in the vertical board application.

MATERIALS AND METHODS

This study used oil palm empty fruit bunch (OEFB) and coconut fiber (CF) as reinforcement materials and phenol formaldehyde (PF) as adhesive. PF was taken from PT. Palmolite Adhesive Indonesia, Jakarta, Indonesia, and oil palm empty fruit bunch (OEFB) and coconut fiber (CF) were taken from Sumedang, Indonesia. OEFB and CF were soaked in the water for 2, 4, and 6 weeks. Then, the fibers dried in sun daylight until the moisture content of about 10-12%. The fibers were dry blended with phenol formaldehyde (PF) concentration of 12% (based on oven dry weight fiber board). The fibers that had been given adhesive printed on mold size 25cm x 25 cm x 0.8 cm and then compressed at a temperature of 145° C and pressured at 10kgf/cm² for 15 minutes. Target density is 0.3 g/cm³. Initial conditioning of the coconut fiber composites performed at environment temperature for 2 weeks. Composite boards were tested for measuring mechanical properties and its physical characteristics depend on its treatment time. The characterization of the composites were MOE, MOR, screw with drawl, internal bonding, water absorption, and thickness swelling.

RESULTS AND DISCUSSION

The result of board testing represented on the figure below. Figure 1 and 2 show fiber strength in tensile test. Figure 1 shows that EFOB has higher tensile strength than CF at no soaking treatment. But, majority of fiber tensile strength value, CF have higher tensile strength than EFOB for other soaking treatment. The highest tensile strength was 144.84 MPa for EFOB with no soaking treatment. Soaking treatment for 6 weeks decreased fiber tensile strength from 144.84 MPa up to 55.65 MPa (61.58%) for EFOB and from 116.47 MPa up to 106.20 MPa (8.82%) for CF. Soaking treatment at CF relative made mechanically characteristic more stable than EFOB. Elongation of single fiber at EFOB and CF in Figure 2, did not have specific pattern. All of them relatively have 4-9 % in elongation, which the lowest value was 4.29 % for EFOB in 4 weeks soaking treatment and the highest was 8.87% for CF with no soaking treatment.

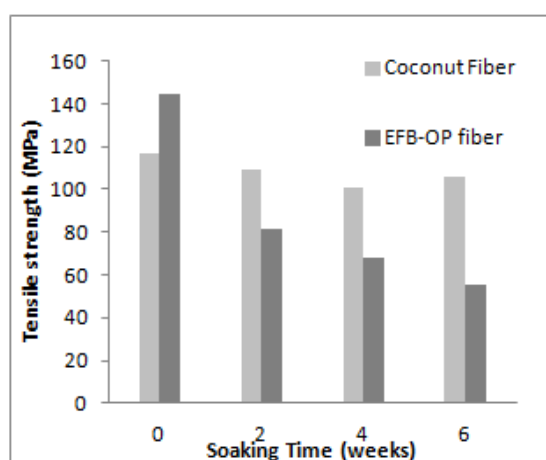


Fig.1. Tensile strength of natural Fiber with soaking time variation

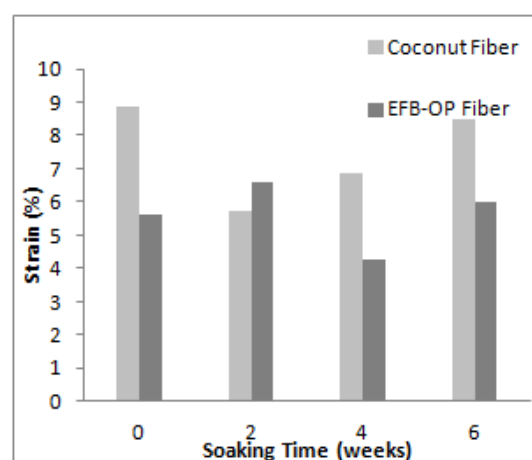


Fig.2. Elongation of Natural Fiber with soaking time variation

Figure 3 and 4 represented the value of flexural strength characteristic of the boards. Both EFOB and Cf have highest value of MOR at 4 weeks soaking treatment. Relatively, CF boards have higher value in MOR than EFOB boards. From Figure 3, highest value of MOR was 12.06 MPa at CF with 4 weeks soaking treatment, higher than EFOB at 7.24 MPa. After soaking treatment more than 4 weeks the value of boards decreased significantly. From the Figure 4, optimum value of boards was reached at 4 weeks soaking treatment too. The highest value of MOE was 319.16 MPa for CF boards with 4 weeks soaking treatment greater than 256.99 MPa for EFOB boards with no soaking treatment. Both, MOR and MOE of EFOB and CF boards relatively decreased after obtained the optimum time of soaking treatment.

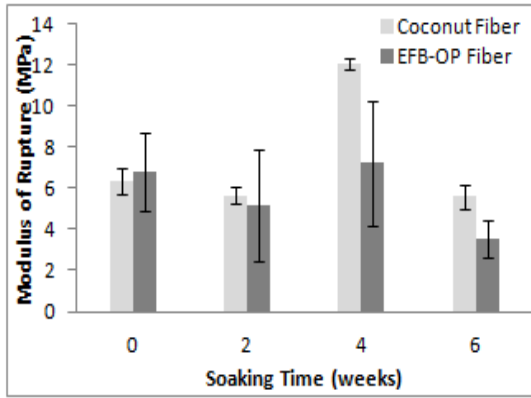


Fig.3. MOR of fiber board with soaking time variation

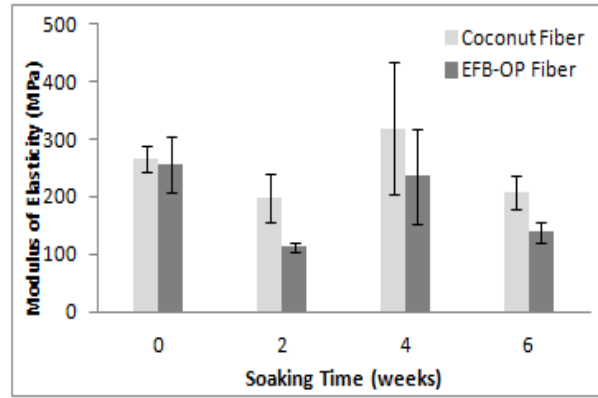


Fig.4. MOE of Fiber board with soaking time variation

Capability and dimension stability to provide water represented at Figure 5 and 6. Figure 5 represented capability of boards to absorb water. All of the boards with differs soaking treatment have water absorption value exceed than 100%. The water absorption increased which addition of time soaking duration. Water absorption of EFOB boards was higher than CF boards relatively. For EFOB boards the highest value of water absorption was 156.06 % at 6 weeks soaking treatment and for CF boards the highest value was 151.78 % for 2 weeks soaking treatment. In Figure 6, the data of thickness swelling of boards was represented. Thickness swelling of boards increased as increasing of soaking treatment duration. The lowest value of thickness swelling was 4.25 % for EFOB boards in 2 weeks soaking treatment.

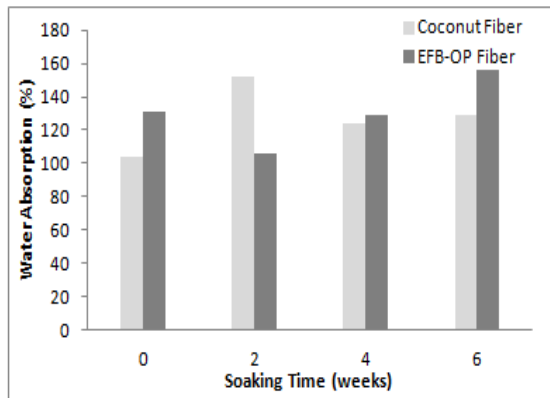


Fig.5. Water absorption with soaking time variation

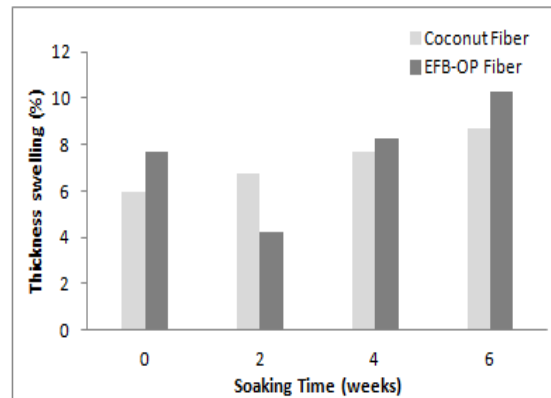


Fig.6. Thickness swelling with soaking time

The highest value of thickness swelling was 10.24 % for EFOB board in 6 weeks soaking treatment. In medium density boards standard (JIS A 5908), the value of thickness swelling must be lower than 12 % for excellent characteristic. Therefore, the value of thickness swelling of both CF and EFOB boards were passed in JIS standard. This result was excellent characteristic for medium vertical boards. It has high water absorption for providing water of the plant requirement which was stable at board dimension. This phenomenon could be caused by compatible bonding between fiber both EFOB and CF with phenol formaldehyde adhesive. High water absorption was caused by low density which was made much porous. But, compatible bonding made dimension of the boards more stable. Therefore, the boards have low thickness swelling value. On the Figure 7 and 8 represented the result of internal bonding and screw with drawl test. From the Figure 7, value of internal bonding was obtained optimum value at 4 weeks soaking treatment both EFOB and CF. From the figure below, CF boards have higher value than EFOB boards for all of the treatment. In the 4 weeks soaking treatment, CF boards obtained optimum value at 0.17 MPa, higher than EFOB board value at 0.09 MPa. Before and after 4 weeks soaking treatment, the value of internal bonding was significantly down. Internal bonding was influenced by fiber soaking treatment. Many impurities were obtained from the raw fiber. EFOB fiber has many impurities than CF. Soaking treatment reduced impurities from the raw fiber, therefore could increased internal bonding of the boards.

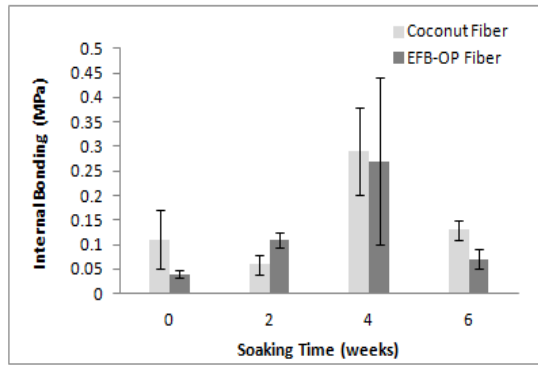


Fig.7. Internal Bonding value with soaking

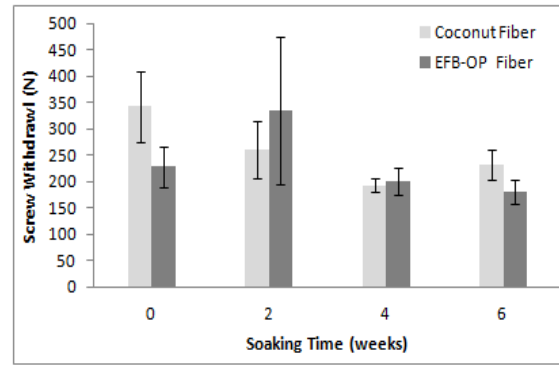


Fig.8. Screw with drawal with soaking time variation

Figure 8 shows value of screw with drawal of CF and EFOB board. From that figure above, the value of CF and EFOB boards did not have different significantly. The optimum value of screw with drawal of CF board was 335.19 N at no soaking treatment, and 342.24 N for EFOB for 2 weeks soaking treatment. After 2 weeks soaking treatment, the value of screw with drawal was decrease. Reducing of impurities at fiber could increase of bonding compatibility in the screw with drawal test.

CONCLUSION

The tensile strength of natural fiber (CF & EFB-OP) was decreased with increased of soaking time in the water. The mechanical properties of CF board shows better characteristic compare than EFB-OP. The mechanical properties of CF boards and EFB-OP (MOR, MOE, and IB) show the optimum value in 4 weeks soaking in the water.

REFERENCES

- [1]. Suwargana, N. and Susanto DETEKSI RUANG TERBUKA HIJAU MENGGUNAKAN TEKNIK PENGINDERAAN JAUH (STUDI KASUS: DI DKI JAKARTA). 14-15 September 2005. MAPIN XIV Annually Meeting, Surabaya,
- [2]. Cochrane T, 2010, Growing up the wall, The Guru, 36, pp. 04-06
- [3]. Direktorat Penataan Ruang, Kementerian Pekerjaan Umum.2012. http://www.penataanruang.net/detail_b.asp?id=1721.
- [4]. Mohanty, A.K., Misra, M., Drzal, L.T. 2002. Sustainable bio-composites from renewable resources: Opportunities and challenges in the green materials world. J. Polymers and the Environment, 10 (1/2): 19-26.
- [5]. Oksman, K., Skrifvas, M., Selin, J.F. 2003. Natural fibers as reinforcement in polylactic acid (PLA) composites. Composites Science and Technology 63: 1317-1324.
- [6]. Wambua, P., Ivens, J., Verpoest, I. 2003. Natural fibres: can they replace glass in fibre reinforced plastics?. Composites Science and Technology 63: 1259-1264.
- [7]. Zimmermann, T., Pohler, E., Geiger, T. 2004. Cellulose fibrils for polymer reinforcement. Advanced Engineering Materials 6 (9): 754-761.

MECHANICAL CHARACTERISTIC OF COCONUT FIBER BASED COMPOSITES WITH TIME WATERING VARIATION IN VERTICAL GARDEN BOARD APPLICATION

Ismadi, M. Gopar, Ismail Budiman, and Subyakto

Research Center for Biomaterials-Indonesian Institute of Sciences
Jl. Raya Bogor KM 46, Cibinong, Bogor, Indonesia 16911
Email : ismadi.0481@gmail.com

ABSTRACT

The convenient vertical garden required specific characteristic of materials. The materials should be strength enough, rigid, durable in differs of weather and also can be planted by more varies of plants. Material candidate for vertical garden board was coconut fiber (CF). The materials were very abundant in Indonesia and many of them not usage full yet. To examine the influence of watering time on the physical and mechanics properties of the composites, it was made of composites with phenol formaldehyde adhesive. For seeking the best properties, coconut fiber was soaked in the water for 0, 2, 4, and 6 weeks. The fibers dried in sun daylight until the moisture content of about 10-12%. The fibers were dry blended with phenol formaldehyde (PF) concentration of 12% (based on oven dry weight fiber board). The fibers that had been given adhesive printed on mold size 25 x 25 x 0.8 cm and then compressed at a temperature of 145° C and pressured of about 10 kgf/cm² for 15 minutes. Target density is 0.3 g/cm³. Initial conditioning of the coconut fiber composites performed at environment temperature, and varied watering treatment for 0, 1, 2, and 3 months. The composites material will get watering two times every day as long as the time variation. Composite boards were tested for measuring mechanical properties and its physical characteristics depend on its treatment time. The characterization of the composites were MOE, MOR, screw with drawl, internal bonding, water absorption, and thickness swelling.

