CENTRAL KALIMANTAN'S FAST GROWING SPECIES: SUITABILITY FOR PULP AND PAPER

Danang S. Adi[1,*], Ika Wahyuni[1], Lucky Risanto[1], Sri Rulliaty[2], Euis Hermiati[1], Wahyu Dwianto[1] and Takashi Watanabe[3]

[1]Research Center for Biomaterials, Indonesian Institute of Sciences, Cibinong Science Center, Bogor 16911, Indonesia
[2]Forestry Engineering and Forest Products Processing, Research and Development Center, Jl. Gunung Batu No.5, Bogor 16610, Indonesia
[3]Research Institute for Sustainable Humanosphere, Kyoto University, Gokasho, Uji, Kyoto, Japan

Received: 21 August 2014, Revised: 6 January 2015, Accepted: 16 January 2015

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Recent studies of fast growing species grown in PT. Sari Bumi Kusuma, Central Kalimantan, show that based on their fiber dimensions there are five species, namely *Endospermum diadenum*, *Dillenia* spp., *Adinandra dumosa*, *Adiandra* sp., and *Nauclea junghuhnii* with good potential for pulp and paper production. The fiber length of those five wood species are was more than 2,200 μm on average. This paper studies the physical properties, fiber dimensions and their chemical contents to predict the paper and pulp quality. The result shows that all of the species were classified in the medium to high density category. All species were classified into the first class quality for pulp and paper. Based on chemical contents, *Dillenia* sp. is the most suitable species due to its high value of holocellulose and α-cellulose, low lignin content, and its fiber length is about 3,119 μm on average. *A. dumosa* also has good opportunities because it had the longest fiber lengths (3,137 μm on average) and high value of holocellulose, even though it has the highest lignin content. While *Nuclea junghuhnii* is less suitable due to low values of holocellulose and α-cellulose.

Keywords: Fast growing wood, fiber characteristic, density, chemical composition, pulp and paper

KAYU CEPAT TUMBUH DARI KALIMANTAN TENGAH: KESESUAIANNYA UNTUK BAHAN BAKU PULP DAN KERTAS. Berdasarkan penelitian sebelumnya terhadap 30 jenis kayu cepat tumbuh dari PT Sari Bumi Kusuma, Kalimantan Tengah menunjukkan terdapat 5 jenis kayu yang berpotensi sebagai bahan baku pulp dan kertas. Panjang serat dari kelima jenis kayu, yaitu Endospermum diadenum*,* Dillenia sp.*,* Adinandra dumosa*,* Adinandra sp.*, and* Nauclea junghuhnii *lebih dari 2.200 µm. Tulisan ini mempelajari potensi penggunaan kelima jenis kayu tersebut untuk bahan baku pulp dan kertas. Hasil penelitian menunjukkan bahwa kelima jenis kayu mempunyai kerapatan medium sampai berat. Berdasarkan penilaian pada dimensi seratnya, kelima jenis kayu dapat diklasifikasikan dalam kelas kualitas satu untuk pulp dan kertas. Berdasarkan kandungan kimia kayunya,* Dillenia sp. *merupakan jenis yang paling potensial sebagai bahan pulp dan kertas karena memiliki panjang serat 3.119 µm, kandungan holoselulosa dan a selulosa tinggi, serta kandungan lignin yang rendah.* A. dumosa *juga berpotensi karena seratnya terpanjang, namun kandungan lignin terbanyak diantara kelima jenis kayu tersebut. Sedangkan* Nauclea junghuhnii *adalah jenis yang paling rendah potensinya untuk dijadikan bahan baku pulp dan kertas karena rendahnya kandungan holoselulosa dan a selulosa.*

Kata kunci: Kayu cepat tumbuh, karakteristik serat, kerapatan, kandungan kimia, pulp dan kertas

[*]Corresponding author: danang@biomaterial.lipi.go.id

I. INTRODUCTION

In the last few decades, Indonesia's pulp and paper industries have grown rapidly and have the potential to become one of the biggest pulp and paper industries in the world. In 2011, these industries produced about 7.3 million ton pulp per year from 7.9 million ton of the mills' production capacities and 10.7 million paper per year from 12.99 million ton of mills' production capacities. These production figures helped Indonesia to become the 9th biggest pulp and paper producer in the world and the 3rd of the Asian countries (Malau & Prasetyo, 2012). These industries have a shining prospect in the future because of the increasing demand for pulp and paper products. The Directorate General of Manufacture Based Industry, Ministry of Industry mentioned that global demand for paper has grown by 2.1% annually; However, in the developing countries it has grown by 4.1% (Malau & Prasetyo, 2012; Koran Jakarta, 2012).

