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Enhancing dissolving pulp quality of mixed raw materials through pre-hydrolysis kraft-cooking: A study on *Acacia crassicarpa* and *Terminalia catappa*

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Abstract

Acacia crassicarpa wood is widely used in Indonesia as a raw material for dissolving pulp (DP) by the kraft-cooking process. Given that Indonesia has a rich variety and abundance of cellulose-rich wood, it is deemed crucial to research alternative raw materials, such as *Terminalia catappa* wood. As an alternative source of raw material, *Terminalia catappa* possesses excellent adaptability to various environmental conditions and is easy to grow everywhere. The current research sought to produce DP using the mixtures of materials from these two plant species as raw materials by pre-hydrolysis, kraft-cooking, and Elementary Chlorine Free (ECF) bleaching. The DP produced had ISO brightness > 88%, alpha-cellulose content > 94%, viscosity > 6.2 cP, and pentosan content of 2.54%. The DP quality traits have met the SNI 938:2017 standards for rayon-grade pulp. *Acacia Crassicarpa* and *Terminalia Catappa* are the prospective wood mixture for producing high-quality dissolving pulp via the kraft-cooking process.

Keywords: Acacia crassicarpa, dissolving pulp, kraft, *Terminalia catappa*, rayon-grade pulp

1. Introduction

Dissolving pulp (DP) is pulp that contains 90–99% alpha-cellulose content, 4–7%, pentosan, > 88% ISO brightness and > 6.2 cP viscosity. It has a high level of cellulose reactivity towards certain chemicals, one of which is carbon disulfide [1]. The demand for DP in the textile and cellulose derivative industries constantly increases every year [2]. The demand in the pulp and paper industry alone was projected to grow by 5% in 2019 [3]. In 2010, textile fibres consumption amounted to 72.5 million tonnes, and it has been projected to increase to 133.5 million tonnes by 2030 [4]. Regenerated cellulose fibres (viscose and lyocell) have been developed from renewable raw materials, wood and non-wood [5]. Cellulose fibres are commonly extracted from plants such as trees, and agricultural wastes as the promising raw material [6]. The characteristics of cellulose fibres from natural origins and their derivatives are found better than those of fossil-sourced synthetic fibres (polyester and polyamide) [5]. The increased demand for pure cellulose fibres or DP also comes from the medical and health sectors, electronics, as well as the additives and plastics industries [6–9].

The manufacture of DP can use both wood and non-wood raw materials [5,10,11]. In the pulp and paper industry in Indonesia, *Acacia crassicarpa* and eucalyptus hybrid woods are widely used as raw materials for making DP by kraft-cooking [2]. In addition to *A. crassicarpa* and eucalyptus, Indonesia is rich of various other types of wood such as *Terminalia catappa* that can be processed into DP. The cellulose content in *A. crassicarpa* ranges from 43.33% to 48.62%, and 41.48% in eucalyptus hybrid [12]. Not much different from one in *A. crassicarpa*, the cellulose content in *T. catappa* wood amounts to 47.49% [13]. At this point, *T. catappa* can be considered as a raw material for the production of pulp for paper making [13]. For being easily to grow and develop throughout the year both in lowlands and highlands, in primary or secondary forests, mixed forests, swamp forests, coastal forests, and teak forests or along rivers, *T. cattapa* plants enjoy wide distribution across various islands in Indonesia [13,15,16].

This plant can be cultivated as an industrial forest

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plantation (HTI), which is one of the industry's efforts to sustain its production in future and to participate in environment preservation. Based upon the Industrial Law of the Republic of Indonesia Number 3 of 2014, green industry is an industry in which in its production process it prioritizes efforts for efficiency and effectiveness in the resources utilization in a sustainable manner purposely not only being able to align industrial development with the preservation of environmental functions but also being able to provide benefits for society. Nowadays, the development of the cellulose industry and its derivatives has led to the concept of an environmentally friendly green industry. This industry strives to make continuous improvements and developments to minimize the impacts of environmental pollution, and to create a green industry based on local wisdom. One of the future challenges in this industry is related to find a solution to the substitution of imported DPs, and the prices that tend to always to rise. Therefore, research efforts are needed to make DPs that utilize Indonesia's biodiversity.