Keywords : watering treatment, coconut fiber, composite, vertical board

INTRODUCTION

Urban population in the majority of city in the world has been increased every year. This case has caused the decrease of green space in the city settlement. One way to solve limitation of green space in the urban city settlement was by creating vertical garden at the wall of the urban house. Cochrane ^[1] reported that cost investment of vertical garden system in 2007 up to US \$ 2,500-10,000/m². Therefore, development of vertical garden system was stagnant. But, the newest innovations in the last years could reduce the cost of production up to US\$ 125-150/m², so development of VGM can be continue. The convenient vertical garden required specific characteristic of materials. The materials should be strength enough, rigid, durable in differs of weather and also can be planted by more varies of plants. Material candidate for vertical garden board was coconut fiber (CF). The materials were very abundant in Indonesia and many of them not usage full yet. Coconut fruits production in Indonesia reach 15,5 billion /years, within 3,75 million tons of coconut water, 0.75 million ton of coconut charcoal, 1,8 million tons of coconut fiber and 3,3 million tons of coconut dust ^[2]. The advantages of natural fiber usage compare than synthetic and plastic materials were renewable, biodegradable, recyclable, safely, the better mechanical properties, cheaper, and lighter ^[3,4,5,6]. For building application, the convenient vertical garden required specific characteristic of materials. Its materials have to strength enough, rigid, durable in differs of weather and also can be planted by more varies of plants. Material candidate for vertical garden board was coconut fiber (CF). More treatment was required to make natural fiber applicable in the vertical board application.

MATERIALS AND METHODS

This study used coconut fiber (CF) as reinforcement materials and phenol formaldehyde (PF) as adhesive. PF was taken from PT. Palmolite Adhesive Indonesia, Jakarta, Indonesia, and coconut fiber from Sumedang, West Java, Indonesia. Coconut fiber was soaked in the water for 0, 2, 4, and 6 weeks. The fibers dried in sun daylight until the moisture content of about 10-12%. The fibers were dry blended with phenol formaldehyde (PF) concentration of 12% (based on oven dry weight fiber board). The fibers that had been given adhesive printed on mold size 25cm x 25 cm x 0.8 cm and then compressed at a temperature of 145° C and pressured of about 10 kgf/cm² for 15 minutes. Target density is 0.3 g/cm³. Initial conditioning of the coconut fiber composites performed at environment temperature, and varied watering treatment for 0, 1, 2, and 3 months. The composites material will get watering two times every day as long as the time variation. Composite boards were tested for measuring mechanical properties and its physical characteristics depend on its treatment time. The characterization of the composites were MOE, MOR, screw with drawl, internal bonding, water absorption, and thickness swelling.

RESULTS AND DISCUSSION

Results of the study were represented below. For mechanically testing, the result was represented on the Figure 1 and 2 below. As seen on the Figure 1, value of CF boards on screw with drawl testing show impressive results as function of watering times. The CF which soaked in the water has stability in screw with drawl ability. The value was increasing as long as water soaking. In the longest watering time, soaking in the water for 6 weeks has the best value.

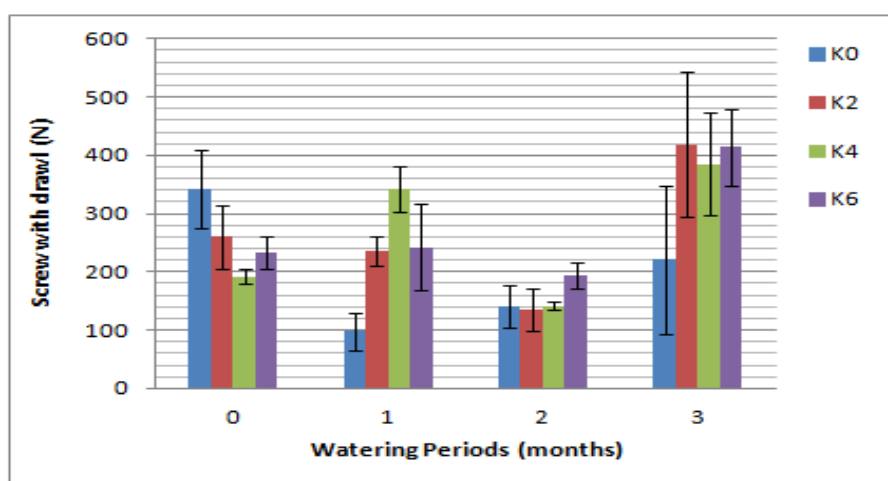


Figure 1. Screw with drawl of CF boards with variation of watering periods.

For the internal bonding test, as represented on Figure 2, CF boards with water soaking treatment in 4 weeks was the best result. Their result decreased as function of watering time. Furthermore, optimum value of internal bonding was 0.29 MPa obtaining on board with CF in 4 weeks of water soaking. The result show that internal bonding decreased as increasing of watering time. From Figure 2, board with CF no water soaking has the lowest value of internal bonding at all variation of watering time.

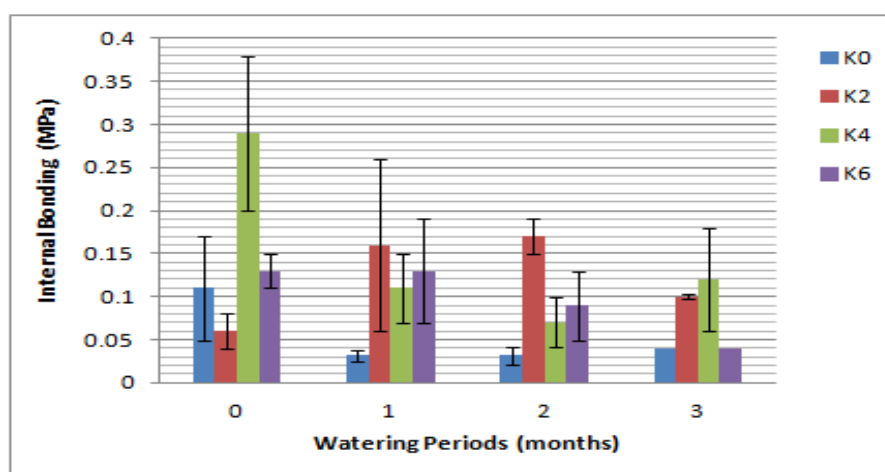


Figure 2. Internal Bonding of CF boards with variation of watering periods.

Figure 3 and 4 showed the value of Modulus of Elasticity (MOE) and Modulus of Rupture (MOR) which were obtained from flexural test. Value of bending MOE and MOR decreased slightly with the increased watering time of composites and gets minimum value in 2 months. For fresh cut of CF boards, bending MOE and MOR value were optimum when coconut fiber soaking in water for 4 weeks. Bending MOE of CF board with 4 weeks of water soaking on 0, 1, 2, and 3 watering time were 157, 88, 35 and 160 MPa.

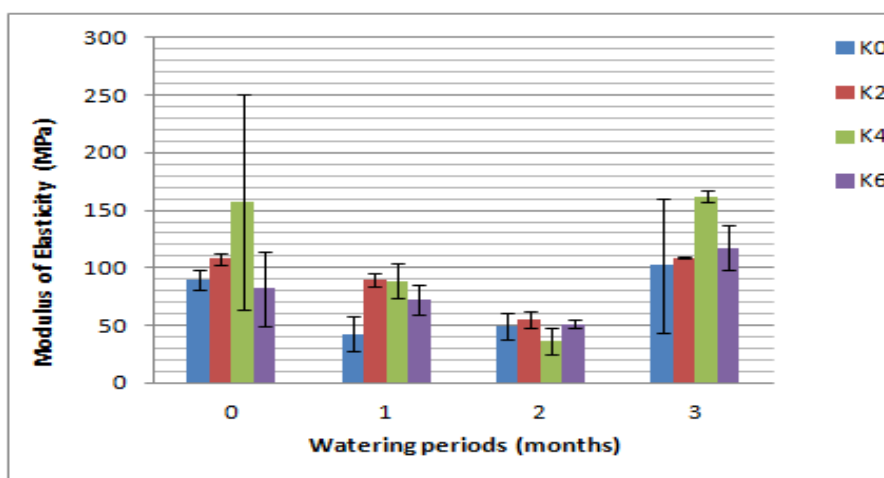


Figure 3. Modulus of Elasticity of CF boards with variation of watering periods.

The recorded optimum flexural strength was 12 MPa for fresh cut of CF boards with soaking treatment 4 weeks in the water. All of the watering time, CF with soaking in 4 weeks has optimum value of MOE and MOR except in 2 month of watering time been the lowest.

CF boards have medium density which suitable for agricultural application. For agricultural application CF boards should resistant in water treatment. CF boards should have high stability in weather change and watering soaking condition. Hence, treatment with watering the CF boards twice a day along the time was required to obtain the best characteristic of CF boards. Value of thickness swelling of CF boards with 0, 2, 4, and 6 weeks of water soaking were 5.9, 6.8, 7.7, and 8.7%.

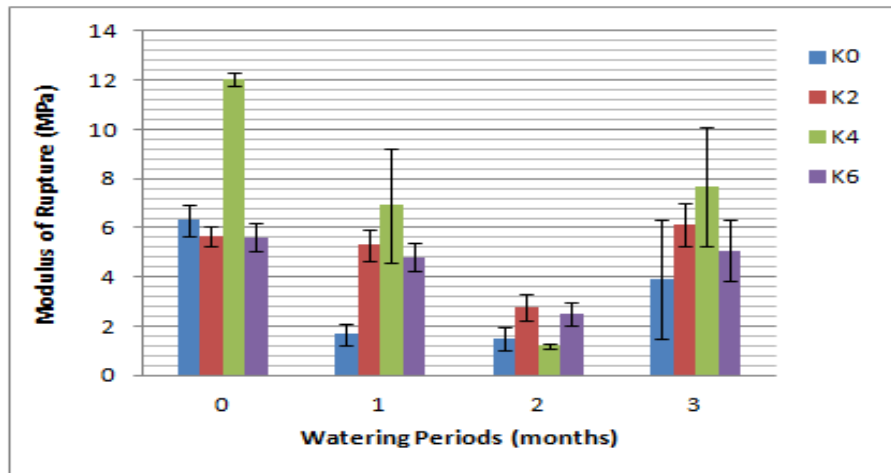


Figure 4. Modulus of Rupture of CF boards with variation of watering periods.

Figure 5 represented water absorption of CF boards in watering treatment. CF boards with no soaking treatment represented on Figure 5a will get stability in water absorption at day of 37th.

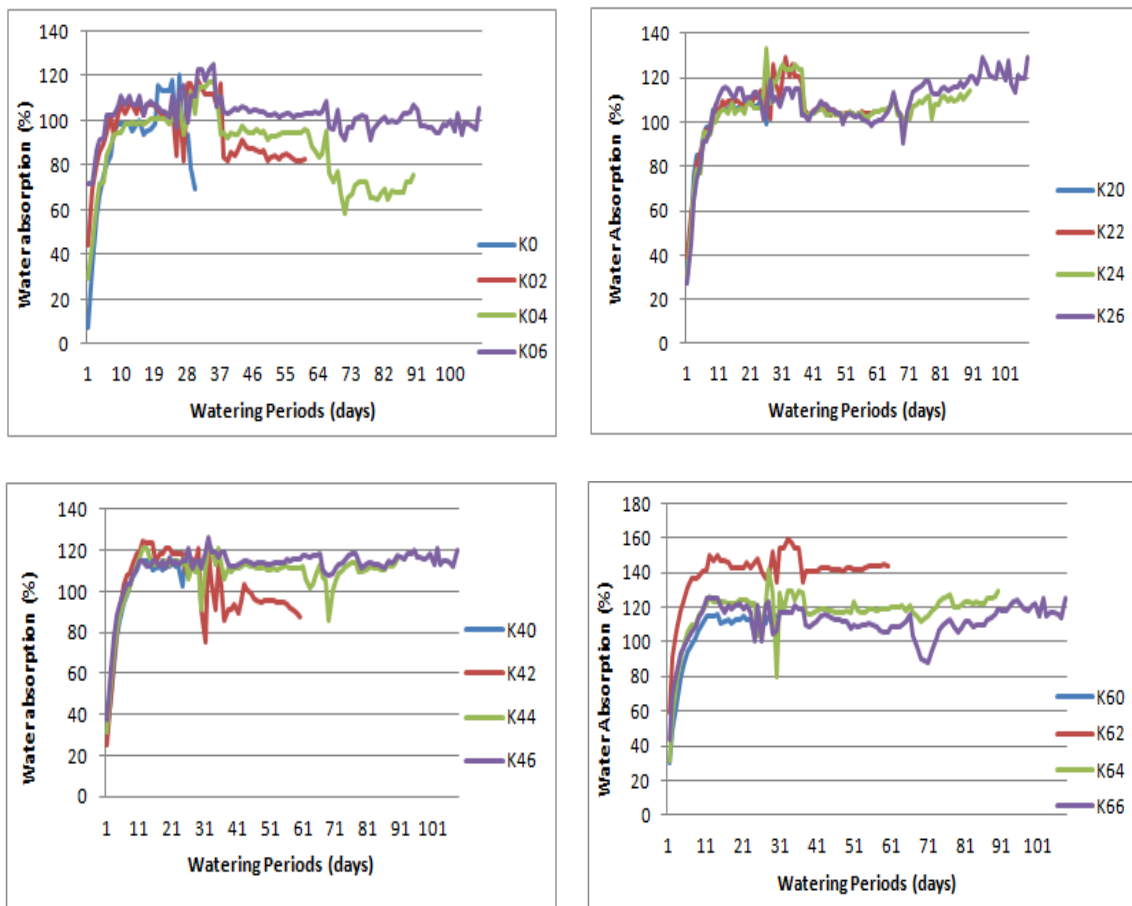


Figure 5. Water Absorption of CF boards with variation of watering periods;
 a) CF without soaking treatment, b) CF with 2 weeks soaking treatment ,
 c) CF with 4 weeks soaking treatment, d) CF with 6 weeks soaking treatment.

CF boards contain CF with 2, 4 and 6 weeks of soaking treatment represented on Figure 5 b, c and d get stability in water absorption at day of 35th, 31th, and 32th. Water absorption of CF board with 0, 2, 4 and 6 weeks soaking treatment were stable in 100, 115, 112, and 120%. Stability of water absorption represented quality of CF boards. It could guarantee plant to survive better.

SUMMARY

The mechanical and physical properties of MDF composites based on coconut fiber were successfully obtained. Mechanical properties of CF boards (MOR, MOE, and IB) show the optimum value in 4 weeks soaking in the water. The mechanical properties of CF boards decreased in order increasing time of watering. CF boards have high stability; CF thickness swelling under 10% along watering treatment. CF boards could absorb much water in stable dimension

ACKNOWLEDGEMENT

The authors would like to thank for Indonesian Institute of Sciences for fund supporting .

REFERENCES

- [1] Cochrane T, 2010, Growing up the Wall, The Guru, 36, pp. 04-06 .
- [2] Indonesian Agency for Agricultural Research and Development-Ministry of Agriculture 2015.
- [3] Mohanty, A.K., Misra, M., Drzal, L.T. 2002. Sustainable Bio-Composites From Renewable Resources: Opportunities And Challenges In The Green Materials World. *J. Polymers and the Environment*, 10 (1/2): 19-26.
- [4] Oksman, K., Skrifvas, M., Selin, J.F. 2003. Natural Fibers As Reinforcement In Polylactic Acid (pla) Composites. *Composites Science and Technology* 63: 1317-1324.
- [5] Wambua, P., Ivens, J., Verpoest, I. 2003. Natural Fibres: Can They Replace Glass In Fibre Reinforced Plastics?. *Composites Science and Technology* 63: 1259-1264.
- [6] Zimmermann, T., Pohler, E., Geiger, T. 2004. Cellulose fibrils for polymer reinforcement. *Advanced Engineering Materials* 6 (9): 754-761.