Domestic paper demand was also predicted to grow in the future. In 2011, Indonesia's paper consumption was about 30 kg/capita/year. It is lower than that of ASEAN's which was about 50-60 kg/capita/year and much lower than Europe which was about 200 kg/capita/year (Karina, 2012; Neraca, 2012). The global population growth as well as economic growth in a developing country such as Indonesia is believed to lead to the enhancement of paper needs.

Indonesia covers tropical area where trees for pulp and paper or other purposes grow well. Some species, such as Acacia wood, which are used as primary raw materials for pulp production, can grow fast (it can reach 265 m^3/ha at 8 years) and has a short rotation period (Soemitro, 2004). Well known primary raw materials for pulp and paper industries in Indonesia are *Acacia mangium* (Marsoem, 2004) and *Pinus merkusii* (Martawijaya, Kartasujana, Mandang, Prawira & Kadir, 1989). Marsoem (2004) reported that a nine year old *A. mangium* plantation has the values of specific gravity, fiber length, Runkel ratio, and felting power of 0.36-0.53 g/cm^3, 0.78-1.12 mm, 0.30-0.45 and 40.5-45, respectively. *A. mangium* from Central Kalimantan, with the diameter of 14 cm and the ages of 7-10 year, has specific gravity, fiber length, Runkel ratio, and felting power of 0.41g/cm^3, 1.314 mm, 0.17 and 43.41, respectively (Adi et al., 2014). *Pinus merkusii* has values of specific gravity, fiber length, Runkel ratio and felting power of 0.55 g/cm^3, 5.57 mm, 0.24, and 111, respectively. Some wood species which have potential for pulp and paper production are also grown in the tropical Indonesian Forest. The pulp and paper properties may be higher than that of acacia and pine wood (Sable et al., 2012).

Recent research result showed that the five fast growing species grown in PT. Sari Bumi Kusuma (PT SBK) can potentially be developed as pulp and paper material, with the average fiber length greater than 2,200 μm and the wood of medium density (Adi et al., 2014). For tropical hardwood species this long fiber length is uncommon. Moreover, these fiber lengths were close to that of softwood species, such as Pine wood (Sable et al., 2012).

Fast growing species are classified as tree which have an annual mean increment of more than 1 cm per year (Dwianto, Amin, Dharmawan & Wahyuni, 2008). The five species studied are generally grow well in the open land after logging activity in the secondary forest at PT SBK's concession area. These species were used and planted by the nursery division of PT SBK (the year of planting is about 2003-2005) for soil reclamation in the concession area. With the diameter of more than 10 cm, these species have an average annual mean increment at least 1 cm/year, so it could be classified as fast growing wood species. For soil reclamation purposes these five species are not included in the logging activity. Neither these species were included as mixed wood forest class in the logging plan.

It is a good opportunity to develop these species to plantation forest since their abilities to grow in open and marginal lands. Combined with sustainable management of plantation forest, such as continuous and balanced planting, harvesting and replanting, the supply of wood to meet the wood demand for any purposes can be better secured. Generally, fast growing wood species have low quality due to their low properties values, such as wood density, strength, and durability (Panshin & de Zeeuw, 1980; Bowyer, Haygreen & Schmulsky, 2003). Therefore, the utilization of fast growing wood species has been limited to paper, pulp, and fuel wood (Kojima et al., 2009a). Fiber characteristics and fiber derived value are important to predict the suitability for pulp and paper, as well as paper sheet properties, e.g. tear and burst index, and tensile strength (Biermann, 1996; Bowyer et al., 2003; Ververis, Georghiou, Christodoulakis, Santas & Santas, 2004).

Parameters of wood properties, such as fiber characteristics, wood density as well as chemical composition, can be used to predict the pulp and paper quality. The chemical composition of wood: holocellulose, lignin, and α-cellulose are important parameters in pulp and paper making (Panshin & de Zeeuw, 1980; Biermann, 1996; Bowyer et al., 2003; Ververis et al., 2004). This paper estimates the three wood parameters for pulp and paper including: fiber characteristic, wood density and chemical content.