The decline in cotton production, coupled with environmental issues, has resulted in a decrease in the availability of raw materials for making DP. This research, in turn, aims to produce DP using a mixture of *A. crassicarpa* and *T. catappa* as the raw materials. DP manufacture using the mixture of *A. crassicarpa* and *T. catappa* has been without precedence. DP is made through pre-hydrolysis, kraft-cooking, and ECF bleaching sequences. Here, modifications should be made to the bleaching process to achieve a targeted ISO brightness level at > 88%, in this case, with chlorine derived under the Elementally Chlorine Free (ECF) method. Instead of using free chlorine (Cl_2), EFC bleaching uses chlorine in the compound form (ClO_2) as the main bleaching chemical.

Several studies have explored pulp making using various wood mixtures. In a research study where pulp was made from a mixture of *Pinus pinaster* with *Populus tremula*, it was found that higher ratio of *Pinus pinaster* in the chip mixture could result in higher kappa number, viscosity, and reject values, improved strength properties, and reduced brightness and smoothness [17]. Other researchers have made pulp from a mixture of *Acacia crassicarpa* (AC), *Acacia mangium* (AM), and eucalyptus (ECA) woods with the optimal results at 70% AC, 20% AM, and 10% ECA that have met the standards [18].

Although previous research has discussed various aspects of dissolving pulp (DP) production from wood raw materials, as described by [1] regarding the process of increasing the accessibility and reactivity of DP from hardwood using enzymatic treatment [1], in-depth research on the use of a mixture of *Acacia crassicarpa* and *Terminalia catappa* wood, to be best of the researchers' knowledge, is still highly limited. Most studies have more focused on *Eucalyptus* and *Acacia* wood as the main raw materials, while the potential of *Terminalia catappa* wood has not been comprehensively explored. In addition, previous research conducted by [5] demonstrated a success in the production of cellulose fibre from renewable raw materials but did not specifically examine the mixture of *A. crassicarpa* and *T. catappa* wood in DP production using pre-hydrolysis kraft-cooking and ECF methods bleaching. This research, in turn, aims to fill this gap by evaluating the potential for using a mixture of *Acacia crassicarpa* wood (ACW) and *Terminalia catappa* wood (TCW) as an alternative raw material in the production of high-quality DP (by prehydrolysis, a kraft cooking, ECF bleaching route) based upon SNI (National Indonesia Standards) 938:2017 for rayon grade pulp.

2. Materials and Methods

T. catappa wood was obtained from an orchard in Panam, Pekanbaru, Riau, Indonesia; meanwhile, *A. crassicarpa* wood was obtained from PT RAPP Riau, Indonesia. The billets of these trees were cut into 0.5–1 cm fibre fragment and dried until the weight was reduced by 10%. The mineral contents of the raw materials were determined with the aid of PANAnalytical Epsilon 3 XRF spectroscopy. Furthermore, the ash content was determined by incinerating at 575ºC for 4 hours according to TAPPI T 211 om-07 [19]. For the extractive analysis, the materials were milled with a Wiley mill and sieved to retain particles 40–80 mesh in size prior to be kept at room temperature and air-dried. The extractives were determined by extraction with acetone and n-hexane according to SNI 8401:2017 [20].

The acid-insoluble lignin (Klason lignin) content of the raw materials was determined through the following procedure: the prepared sample (0.5 g, as oven-dried weight) was primarily hydrolysed with 72.5% sulfuric acid for 2.5 hours and further hydrolysed with 4.0% sulfuric acid at 121ºC for 1 hour. The sample subsequently was filtered to obtain the residue and filtrate with a glass filter (1G P16). The weight of the residue was measured as acid-insoluble lignin. The amount of acid-soluble lignin was determined by means of UV spectrophotometry at a wavelength of 205 nm (TAPPI T 222 om-02 and T 222 om-011) [21, 22].

2.1. Pre-hydrolysis and cooking

The raw materials of *A. crassicarpa* and *T. catappa* were mixed at the ratios of 95:5, 90:10, and 85:1. The mixed materials (70 g, as oven-dried weight) were placed in a 600 mL steel reactor and subjected to pre-hydrolysis with 490 mL of distilled water for the duration of 90–180 mins at 150ºC [5, 23]. Afterwards, a part (280 mL) of the pre-hydrolysis liquor (PHL) was removed. For the PHL removal treatment, the ratio of pre-hydrolysis liquor-to-solid was 14 mL/g. The mixed materials (70 g) were subjected to a further pre-hydrolysis process with 210 mL of distilled water for 90–180 min at 150ºC [23] without any PHL removal. The pre-hydrolysis liquor-to-solid ratio was 3 mL/g for the PHL non-removal treatment. Having performed the pre-hydrolysis, the wet solid residue was further subjected to kraft-cooking for 180 min at 160ºC with 20%, 21%, and 22% active alkali (AA) dosages by adding 280 mL of fresh cooking liquor [23]. The wet pulp was subjected to washing with water for several times. Then, it was soaked in technical hexane for 5 hours, separated from hexane, washed with water, and bleached. Air-dried pulp sheets were then prepared to measure the pulp yield after cooking.