MORPHOLOGY AND PHYSICAL CHARACTERISTICS OF POLYPROPYLENE-PULPED EMPTY FRUIT BUNCH FIBER COMPOSITES WITH CHITOSAN AS FILLER

Kurnia Wiji Prasetyo and Lisman Suryanegara

Research Centre for Biomaterials, Indonesian Institute of Sciences,
Jalan Raya Bogor KM 46 Cibinong Bogor Indonesia

ABSTRACT

Thermoplastic composites is still dominated by petroleum-based polymers. This condition encourage many studies on the possibility of using natural fibers or organic materials as filler in place of synthetic fibers or inorganic materials to reduce the dominance of synthetic polymers. The purpose of this research was to examine the effect of added chitosan as filler on morphology and physical characteristics of polypropylene-pulped empty fruit bunch fiber composites. Variations in the size and concentration of chitosan used as a parameter in this study. The compound of composites were processed by laboplastomill using the dry method at a temperature of 180° C, 60 rpm for 20 minutes. Composites were molded in sheet form size 11 x 11 x 0.2 cm with temperature of 180° C, pressure of 1 MPa for 30 seconds and 10 minutes followed felt cold. The morphology and physical properties of composites were evaluated by light microscope, SEM, FTIR, TGA and physical test. Result showed that variations in the size and concentration of chitosan affects the homogeneity of the mixture and thus affects the physical and morphological characteristics of composites.

Keywords: polypropylene, pulped empty fruit bunch fiber, chitosan, filler, composites, morphology and physical characteristics

INTRODUCTION

High oil process have induced a change in consumption habits. Renewable and low energy cost materials are gaining popularity. This condition encourage many studies on the possibility of using natural fibers or organic materials as filler in place of synthetic fibers or inorganic materials to reduce the dominance of synthetic polymers. The use of light weight, renewable natural materials instead of heavy metal or mineral-based materials is important to generate lighter materials. It has been used as a filler in thermoplastic composites. However, the main disadvantage in natural fibers-synthetic polymer composites is the poor compatibility between the hydrophobic properties from polymer matrix and the hydrophilic properties of natural fibers.

Polypropylene (PP) is the most important commercial plastic currently used as the matrix polymer in composites because of its relatively superior properties such as high melting temperature (T_m), excellent mechanical and thermal properties, and low density (Husseinsyah et.al. 2010). Natural fiber-PP composites have acceptable mechanical properties but surface incompatibility and water absorption from composites are still major problems. These problems are caused by the hydrophilic hydroxyl groups existing in the natural fiber's structure.

Chitosan polymers is natural aminopolysaccharides having unique structures, multidimensional properties, highly sophisticated functions and wide ranging applications in biomedical and other industrial areas (Muzzarelli et al. 2005). Chitosan is a biopolymer and biodegradable in the natural environment. Some researchs have been done to improve the properties of thermoplastic composites for example with chitosan as filler. According Husseinsyah et al. (2011), chitosan as filler with chemical modification by acrylic acid could be increased Young's modulus of PP composites. This phenomena shows that chitosan promise as a bio-filler in composites to replace various materials such as synthetic polymer plastic and construction materials products.

In this research, homopolymer polypropylene was used as the matrix and pulped empty fruit bunch fiber used as the reinforcing filler to prepare composites. Poor interfacial bonding between PP and pulped

empty fruit bunch fiber reduces the homogeneity and compatibility of the composites. Therefore, the addition of chitosan as filler be expected to improve the properties of PP-pulped empty fruit bunch fiber composites with variations in the size and concentration of chitosan used as a parameter. The presence of free amino groups in chitosan can be a coupling agent between PP and pulped empty fruit bunch fiber.

The aims of this research was to investigate the effect of added chitosan as filler on morphology and physical characteristics of polypropylene-pulped empty fruit bunch fiber composites.

MATERIALS AND METHODS

Homopolymer polypropylene (PP) used in this study was obtained from PT. Tri Polyta Cilegon Banten Indonesia with type HI10HO. Chitosan was industrial grade obtained from PT. Biotech Surindo Cirebon Indonesia with degree of deacetylation (DD) of 90%. Maleic anhydride polypropylene (MAPP) UMEX 1001 Lot No. GI8070244 from Sanyo Chemical Industries Kyoto Japan was used in this study.

The composites production process begin with the manufacture of pulp fibers empty fruit bunch using soda pulping process that draws on research Gopar et al. [4] where the fiber bundle of empty fruit bunch fiber was cutted about 2 to 3 cm using ring flaker machines. Fibers was immersed in a solution of 4% NaOH ratio (1 : 5) for 24 hours. Proceed with the manufacture of pulped empty fruit bunch fiber was used disc refiner machine. The process of making thermoplastic composites with PP matrix was carried out with dry method which refers to the results of research Subyakto et al. (2010). Pulped fibers from empty fruit bunch made into a fairly thin sheet of paper with a filter size of 40 mesh gauze and dried, then shredded into small size. Empty fruit bunch fibers then blended with PP in comparison 50 : 45 (%) then added with 5% MAPP (referring to research Gopar et al. 2010) of the total weight of the composites as a coupling agent in the laboplastomill machine. PP substitution with chitosan are varied in composition chitosan : PP (%) = 0 : 100, 10 : 90, 20 : 80, 30 : 70 and 40 : 60 of the total 45% from the overall PP in thermoplastic composites then processed with laboplastomill at a temperature of 180° C, 60 rpm for 20 minutes.

Composites samples were sheet from with length x width x thickness = 11 x 11 x 0.2 cm. This samples made using hot press machine at a temperature of 180° C, a pressure of 1 MPa for 30 seconds followed felt cool 10 minutes by cold press machine were referred from research Subyakto et al. (2010) with a target density of 1.0 g/cm³. The morphology and physical properties of composites were evaluated by light microscope, SEM, FTIR, TGA and physical test.

RESULTS AND DISCUSSION

Phisically, all the material of thermoplastics composites has been mixed during mixing process in laboplastomill. However, the results of imaging with light microscope for PP-pulped empty fruit bunch fiber composites still visible white spots from chitosan filler that has not decomposed perfectly (Figure 3-4).

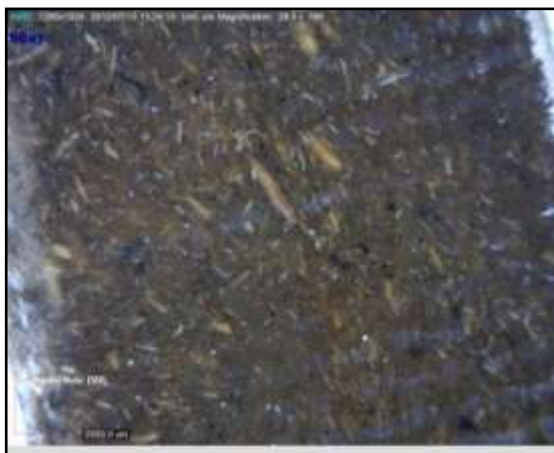


Figure 1. Surface of composite without chitosan

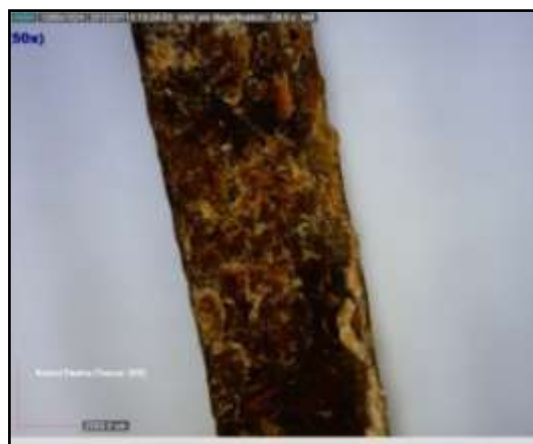


Figure 2. Surface of tensile fracture from composite without chitosan

In the other hands, it is possible to observe the appearance of pulped empty fruit bunch fiber on the surface of composites without chitosan (Figure 1-2) due to the use of the fiber in microsize.

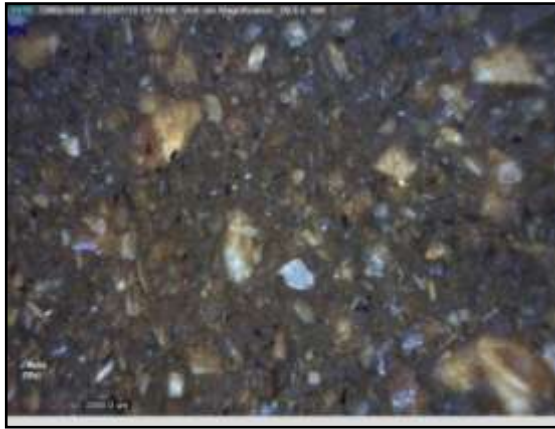


Figure 3. Surface of composite by chitosan filler

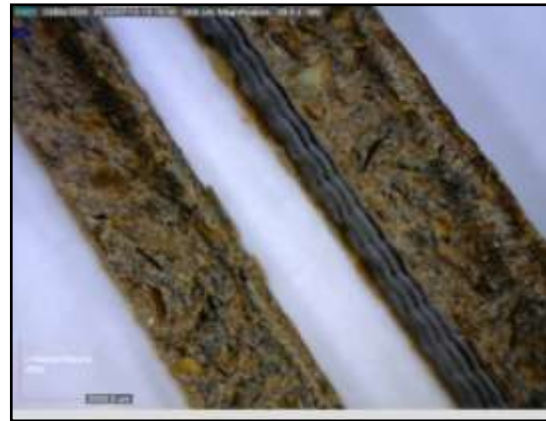


Figure 4. Surface of tensile fracture from composite by chitosan filler

The SEM micrographs of the tensile fracture surface from composites without chitosan (Figure 5) exhibit poor wetting of pulped empty fruit bunch fiber by the PP matrix. It can be seen that the fracture occurred at the interface of fiber and the matrix that the fiber was pulled out because of the insufficient adhesion between pulped empty fruit bunch fiber and the PP matrix. This fact also can be call agglomeration. The occurrence of agglomeration is due to differences between the decomposition temperature of chitosan materials were particularly higher than PP matrix, fibers and hot temperatures are used. Decomposition temperature difference between material causes mixing process is not perfect so there is still material to agglomerate in some areas. However, for composites by chitosan filler (Figure 6-7), the fractured surfaces show that chitosan was covered by layers and there was less pull-out from PP matrix. This result showed that adding chitosan has improved interfacial bonding between chitosan an the matrix and increased the homogeneity and compatibility of composites.

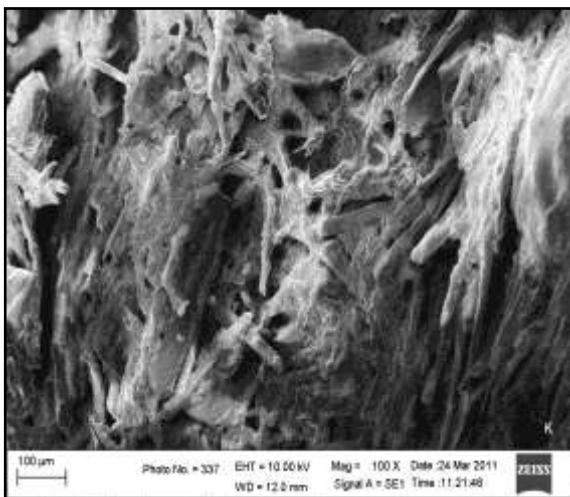


Figure 5. SEM micrograph of tensile-fractured surface from composites without chitosan at magnification 100x

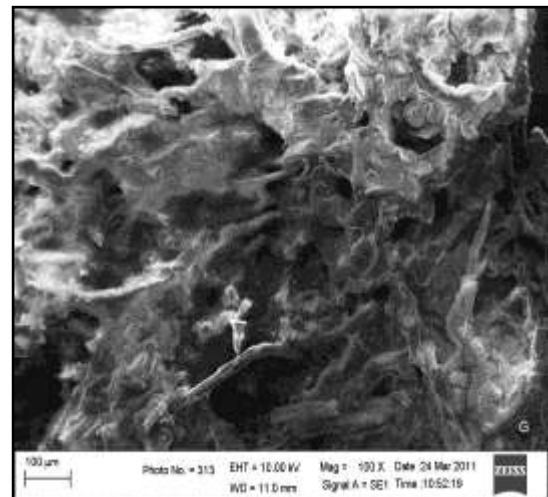


Figure 6. SEM micrograph of tensile-fractured surface from composites by chitosan (20 to 40 mesh in size) at magnification 100x

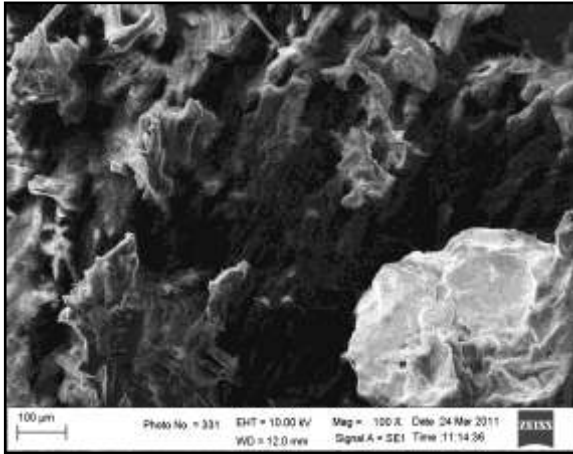


Figure 7. SEM micrograph of tensile-fractured surface from composites by chitosan (10 mesh in size) at magnification 100x

Figure 8-9 shows the thermogravimetric analysis (TGA) of PP-pulped empty fruit bunch fiber (Figure 9) and PP-pulped empty fruit bunch fiber-chitosan (Figure 8) composites. The phenomena of persistence from chitosan spots at composites related to the decomposition temperature of chitosan itself which results from concerning TGA test (Figure 8) for chitosan is approximately 270° C-450° C. In this range corresponds to the degradation and deacetylation of chitosan. So, the mixing and hot pressing temperature at 180° C have not been able to melt and composed chitosan filler completely. According Kaban (2009), chitosan tends to decompose rather than melt at the time of heating. In figure 9 can be seen that composites without chitosan filler might undergo a one-step degradation process from 300° C-450° C.

This result confirmed that PP has carbon-carbon bonds in the main chain that allow a temperature increase to promote random scission with associated thermal degradation and thermal depolymerization occurring at the weak sites of the chain. So, increasing chitosan filler had a positive effect on thermal stability of the composites due to enhanced interfacial adhesion and formation of the covalent bond between the chitosan amino group and PP-pulped empty fruit bunch fiber.