II. MATERIAL AND METHOD

A. Sampling Method

The wood species were taken from concession area at KM 35, Camp Nanga Nuak, PT SBK, Central Kalimantan (111054' E - 112026' E and 00038' S - 01007' S), Indonesia in March 2012. Species studied were *Endospermum diadenum* (dbh 12 cm), *Dillenia* sp. (dbh 18 cm), *Adinandra dumosa* (dbh 19.6 cm), *Adinandra* sp. (dbh 13.5 cm), and *Nauclea junghuhnii* (dbh 19.1 cm). *A. mangium* (dbh 14 cm) also was taken from the same place. These trees then were cut into discs with the thickness of 6-8 cm, beginning from 30 cm above the ground up to the diameter at breast high (Figure 1).

For each species only one tree was felled, and 10-15 discs from that tree were used to analyse its properties. The discs were then sawn for wood density analysis, and also for chips and meals. Randomly, chips were taken and would be used for fiber maceration, whereas the wood powders were used for chemical analysis. In the field, wood identification was determined using local name. Some part of the trees, such as leaf, flower, and fruit were taken to herbarium to determine its scientific name. Tree species identification was conducted from herbarium identification in Herbarium Bogoriense, Research Center, LIPI. In order to support the species identification, wood identification was also conducted in The Forestry Engineering and Forest Product Processing R&D Center, Ministry of Forestry.

B. Density and Fiber Characteristics

Wood density and moisture content analysis were conducted by referring to British Standard 373-1957 (BSI 07-1999). The maceration of the five woods was conducted to analyse fiber characteristics e.g. fiber length and fiber derived value. The method was conducted by Franklin's method, utilizing equal parts of hydrogen peroxide and acetic acid glacial, and then heated at 600°C for 1-2 days (Dodd, 1986).Variables tested for fiber derived values determination were Runkel ratio, felting power, Muhlsteph ratio, coefficient of rigidity, and flexibility ratio (Silitonga, Siagian & Nurahman, 1972; Ververis et al., 2004). *Acacia mangium* and *Pinus merkusii* were used as a comparison of the five species studied. The results were then analysed according to Vademiecum Kehutanan (1976) and Smook (1997) (Tabel 1).

C. Chemical Analysis

The woods were grinded into 40-60 mesh sizes meals. The parameters of chemical analysis i.e. extractives soluble in alcohol-benzene, holocellulose, α-cellulose, and lignin contents were determined according to the Mokushitsu Kagaku Jiken Manual (2000). Extraction were performed in ethanol: benzene 1:2 (v/v) for 6 h. Holocellulose was determined by using 1.5 g of the extracted wood meals. The samples were then treated in 90 ml of distilled water (aquades), 2.4 ml $NaClO_2$ 25% and 0.12 ml of acetic acid. Then, they were boiled in the water bath at 80°C. 2.4 ml $NaClO_2$ 25% and 0.12 ml

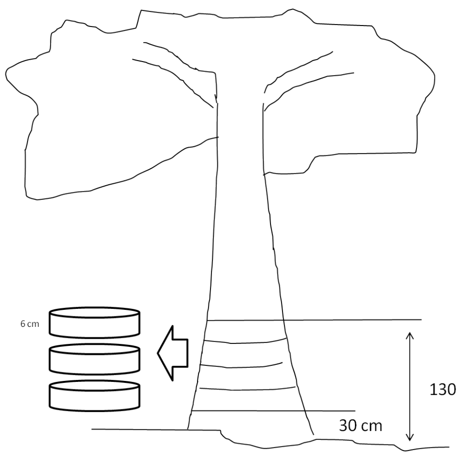

Figure 1. Scheme of wood sample

Table 1. Classification of fiber length and fiber derived value by Vademecum Kehutanan

Parameter	Class I		Class II		Class III		Class IV		Hardwood*	Softwood*
		Score								
Fiber Length (µm)	2200	100	1600-2200	75	900-1600	50	900	25		
Runkel ratio	0.25	100	0.2-0.5	75	0.5-0.1	50	1	25	0.4-0.7	0.35
Felting power	90	100	70-90	75	40-70	50	40	25	55-75	95-120
Flexibility ratio	0.8	100	0.6-0.8	75	0.4-0.6	50	0.6	25	55-70	75
Coefficient of rigidity	0.1	100	0.1-0.15	75	0.15-0.2	50	0.2	25		
Muhlsteph ratio	30%	100	30-60 %	75	60-80 %	50	80%	25		
Total Score	451-600		301-450		151-300		150			

