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Comparative characterization of *Macaranga* species collected from secondary forests in East Kalimantan for biorefinery of unutilized fast growing wood

RUDIANTO AMIRTA[1,♥], SYAFFIYA ISNU NAFITRI[2], RETNO WULANDARI[3], YULIANSYAH[1], WIWIN SUWINARTI[1], KRISHNA PURNAWAN CANDRA[4], TAKASHI WATANABE[5]

[1]Faculty of Forestry, Mulawarman University. Jl. Ki Hajar Dewantara, Samarinda 75119, East Kalimantan. Indonesia, Tel./fax. +62-541-748683, ♥email: r_amirta@yahoo.com
[2]Graduate School of Environmental Science, Mulawarman University. Jl. Ki Hajar Dewantara, Samarinda 75119, East Kalimantan, Indonesia.
[3]Faculty of Engineering, Mulawarman University. Jl. Sambaliung No. 9, Samarinda 75119, East Kalimantan, Indonesia.
[4]Faculty of Agriculture, Mulawarman University. Jl. Pasir Balengkong, Samarinda 75119, East Kalimantan, Indonesia.
[5]Research Institute for Sustainable Humanosphere (RISH), Kyoto University, Gokasho, Uji, Kyoto 611-0011, Japan.

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Abstract. *Amirta R, Nafitri SI, Wulandari R, Yuliansyah, Suwinarti W, Candra KP, Watanabe T. 2016. Comparative characterization of* Macaranga *species collected from secondary forests in East Kalimantan for biorefinery of unutilized fast growing wood. Biodiversitas 17: 116-123.* Wood species for industrial forest plantation has been selected to produce construction wood materials, boards and papers, and unutilized fast growing wood as a source for biofuel production has been out of the scope for selection. *Macaranga* Thouars (Euphorbiaceae) is widely distributed in the tropics and importance of the genus has been recognized due to its high level of growth rate and adaptability to constitute forest ecosystem. However, potency of the genus as a source for bioethanol production has not been systematically studied. We herein first report differential properties of six *Macaranga* wood species collected in East Kalimantan, Indonesia, as a raw feedstock for enzymatic saccharification for bioethanol production. Among the wood species examined, the highest sugar yield 48.6% (weight of original wood basis), which corresponds to 315 mL ethanol/kg biomass, was obtained with 5.0% NaOH at 160ºC for *M. hypoleuca*. Significant differences in the sensitivity to alkaline concentration and temperature have been found among the species. A high sugar yield, 40.4% was obtained for *M. winkleri* with a low alkaline concentration, 3.5% NaOH at 150ºC, while *M. motleyana* gave the sugar yield 12.8% under the same condition. *M. motleyana* required a set of the conditions with higher NaOH concentration 5.0% and temperatures over 160ºC. The harsh condition with 5.0% NaOH at 170ºC promoted delignification of all the species but *M. hypoleuca* decreased the saccharification yield by raising the temperature from 160ºC to 170ºC, probably due to decomposition of carbohydrate cores. This temperature-dependent negative effect was not observed with 3.5% NaOH for *M. hypoleuca*. These results indicate that differences in the balance between disintegration effects and excess degradation of carbohydrates are different among the species and the variation should be taken into account on screening. Thus, we found a wide range of diversity in the susceptibility to alkaline pretreatment in the genus *Macaranga* and selected the wood species giving high productivity of fermentable sugars.

Keywords: Alkaline pretreatment, biorefinery, ethanol, *Macaranga*, wood biomass

INTRODUCTION

Recently, it has been recognized that conversion of abundant lignocellulosic biomass to biofuels presents a viable option for improving energy security and reducing greenhouse emissions. Biofuels are cleaner-burning than fossil fuels, and the short cycle of growing plants coupled with their burning emits much less CO_2 to the atmosphere. It has been reported that bioethanol from lignocellulosic biomass has the potential to reduce greenhouse gas emissions by 86% (Wang et al 2008).

As one of the countries which have abundant reserves of forest biomass and agricultural residues and expect future energy crisis, Indonesia government has declared to start production of fuels and energy from renewable sources. The government realizes that the biofuels and bioenergy industries will increase the amount of domestic supply of fuels with decrease in subsidy for promotion of the biofuels (Watanabe et al. 2008). Thus far, industrial forest plantation has been designed to produce construction wood materials, boards and papers, and potency of unutilized fast growing wood as a source for biofuel production has received much less attention. However, tropical rain forest includes a wide variety of wood species which has no values for the current industry but may have a great deal of potential for production of biofuels and chemicals.