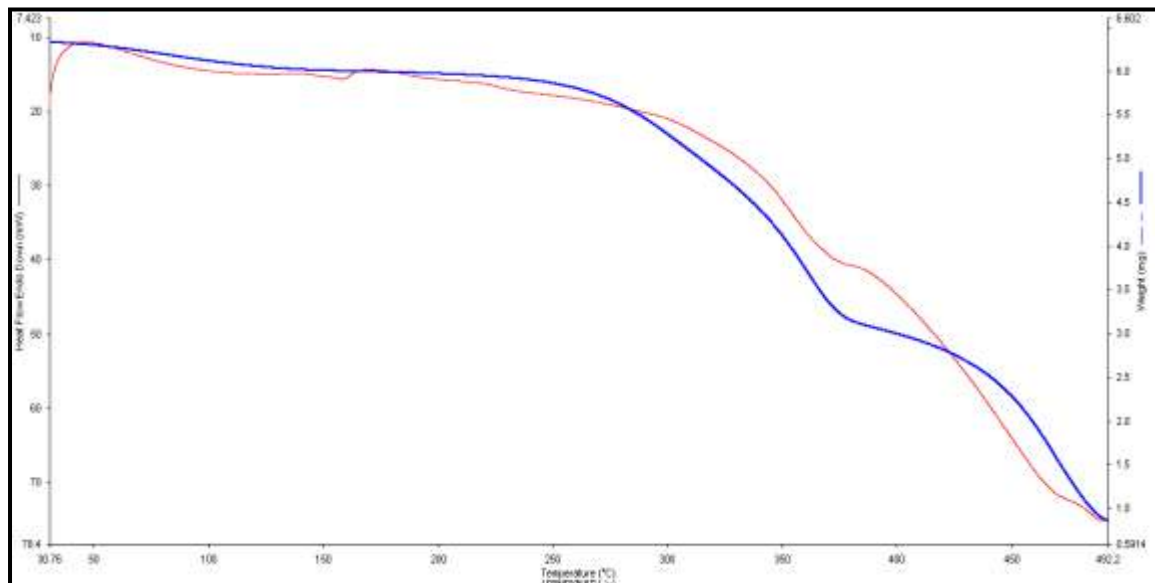


Figure 8. TGA curves of PP-pulped empty fruit bunch composites by chitosan filler.

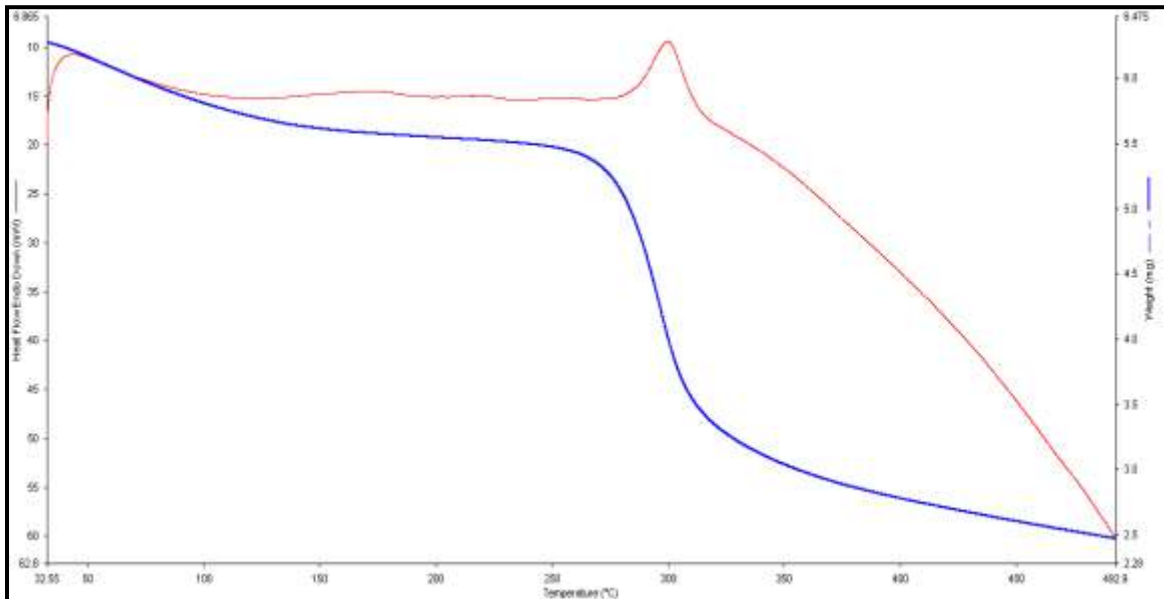


Figure 9. TGA curves of PP-pulped empty fruit bunch composites without chitosan filler.

According Bangyekan et al. (2006), structure of chitosan is similar to cellulose but contains NH_2 group at position C-2 hydroxyl group. So it is possible that wave absorption band is found in the FTIR spectra are similar between the composite control with the composite by chitosan filler. The difference of decomposition temperature between PP and fiber which lower than chitosan resulted unperfect compound mixing. This is evidenced by the absence of new functional groups that would indicate the occurrence of chemical bonds between the chitosan with PP and fibers.

The increasing of absorption wave from 1050 cm^{-1} (Figure 10) to 1114 cm^{-1} (Figure 11) have not shown the occurrence of chemical bonds but only an indication of the physical bond between chitosan with PP matrix and fibers. According to Kaban (2009), that blends physics is physically blending process between two or more types of polymers that have different structures and do not form covalent bonds between components.

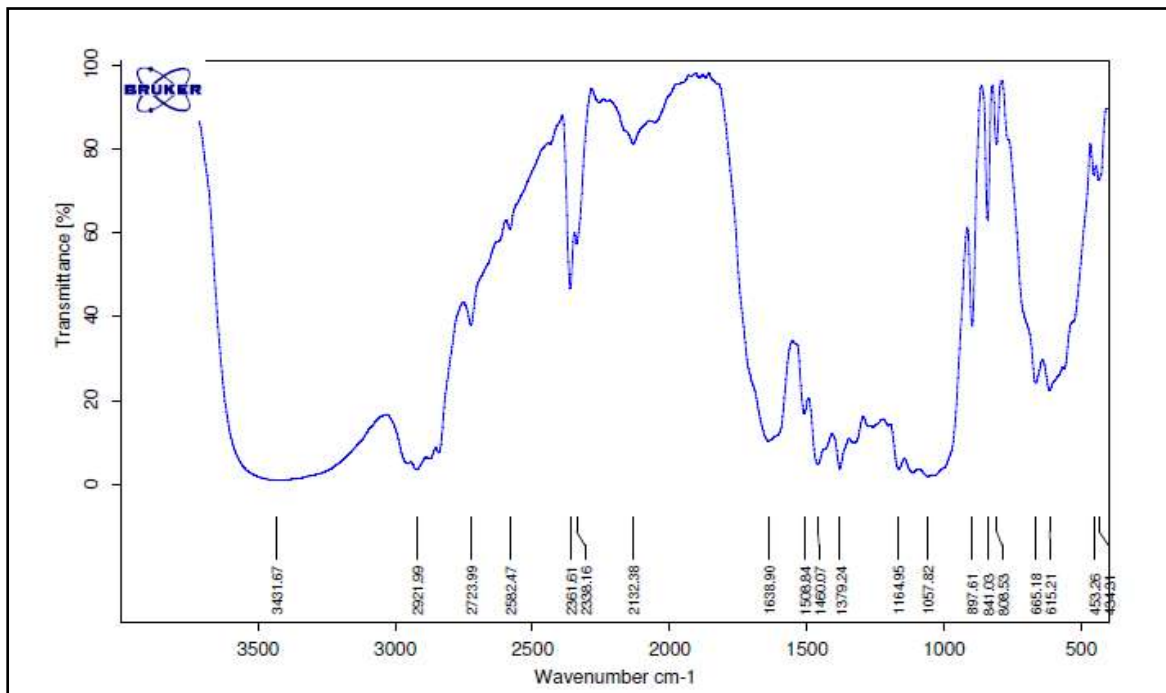


Figure 10. FTIR spectra of PP-pulped empty fruit bunch composites without chitosan filler.

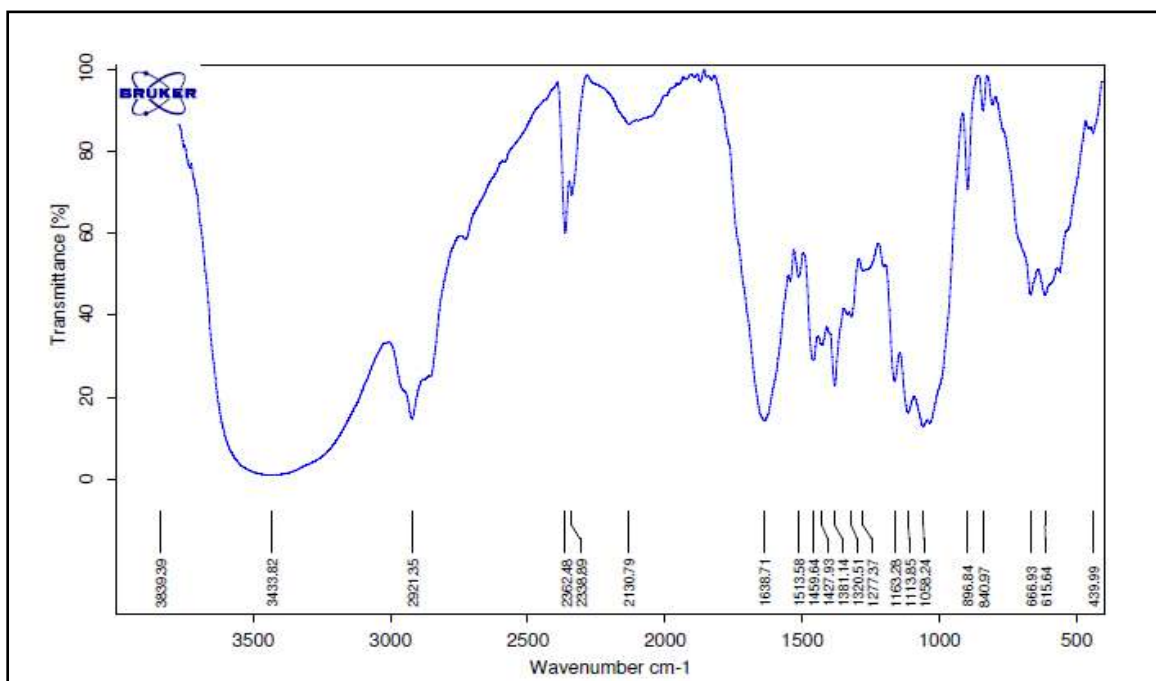


Figure 11. FTIR spectra of PP-pulped empty fruit bunch composites by chitosan filler.

CONCLUSION

The influence of added chitosan filler on the morphology and physical properties of composites were examined. Commonly, the results showed that variations in the size and concentration of chitosan affects the homogeneity of the mixture and thus affects the physical and morphological characteristics of composites. Decomposition temperature difference between material causes mixing process is not perfect so there is still material to agglomerate in some areas. Studies by SEM, the fractured surfaces on composites by chitosan showed that chitosan was covered by layers and there was less pull-out from PP matrix. This result showed that adding chitosan has improved interfacial bonding between chitosan and the matrix and increased the homogeneity and compatibility of composites. The increasing of absorption wave have not shown the occurrence of chemical bonds but only an indication of the physical bond between chitosan with PP matrix and fibers, however the thermal stability of composites by chitosan filler was higher than composites without chitosan.

ACKNOWLEDGMENT

This work was supported by Competitive Program of Indonesian Institute of Sciences 2014. This paper is also a part of the outcome of the DIPA Program of LIPI 2014: The Manufacture of Bionanocomposites Based on Microfibril Cellulose for Raw Materials Industry.

REFERENCES

- Bangyekan, C., Aht-Ong, D. and Srikulkit, K. 2006. Preparation and Properties Evaluation of Chitosan Coated Cassava Starch Films. *Journal of Carbohydrate Polymers*, 63, 61-71.
- Gopar, M., Subyakto, Prasetyo, K.W. and Ismadi. 2010. Characteristics of Plastic Biocomposites from Empty Fruit Bunch Microfibers. *Proceedings The 13th National Seminar of MAPEKI 10-11 Nov. Sanur, Bali*.
- Husseinsyah, S., Amri, F., and Husin, K. 2010. Chemical modification of chitosan-filled polypropylene (PP) composites: The effect of 3-Aminopropyltriethoxysilane on mechanical and thermal properties. *International Journal of Polymeric Materials*, 60:429-440.

- Husseinsyah, S., Amri, F., Husin, K., and Ismail, H. 2011. Mechanical and thermal properties of chitosan-filled polypropylene composites: The effect of acrylic acid. *Journal of vinyl and additive technology*.
- Kaban, J. 2009. *Chemical Modification of Chitosan and Product Application*. Inagural Speech: Noth Sumatra University-Medan.
- Muzzarelli RAA. and Muzzarelli C. 2005. Chitosan chemistry: relevance to the biomedical sciences. *Advanced Polymer Science*. 186: 151-209.
- Subyakto, Hermiati, E., Yanto, D.D.H, Masruchin, N., Fitria, Prasetyo, K.W and Ismadi. 2010. Biocomposites of PLA Reinforced with Sisal or Bamboo Microfibers. *Proceedings The First International Symposium of IWORS 2-3 Nov*. pp. 106-110.

THE EFFECTIVENESS OF ANTIARIS AND KI PAHIT BARK EXTRACTS AGAINST SUBTERRANEAN TERMITE *Coptotermes curvignatus* THROUGH MACERATION AND SOXHLET METHODS

Arief Heru Prianto

Research Center for Biomaterials-Indonesian Institute of Sciences
Jl. Raya Bogor Km.46, Cibinong, Bogor 16911, Indonesia

ABSTRACT

This study was conducted to compare the effectiveness of bark extract of *Antiaris toxicaria* (*Antiaris*) and *Picrasma javanica* (*Ki Pahit*) with a maceration and soxhlet methods toward subterranean termite *Coptotermes curvignatus*. This research was conducted in some stages. They were sample extraction, the extract application on termites and data analysis. Extraction has been done by two ways. They were maceration and soxhlet. Four different polarity solvents were used. They are n-hexan, ethil acetate, acetone and methanol. The extracts were applied to termites by paper disk baiting. Termites mortality rate was then analyzed. The result showed that bark extract of *Antiaris toxicaria* (*Antiaris*) and *Picrasma javanica* (*Ki Pahit*) obtained by maceration was more effective to *Coptotermes curvignatus* rather than the ones obtained by soxhlet.

Key words : extract, maceration, soxhlet.

INTRODUCTION

The resistance of wood on termite attack is depend on its extractives. It is well known that wood extractives were responsible for natural durability of wood, but it has different level of toxicity. So, there were many research to isolate the toxic compound from wood. Effectiveness of each extract has been reported by many researcher, such as Indrayati (1987), Syafii (2001), Falah *et al* (2005), Shibutani and Katayama (2005).

Plant basically has the mecanism to protect themselves from insect attack. Falah (2004) reported that bark has some substances that were distasteful, reppelent, or toxic to termite. Generally, study on evaluation of antitermite activities of extract used maceration method. Due to many kinds of compound in plant, study on extraction using soxhlet method is expected to result more compound that will extracted. The aims of the research are to compare the effectively of bark extract of *Antiaris toxicaria* (*Antiaris*) and *Picrasma javanica* (*Ki Pahit*) with a maceration and soxhlet methods toward subterranean termite *Coptotermes curvignatus*.

MATERIAL AND METHODS

Extraction by maceration

250 grams of powder samples were extracted using n-heksan with ratio 1: 6 (w / w) and then were soaked for 24 hours. Extract and residue were separated by filtering. The residue was extracted with a second solvent ethyl acetate for 24 hours. After that the residue was extracted again with solvent acetone and methanol. Each solution was extracted and then was concentrated with a rotary vacuum evaporator at a temperature of 45 °C, then dried and weighed.

Extraction by Soxhlet

The extraction procedure was refered to ASTM D1107-56. Two grams air dried sample was extracted using soxhlet methods, extraction temperature ranges from 80 – 85 °C, and the extraction was carried out until the time it took. In the last cycle of the heater was turned off, and then samples were removed from soxhlet and the solvent was evaporated. Each performed five replications.