Source: *Smook (1997), Vadamecum Kehutanan (1976)

of acetic acid was added to the sample until the color became white. For α-cellulose analysis, 0.5 g of holocelullose were soaked in 12.5 ml NaOH 17.5 %, and stirred for 30 minutes. Then, to the mixture was added 12.5 ml distilled water (aquades) and was filtered using fritted-glass filtering crucible (IG3). After washing the mixture using distilled water (aquades ",") 20 ml of acetic acid were added for the last washing. Klason Lignin was analyzed by using 0.5 g of the previously extracted wood meal. The meals were soaked in 7.5 ml H_2S0_4 72 %, then was stirred for 4 hours. After that, the sample was hydrolysed by 280 ml of distilled water (aquades) and boiled at autoclave 121°C for 15 minutes, then was filtered using fritted-glass filtering crucible.

III. RESULT AND DISCUSSION

The density of wood based on Panshin and de Zeeuw (1980) are classified as medium density (0.36-0.50) *i.e Endospermum diadenum* and *Adinandra* sp. and also high density (>0.50) *i.e Dillenia* sp., *Adinandra dumosa*, *Nauclea junghuhnii*. Generally, the higher the density of wood, the higher the yield of the pulp. (Bowyer et al., 2003). The high density of hardwood species indicates that there are high content of cellulose in the wood, which can increase the yield of the pulp (Casey, 1980). The density of wood are reported to have effect on yield, transportation and production cost. Panshin and de Zeeuw (1980) has reported that wood density may affect the quality of pulp, due to cell size and variations in the cell wall thickness. The value of wood density, fiber length and fiber derivative (Table 2 and 3) shows that

Table 2. Wood density, derivative value and scoring of species studied

Species	Fiber length (µm)	Density	Total Score	Class
Endospermum diadenum	2631	0.36	550	I
Dillenia sp.	3119	0.62	550	I
Adinandra dumosa	3137	0.53	550	I
Adinandra sp.	2868	0.44	550	I
Nauclea junghuhnii	2462	0.56	550	I
Acacia mangium[1*]	1071	0.68		
Pinus merkusii[2*]	5457	0.55		
Pinus silvestris[3*]	2150	0.455		
Acacia mangium[4*]	1120	0.53		
Acacia mangium[5*]	1314	0.41	550	I

Source: [1*]Kojima et al., (2009b); [2*]Martawijaya et al., (1989); [3*]Sable et al., (2012); [4*]Marsoem, (2004); [5*]Adi et al., (2014)

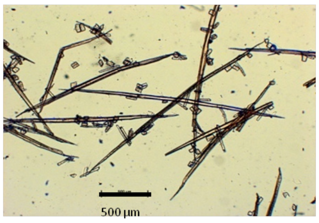

Figure. 2. *Endospermum diadenum*

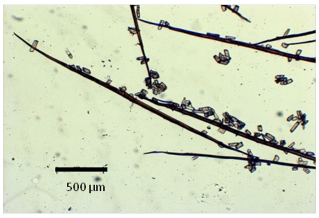

Figure 3. Dillenia sp.

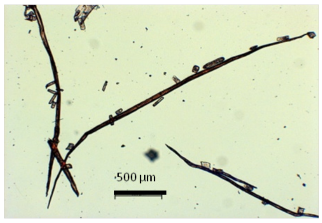

Figure 4. Adinandra dumosa

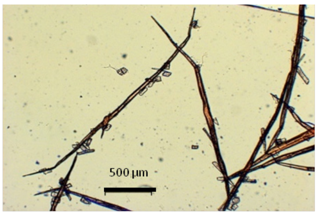

Figure 5. Adinandra sp.