From the view point of biodiversity and potential of the bioresources for sustainable society, WWF Indonesia pointed out importance of the tropical forests in Indonesia, particularly in Kayan Mentarang Forest, Malinau, East Kalimantan, which includes around 15,000 species of plants (Pio and D'Cruz 2005). The biodiversity value of the forest is the highest compared to other places on the earth. Forest in Kalimantan is characterized also by richness in endemic species. There are at least 6,000 endemic species

of plants, including 155 dipterocarp trees species and more than 30 of the genus *Macaranga* and *Mallotus* (Euphorbiaceae) plants (Pio and D'Cruz 2005; Slik 2003, 2005).

Macaranga is known as one of the pioneer species classified in very fast growing species in the tropical forest ecosystem. Distribution of more than 300 of the genus *Macaranga* spreads in the southern part of Asia, Africa, Australia, and the South Pacific regions (Webster 1994). Although importance of *Macaranga* for biological diversity and its potential as a source for biorefinery can be expected, the biomass potency of *Macaranga* is not fully perceived benefits. The lack of information on the basic properties, function and suitability as the feedstock for the fuels and energy production, is believed as the main reason and barrier factor for utilization of this wood species. *Macaranga* has a wide variety of variations in its genus, and understanding of the properties of each species as a feedstock for biofuels is important for establishment of biorefinery.

Woody biomass, including many species in the genus *Macaranga* has a complex composite structure, and its efficient utilization requires exposure of cellulose and hemicelluloses from the cell walls coated with lignin. Lignin is a major factor limiting the degradation of lignocellulosics by microbial, physical and chemical pretreatments. To break the composite structure, various pretreatment methods such as microbial treatment using white-rot fungi, diluted and concentrated acids, steam explosion, microwave irradiation, milling, CO_2 explosion, ammonia fiber explosion (AFEX), autohydrolysis and alkaline treatments have been studied (Itoh et al. 2003, Nakamura and Godliving 2003; Amirta et al. 2006; Kumar et al. 2009a; Verma et al. 2010; Chiaramonty et al. 2012). In this study, we selected alkaline pretreatments for processing of 6 species of *Macaranga* wood collected in secondary forests in East Kalimantan, Indonesia. The susceptibility of the wood species to alkaline pretreatment for enzymatic saccharification is reported.

MATERIALS AND METHODS

Study area

The field observation and plant material including wood biomass was collected from Bukit Soeharto Education Forest of Mulawarman University located at Kutai Kertanegara District, East Kalimantan, Indonesia (116°50'6.89"E-117°9'53.81"E, 0°38'43.38"S-1°5'24.71"S). This education forest has an area of about 22,000 ha and annual temperature of 24-30°C, while the daily temperatures fluctuate between 3-4°C. The mean annual precipitation was 1921.3 mm, whereas the highest monthly rainfall was obtained in March and the lowest occurs in September amounted to 54.3 mm, respectively.

Wood material

Wood samples from six species of *Macaranga* with diameter about 10-20 cm and their leaves and branches were collected from Mulawarman University Education Forest located at Bukit Soeharto, Kutai Kertanegara, East Kalimantan, Indonesia. Leaves of wood samples were identified as *Macaranga conifera*, *M. gigantea*, *M. hypoleuca*, *M. motleyana*, *M. pearsonii* and *M. winkleri* in the Laboratory of Forest Dendrology, Faculty of Forestry, Mulawarman University, Samarinda, East Kalimantan, Indonesia. The wood samples were debarked, chipped and air dried up to approximately 12% moisture content (MC), and used throughout this study.

Alkaline pretreatment of woody biomass

Alkaline pretreatment of *Macaranga* wood was carried out for 60 min at 150° and 170°C using a liquid-to-solid ratio 8:1 (w/w) and NaOH concentration between 3.5% and 5.0% based on dry weight of the woody biomass. The reactions were carried out using a rotary digester equipped with a controller for pressure, rotary speed and temperature. After the reaction, the pulp fraction was separated by filtration and washed extensively with tap water until neutral pH.

