Acta. Chim. Asiana., 2023, 6(1), 247 –253
e-ISSN/p-ISSN 2550-0503/2550-049x
Available online at: www.aca.unram.ac.id

RESEARCH PAPER

Pulp synthesis using bamboo raw materials through unbleached and bleached processes

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DOI: 10.29303/aca.v6i1.135

Article info:

Received 16/07/2022

Revised 28/12/2022

Accepted 30/01/2023

Available online 04/02/2023

Abstract: This study aims to see the potential of bamboo as a new raw material for the Indonesian pulp industry, specifically for the manufacture of pulp products, because in Indonesia, the import value for dissolving is still high, and the raw materials used still use wood plants. This study consists of three stages: the pre-hydrolysis stage using water, the cooking stage with the kraft pulping method, and bleaching using the elemental chlorine-free (ECF) method. Bamboo flakes that run into the pre-hydrolysis process decreased the Kappa Number value of pulp produced, which ranges from 4.63% - 14.52% compared to bamboo flakes that do not run into the pre-hydrolysis process. The brightness increase to 0.844% - 2.96% compared to bamboo flakes that do not run into the process of pre-hydrolysis. For pulp products, the value of Alpha Cellulose obtained is around 89.18% - 90.32%.

Keywords: Bamboo; Pulp; Kraft Pulping; Elemental Chlorine Free

Siregar S. H, Syafri, R. Prasetya, Nasution. H., Ramadhanti, A. R. K. (2023). Pulp synthesis using bamboo raw materials through unbleached and bleached processes. *Acta Chimica Asiana 6*(1), pp 247-252 DOI: 10.29303/aca.v6i1.135

INTRODUCTION

The pulp industry is one of the industries in the world that contributes the most to the consumption of wood as the main raw material for making pulp that comes from nature. Pulp-processed products for world paper needs will reach 4.9 billion tons compared to 2017, which only reached 3.9 billion tons or an increase of around 24.5% [1, 2]. As for the value of export commodities, Indonesia can only export around 4.26 million tons [3].

In 2017 the raw demand from the wood sector for the pulp industry in Indonesia reached 45 million m3 compared to the previous year, which only reached 35 million m3 or an increase of around 27.5% [1]. According to data from the Indonesian Forestry Statistics Agency, forests in Indonesia have an area of around 99.6 million hectares, or 52.3% of Indonesia's area. Each pulp industry producing as much as 1.2 tons of paper requires 4.6 m3 of wood as raw material, and each hectare of forest can produce around 160 m3 of wood [4]. If this continues to increase, it can decrease the availability of wood in nature and harm the environment, disrupting all living ecosystems in nature and the function of forests. Alternative raw materials are needed for pulp production from the non-timber sector to reduce the unfavorable effects.

Consequently, the search for non-timber raw materials in the paper-making industry has been given more attention due to the increasing consumption of wood sources for paper production. From 1970 to the present, the fiber pulping capacity of non-timber crops increased globally, two to three times faster than wood manufacturing capacity. It is also estimated that over the next decade, annual non-timber pulp production will grow by an average of 6%, three times faster than wood-based pulp production [5].

Non-timber fiber sources have the potential to supplement conventional wood supplies because they are abundant, have a short cycle and fast regeneration, and are relatively low in cost. Therefore, non-wood fiber is very important as a raw material for making paper.

Non-wood fiber sources as raw materials for pulp production include rice straw [6], water hyacinth [2], banana peels, red jambon leaves, palm fiber, empty oil palm bunches, banana stems, pineapple leaf fiber [5], bagasse [7].

Currently, using wood as a raw material for pulp industry activities has received much criticism from various parties, especially from organizations and communities, both national and international, based on environmental movements. Meanwhile, bamboo has several advantages compared to woody plants. It grows fast and can be harvested after 3-5 years of planting, much shorter than needle wood which takes 10-20 years. In addition, bamboo has high productivity and can grow in arid soils [8]. Bamboo can be used as a raw material for the pulp and paper industry, plywood, furniture, wicker, and agricultural and livestock equipment. In addition, bamboo leaves can be used for animal feed, and bamboo shoots can be processed into human food. In addition, bamboo plants are a local resource that does not need to be imported but has high economic value [11].