Bioassay Test

Anti-termite test referred to Prianto *et al* (2005). Paper discs with oven-dried at a temperature of 60 °C for three days. Paper disc was treated by 5 % and 10 % extracts and were vacuumed in dessicator to evaporate the solvent. Treated paper disc and 50 termites worker and 5 termites soldier of *Coptotermes sp*, were entered in petri disc coated by plaster paris 3 mm. Each treatment (concentration) and controls were performed three replications. Termites mortality was observed per two days and in the end of observation the weight loss of paper disc also was measured.

RESULT AND DISCUSSIONS

Rendemen

Rendemen was obtained by extraction using two methods and four kinds of solvent. Rendemen of Antiaris bark and Ki pahit bark could be seen in Tables 1.

Tabel 1. Extract rendemen of Antiaris and Ki pahit bark

Solvent	Rendemen of Antiaris (%)		Rendemen of Ki pahit (%)	
	Maceration	Soxhlet	Maceration	Soxhlet
n Hexane	0,47	3,17	0,89	5,82
Ethyl acetate	0,45	2,95	1,55	5,38
Aceton	0,14	4,03	1,04	6,55
Methanol	0,99	4,78	7,50	12,78

In Table 1 could be seen that the extractive contents of the Antiaris and Ki pahit bark were varied. The using soxhlet in extraction gave rendemen was greater than maceration, both of the Antiaris and Ki pahit. This was due to temperature extraction of soxhlet was higher than maceration It was indicated that temperature during extraction affected to the solubility level of compounds, if the temperature increased the solubility of the compounds also would increase. From the result of the experiments was known that kind of solvent was also determine the total of rendemen. Methanol produced extract greater than ethyl acetate, acetone, and n-heksan. This was indicated that the compound contained in the bark of Antiaris and Ki pahit polar largely.

Termites Mortality

Termite mortality rate by extract with maceration method could be seen in Figure 3 and 4, whereas the mortality rate by extract with soxhlet method could be seen in Figure 5 and 6.

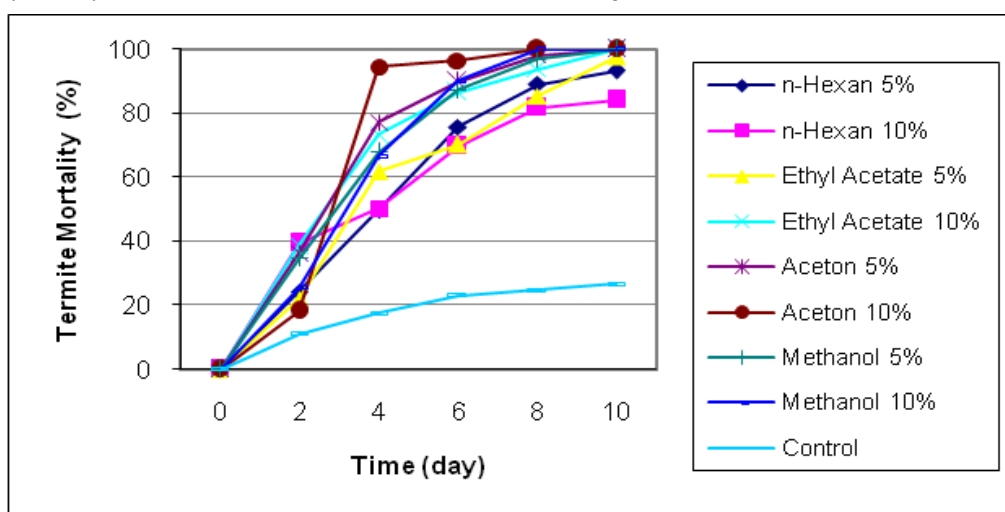


Figure 3. Termite mortality by the extract of Antiaris bark with maceration methods.

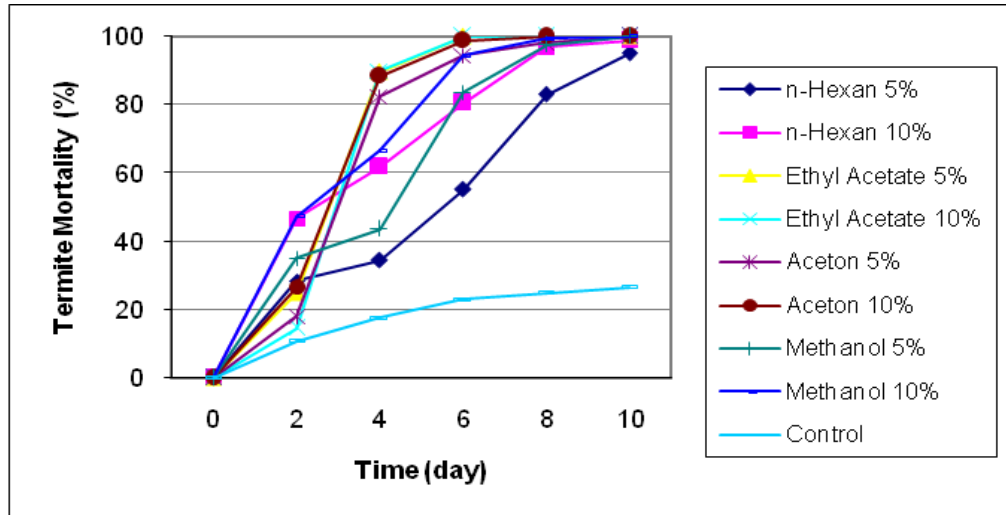


Figure 4. Termite mortality by the extract of Ki pahit bark with maceration methods.

Antiaris and Ki pahit were extracted by maceration caused termite mortality rates from 84.24% to 100% at the end of the observation. Figure 3 and 4 showed that there were five extracts with concentrations of 10% which gave 100% termites mortality, such as antiaris extract with ethyl acetate and methanol solvent and Ki pahit extract with ethyl acetate, acetone and methanol solvent. Whereas at 5% concentration extract, there were only acetone and methanol solvent in Antiaris extract that gave 100% of termite mortality, on the other hand Ki pahit at 5% concentration extract gave similar condition with 10% extract concentration. The result of bioassay showed that in the method maceration, Ki pahit extract caused higher termite mortality than Antiaris bark extract. It was indicated that the active compounds contained in the bark of Ki pahit more toxic to termites than Antiaris.

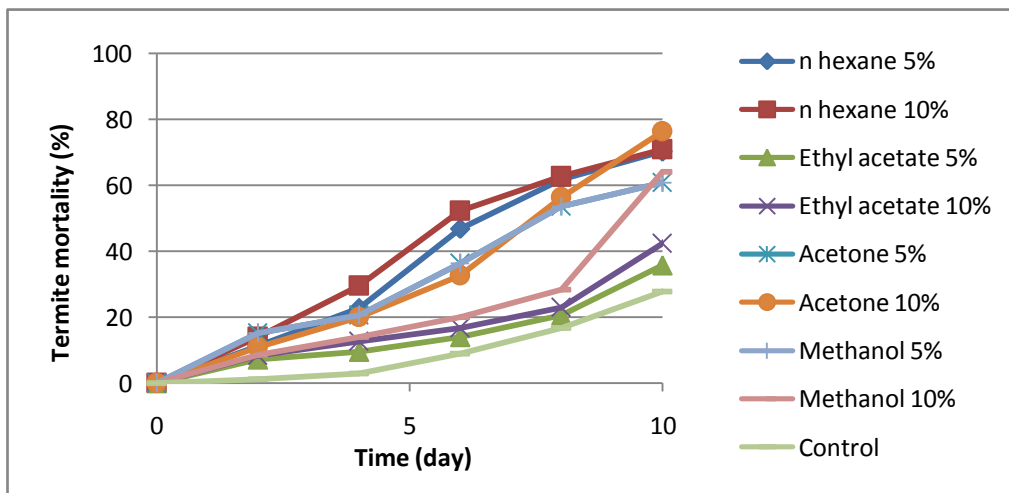


Figure 5. Termites mortality by the extract of Antiaris bark with Soxhlet methods.

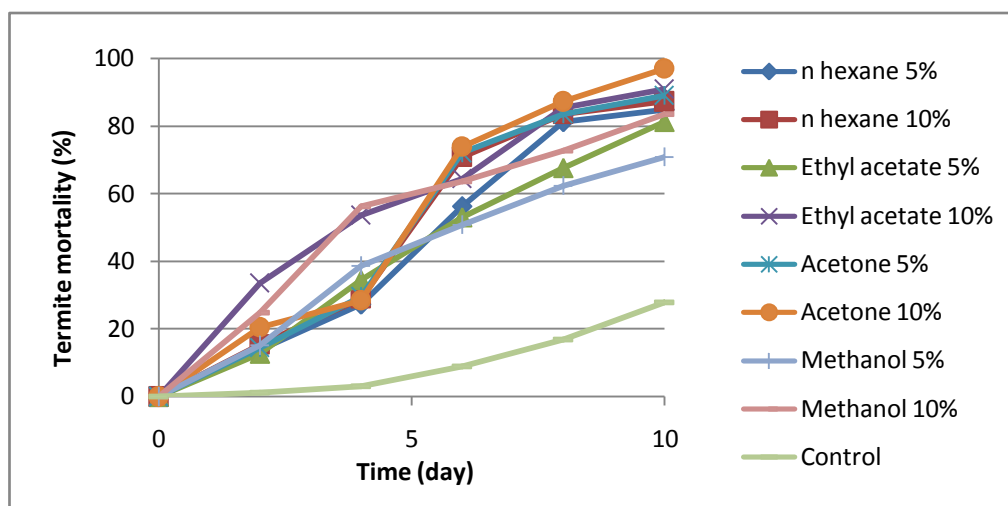


Figure 6. Termites mortality by the extract of Ki pahit bark with Soxhlet methods.

According to Figure 5 and 6, Antiaris was similar in termite mortality with Ki pahit by acetone solvent at the 10 % concentration of extract. The result of bioassay showed that in the soxhlet method, Ki pahit extract caused higher termite mortality than Antiaris bark extract.

According to Figure 3, 4, 5, and 6, termites mortality were varies depending on the kind of material extracts, solvent, and method of extraction. Termite mortality on the maceration method was higher than soxhlet method. It was possible that the active compounds contained in the materials were not stable to heat, so at the time of extraction the active compounds were changing its basic form.

Weight Loss

Table 2 showed the percentage of weight loss from paper disc after baited to termite. Extract treatment affected paper disc resistance to termite attack significantly. On the same concentration treated paper disc of Ki pahit gave less weight loss than treated paper disc of Antiaris. Each extract with high termite mortality has resulted low weight loss (Prianto, 2005). Based on percentage of weight loss, termite's ability to consume paper disc was affected by concentration, if the concentration was greater, the consumption of paper disc would be decrease.

Tabel 2. *Weight Loss of Paper Disc* after feeding to termite

Solvent	Concentration (%)	Weight loss(%)			
		Maceration		Soxhlet	
		Antiaris	Ki Pahit	Antiaris	Ki Pahit
n-hexane	5	17.19	15.35	43.05	25.72
	10	8.82	9.01	32.76	21.43
Ethyl acetate	5	15.48	9.89	36.08	4.76
	10	11.42	6.87	18.93	0.00
Aceton	5	15.22	7.87	38.77	21.23
	10	10.83	2.95	13.98	8.12
Methanol	5	20.03	13.65	22.84	14.24
	10	15.74	7.85	14.85	0.00
Control		43.96		68.75	

CONCLUSIONS

From discussion above, it could be concluded that:

1. Extracts that were obtained from maceration method was more effective against termite *Coptotermes curvignatus* than soxhlet method, both of the Antiaris and Ki pahit.
2. Ki pahit bark extract more effective against termite *Coptotermes curvignatus* than Antiaris bark extracts.

REFERENCES

- Encyclopedia Fauna of Indonesia Series. 1989. Insects. PT Intermedia. Jakarta
- Fieser, LF and Mary Fieser. 1959. Steroids. Reinhold Publishing Corporation. New York
- Harborne, J.B. 1987. Phytochemical methods Analyze Wizard How Modern Plant. Translated by Padmawinata, K and Iwang Soediro. Publisher ITB.Bandung
- Indrayati, 1987. Mempelajari Aktivitas Anti Bakteri Biji Picung (Pangium Edule) Terhadap Beberapa Bakteri Pembusuk Ikan Secara Invitro. Skripsi Jurusan Teknologi Pertanian. Institut Pertanian Bogor. Bogor.
- Lenny, Sofia. 2006. Isolation and Gynecology Chemistry Test Home Bioaktivitas Red Pudding with brine Test Method. University of North Sumatra.
- Prianto, A.H.; I. Guswenrivo; T. Kartika; D. Tarmadi; S.Yusuf. 2005. Study on Utilization of Active Component in Leaves and Bark of Neem (*Azadirachta indica* A. Juss) As Anti-Termite. Proceeding of the 6th International Wood Science Symposium, pp. 351-355.
- Shibutani, S.; S. Doi; S. Yusuf. 2004. Antitermite Property of *Artocarpus heterophylla*-Identification of Termite-resistant Component. Proceeding of the 5th International Wood Science Symposium, pp. 171-174.
- Syafii, W. 2001. Eksplorasi dan Identifikasi Komponen Bio-Aktif Beberapa Jenis Kayu Tropis dan Kemungkinan Pemanfaatannya sebagai Bahan Pengawet Alami. Prosiding Masyarakat Peneliti Kayu Indonesia IV, pp. III 43- III 53

STUDY ON THE INFLUENCE OF NEEM BARKS EXTRACT TO INTESTINAL PROTOZOA, *Coptotermes gestroi*

Arief Heru Prianto and Sulaeman Yusuf

Research Center for Biomaterials-Indonesian Institute of Sciences
Jl. Raya Bogor Km.46, Cibinong, Bogor 16911, Indonesia

ABSTRACT

Neem is a plant that has found varied biological activities especially seed part to cancer, bacteria, fungi and insect. Another part of plant like bark no many research done yet. The purpose of this research was to evaluate the influence of neem bark extract to protozoa on termite gut. There were four fractions tested to termite that were methanol, ethyl acetate, diethyl ether and aqueous fraction. The tests were done in 0.25 and 0.50% (w/v) of concentrations. Observation of protozoa was done until four days. Observation of activities from each fractions showed the various effectiveness and need further study to investigate the active compounds.

Keywords : *Azadirachta indica*, *Coptotermes gestroi*, protozoa

INTRODUCTION

Termites can destroy of human building especially cellulose-based materials. Decomposition of lignocellulose are carried out by protozoa in the termite gut. One of the species termite is *Coptotermes gestroi*. It is lower termite that can't produce enzyme to digest cellulose by it self. Cellulose on termite gut can be convert because of mutualism symbiosis with protozoa. *Coptotermes* has three kinds of protozoa in its intestinal: *Pseudotrichonympha grasioi* Koidzumi, *Holomastigotoides hartmanni* Koidzumi and *Spirotrichonympha leidy* Koidzumi. (Yoshimura,1995). Lignocellulose digestion by wood-feeding termites depend on the mutualistic interaction of unusual, flagellate protists located in their hindgut (Stingl, 2004). Termite nutrition depends on symbiotic organism.

Termites crushing the wood mechanically, then the protozoans in their guts break down the chewed mass into sugars, which are readily absorbed through the termites' guts. Both the termites and their protozoans share in the nutritional benefit of these released sugars.