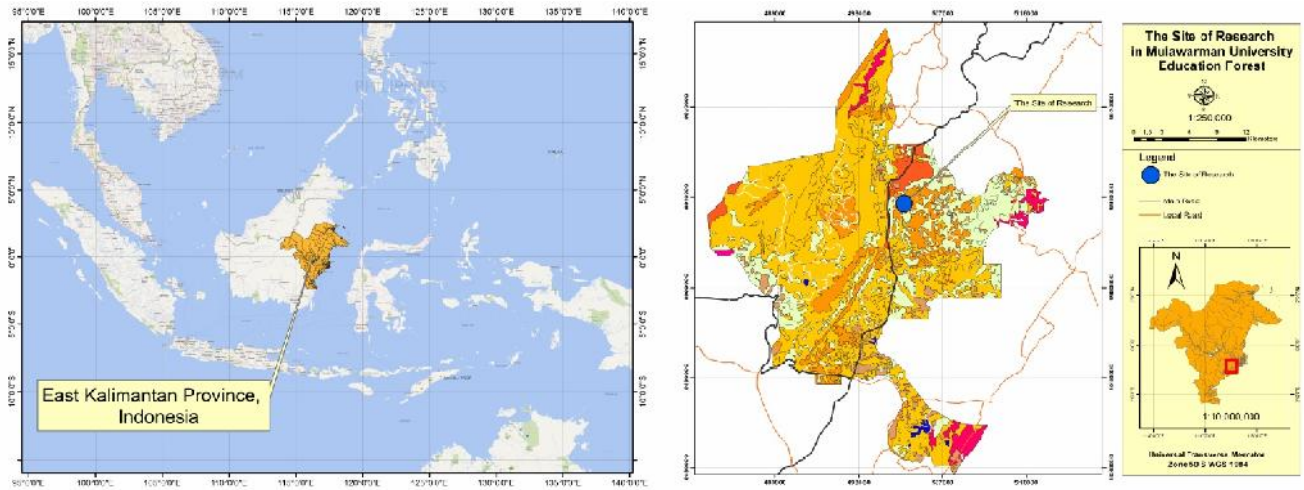

Figure 1. Sampling location at Bukit Soeharto Education Forest of Mulawarman University, Kutai Kertanegara, East Kalimantan, Indonesia

Wood component analysis

The Klason lignin content was determined by the TAPPI standard method (1998). The holocellulose and α-cellulose contents were determined according to Wise's chlorite method (Wise et al. 1946) and the TAPPI standard method (1988), respectively. The reducing sugar content was determined by the Somogyi-Nelson method (Somogyi 1952).

Enzyme activity

Filter paper unit activities were assayed in reaction mixture containing 50 mg (w/v) Whatman filter paper number 1, 50 mM tartrate buffer, pH 4.5 and the enzyme. After incubation at 50ºC for 30 min., the reducing sugars produced were determined by Somogy-Nelson method (Somogy 1952). One unit (U) of each enzyme activity is defined as the amount of enzyme, which produce 1 µmol reducing sugar as glucose in the reaction mixture per minute under above specific condition.

Saccharification of wood biomass

The wet pulp fraction was hydrolyzed with a commercial cellulose preparation, meicellase from *Trichoderma viride* (Meiji Seika Co., Ltd., Japan), 224 filter paper units (FPU)/g, β-glucosidase activity 264 IU/g). The cellulase enzyme loading was an 8-FPU/g substrate. Enzymatic hydrolysis was performed at a substrate concentration of 2% in 0.05 M sodium citrate buffer (pH 4.5) containing 0.02% sodium azide at 45ºC on a rotary shaker (NTS-4000C, Rikakikai, Japan) at 140 rpm for 48 h (Itoh et al. 2003). The saccharification ratio per pulp was calculated according to the NREL LAP-009 procedure (Brown and Torget 1996). The sugar yield per wood is based on the weight percentage of the reducing sugars to the original wood. The overall yield of sugars per wood is calculated by multiplying the saccharification ratio per pulp and the pulp yield. All enzymatic hydrolysis experiments were performed in triplicate.

Estimation of ethanol production from woody biomass

Potential ethanol production from *Macaranga* wood was estimated based on the amount of hexose sugar (HXTEL) in the lignocellulosic material obtained by enzymatic saccharification of the insoluble pulp fraction. Due to the high content of glucose in the pulp fraction, HXTEL was approximated by the amount of reducing sugars obtained from the pulp fraction (equation 1). The ethanol yields (ETOHBIO) based on the weight of original biomass was calculated from equation (2).

$$HEXTEL = HEX \times a \quad (mg/kg) \quad \text{eq.1}$$

$$ETOHBIO = HXTEL \times Ye.h/b \quad (mL/kg) \quad \text{eq.2}$$

Where HEX is the hexose (D-glucose) yield upon saccharification from hexosan (w/w, of original wood basis), a is the weight of substrate (1000 mg, 1kg), Ye.h is the theoretical ethanol yield from hexose (D-glucose) (0.511), and b is the ethanol density (0.789 kg/L) (Premjet et al. 2013-Modified).