2.2. Bleaching sequences and conditions

For ECF bleaching sequences, the pulp cooking sample

resulted (10 g, as oven-dried weight) was treated in a bag made of polyvinylidene chloride sheets with ClO_2 at a pulp consistency (PC) of 10%. After washing, the pulp was treated in a polyethylene bag with NaOH and H_2O_2, washed again, and treated in the polyvinylidene chloride bag with ClO_2, followed by oxygen (O) bleaching at a PC of 30% for the oxygen-peroxymonosulfuric acid-extraction with peroxide-peroxymonosulfuric acid-extraction (O–Psa–Ep–Psa–E) TCF sequence. According to previous procedures [23, 24], peroxymonosulfuric acid (Psa) was synthesized by dropping 95% sulfuric acid (Wako Pure Chemical Industries, Ltd.) into a 45% hydrogen peroxide aqueous solution (Mitsubishi Gas Chemical Company, Inc.) at 70°C. A target amount of Psa and a small amount of NaOH aqueous solution for the adjustment to pH 3.0 were added to the pulp suspension at a PC of 10% in a polyethylene bag.

2.3. Evaluation of pulp quality traits

The acid-insoluble and acid-soluble lignin contents as well as the carbohydrate composition were determined according to the methods presented previously. The kappa number was determined using TAPPI T 236 om-06 [25], the viscosity was determined using TAPPI T 230 om-08 [26], the alpha-cellulose content was determined using TAPPI T 230 om-08 [27], and the brightness (ISO) was measured using a Tokyo-Denshoku Digital Color Meter Model TC-1500 SX.

3. Results and Discussion

In general, in Indonesia, *A. crassicarpa*, *A. mangium*, and eucalyptus hybrid are widely used as raw materials for making pulp and DP. However, apart from these types of wood, Indonesia also has a variety of other types of woods that have the potential to be used as raw materials for making DP, such as *T. catappa*. Data on the physical and anatomical properties of wood are required as the indicators of whether a type of wood can be used as a raw material for making pulp. Table 1 presents the physical and anatomical properties of some woods growing in Indonesia.

Table 1. Physical and anatomical properties of some woods

Physical and morphological properties	*A. crassicarpa*[25]	*A. mangium*[26]	*T. catappa*[11]	*E. hybrid*[25]
Fibre length (mm)	1.34	1.40	1.67 – 1.81	1.26
Fibre diameter (μ)	35.68	18.36	20 - 40	25.61
Coef. flexibility	0.88	0.72	0.30 - 0.57	0.82
Density (g/cm^3)	0.55 – 0.70	0.55 – 0.70	0.43 – 0.55	0.46 – 0.51
Coef. Rigidity	0.06	0.14	0.001 - 0.004	0.08

Wood properties that influence pulp and paper production are anatomical, including fibre length and fibre diameter [28]. Fibre length here becomes the most important factor in establishing fibre bonds; the longer the fibre, the greater the tear strength of the pulp or paper. The fibre length of *T. catappa* anywhere is in the range between 1.67 mm and 1.81 mm, longer than that of other woods (Table 1). Based on the data on fibre length and fibre diameter, *T. catappa* is grouped into the same type of hardwood as *A. crassicarpa* and eucalyptus hybrid. Smook (2016) confirmed that the flexibility coefficient values for hardwood are 0.55–0.80, and the flexibility coefficient values for softwoods are > 0.75 [30]. The flexibility value refers to the ratio between the diameter and the wall thickness of the fibre, which have a complex relationship to each other and influence the lumen diameter and fibre diameter with good strength [28].