Many research of using nature material as anti termite have done. But, It's little bit observation of bioactive mechanism in termite digestive. Natural compound have many characteristic such as antifeedant or toxic. Study about characterization of protozoa in termite gut is able to give essential contribution for termite control in the future (Kartika,2005). The purpose of this research was to evaluate the influence of neem bark extract to protozoa on termite gut.

METHODS

Fractination Process

Barks of neem were used for this reseach. It were powdered with machine to pass through an 40 mesh screen and air dried to get moisture content for about 15%. One kg of powdered barks of neem were extracted with methanol for 24 hours at room temperature. The methanol extract was separated by several solvents in order to obtain fractions of increasing polarity. First, The methanol extract was partitioned between equal quantities of water and n-hexane (1:1), obtaining n-hexane fraction and an aqueous fraction. The aqueous fraction was partitioned with diethyl Ether, and the last aqueous fraction was then partitioned with Ethyl acetate. All fractions were tested for their biological activity on termite.

Bioassay using *Coptotermes gestroi*

Filter paper (33 mm diameter) were used in forced-feeding termite test. The Filter paper was dropped by 0.25% and 0.5 % extract fraction. As a comparison filter paper without treatment was used to control. Untreated (control) and treated filter paper were placed at the bottom of petri discs that were coated by plaster paris 3mm. Twenty five termites worker of *Coptotermes gestroi* and extract-treated filter paper were entered in it. The survivors were counted each day and by the end, the consumption rate of filter paper were measured.

Measurement of Protozoa

Termite gut was pulled out from the posterior end. About 50 ul NaCl 0.6 % solution was dropped onto glass slide. The termite gut were place on the glass slide. 2 ul of suspension was taken from the slide and transferred onto different glass slide. The number of protozoa was measured by using microscope.

RESULT AND DISCUSSION

Neem bark extract treatment affected filter paper resistance to termite attack and filter paper consumption rate. Survival rate of *Coptotermes gestroi* was showed in figure 1 (0.25 and 0.5 % concentration). Fraction diethyl eter at 0.5 % concentration gave lowest survival rate of termite was 0%. Second fraction that give low survival rate was ethyl acetate at 4% in concentration 0,5%. Concentration 0,25% in fourth fractions gave survival rate that still high at over 30%.

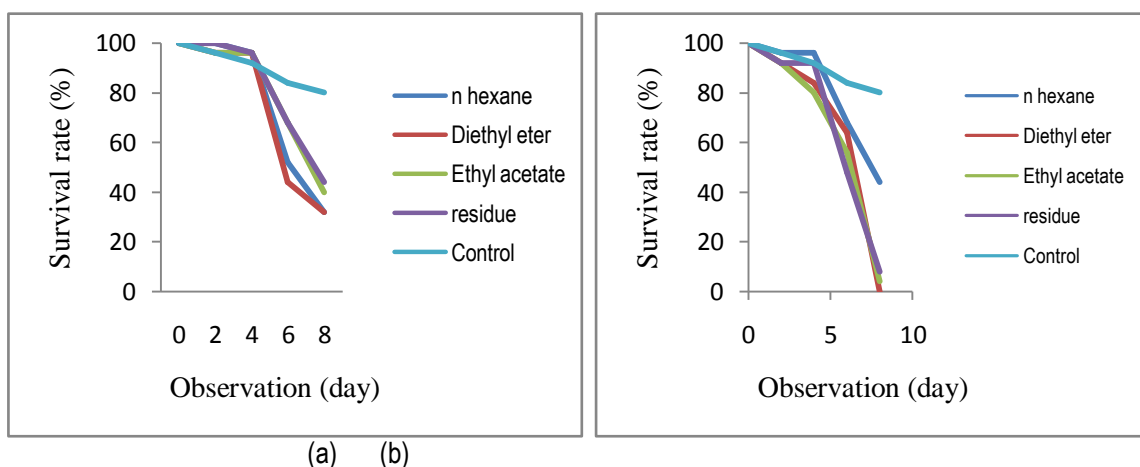


Figure 1. Survival rate of *Coptotermes gestroi*. (a) Concentration 0.25 %, (b) Concentration 0.5 %

Based on filter paper consumption, it can be seen that each fraction has resulted difference of consumption rate. Each fraction significantly affected consumption rate. Diethyl eter fraction gave the lowest consumption rate. Figure 2 showed that termites could consume 2.64% and 1.33% filter paper by diethyl eter fraction at concentration of 0.25 % and 0.5 % respectively. Diethyl eter fraction gave lowest consumption rate than others. The lowest survival rate and consumption rate showed the effectiveness of diethyl eter fraction than others.

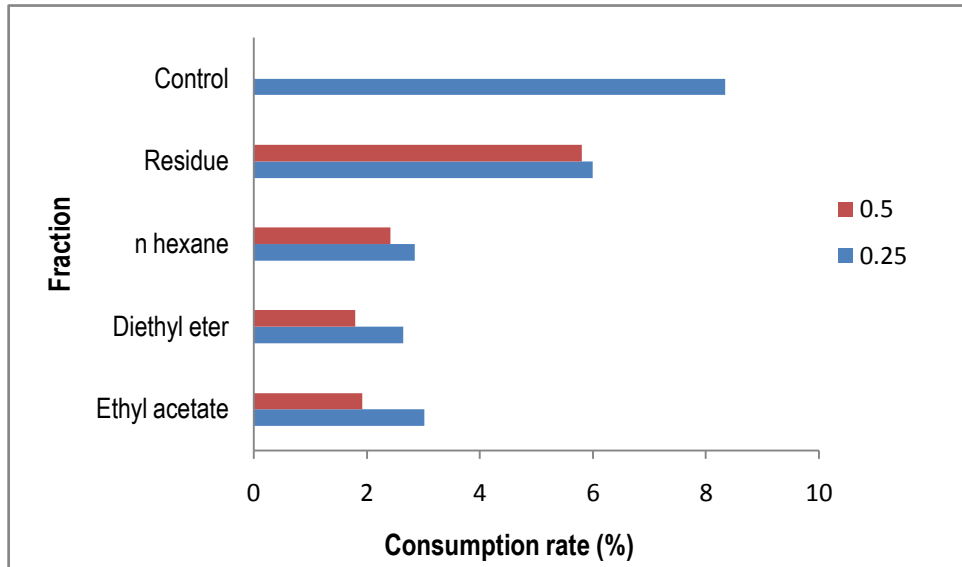


Figure 2. filter paper consumption rates of *Coptotermes gestroi*

Identification protozoa of *Coptotermes gestroi* showed there are three kinds of protozoa such as *Pseudotriconympha grasii* Koidzumi, *Holomastigotoides hartmanni* Koidzumi and *Spirotrichonympha leidy* Koidzumi.

According to survival rate, consumption rate protozoa observation, It could be assumed that there was influence of extract treatment to a number protozoa on the termite gut. There was decreased number of protozoa every day. Figure 4 showed the change of protozoa number.

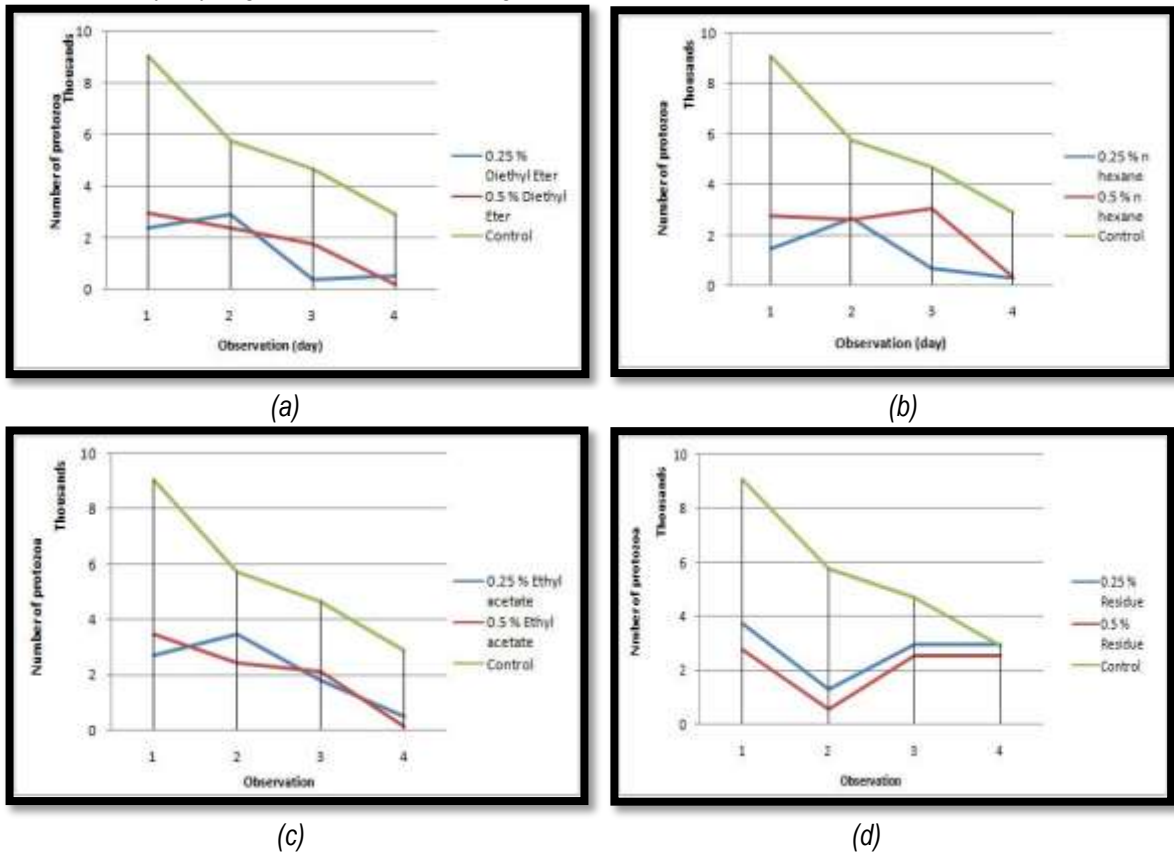


Figure 4. Average protozoan number. (a) diethyl eter fraction (b) n hexane fraction (c) ethyl acetate fraction (d) residue fraction

Diethyl ether and ethyl acetate fractions showed reduction number of protozoa, whereas n-hexane and residue fraction didn't cause it during observation consistently. In concentration 0.5% diethyl ether and ethyl acetate fraction caused significant reduction number of protozoa during observation. In concentration 0.5% of diethyl ether and ethyl acetate fractions weren't found protozoa. All of fractions showed There were significant influence due to concentration increasing from 0.25% to 0.5% through number of protozoa. Residue fraction in the concentration of 0.5% gave little reduction number and until four day the protozoa number was 2550. On the other hand Protozoa number in control was 4675 in the end of observation (4 days)

CONCLUSION

- The effect of addition of neem bark extract was influence of survival rate and filter paper consumption, it showed that the treatment increased the resistance of filter paper to the termite attack.
- Diethyl ether fraction (0.5%) gave the most influence to reduce protozoa number.
- The studies show that after treatment with neem extract the protozoa will decreased every day.

REFERENCE

- Kartika, T dan S. Yusuf.2008. Study about Intestinal Protozoa of Subterranean Termite, *Coptotermes* sp. Proceedings-TRG 5. Bali Indonesia
- Pearce M.J. 1997. Termite, Biology and pest management. CAB International. Cambridge
- Yatagai M, Madoka Nishimoto, Keko Hori, Tatsuro Ohira and Akira Shibata. (2002). Termiticidal activity of wood vinegar, its components and their homologues. Jurnal of Wood Science. Japan Wood Research Society.
- Yoshimura T. 1995. Contribution of protozoan fauna to nutritional physiology of the lower termite, *Coptotermes formosanus* Shiraki. Doctor's thesis. Kyoto University, Japan.

VARIATION OF SURFACE LAYER AND GLUE SPREAD LEVEL ON LAMINATED BOARD WITH CORE OF OIL PALM TRUNK

Rudi Hartono¹, Tito Sucipto¹, Felix Simarmata P¹, Bastanta Ginting¹, Rahmat Hidayat¹,
David Pangihutan Pasaribu¹, Wahyu Dwianto²

¹Forestry Department, Faculty of Agriculture, University of Sumatera Utara

²Biomaterial Research Center, LIPI-Cibinong

Corresponding author : rudihartono_usu@yahoo.co.id

ABSTRACT

Improvement of oil palm trunk (OPT) as laminated board could be done by using surface layer (face and back layer) and optimum of glue spread. The objective of this research was to evaluate the effect of surface layer and glue spread on properties of laminated board using core from oil palm trunk. Laminated board was made by three layers with core of densified-OPT. The layer of laminated board were OPT/densified-OPT/OPT; sengon/densified-OPT/sengon; meranti/densified-OPT/meranti. The variation of glue spreader were 240, 260 and 280 g/m². The dimension of laminated board was 5 cm (width) x 3 cm (thick) x 45 cm (length). The physical and mechanical properties would be compared by JAS 234 : 2003. The result showed that moisture content, density, delamination test, modulus of elasticity (MOE) and modulus of rupture (MOR) were 6.85~8.50%, 0.36~0.69 g/cm³, 0%, 17918~110727 kg.f/cm² and 112.28~441 kg.f/cm², respectively. The surface layer of laminated board using meranti wood fulfilled all of JAS 234 (2003). The surface layer using OPT and sengon wood didn't fulfilled the mechanical properties except the sengon surface layer using glue spread of 260 g/m². Then the physical properties such as moisture content and the lamination test had fulfilled the standard. The optimum in this research was obtained with surface layer using meranti and glue spread of 240 g/m².

Key words: oil palm trunk, laminated board, surface layer, glue spread.

INTRODUCTION

In Indonesia, oil palm (*Elaeis guineensis* Jacq) plantations spread across 22 provinces. In 2005, Oil palm plantation has been reached 5,5 million ha and in 2011 increased become 8,4 million ha (Departemen Pertanian, 2012). Usually, at the age of 25 years-old, the oil palm plantation will be replanted and will found the waste, such as oil palm trunk (OPT). The OPT waste will be increased along with increasing of oil palm plantation area. According to Febrianto and Bakar (2004), rejuvenation of oil palm plantation can produce 50.1 m³/ha saw wood originated from hard outer part of the trunk while 2/3 of its soft inner part still becomes waste.

OPT as natural materials have several of weakness, such as low specific gravity, high moisture content, low dimensional stability, strength and durability. Bakar (2003) stated that OPT had the high moisture content ranged between 156-365 % and low of Specific gravity ranged from 0.2-0.35. This causes the low dimension stability of OPT. Bakar *et al.* (1998) also stated that the inner part of OPT had starch up to 40% and its made susceptible to termites (Rahayu, 2001).

One of the utilization of OPT was made for laminated wood. Laminated wood (glue laminated timber, glulam) is produced by gluing two or more layers or lamellae of wood with their grain parallel. Laminated wood is produced in a variety of shapes and sizes. Usually the grain of wood is parallel to length (Tsoumist, 1991)

Previous research, Ginting (2012) reported that the laminated board of OPT had a low mechanical properties, especially its MOR and MOE values and didn't fulfilled the JAS standard 234 : 2003. One of efforts was to used the outer layer to improved the quality of laminated board. The outer layer density that used must be higher than the core layer density of laminated board. The laminated board made from OPT can be combined with sengon and meranti layers.