RESULTS AND DISCUSSION

Lignocellulosic composition of *Macaranga*

The genus *Macaranga* widely distributes in tropical regions in the world with a wide range of diversity counting 300 different species. Since many years ago, the light density hardwood from a pioneer tree species of *Macaranga* was traditionally used as fuel wood material and to be a primary source of energy for the people living in the remote area and surrounding of forest area, particularly in Southeast Asia countries and India (Bhatt and Tomar 2002; Yuliansyah et al. 2012). Instead of fuelwood, utilization of *Macaranga* is still limited due to lack in natural physical strength as a construction material and short fiber morphology for paper production (Ang et al. 2009; Adi et al. 2014). However, the weak physical properties may contribute biorefinery process including production of biofuels through enzymatic saccharification and fermentation. We collected *Macaranga* species from the secondary forest in East Kalimantan and evaluated their properties as the source for sugar production by enzymatic saccharification, aiming at constituting a new biorefinery process of unutilized fast growing wood species in the tropics. Because the collected wood species is suitable to grow on the soil under the climate conditions of the collected area, selection of the wood species directly lead to the new forest plantation industry coupled with the biofuel production.

We characterized changes in the lignin content and susceptibility to enzymatic saccharification after alkaline pretreatment at temperatures between 150ºC and 170ºC with 3.5-5.0% NaOH. The pretreatment demonstrated that the alkaline pretreatment decreased the lignin content and gave a high level of sugar yields by enzymatic saccharification to the extent comparable to other hardwood and softwood species reported for bioethanol production (Zhao et al. 2008; Mirahmadi et al. 2010; Verma et al. 2010; Alvarez et al. 2013). The alkaline pretreatment effectively decreased the Klason lignin content and produced residual pulp fractions as a result of disintegration of the cell wall structure (Table 2 and 3). The removal of lignin is beneficial for enzymatic saccharification due to increased accessibility of hydrolases to cellulose and hemicelluloses and decrease in non-productive binding between lignin and the enzymes (Zhao et al. 2008; Alvarez et al. 2013; Rahikainen et al. 2013).

The highest decrease in lignin content was obtained when 5.0% NaOH was applied at 170ºC. Under this condition, decrease in Klason lignin content was from 27.6% to 4.8% (*M. hypoleuca*), 27.6% to 4.7% (*M. gigantea*), 30.8% to 5.2% (*M. motleyana*), 26.5% to 5.2% (*M. conifera*), 32.9% to 5.4% (*M. pearsonii*) and 28.7% to 3.1% (*M. winkleri*), (Table 3). As for *M. winkleri* 89% of the lignin was removed by the pretreatment. Although the pretreatment condition was suitable for delignification, the high temperature decreased the pulp yield owing to the decomposition of carbohydrates, resulted in the lower overall sugar yields (Table 4). For instance, when the reaction temperature was raised from 160ºC to 170ºC using 5.0% NaOH, the pulp yield decreased from 53.5% to

45.0% (*M. hypoleuca*), 50.3% to 44.5% (*M. motleyana*), 60.4% to 44.5% (*M. conifera*), 54.3% to 46.6% (*M. winkleri*), 56.1% to 49.5% (*M. pearsonii*) and 45.4 to 41.7% (*M. gigantea*) (Table 2).

The effects of alkali pretreatment on enzymatic saccharification was analyzed at two different concentrations of NaOH and three set of temperatures using a commercial cellulase from *T. viride*, meicelase (Table 4). The ethanol yields estimated by the sugar yield are tabulated in Figure 3. Neutral sugar composition of the pulp obtained using 3.5% and 5.0% NaOH at 160ºC for 60 min was analyzed by HPLC equipped with a fluorescence detector and post-labeling reactor (Figure 2). The pulp fraction processed at 3.5% and 5.0% of NaOH at 160°C for 60 min contained 94.9% and 97.1% glucose as the major sugar with 5.1% and 2.9% xylose, respectively. The amount of arabinose and mannose were below the background level, indicating that the pulp fraction contained cellulose as a major carbohydrate component with a small amount of xylan. General trend for promotion of sugar yield by higher concentration of NaOH with the decreased amount of remaining lignin was found (Table 3 and 4), in accordance with the previous report by Taherzadeh and Karimi (2008); Wang et al. (2008); and Kumar et al. (2009b), who described that the hydrolizability of NaOH-treated hardwood increased with decrease in lignin content. However, we found exceptions of the theory and striking differences in the susceptibility to the concentration of NaOH among the *Macaranga* wood species examined.