The density of *Acacia* wood ranges from 0.55 gr/cm^3 to 0.70 gr/cm^3, higher than that of eucalyptus hybrid and *T. catappa*. Chemical components such as extractives and lignin in wood are thought to increase the wood density [29]. Wood density greatly determines the quality of the chips produced and the energy requirements during chipping (refining or beating). The higher the wood density, the more uniform the chip quality and the higher the energy used for refining [31]. Apart from that, the wood density can affect the cooking process where the higher the density of wood chips, the slower the penetration of cooking solutions or chemicals into the chips, thus, the longer the cooking time required and the more the cooking solution required. Usually, to overcome this density problem in industry, a mechanical pre-treatment process is carried out on wood chips prior to perform the cooking process [32].

The rigidity coefficient is the ratio between the fibre wall thickness and the fibre diameter. The lower the coefficient of rigidity, the less easily the resulting paper breaks when exposed to tensile loads. The rigidity coefficients of *A. crassicarpa* and eucalyptus hybrid were found to be lower than those of *A. mangium* and *T. catappa* (Table 1). It is little wondering that *A. crassicarpa* and eucalyptus hybrid are widely used in the pulp and paper industry.

In this study, an analysis of the mineral contents of *T. catappa* was carried out before and after treatment (Table 2). The raw material treatment process was carried out by soaking a number of raw materials in an H_2SO_4 solution at a temperature of 70°C for 30 min. After soaking for 30 min, the raw materials were separated from the acid solution and rinsed with water until the pH of the rinse water reached neutrality. Then the raw materials were soaked in a 1 N NaOH solution at a temperature of 70°C for 30 min. After that the raw materials were separated from the alkaline solution and rinsed with water until the pH of the rinse water reached neutrality. The raw materials were dried at room temperature before being used for the pre-hydrolysis and cooking processes.

Apart from the physical and morphological properties of the raw materials, the mineral contents of the raw materials also influence the viscosity and ash content of the dissolving pulp produced. Table 2 shows the treatment of the raw materials causing decreases in the mineral contents such as the mineral contents of SiO_2, Al_2O_3, Fe_2O_3, CuO, and ZnO. These metal oxide compounds cause high viscosity and ash content in the DP product for containing heavy metals with a density value of > 3 g/mL.

The amount of minerals before and after treatment tended to decrease; while, some mineral amounts were inconsistent

(Table 2). This treatment aimed to reduce the minerals SiO_2, Al_2O_3, Fe_2O_3, CuO, and ZnO with a prediction that after treatment only these minerals would decrease in quantity. However, the results of the treatment had an impact on reducing the amount of CaO, K_2O and P_2O_5 minerals though very insignificant. This is because the minerals CaO, K_2O and P_2O_5 in general do not stand alone; they are always in the form of calcium silicate, potassium silicate, phosphorus pentoxide silicate compounds, where these compounds can react with sulfuric acid (H_2SO_4) and NaOH. Sulfuric acid is an inorganic solvent and acts as a strong oxidizing agent with an ability to dissolve minerals, similar with the NaOH solvent that is able to dissolve minerals in T. catappa wood.

Table 2. Mineral contents in the raw materials

Mineral	Before treatment (%)		After treatment (%)	
	A. crassicarpa	*T. catappa*	*A. crassicarpa*	*T. catappa*
CaO	20.65	52.93	20.59	52.87
P_2O_5	46.79	20.49	46.41	20.03
SiO_2	7.91	9.96	1.88	1.97
K_2O	6.54	9.07	6.32	8.83
Al_2O_3	11.84	3.57	5.64	1.80
Ag_2O	3.78	1.29	1.83	0.51
CuO	1.63	–	0.49	–
Fe_2O_3	0.64	0.53	0.08	0.50
In_2O_3	–	0.55	–	0.34
TiO_2	–	0.51	–	0.36
ZnO	0.17	0.08	0.04	0.01
Cl	1.30	1.06	1.18	0.94

Table 3. Results of analysis of water and ash contents

Parameter	Before treatment (%)		After treatment (%)	
	A. crassicarpa	*T. catappa*	*A. crassicarpa*	*T. catappa*
Ash content	5.74	7.35	1.98	2.36
Water content	46.78	20.39	46.78	20.39

The ash content in the *T. catappa* wood sample before treatment exceeded the required ash content in wood raw materials (> 6%) (Table 3). However, after treatment, the ash content of both *T. catappa* and *A. crassicarpa* decreased below 6% and met the standard requirements for raw materials for making pulp. A high ash content (> 6%) of wood raw materials will affect the quality of the pulp and paper produced [29]. Table 4 presents the chemical compositions of the two woods with eucalyptus hybrid and *T. bellirica* woods being used for comparison (Table 4).