In addition, the laminated board quality was determined by the glue spreader. If the glue spreader was very high or very low, it will lead to failure of adhesive lines. It was necessary to found an appropriate of glue spreader to increase the quality of laminated board.

The objective of this research were to evaluate the effect of surface layer and glue spread on properties of laminated board using core from oil palm trunk. The result will be compared with the JAS 234:2003.

MATERIAL AND METHODS

Material

Material used in this study were the 30 years of oil palm trunk (OPT) from Kuala Bekala, Medan, Sengon (*Paraserianthes falcataria*), Meranti wood (*Shorea* sp.) and PF adhesive produced by PT. Pamolite Adhesive Industri with resin content of 46.86%.

Methods

The average density of the outer-OPT were 0.40~0.44 g/cm³, Sengon was 0.42 g/cm³, and meranti was 0.64 g/cm³. In this research, lamina board consists of three layers. Upper and bottom layers made from the outer of the OPT, sengon and meranti with size of layer was 45 cm x 5 cm x 1 cm. Whereas the core layer made from the inner of the OPT with density ranged between 0.25-0.29 g/cm³. The inner of the OPT with size of 45 cm x 5 cm x 2 cm and then compressed up to 45 cm x 5 cm x 1 cm.

The laminated board was made with size of 45 cm x 5 cm x 3 cm. Adhesive used was phenol formaldehyde (PF) and spread variations were 240, 260, 280 g/m², using double spread. Curing adhesive at temperature of 150 °C for 15 minutes. The variation of surface layer of laminated boards were showed at Figure 1.

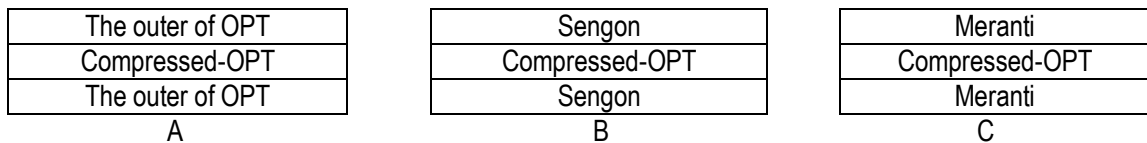


Figure 1. The variation of surface layer of laminated board

The physical property measurements carried out were density (ρ) and moisture content (MC) with a sample size of 3 x 3 x 3 cm, delamination with a sample size of 8 x 3 x 3 cm, while the mechanical properties measured were Modulus of Elasticity (MOE) and Modulus of Rupture (MOR) with a sample size of 45 x 3 x 3 cm. The replication in this study was 3 replication. The results will be compared with the JAS standard 243:2003.



Figure 2. Hot press for curing adhesive



A = OPT/ compressed-OPT/ OPT
 B = Sengon/ compressed-OPT/ Sengon
 C = Meranti/ compressed-OPT/ Meranti

Figure 3. The sample of laminated board

Physical and mechanical properties

The physical properties test of laminated board were moisture content, density and delamination. Then, the mechanical properties test were MOR dan MOE. The physical and mechanical properties test were calculated using the following equations :

1. Moisture Content = $\{(B_A - B_{KT})/B_{KT}\} \times 100\%$,

B_A : weight prior to the test; and B_{KT} : weight oven dry

2. Density = B_{KU}/V_{KU} (g/cm³)

B_{KU} : weight to the air dry condition; and V_{KU} : volume to the air dry

3. The lamination

The lamination test was done by soaking the sample in the cold water for 6 hours. Then, take away from the water and wait for 18 hours. Delamination ratio should not more than 10% of total glue lines. The delamination rate shall be calculated by the following equation:

$$\text{Delamination} = \frac{\text{Sum of the length of delamination on both butt ends (cm)}}{\text{Sum of the length of glue lines on both butt (cm)}} \times 100\%$$

4. Modulus of Rupture (MOR) = $(3 PL)/(2 bh^2)$ kg/cm²

5. Modulus of Elasticity (MOE) = $(\delta PL^3)/(4 \delta ybh^3)$ kg/cm²

Where

P = max load (kg),

δP = load before proportional limit (kg),

δy = deflection (cm),

L = span length (cm),

b = sample width (cm),

h = sample thickness (cm)

Data Analysis

The data of physical (density, moisture content, delamination) and mechanical properties (MOE dan MOR) will be compared with JAS 243 : 2003 Laminated Board for Structural. The JAS 243:2003 was shown at Table 1.

Table 1. The JAS 243 : 2003

No	Properties	Standard
1	Moisture Content	$\leq 15\%$
2	Delamination	$\leq 10\%$
3	MOR	≥ 300 kg/cm ²
4	MOE	≥ 75000 kg/cm ²

RESULT AND DISCUSSION

The result showed that physical properties such as density, moisture content and delamination test were 0.36-0.69 g/cm³, 6.85-8.85%, and 0%, respectively. Then for mechanical properties such as MOR ranged around 112.28-440.63 kg/cm² and MOE ranged around 17918-110727 kg/cm². The physical and mechanical properties of laminated board was showed at Table 2.

Table 2. The physical and mechanical properties of laminated board

Surface Layer	Glue Spread (g/m ²)	Density (g/cm ³)	Moisture Content (%)	Delamination (%)	MOR (kg/cm ²)	MOE (kg/cm ²)
OPT	240	0.42	8.48*	0*	168.79	30115
	260	0.40	8.5*	0*	191.10	31732
	280	0.36	8.32*	0*	112.28	17918
Sengon	240	0.44	8.06*	0*	251.55	51808
	260	0.40	8.34*	0*	203.22	43257
	280	0.41	8.32*	0*	330.22*	44036
Meranti	240	0.63	6.85*	0*	438.29*	100454*
	260	0.66	7.19*	0*	440.63*	93112*
	280	0.69	6.96*	0*	424.90*	110727*
JAS Standar	-	-	≤ 15%	≤ 10%	≥ 300	≥ 75000

Note : *fulfilled the JAS 243:2003

Table 2 showed that physical properties of laminated board value such as moisture content and delamination test had fulfilled the JAS 243: 2003. Then for mechanical properties (MOE and MOR), the outer layer using meranti wood had fulfilled the JAS 243: 2003. For Sengon layer, only glue spread of 280 g/m² had fulfilled the standard for MOR.

The value of moisture content and delamination were similar in all treatments, either glue spread (240, 260 dan 280 g/m²), or surface layer of laminated board (OPT, sengon and meranti). Moisture content ranged from 6.85-8.50%, while all of delamination value was 0%. The lowest of delamination value was because by adhesive used, that was Phenol Formaldehyde (PF). Achmadi (1990) suggested that PF adhesive was resistant to moisture condition and weather. The PF Adhesives had low viscosity, make it possible to penetrate into the pores of wood and function as a mechanical anchor in the gluing. Furthermore, Vick (1999) states that the delamination test was an indicator of the adhesive resistance on swelling and shrinkage caused by moisture and heat condition.

Also Table 2 showed that density values vary widely when see from surface layer. The laminated board that consist of high density layer will be caused higher density of laminated board. Meranti density value was higher than the density of sengon wood and OPT. The density of meranti layers, sengon layers and OPT layers were 0.63~0.69 g/cm³, 0.40~0.44 g/cm³ and 0.36~0.42 g/cm³, respectively. Meranti layer density for raw materials of laminated board was 0.64 g/cm³. Its caused the laminated board density was around the raw materials used. While sengon density was 0.42 g/cm³ and outer-OPT density ranged around 0.40~0.44 g/cm³.

There was relationship density value with the mechanical properties. The high density of laminated board will resulted high mechanical value of laminated board. In Table 2 showed that density of laminated board f

rom meranti layers had higher than sengon layers and OPT layers. In connection with that, mechanical properties from meranti layers had higher than sengon and OPT. MOE and MOR values meranti fulfilled the JAS 243: 200. Walker (1993) states the factors that affect the strength of wood was density. High-density wood had greater strength. Likewise Bowyer et al., (2003) stated that the mechanical properties increased according with increasing of density wood.

CONCLUSION

1. The physical properties (moisture content and delamination) had fulfilled the standard of JAS 234 (2003), and for mechanical properties (MOE and MOR), only the surface layer of laminated board using meranti wood fulfilled all of JAS 234 (2003).
2. The optimum in this reseach was obtained with surface layer using meranti and glue spread of 240 g/m².

ACKNOWLEDGEMENTS

The authors gratefully acknowledge Directorate General of Higher Education of Indonesia for financial support in Fiscal Year 2014 under Program Hibah Bersaing.

REFERENCES

- Achmadi, S. S. 1990. Kimia Kayu. Departemen Pendidikan dan Kebudayaan. IPB Press. Bogor.
- Bakar, E. S. 2003. Kayu sawit sebagai substitusi kayu dari hutan alam. Forum Komunikasi dan Teknologi dan Industri Kayu 2: 5-6. Bogor.
- Bowyer, J.L., Shmulsky, R., Haygreen, J.G. 2003. Forest Products and Wood Science : An Introduction. Fourth Edition. Iowa State Press.
- Febrianto F dan Bakar ES. 2004. Kajian Potensi, Sifat-sifat dasar dan Kemungkinan Pemanfaatan Kayu Karet dan Biomassa Sawit di Kabupaten Musi Banyuasin. Kerjasama antar Pemerintah Daerah Musi Banyuasin dengan Lembaga Manajemen Agribisnis Agroindustri IPB.
- Ginting, D.A.R. 2012. Balok Laminasi dengan Kombinasi dari Batang Kelapa Sawit (*Elaeis guineensis*) dan Kayu Mahoni (*Swietenia mahagoni*). Skripsi. Universitas Sumatera Utara. Medan.
- [JAS] 243. 2003. Japanese Agricultura Standard for glued laminate timber. Ministry of Agricultura, Forestry and Fisheries.
- Rahayu, I. S. 2001. Sifat dasar vascular bundle dan parenchime batang kelapa sawit (*Elaeis guineensis* Jacq.) dalam kaitannya dengan sifat fisis, mekanis serta keawetan. Tesis. Institut Pertanian Bogor. Bogor.
- Tsoumis, G. 1991. Science and Technology of Wood : Structure, Properties, Utilization. Van Nostrand Reinhold. New York.
- Walker, J. C. F. 1993. Primary wood proceesing and practice Chapman and Hall. London
- Vick, C.B.1999. Adhesive Bonding of Wood Material. In: Wood Handbook, Wood as an Engineering Material. WI: USDA, Forest Product Service, Forest Products Laboratory. Madison, hal. 9.1 – 9.24.

APPENDIX

COMMITTEE OF IWORS

Advisory Board	: Rector of University of Sumatera Utara (USU)
Steering committee	: Dean of Agriculture Faculty - USU Head of Indonesian Wood Research Society (IWORS) Vice Dean I of Agriculture Faculty - USU Head of Forestry Department - USU Prof. Dr. Erman Munir – USU Prof. Dr. Yusuf. Sudohadi - IPB Prof. Dr. Yusram Massijaya - IPB Prof. Dr. Bambang Subiyanto – LIPI Prof. Dr. Sipon Muladi – UNMUL Dr. Sri Nugroho Marsoem - UGM
Executive committee	
Chairman	: Dr. Rudi Hartono, S.Hut, M.Si
Secretary	: Tito Sucipto, S.Hut, M.Si
Treasurer	: Irawati Azhar, S.Hut, M.Si
Secretariat	: Dr. Kansih Sri Hartini, S.Hut, MP. Dr. Ma'rifatin Zahra, S.Hut, MSi Dwi Endah, S.Hut, M.Si Dr. Ir. Yunasfi, M.Si Rahmawaty, S.Hut, M.Si, Ph.D Teguh, S.P
Publication & Proceeding	: Luthfi Hakim, S.Hut, M.Si Dr. Muhdi, S.Hut, M.Si Nelly Anna, S.Hut, M.Si Ridwanti Batubara, S.Hut, MP
Seminar	: Dr. Apri Heri Iswanto, S.Hut, M.Si Dr. Deni Elfiati, SP, MP. M. Basyuni, S.Hut, M.Si, Ph.D Onrizal, S.Hut, M.Si Dr. Arida Susilowati, S.Hut, M.Si Dr. Anita Zaitunah, S.Hut, M.Sc. Dr. Ir. Edy Batara Mulya Siregar, M.S
Fund Rising	: Dr. Agus Purwoko, S.Hut, M.Si Dr. Budi Utomo, SP, MP. Dr. Delvian, SP, MP.
Fieldtrip	: Yunus Affuddin, S.Hut, M.Si Pindi Patana, S.Hut, M.Sc Afifuddin Dalimunthe, SP, M.P

**THE 6TH INTERNATIONAL SYMPOSIUM OF
INDONESIAN WOOD RESEARCH SOCIETY (IWORS)
Garuda Plaza Hotel, Medan-Indonesia, November 12-13, 2014**

Wednesday, November 12, 2014

08.00 - 08.30: Registration

08.30 - 09.30: Opening Symposium

09.30 - 10.00: Documentation (photograph)

10.00 - 10.30: Coffee Break

10.30 - 11.30: Keynote Speeches

1. Prof. Dr. Nan-Hun KIM (Kangwon National University, Korea)

2. Prof. Dr. Shigehiko SUZUKI (Suzuoka University, Japan)

11.30 - 12.30: Parallel Session 1

12.30 - 13.30: Lunch

13.30 - 14.00: Invited Speeches

14.00 - 15.00: Parallel Session 2

15.00 - 16.00: Parallel Session 3

16.00 - 16.15: Coffee Break

16.15 - 17.15 : Parallel Session 4

19.00 - 21.00: Banquet

Thursday, November 13, 2014

08.00 - 08.30: Standing Poster and Coffee Break

08.30 - 09.30: Keynote Speeches

1. Prof. Dr. Dodi Nandika (Institut Pertanian Bogor, Indonesia)

2. Prof. Dr. Nobuaki HATTORI (President of Wood Technological
Association of Japan/ Tokyo University, Japan)

09.30 - 10.30: Parallel Session 5

10.30 - 11.15: Parallel Session 6

11.15 - 12.00: Closing Symposium

12.00 - 13.00: Lunch

THE PARTICIPANT IN THE 6TH INTERNATIONAL SYMPOSIUM OF INDONESIAN WOOD RESEARCH SOCIETY (IWoRS)