High sugar yield, 40.4% (weight of original wood basis) was obtained for *M. winkleri* even at lower alkaline concentration, 3.5% NaOH at 150ºC. Increase in the NaOH concentration from 3.5% to 5.0% increased the sugar yield just by 3.2%. On the contrary, sugar yield of M. motleyana with 3.5% NaOH at 160ºC was only12.8%, while the pretreatment with 5.0% NaOH gave the sugar yield 45.3% at the same temperature. Thus, the higher concentration increased the sugar yield from *M. motleyana* by 3.5 times. This effect was not prominent at 150ºC for the same wood as found in the yields 12.8% and 14.6% at the NaOH concentration 3.5% and 5.0%, respectively. Thus, temperatures breaking the cell wall structures depends both wood species, and increase in the alkaline concentration below the breaking temperature is useless for the pretreatment. Thus, a wide range of diversity existed in the genus, *Macaranga* in terms of suitability to alkaline pretreatment for enzymatic saccharification and fermentation. Among the *Macaranga* wood species, *M. winkleri* can be highlighted by its high degradability caused by low concentration of NaOH at low temperature. In the series of *Macaranga* wood, *M. hypoleuca* gave the highest sugar yield 48.6% based on the weight of original wood with 5.0% NaOH at 160ºC. The sugar yield corresponds to 315 mL ethanol/kg of the original wood (Figure 3).

Table 1. Composition of original *Macaranga* wood

Wood species	Chemical component* (%)		
	Lignin	Holocellulose	Cellulose
M. hypoleuca	27.6 ± 0.2	73.0 ± 0.8	68.8 ± 0.5
M.gigantea	27.6 ± 0.7	71.0 ± 0.3	63.0 ± 0.1
M. motleyana	30.8 ± 0.4	72.2 ± 1.7	65.4 ± 0.3
M. conifera	26.5 ± 0.7	70.7 ± 0.3	61.0 ± 0.7
M. winkleri	28.7 ± 0.9	69.7 ± 0.2	63.2 ± 0.9
M. pearsonii	32.9 ± 1.1	70.7 ± 0.2	67.4 ± 1.1

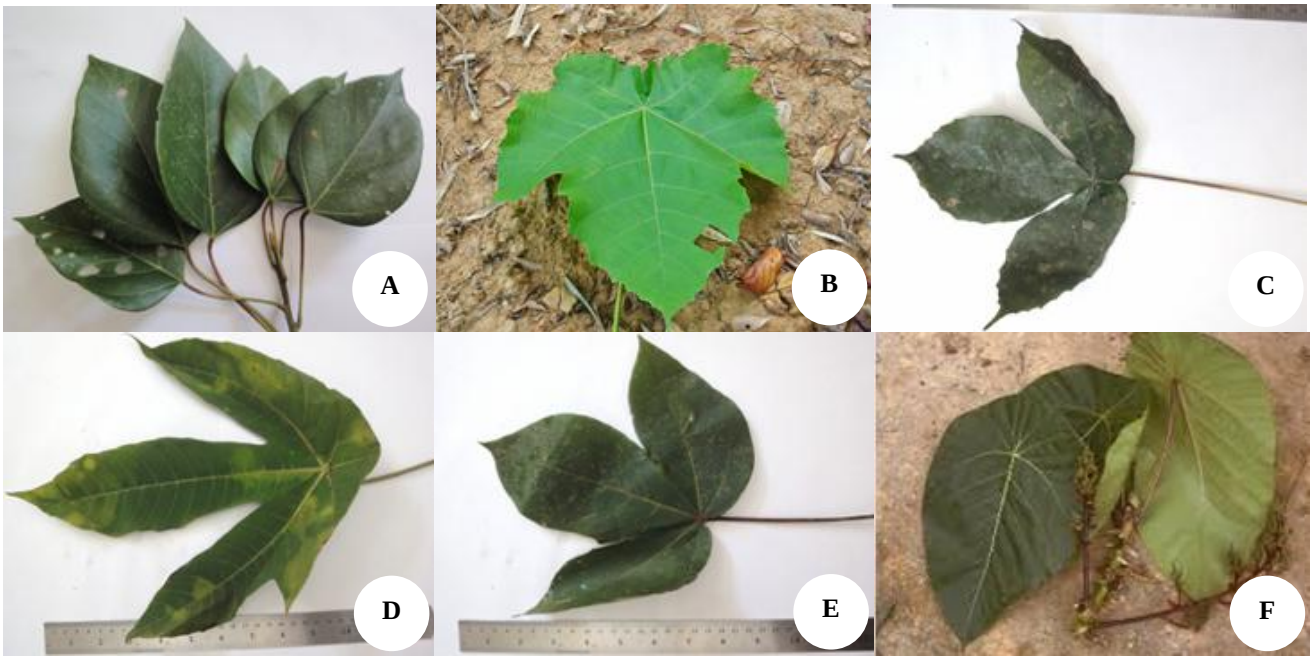

Figure 1. *Macaranga* plant species used in this research. A. *Macaranga conifera,* B. *M. gigantea*, C. *M. hypoleuca*, D. *M. motleyana,* E. *M. pearsonii* and F. *M. winkleri*