In general, the cellulose content in wood ranges from 40% to 75% of the wood's wet weight, while in cotton it is ± 90% [29]. Cellulose purity is often expressed through the alpha-cellulose parameter. Commonly, the higher the alpha-cellulose content in wood, the better the quality of the wood as a raw material for making pulp [29]. For this reason, *A. crassicarpa* wood, which has an alpha-cellulose content of 48.56%, is widely used as a raw material. Meanwhile, *T. catappa* also has the potential to be used as a raw material for making pulp [14].

Table 4. Chemical compositions of some woods

Parameter analysis (%)	*A. crassicarpa*[10]	*E. hybrid*[26]	*T. catappa*[11]	*T. bellirica*[9]
Cellulose	43.33 – 48.62	41.48	45.65	47.49
Alpha cellulose	48.56	–	37.82	–
Pentosan	17.39 – 18.88	–	–	16.51
Extractives	1.84 – 2.08	2.68	7.67	6.48
Lignin	26.95 – 27.31	24.03	26.77	29.41
Solubility in cold water	1.45	–	2.33	2.71
Solubility in hot water	2.19	1.45	7.01	6.88
Solubility in NaOH 1%	15.68	2.19	16.85	17.72
Ash content	0.25	0.31	0.37	0.74
Silica content	0.16	0.20	0.18	0.21

Cellulose has a crystalline part, and the strong inter- and intra-molecular bonds in the cellulose hydrogen chains make it difficult for cellulose to dissolve in various types of organic solvents. To separate lignin and hemicellulose, which are bound to cellulose, an alkaline NaOH solution is used in the cooking process. NaOH is capable of penetrating into the cellulose structure and damaging the crystalline part of cellulose, allowing it to enlarge the amorphous part of cellulose. As a result, cellulose can bind more water, and hemicellulose can be separated from cellulose [33]. The relationship between the concentration of NaOH as a cooking solution and lignin is that if the concentration of NaOH is too low, it is difficult for lignin to be separated from cellulose; as a consequence, the cellulose yield obtained will also be low. However, if the NaOH concentration is too high, the cellulose fibres will also be degraded [34,35]. Additionally, the more NaOH is used, the more side reactions will occur, namely the formation of NaCl and sodium glyconate [36].

Extractive substances and lignin affect pulp products. *A. crassicappa* has a lower extractive content (1.96%) than does *T. catappa* (7.67%). A high extractive content in wood will reduce the pulp quality due to the appearance of stains (dirt) in the pulp, which later on can affect the brightness value of the pulp [37]. Extractive substances such as dyes, pectin, sugar, tannin, gum, resin, fat, resin, and flobatin are partially soluble in both water and organic solvents (alcohol, gasoline, and ether). The solubility properties and affinity of extractive substances for other components typically have either a bad or a good influence on both product quality and the operations of the pulp production processes. The bad influences include the formation of dirt, scaling, or foaming during the operation process. Each type of wood provides a different amount of content and effect. Usually, in the process of cooking wood into pulp the target is that the pulp has as low an amount of extractives as possible. The wood components that dissolve in cold water are tannins, gum, carbohydrates, and pigments, while those that dissolve in hot water are the same as those that dissolve in cold water, plus the starch component [38].

The solubility values of *T. catappa* wood components in cold water and hot water were found at 2.33% and 7.01%, respectively, higher than the solubility values of *A. crassicarpa* wood components (1.45% in cold water and 2.19% in hot water). This shows that tannins, gum, carbohydrates, pigments, and starch are easier to dissolve in *T. catappa* wood rather than in *A. crassicarpa* wood.

The solubility values of the wood components in 1% NaOH of *T. catappa* and *A. crassicarpa* were 16.85% and 15.68%, respectively, indicating that both types of wood experienced damage, which might be caused by degradation by light, heat, and oxidation. The higher the solubility value in 1% NaOH, the greater the level of wood damage. The soda or soda pulping process is a method of making chemical pulp using sodium hydroxide as a chemical. The NaOH solution is believed to be capable of breaking the bonds between fibres, which allows for an accelerated pulping process. Additionally, the waste resulting from pulping using the soda process is harmless for generating no environmental pollution [23].