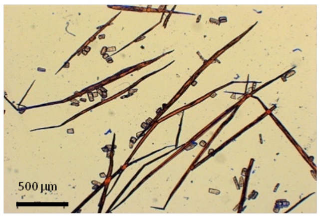

Figure 6. Nauclea junghuhnii

these five species as raw material for pulp and paper can be classified into the class I category. Moreover, these species tend to have the same properties as the softwood species, i.e. long fiber length and also low value of Runkel ratio, but the value of felting power is lower than that of softwood species. Generally, fiber length of hardwood species is shorter than that of softwood species (Biermann, 1996). Fibers of each species is shown in Figures 2-6.

The result is interesting as these five hardwood species from PT SBK has comparatively long fibers, the longest is *A. dumossa* (3.1 mm). Even concerning the levels of fiber lengths these species have similarities to the softwood species *Pinus silvestris* (2.1 mm), but the level of fiber length is lower than that for *Pinus merkusii* from Indonesia. *Acacia mangium*, which is the main raw material for pulp and paper production in Indonesia, has lower fiber length than these five species from Central Kalimantan. It seems that these species are promising as alternative wood sources for pulp and paper. The density of wood also has similarity with that of the Mangium wood from the same place (Central Kalimantan) or another place.

Fiber derived values (Table 2 and 3) show that these five species can be classified in the first quality for pulp and paper production.

Table 3. Fibre dimensions and derived values of fast-growing wood species from Central Kalimantan

Species	Fibre Dimensions (µm)				Fibre Derived Value				
	Fibre length	Diameter	Lumen	Cell wall thickness	Runkel ratio	Felting power	Flexibility ratio	Coefficient of rigidity	Muhlsteph ratio
E.diadenum	2631	52.37	47.07	2.65	0.12	52.93	0.90	0.05	19.34
Dillenia sp.	3119	54.62	48.85	2.89	0.12	55.21	0.89	0.05	20.16
A.dumosa	3137	60.77	55.15	2.81	0.11	52.78	0.91	0.05	17.77
Adinandra sp.	2868	59.41	52.99	3.21	0.12	49.44	0.89	0.05	20.48
N.junghuhnii	2462	43.89	37.97	2.96	0.16	57.13	0.86	0.07	25.22
A. mangium	1314	30.75	26.40	2.18	0.17	43.41	0.86	0.07	26.49

Moreover, the value of Runkel ratio, which is the most important fiber derived value, is close to that of *Pinus merkusii* (0.24). Runkel ratio indicates fiber to fiber bonding (Biermann, 1996, Bowyer et al., 2003). Runkel ratio can be used to determine the suitability of fiber for pulp production (Ogbonnaya, Roy-Macauley, Nwalozie & Anneros, 1997). It means that the lower the value of Runkel ratio, the higher is the contact area of fiber to fiber and the greater is the burst and tensile strength. According to Smook (1997), the value of flexibility ratio also has similarity with the softwood species. Flexibility ratio was reported to influence the burst and tensile strength as well as folding endurance (Ververis et al., 2004). Therefore, it can be assumed that these five species will have high burst index, tensile index, and folding endurance due to the high value of flexibility ratio.

Chemical properties of these fast growing wood (Figure 7) show that holocellulose content were relatively lower than those of Acacia wood, which was reported by Marsoem (2004), but it was similar with Acacia wood from PT SBK. Holocellulose is a term for the entire carbohydrate fraction of wood, i.e. cellulose and hemicelluloses (Fengel & Wegener, 1995; Biermann, 1996). Holocellulose is a carbohydrate fraction which is produced by wood delignification (Fengel & Wegener, 1995). Generally, pulping process is defined as removing lignin by taking the fiber (cellulose) from the lignocellulosic material. This means that the higher holocellulose content, the higher pulp yield from the pulping process. Hemicellulose reportedly could increase the properties of paper sheet, e.g. burst, tear, and tensile strength (Bierman, 1996). Figure 7 shows that four fast growing woods contain about 70 % of holocellulose. Thus, it can be predicted that the yield of pulping from these species are nearly similar to those from Acacia wood. The lowest holocellulose content is found in *Nauclea junghuhnii* (62.73 %) and is predicted to have lower pulp yield than the others.