Table 2. Pulp yield of *Macaranga* wood pretreated with 3.5 and 5.0% of NaOH at 170°C for 60 min

Wood species	Pulp yield[a] (%)					
	150°C		160°C		170°C	
	3.5% NaOH	5.0% NaOH	3.5% NaOH	5.0% NaOH	3.5% NaOH	5.0% NaOH
M. hypoleuca	76.4[b]	72.1	71.4	53.5	66.0	45.0
M. gigantea	68.5[b]	60.7	61.2	45.4	49.8	41.7
M. motleyana	75.7[b]	66.6	71.3	50.3	56.8	44.5
M. conifera	74.5[b]	69.2	69.7	60.4	65.5	44.5
M. winkleri	69.2[b]	64.0	63.3	54.3	57.1	46.6
M. pearsonii	73.5[b]	71.7	68.1	56.1	56.7	49.5

Note: [a]Pulp yield based on the weight of original wood; [b]Pulp was not fibrillated completely

Table 3. Residual lignin content of *Macaranga* wood pretreated with 3.5% and 5% NaOH at 170°C for 60 min

Wood species	Lignin[a] (%)					
	150°C		160°C		170°C	
	3.5% NaOH	5.0% NaOH	3.5% NaOH	5.0% NaOH	3.5% NaOH	5.0% NaOH
M. hypoleuca	9.6 ± 0.2	9.2 ± 0.1	8.9 ± 0.1	5.7 ± 0.2	8.2 ± 0. 1	4.8 ± 0.1
M. gigantea	8.7 ± 0.3	7.6 ± 0.4	7.9 ± 0.2	5.3 ± 1.1	5.8 ± 0. 1	4.7 ± 0.1
M. motleyana	9.6 ± 0.1	8.7 ± 0.0	8.9 ± 0.1	5.8 ± 0.2	7.4 ± 1.2	5.2 ± 0.3
M. conifera	9.1 ± 0.2	8.6 ± 0. 3	9.1 ± 0.1	7.8 ± 0.1	8.4 ± 0.1	5.2 ± 0.1
M. winkleri	8.7 ± 0.1	7.9 ± 0.1	7.9 ± 0.3	6.2 ± 0.1	6.8 ± 0.0	3.1 ± 0.0
M. pearsonii	9.5 ± 0.1	9.2 ± 0.1	8.9 ± 0.1	7.1 ± 0.2	7.1 ± 0.2	5.4 ± 0.9

Note: [a] Klason lignin was determined based on the weight of original wood

Table 4. Enzymatic saccharification yields of *Macaranga* wood pretreated with 3.5% and 5% NaOH for 60 min

Wood species	Reaction temperature (°C)	Saccharification yield (%)			
		3.5% NaOH		5.0% NaOH	
		Based pulp[a]	Based wood[b]	Based pulp[a]	Based wood[b]
M. hypoleuca	150	27.0 ± 2.0	20.7 ± 4.5	41.8 ± 5.4	30.2 ± 3.0
M. gigantea		22.3 ± 1.7	15.3 ± 0.9	35.5 ± 2.4	21.5 ± 1.1
M. motleyana		16.9 ± 1.7	12.8 ± 2.9	21.9 ± 3.3	14.6 ± 0.9
M. conifera		28.1 ± 1.4	21.0 ± 2.3	58.1 ± 2.4	40.2 ± 3.5
M. winkleri		58.8 ± 0.9	40.4 ± 0.6	68.1 ± 0.7	43.6 ± 0.4
M. pearsonii		18.1 ± 0.9	13.3 ± 0.0	25.6 ± 3.9	18.3 ± 2.5
M. hypoleuca	160	31.1 ± 6.9	22.2 ± 4.4	91.0 ± 0. 7	48.6 ± 0.3
M. gigantea		26.5 ± 3.6	16.3 ± 2.0	83.1 ± 0.3	37.8 ± 0.1
M. motleyana		18.0 ± 6.0	12.8 ± 3.6	90.1 ± 1.7	45.3 ± 0.5
M. conifera		37.1 ± 1.0	25.8 ± 0.6	69.7 ± 5.7	42.1 ± 3.0
M. winkleri		58.4 ± 0.9	40.1 ± 1.6	80.2 ± 0.8	43.6 ± 0.4
M. pearsonii		33.0 ± 1.7	22.4 ± 1.1	54.4 ± 6.5	30.6 ± 3.4
M. hypoleuca	170	50.6 ± 5.0	33.4 ± 3.0	90.9 ± 0.8	40.9 ± 0.3
M. gigantea		53.0 ± 3.3	26.4 ± 1.2	81.4 ± 3.6	34.0 ± 0.2
M. motleyana		41.5 ± 6.3	23.6 ± 3.3	94.0 ± 3.9	41.8 ± 2.7
M. conifera		41.1 ± 1.9	26.9 ± 1.1	99.6 ± 5.1	44.4 ± 2.0
M. winkleri		71.8 ± 0.7	41.0 ± 0.5	96.9 ± 5.3	45.2 ± 2.2
M. pearsonii		51.3 ± 5.5	29.0 ± 3.0	63.3 ± 0.9	31.6 ± 0.4