Apart from extractive substances, lignin also affects the pulp quality. A high lignin content in the pulp can cause the pulp to become brittle [39]. Lignin is a natural glue found in wood, which causes the bonds between wood fibres to become tighter and denser. The lignin content in *T. catappa* was found at 26.77%, higher than the lignin in *A. crassicappa* and eucalyptus hybrid. The higher the lignin content in the wood, the denser and tighter the bonds between the fibres [40].

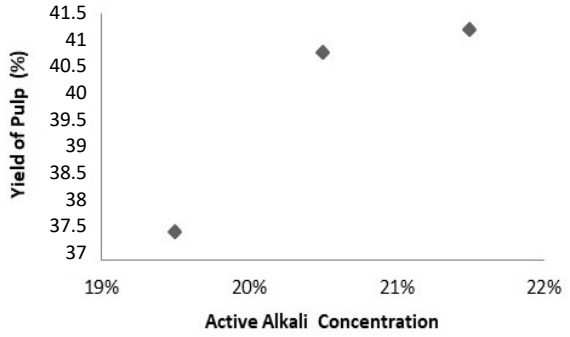

Fig. 1. Effect of active alkali concentration on pulp yield

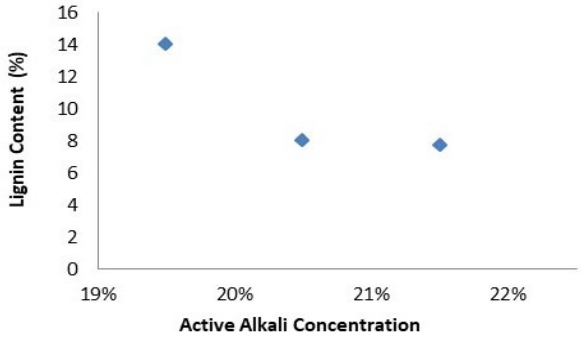

Fig. 2. Effect of active alkali concentration on lignin content

The concentration of active alkali in the cooking solution was made variable to study the delignification process and obtain the maximum pulp product yield (Fig. 1 and Fig. 2). The active alkali concentration affected the yield and lignin content (Fig. 1 and Fig. 2). The higher the active alkali concentration, the higher the yield of the pulp and the lower the lignin content. When the cooking was performed with a solution concentration of 19%, the yield of the pulp increased significantly compared to when the solution concentration of 20% was used. On the other hand, the lignin content decreased drastically from 14% to 8%. This showed that the delignification process ran smoothly. However, when compared to the cooking solution concentration of 21%, the cooking solution concentration of 20% resulted in an increase in yield and a decrease in lignin content, but in very small amounts. It is assumed that the delignification process had reached a maximal point when using the cooking solution concentration of 20% or 21%.

The bleaching sequence applied in this study affected the alpha-cellulose content, viscosity, and brightness of the pulp (Table 5). This table shows that the quality of DP made from a mixture of *T. catappa* and *A. crassicappa* is a very promising compared to the DP's quality of other raw materials. According to the Indonesian National Standard (SNI), the minimum thresholds for DP for rayon were 6.2 cP for viscosity, 94% for alpha-cellulose content, and 88% for ISO brightness. In this study, the DP produced had a higher brightness level with a lower dose of ClO, indicating the potential for DP production from *T. catappa* and *A. crasicarpa* by using a combination of pre-hydrolysis, kraft-cooking, and ECF bleaching. Fig. 3(a) illustrates the perspective image of DP made from *T. catappa* wood fibre and Fig. 3(b) illustrates the perspective image of DP made from a mixture of *T. catappa* and *A. crassicarpa* wood fibres.