Alpha cellulose content is the most important chemical component for pulp and paper sheet. Generally, it is considered that pure cellulose or α-cellulose is the substance in the wood fiber affecting most on the paper's strength, fiber bonding, and the characteristic of the paper sheet. Hydrogen bonding of OH groups in the cellulose could influence the physical properties of paper sheet (Biermann, 1996). The result shows that the α-cellulose content in the 5 investigated species is lower than those of in Acacia woods. However, α-cellulose content of these species was near to 40 %, thus, it has the potential to be used as raw material for pulp and paper production. Nieschlag et al. (1960) in Ververis et al. (2004) proposed that plant materials with a α-cellulose content of 34 % and more were characterized as promising for pulp and paper manufacturing from a chemical composition point of view. These five species have potential to produce high tear strength of pulp or paper due to their long fiber lengths and the low Runkel ratio.

Lignin contents of these five fast growing wood species were higher than those of Acacia and Pine wood (Figure 8). Ververis et al. (2004)

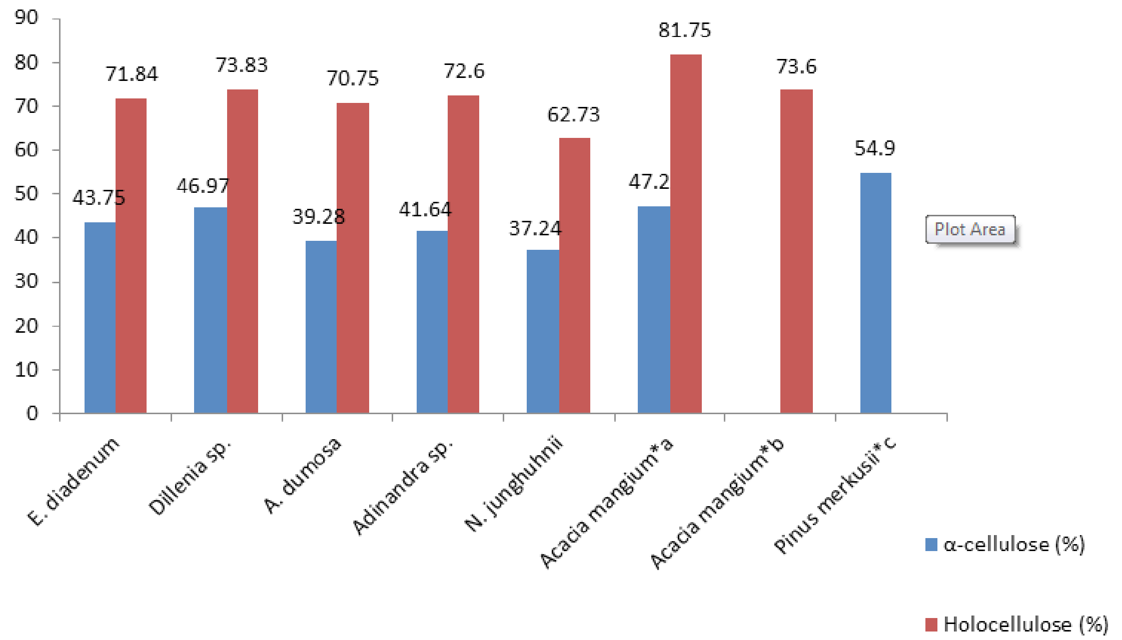

Figure 7. Holocellulose and α-cellulose of fast growing species

Source : a) Marsoem (2004) b) Adi et al. (2014) c) Martawijaya et al. (1989)