Note: [a]Weight percentage of the pulp based on the weight of pulp fraction obtained. [b]Weight of pulp based on the weight of original wood

Macaranga hypoleuca was also sensitive to alkaline concentration like *M. motleyana* and it gave only 22.2% sugar yield at the same temperature 160ºC with 3.5% NaOH. The sugar yield is equivalent to 83 mL ethanol/kg of the original wood. Interestingly reducing sugar yield of *M. hypoleuca* decreased from 48.6% to 40.9% when the temperature was raised from 160ºC to 170ºC with 5.0% of NaOH whilst the same temperature increase with 3.5% NaOH increased the sugar yield from 22.2% to 33.4%. Under the high concentration of NaOH at 170ºC, degradation of carbohydrate core structures may become prominent over the range of disintegration effects of the

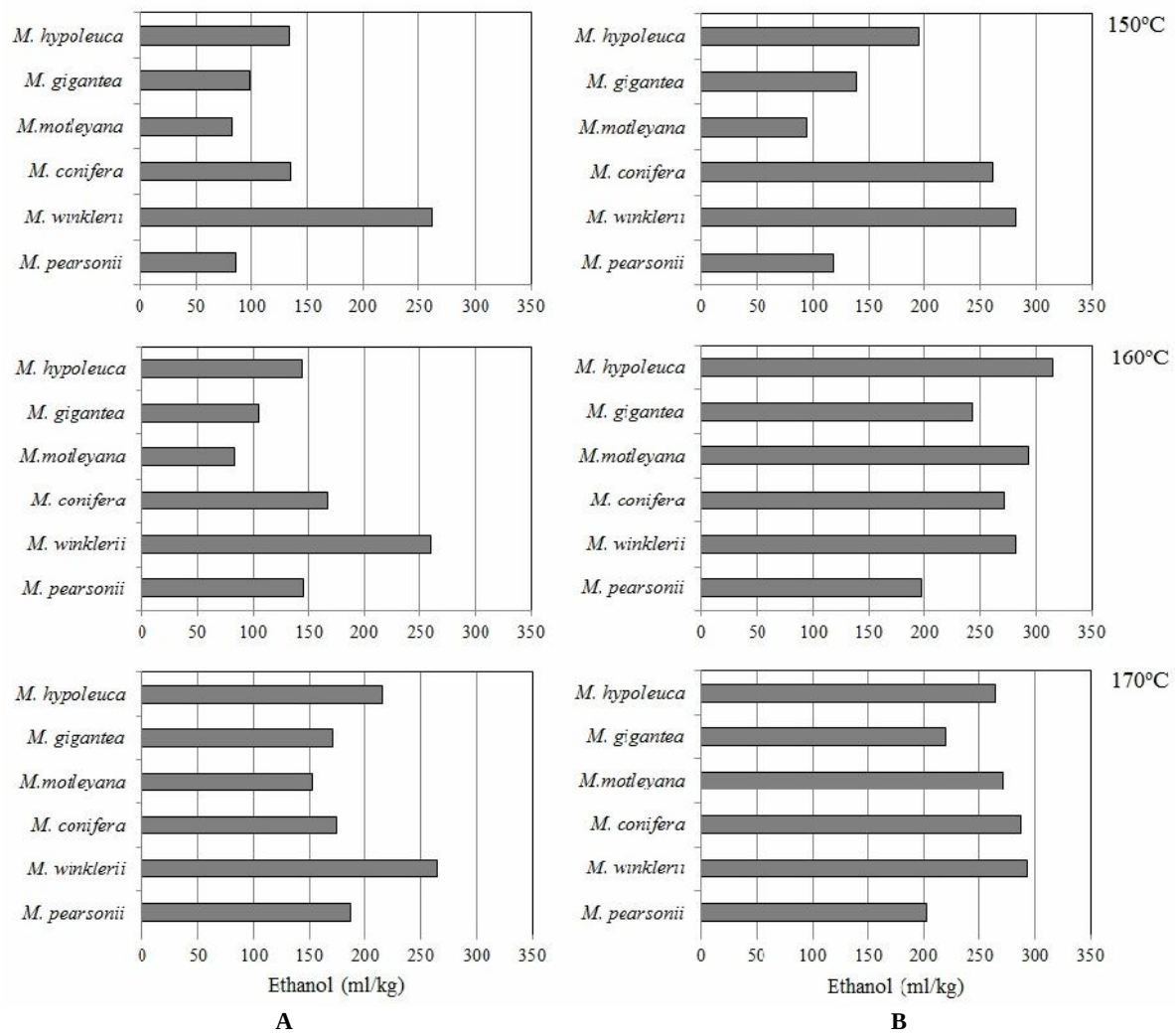

Figure 3. Estimated ethanol yields from *Macaranga* wood pretreated with 3.5% and 5% NaOH at 150°C-170°C for 60 min: A. 3.5% NaOH, and B. 5% NaOH. The values are expressed by the weight of original biomass

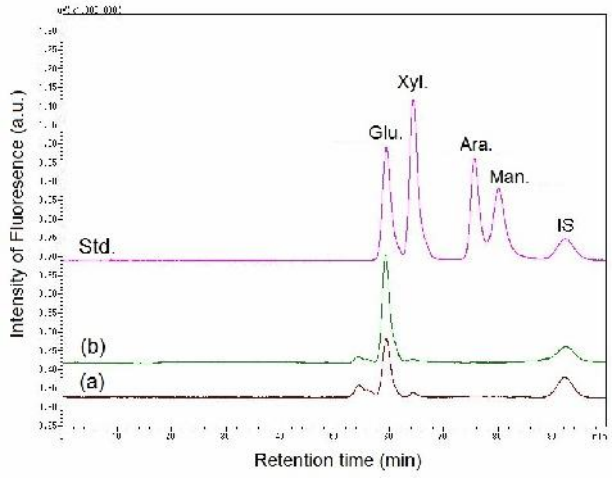

Figure 2. HPLC profile of the saccharified sugar obtained from *M. hypoleuca* by pretreatment with (a) 3.5% and (b) 5.0% of NaOH at 160ºC for 60 min

wood cell walls. This trend was also found for *M. gigantea* and *M. motleyana*. However, the theory was not true for *M. winkleri*, *M. conifera* and *M. pearsonii*. These wood species increased the sugar yield slightly with 5.0% NaOH by increasing the temperature from 160ºC to 170ºC. The effects of disintegration of the cell walls are prominent over the range of decomposition of the carbohydrate cores.

In this study a broad range of differences in adaptability to enzymatic saccharification for ethanol fermentation was found in the genus *Macaranga*. This phenomenon inline with the previous results reported. Biomass properties vary and are commonly associated with plant species (Avelin et al. 2014). *Macaranga hypoleuca* and *M. winkleri* are attractive for their high conversion efficiency and susceptibility to the pretreatment. *Macaranga motleyana* and *M. conifera* are also suitable for the bioethanol production while *M. pearsonii* lacks in the suitability for the conversion. *Macaranga gigantea*, *M. hypoleuca*, and *M. winkleri* have been used as a secondary firewood