Table 5. Dissolving pulp composition of some raw materials

Raw Material	Alpha-cellulose (%)	Pentosan (%)	Brightness (%ISO)	Viscosity (cP)
A. crassicarpa[40]	92.99 ± 1.14	1.06 ± 0.41	89.25 ± 0.45	8.18 ± 1.01
Eucalyptus urograndis[41]	96.55 ± 1.15	2.70 ± 1.2	89.90 ± 0.50	9.11 ± 0.90
A. mangium[42]	88.53 ± 1.53	1.59 ± 0.46	86.28 ± 0.04	5.50 ± 0.32
Jute[43]	91.70 ± 0.70	6.60 ± 0.10	88.46 ± 0.14	3.30 ± 0.24
Banana[44] *plant stem*	92.45 ± 1.75	2.60 ± 1.10	77.45 ± 4.85	5.22 ±0.01
Kenaf[45]	86.53 ± 0.18	14.84 ± 0.13	86.25 ± 0.02	28.30 ± 0.76
Terminalia catappa	92.14 ± 2.28	1.12 ± 0.54	88.21 ± 0.95	8.79 ± 0.76
Mixture of *A.crassicarpa* and *T. catappa* (9:1)	95.00 ± 0.02	2.63 ± 0.05	89.03 ± 0.81	8.72 ± 0.76
Mixture of *A.crassicarpa* and *T. catappa* (8:1)	94.35 ± 0.18	2.72 ± 0.03	89.31 ± 0.61	8.55 ± 0.72
Mixture of *A.crassicarpa* and *T. catappa* (7:1)	90.76 ± 0.54	2.90 ± 0.06	87.38 ± 5.27	8.50 ± 0.35
SNI 938:2017 Pulp-grade rayon	Min. 94	2 – 4	Min.88	Min. 6.2

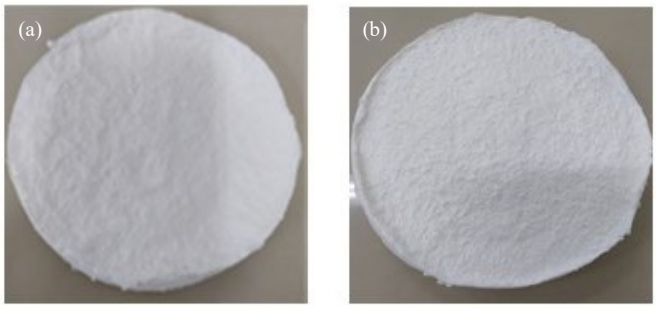

Fig. 3. (a) is a perspective view of DP made from Terminalia catappa wood fibre, and (b) is a perspective view of DP made from a mixture of Terminalia catappa and *Acacia* crassicarpa wood fibres

The alpha-cellulose content of DP obtained from the mixed raw materials of *T. catappa* and *A. crassicarpa* met the minimum value limit for alpha-cellulose content in accordance to the SNI 938:2017 for rayon-grade pulp, and so did the alpha-cellulose content of DP obtained from *T. catappa* alone as a raw material (Table 5). The DP obtained by kraft-cooking the mixture of *T. catappa* and *A. crassicarpa* had a pentosan content that was insignificantly different from the pentosan content in DP made by kraft-cooking *T. catappa* or *A. crassicarpa* alone. Pentosan is a type of hemicellulose compound, which has an important function as a binder between fibres in the pulp and paper making process [41–44]. It is assumed that the pentosan content in DP strengthened the bonds between fibres in DP sheets.

The brightness and viscosity values of DP obtained from *T. catappa* wood in isolation and from a mixture of *A. crassicappa* and *T. catappa* woods met the SNI 938:2017 for rayon-grade pulp (> 88% ISO and > 6.2 cP, respectively) (Table 5). Viscosity indicates the degree of polymerization of pulp cellulose from the delignification process, while the degree of polymerization reflects the chain length of repeated chemical units. In other words, the greater the degree of polymerization, the longer the cellulose group chain. Delignification by oxygen was placed first in the stages in ECF bleaching as it could delignify and increase the brightness of the pulp without any substantial reductions in pulp yield, viscosity, and alpha-cellulose. The target ISO brightness of 88% could be achieved for the ECF bleach sequence. ISO brightness levels above 88% still indicated the potential for ECF bleaching applications for making DP from the mixed raw materials of *A. crassicarpa* and *T. catappa* with the ratios of 9:1 and 8:2.

4. Conclusion

High-quality dissolving pulp has been produced from the mixtures of *T. catappa* and *A crassicarpa* woods by sequence of prehydrolysis, kraft cooking, ECF bleaching route. The produced dissolving pulp had an ISO brightness of > 88%, an alpha-cellulose content of > 94%, viscosity of > 6.2 cP, and a pentosan content of 2.54%, all of which met the SNI 938:2017 for rayon-grade pulp. *Terminalia. catappa*, which has high fibre length and cellulose content, can be a promising alternative to *A. crassicarpa* as a pulp feedstock. The treatment of the feedstock with H_2SO_4 and NaOH was found effective in reducing mineral content and improving pulp quality. The results of this study indicated a great potential for the production of high-quality soluble pulp utilizing local Indonesian wood blends, which could contribute to a more sustainable pulp and paper industry.

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