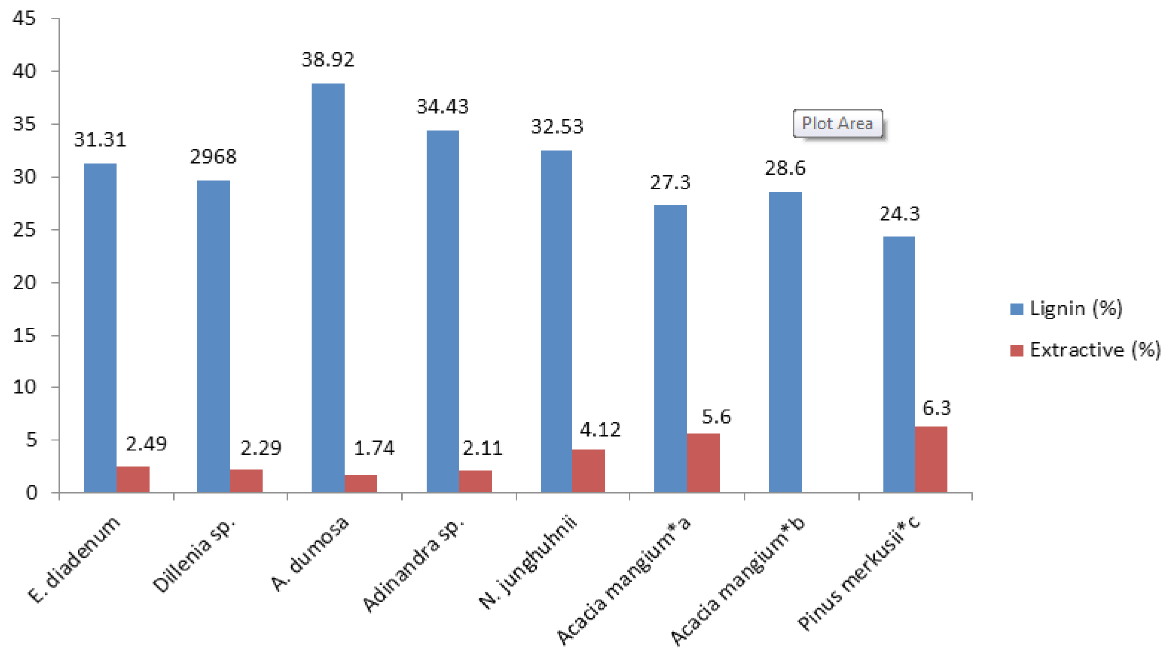

Figure 8. Lignin and extractive content

Source : a) Marsoem (2004) b) Adi et al. (2014) c) Martawijaya et al. (1989)

in their research reported that woods with 30% of lignin content are potential to be used as a raw material for pulp and paper. Lignin is a binder between fiber to fiber in the wood, thus in a pulping process it should be removed. Therefore, the 5 fast growing wood species, especially *Adinandra dumosa* (38%), tend to need more cooking chemicals, time, and temperature during cooking process in the chemical pulping process and more chemicals in the bleaching process than *A. mangium* and *P. merkusii.* Lignin is dominant compound in middle lamella and will be destroyed in the pulping process, while some remaining in the secondary cell wall of the fibers is removed in the bleaching process (Panshin & de Zeeuw, 1980). The high content of lignin, booth in the middle lamella and the secondary cell wall, required more chemical reagent in the pulping and bleaching process. Lignin can decrease the burst strength because it can be a barrier for hydrogen bonding in the fiber formation (Bierman, 1996).

Extractive content can be a problem in the cooking process because it will decrease the ability of chemical cooking. Extractive which is retained in the pulp can be affected to the colour or brightness of pulp and require expensive bleaching for their removal (Panshin & de Zeeuw, 1980). Figure 8 also shows that extractive contents in the five fast growing woods are lower than those in pine and acacia wood. It means that pulp which is made from these species tend to have higher brightness than pulp from pine and acacia wood.

IV. CONCLUSION

According to their fiber characteristics, derived value, and chemical compositions, the five fast growing wood species are potentially suitable as alternative wood resources for pulp and paper industries. *Dillenia* sp. is the most suitable species due to its high value of holocellulose and α-cellulose, low lignin content, and its fiber length of about 3,119 μm on average. *A. dumosa* also has good opportunities because it has 3,137 μm long fiber lengths as well as high holocellulose and α-cellulose, but it has the highest lignin content. High lignin content in these woods can be a problem in the cooking process because it will need more chemicals, time, and temperature during the cooking process. The *Nuclea junghuhnii* is less suitable due to low value of holocellulose and α-cellulose. However, because of their high α-cellulose content (at least 34%) and long fiber length (> 2,200 μm) these species can be considered as raw materials for pulp and paper.

This research only focuses on the wood basic properties. Therefore, further study on pulping process and its quality is needed to confirm the results derived in this study.

ACKNOWLEDGEMENT

This study is partially supported by Japan Science and Technology Agency (JST) under the program entitled "Creation of the Paradigm of Sustainable Use of Tropical Rainforest by the Intensive Forest Management and Advanced Utilization of Forest Resources", sub program B2 "Screening of Fast Growing Wood Species for Bioethanol Production" 2010-2013.

The authors gratefully acknowledge management and staffs of PT Sari Bumi Kusuma, Central Kalimantan, Indonesia, for their assistance in collecting wood samples at the concession area.

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