No	Name	Email	Institution
1	A.W. Noraida	aidawahob@gmail.com	Faculty Of Economics and Management, UPM
2	Achmad Solikhin	achmad.solikhin1993@gmail.com	Faculty of Forestry, Bogor Agricultural University
3	Adi Santoso		Research and Development of Forest Engineering and Forest Products Processing, Bogor
4	Adrian Choo Cheng Young	ccy.adrian@gmail.com	UPM, Malaysia
5	Agus Purwoko		Forestry Department, Faculty of Agriculture, USU
6	Agus Sulistyo Budi		Faculty of Forestry, Mulawarman University
7	Aida Adnan		University Putra Malaysia
8	Aji Kusumo Wibowo	ajikusumowibowo7@gmail.com	Faculty of Forestry, Bogor Agricultural University
9	Ajun Hariono	hariono_ajun@yahoo.co.id ; anitafirman150660@gmail.com	Research Institute of Human Settlement, Ministry of Public Works
10	Alhassan Y. Abare	edisuhaimi@upm.edu.my	Department of Forest Production, Faculty of Forestry, Universiti Putra Malaysia
11	Ana Agustina		Bogor Agricultural University
12	Andi Detti Yuniarti	detti_yuniarti@yahoo.com	Faculty of Forestry, Hasanuddin University
13	Andi Sri Rahayu Diza Lestari	ayudiza@gmail.com	Post-Graduate Student at Forest Products Department, Faculty of Forestry, Bogor Agricultural University
14	Anindya Marsabella Rosiarto	kusuma_iw@yahoo.com	Laboratory of Forest Products Chemistry, Faculty of Forestry, Mulawarman University
15	Anita Firmanti		Research Institute of Human Settlement, Ministry of Public Works
16	Apri Heri Iswanto	apriheri@yahoo.com	Forestry Department, Faculty of Agriculture, USU
17	Arida Susilowati		Forestry Department, Faculty of Agriculture, USU
18	Arief Heru P.		Research Center for Biomaterials-LIPI
19	Arinana	arinanaiskandaria@yahoo.co.id	Faculty of Forestry, Bogor Agricultural University
20	Arsenio B. Ella	arsenioella@gmail.com	Researchers, Forest Products Research and Development Institute (FPRDI), Department of Science and Technology (DOST)
21	Asep Hidayat	ashephidayat@yahoo.com	Research Institute of Fiber Technology of Forest Plants, Kuok-Riau
22	Astuti Arif	astuti_arif@yahoo.com	Fac. of Forestry, Hasanuddin University, Makassar
23	Atmawi Darwis	atmawi@sith.itb.ac.id	School of Life Sciences and Technology Institut Teknologi Bandung
24	Budi Utomo		Forestry Department, Faculty of Agriculture, University of Sumatera Utara
25	Budi Winarni	orcaella@yahoo.com	Samarinda Agricultural Polytechnic
26	Danang Sudarwoko Adi	danang@biomaterial.lipi.go.id	Research Center for Biomaterials-LIPI
27	Deddy Hadriyanto		Faculty of Forestry, University of Mulawarman
28	Deded Sarip Nawawi	dnawawi66@yahoo.com	Faculty of Forestry, Bogor Agricultural University
29	Delvian		Forestry Department, Faculty of Agriculture, USU
30	Deni Elfiati		Forestry Department, Faculty of Agriculture, USU
31	Dodi Nandika	dodina@ipb.ac.id	Faculty of Forestry, Bogor Agricultural University
32	Dwi Astiani	astiani.dwi@gmail.com	Forestry Faculty Tanjungpura University Indonesia
33	Dwi Endah	dwierendah@usu.ac.id	Forestry Study Program, Faculty of Agriculture, USU
34	Edi S. Bakar UPM	edisuhaimi@upm.edu.my	Faculty of Forestry, University Putra Malaysia
35	Effendi Tri Bahtiar	bahtiar_et@yahoo.com	Faculty of Forestry, Bogor Agricultural University
36	Eka Novriyanti	kee.november09@gmail.com	Research Institute of Fiber Technology of Forest

			Plants, Kuok-Riau
37	Eko Kuswanto		School of Life Sciences & Technologi, ITB
38	Enggar Apriyanto	Enggavan@yahoo.com	the Agriculture Faculty, Bengkulu University
39	Enos Tangke Arung	tangkearung@yahoo.com	Faculty of Forestry, Mulawaman University
40	Euis Hermiati	euis.hermiati@lipi.go.id	Research Center for Biomaterials-LIPI
41	Farah Diba	farahdiba1611@gmail.com	Forestry Faculty Tanjungpura University Indonesia
42	Fauzi Febrianto	kimnh@kangwon.ac.kr	Faculty of Forestry, Bogor Agricultural University
43	Firda Aulya Syamani	firda.syamani@biomaterial.lipi.go.id	Research Center for Biomaterials-LIPI
44	Fitria	fitria@biomaterial.lipi.go.id	Research Center for Biomaterials-LIPI
45	Gustan Pari		Forestry Engineering and Forest Products Processing Research and Development Center
46	Gusti Hardiansyah	gusti.hardiansyah@gmail.com;	Forestry Faculty, Universitas Tanjungpura, Indonesia
47	Hairi Cipta	wdnugroho96@yahoo.co.id	Faculty of Forestry, University of Gadjah Mada
48	Hamid Reza Najj	hrnaji2000@gmail.com	Institute of Tropical Forestry and Forest Products (INTROP), Universiti Putra Malaysia (UPM)
49	Harlinda Kuspradini	hkuspradini@fahatan.unmul.ac.id	Forestry Faculty of Mulawarman University
50	Haruna Aiso		Utsunomiya University, Japan
51	Hikaru KOBORI	kobori.hikaru@shizuoka.ac.jp	Graduate school of agriculture, Shizuoka University
52	I.M. Sulastiningsih		Research and Development of Forest Engineering and Forest Products Processing, Bogor
53	Ichsan Suwandhi	ichsan@sith.itb.ac.id	School of Life Sciences & Technologi, ITB
54	Ihak Sumardi	ihak@sith.itb.ac.id	School Life Sciences and Technology-Bandung Institute of Technology
55	Imam Wahyudi	imyudarw16@yahoo.com	Faculty of Forestry, Bogor Agricultural University
56	Irawan Wijaya Kusuma	kusuma_iw@yahoo.com	Laboratory of Forest Products Chemistry, Faculty of Forestry, Mulawarman University
57	Irawati Azhar		Forestry Department, Faculty of Agriculture, USU
58	Ismadi		Research Center for Biomaterials-LIPI
59	Ismail Budiman	budimanismail@gmail.com	Research Center for Biomaterials-LIPI
60	Isna Yuniar Wardhani	isnaywh@yahoo.com	Forestry Faculty Mulawarman University
61	Istie Rahayu	istiesr@yahoo.com	Faculty of Forestry, Bogor Agricultural University
62	Iwan Risnasari	febrianto76@yahoo.com	Graduate School, Bogor Agricultural University (IPB)
63	Izumi Arakawa	50014535001@st.tuat.ac.jp	Faculty of Agriculture, Tokyo University of Agriculture and Technology, Fuchu-Tokyo, Japan
64	Jae-Hyuk Jang	jhtojh@kangwon.ac.kr	College of Forest and Environmental Sciences, Kangwon National University
65	James Rilatupa	jrilatupa@gmail.com	Christian University of Indonesia
66	Jessica	chikajessica51@yahoo.com	Master Student of Forest Products Department, Faculty of Forestry, Bogor Agricultural University
67	Joko Sulisty		Faculty of Forestry, UniversitasGadjahMada
68	Juliana Abdul Halip UPM	parida.introp@gmail.com; julianahalip@gmail.com	Institute of Tropical Forestry and Forest Products Universiti Putra Malaysia
69	Julianus Kinho	ragilkinho@gmail.com	Manado Forestry Research Institute
70	K.L. Chin	dwinackl@gmail.com	Institute of Tropical Forestry and Forest Product, Universiti Putra Malaysia
71	Kansih Sri Hartini		Forestry Department, Faculty of Agriculture, USU
72	Kurnia Wiji Prasetyo	jundiazam@yahoo.com	Research Center for Biomaterials-LIPI
73	Linda Kriswati		Research Center for Biomaterials-LIPI
74	M. Adly Rahandi		Research Center for Biomaterials-LIPI
75	M. Anuar Ridzuan Saliman		University Putra Malaysia
76	M. Gopar		Research Center for Biomaterials-LIPI

77	M. Yusram Massijaya		Faculty of Forestry, Bogor Agricultural University
78	Ma'rifatin Zahrah	titiemirza@yahoo.com	Sekolah Tinggi Ilmu Kehutanan Pante Kulu, Banda Aceh
79	Makkarennu	akha_unhas@yahoo.com	Faculty of Forestry, Hasanuddin University
80	Maria Ulfah	Mrhlf.hut@gmail.com	Forestry Study Program, Faculty of Agriculture, University of Sumatera Utara
81	Marjenah		Faculty of Forestry, University of Mulawarman
82	Masturoh Surachman	tedongbayao@gmail.com	Faculty of Forestry, Bogor Agricultural University
83	Maulida Oktaviani	maulida.oktaviani@lipi.go.id	Research Center for Biomaterials-LIPI
84	Mohammad Basyuni	Mohammad Basyuni	Forestry Study Program, Faculty of Agriculture, University of Sumatera Utara
85	Muhammad Navis Rofii	navis_r@ugm.ac.id	Faculty of Forestry, Universitas Gadjah Mada
86	Muhdi	muhdisyehamad@yahoo.com	Forestry Study Program, Faculty of Agriculture, USU
87	Mulyani Efendi	efendy_2084@yahoo.co.id	Faculty of Forestry, Bogor Agricultural University
88	Musrizal Muin	musrizal@yahoo.com	Hasanuddin University
89	N Hadjib	nurwati_hadjib@yahoo.com	Research and Development of Forest Engineering and Forest Products Processing, Bogor
90	Nam-Hun Kim	lah0818@kangwon.ac.kr	College of Forest and Environmental Sciences, Kangwon National University
91	Naresworo Nugroho	naresworo@yahoo.com	Faculty of Forestry, Bogor Agricultural University
92	Noor Farikhah Haneda		Faculty of Forestry, Bogor Agricultural University
93	Nur Nabilah UPM	hazebelnabilah@gmail.com	Department of Forest Product, Faculty of Forestry, Universiti Putra Malaysia
94	Nurliyana M.Y. UPM	leeya51@gmail.com	Department of Forest Product, Faculty of Forestry, Universiti Putra Malaysia
95	Nyoman J Wistara	nyomanwis@gmail.com	Depart. of Forest Products, Faculty of Forestry, Bogor Agricultural University (IPB)
96	Paridah Md. Tahir		Institute of Tropical Forestry and Forest Products (INTROP), Universiti Putra Malaysia (UPM)
97	Pindi Patana	pindipatana@gmail.com	Forestry Study Program, Faculty of Agriculture, USU
98	R. Permana Budi		Research Center for Biomaterials-LIPI
99	Ragil Widyorini	rwidyorini@gmail.com	Fac. of Forestry, University of Gadjah Mada
100	Rahma Nur Komariah	rahma_nur_komariah@ymail.com	Forest Products Department, Faculty of Forestry, Bogor Agricultural University
101	Rahmawaty	rahmawaty@usu.ac.id	Forestry Study Program, Faculty of Agriculture, USU
102	Ratih Ayu Syafriza	RaatihRaatih@gmail.com	Student of Faculty of Forestry Department, Bogor Agricultural University
103	Rita Diana	ritdh@yahoo.com	Center for Climate Change Studies, University Mulawarman
104	Rogerson Anokye	edisuhaimi@upm.edu.my	Faculty of Forestry, University Putra Malaysia
105	Rohny S. Maail	rohny_maail@yahoo.com	Forestry Department, Faculty of Agriculture, University of Pattimura
106	Rudi Hartono	rudihartono_usu@yahoo.co.id	Forestry Study Program, Faculty of Agriculture, USU
107	Rudianto Amirta	r_amirta@yahoo.com / rudiantoamirta@unmul.ac.id	Faculty of Forestry, Mulawarman University, Samarinda
108	Sanusi		Research Center for Biomaterials-LIPI
109	Sasa Sofyan Munawar		Indonesian Institute of Sciences
110	Satoshi Nakaba, Japan	nakaba@cc.tuat.ac.jp	Faculty of Agriculture, Tokyo University of Agriculture and Technology, Japan
111	Seyed Eshagh Ebadi UPM	eshaghebadi@gmail.com	Institute of Tropical Forestry & Forest Products (INTROP), Universiti Putra Malaysia

112	Siti Latifah	sitilatifah164@yahoo.co.id	Forestry Study Program, Faculty of Agriculture, USU
113	Sofiatin		School of Life Sciences and Technology, Bandung Institute of Technology
114	Sopandi Sunarya	sopandi@sith.itb.ac.id	School of Life Sciences and Technology, Bandung Institute of Technology
115	Sri Nugroho MARSOEM	snmarsoem@ugm.ac.id	Faculty of Forestry, Universitas Gadjah Mada
116	Subyakto	subyakto@biomaterial.lipi.go.id	Research Center for Biomaterials-LIPI
117	Sudarmanto		Research Center for Biomaterials-LIPI
118	Suhasman	suhasman@yahoo.com	Faculty of Forestry, Hasanuddin University, Makassar
119	Sulaeman Yusuf		Research Center for Biomaterials-LIPI
120	Syamsul Falah	syamsulfalah@yahoo.com	Department of Biochemistry, Faculty of Mathematics and Natural Sciences, Bogor Agricultural University
121	Taiyo OKADA	t0336006@ipc.shizuoka.ac.jp	Shizuoka University, Faculty of Agriculture
122	Taman Alex	tamanalex2@gmail.com	Samarinda Agricultural Polytechnic
123	Tati Karliati	karliati@sith.itb.ac.id	School of Life Sciences and Technology, Bandung Institute of Technology
124	Tekat Dwi Cahyono	tekatdwicahyono@gmail.com	Faculty of Agriculture, Darussalam University Ambon
125	Tito Sucipto		Forestry Department, Faculty of Agriculture, USU
126	Tomy LISTYANTO	tomy.listyanto@gadjahmada.edu	Faculty of Forestry, Universitas Gadjah Mada
127	Trisna Priadi	trispriadiipb@yahoo.com	Faculty of Forestry, Bogor Agricultural University
128	Triyono Sudarmadji	triyono_sudarmadji@yahoo.com	Laboratory of Soil and Water Conservation, Faculty of Forestry Mulawarman University (FoF UNMUL)
129	Wahyu Dwianto	wahyudwianto@yahoo.com	Research Center for Biomaterials, Indonesian Institute of Sciences
130	Wahyu Hidayat	away_rie@yahoo.com	Department of Forestry, Faculty of Agriculture, University of Lampung
131	Wahyudi	wahyudi.s.pono@gmail.com	Faculty of Forestry, The State university of Papua
132	Wasrin Syafii	wasrinsy@indo.net.id	Faculty of Forestry, Bogor Agricultural University
133	Wayan Darmawan.	wayandar@indo.net.id	Faculty of Forestry, Bogor Agricultural University
134	Whicliffe F. Pasedan	whicliffe@gmail.com	Faculty of Forestry, Mulawarman University
135	Wida B.Kusumaningrum	wida.banar@biomaterial.lipi.go.id	Research Center of Biomaterials LIPI
136	Widya Fatriasari	widya_fatriasari@yahoo.com	Research Center of Biomaterials LIPI
137	Wiwik Ekyastuti	wieky_serdam@yahoo.co.id	Faculty of Forestry Tanjungpura University
138	Wiwini Suwinarti	wsuwinarti@fahatan.unmul.ac.id	Faculty of Forestry, Mulawarman University, Samarinda, Indonesia
139	Yoichi KOJIMA	aykojim@ipc.shizuoka.ac.jp	Shizuoka University, Faculty of Agriculture
140	Yoyo Suhaya	yoyo@sith.itb.ac.id	School of Life Science and Technology, ITB
141	Yudha Aditiya	yuda.aditiya25@yahoo.com	Faculty of Forestry, Bogor Agricultural University
142	Yudhi Dwi Kurniawan	l_suryanegara@yahoo.com	Research Center for Biomaterials-LIPI
143	Yuliati Indrayani	mandaupermai@yahoo.com	Faculty of Forestry Tanjungpura University
144	Yusuf Sudo Hadi		Faculty of Forestry, Bogor Agricultural University
145	Zaidon Ashaari	zaidon@upm.edu.my	Laboratory of Biocomposite Technology, Institute of Tropical Forestry and Forest Products, UPM