species by local people in East and North Kalimantan Provinces, instead of the higher density wood species such as *Vitex pinnata*, *Nephelium lappacelum*, *Blumeodendron kurzii* and *Dipterocarpus* sp. (Yuliansyah et al. 2012). The selected fast growing wood species belonging to *Macaranga* are the pioneer woods that usually grow after forest fire or opening area for the shifting cultivation. *Macaranga* was also reported growth sporadically on the gap of forest canopy, open area and degraded land (Slik et al. 2003). Instead of firewood, *Macaranga* was also traditionally used by Dayak people in East Kalimantan as the natural plant indicator to determine the end of the recovery period of forest land after ground fire or shifting cultivation activities. The present study gives a new role in the *Macaranga* as a resource for biorefinery. Design of the sustainable cycle including forest plantation of the *Macaranga* wood and other wood species, and their conversion into fuels and chemicals will activate the local economy in the tropics with concomitant contribution to the global environment.

Finally, our finding suggested that tropical wood biomass *Macaranga*, particularly *M. hypoleuca* is a promising material in term of pulp yield, and sugar production and potentially used as the feedstock or raw material for the lignocellulosic bioethanol production and chemical in the near future. Even, further investigation required to explore and find more attractive tropical fast growing wood plant species that available in the tropical rain forest, particularly in East Kalimantan, and also Indonesia in combination with the more effective pretreatment processes. Last but not least, based on our knowledge this is the first paper that report on the potential saccharified sugar and estimation of ethanol production from *Macaranga* wood biomass as far.

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