Bamboo is a non-timber forest product that can be developed, cultivated, and can be used as raw material for pulp and paper processing, empowered for various purposes utilizing mechanical technology and simple technology. Bamboo is a long fiber with advantages in terms of harvesting period, which can be harvested within 3-4 years, shorter than 8-20 years for fast-growing woody species. In addition, bamboo is one of the lignocellulosic materials, which produces cellulose per hectare 2-6 times greater than pine. The increase in biomass per day is 10 - 30%, which is higher than wood which is only 2.5%. The cellulose content of bamboo is quite high, between 40% - 54% [9].

Bamboo fiber has two types, namely long fibers and short fibers. Short fibers,\ has fractions in millimeters. Examples are felted mats and short fibers for injection molding. Fiber from Betung Bamboo (Dendrocalamus asper) has two main ingredients, cellulose, and lignin. Cellulose has a role in giving strength to the fiber. Bamboo has advantages when used as a raw material for paper, including the fast growth rate and easy bleaching after being processed into pulp using the kraft process because the texture of bamboo is a monocot plant (where there is more parenchyma tissue), so it is not as dense as wood [16].

Pulp is a raw material used in the paper industry. In general, the raw materials used by the industry for pulp production use woody plants, namely, eucalyptus and acacia. The pulping process includes raw material preparation, pre-hydrolysis, cooking, and bleaching, which also determines the quality of the pulp. Differences in raw material preparation result in different dimensions of raw materials, water content, and chemical components such as cellulose, lignin, ash, and extractives, affecting pulp quality [10].

Currently, using wood as a raw material for pulp industry activities has received much criticism from various parties, especially from organizations and communities, both national and international, based on environmental movements. Meanwhile, bamboo has several advantages compared to woody plants. It grows fast and can be harvested after 3-5 years of planting, much shorter than needle wood which takes 10-20 years. In addition, bamboo has high productivity and can grow in arid soils [8].

So for that, we need alternative new raw materials for the pulp industry, especially the pulp industry, to replace or reduce the use of raw wood materials for industrial activities.

MATERIALS AND METHODS

The tools used in this study were a 6-tube Rotary Digester, Water Bath, Desintegrator, Pulp Screen Tool, Defiberator, Oven, Bucket, 100 mL measuring pipette, Analytical Balance, 100 mL beaker, 250 mL Erlenmeyer flask, Burette, 10 mL and 1 mL Volumetric Pipettes, 100oC Thermometer, Funnel, Tongs, Stainless Spatula, Stirring Rod, Suction Ball, Desiccator, Measuring Cup, Dropper Pipette, Hot Hands and Hot Plate. The materials used in this study were bamboo with green ampel species, NaOH, Na_2S, distilled water, H_2O_2 (One Med), ClO_2, and 37% H_2SO_4 (Merck).$_2$ (One Med), ClO$_,$ 37% H_2SO_4 (Merck).

Sample Preparation

Bamboo has been collected with a green ampel from one of the villages/villages in Perawang, Tualang sub-district. Bamboo meat and part of the bamboo skin are separated, then the bamboo which has been separated from the bamboo skin is made into flakes with a size of 3x2 cm. The moisture content of the bamboo chips is calculated to facilitate the calculation of the dry weight of the bamboo chips for the next process.

Prehydrolysis Stages

In this prehydrolysis process, a rotary digester is used, which has six autoclaves, each of which has a capacity of up to 2 liters. Prepare 300 grams of bamboo chips for each autoclave. In this prehydrolysis process, the number of autoclaves used is 3. The chemical used in this prehydrolysis process is distilled water. A temperature of 160oC is used in this process with a holding time of 60 minutes. The ratio of the chemicals used to the raw material for bamboo chips is 4: 1. After the prehydrolysis process is complete, the bamboo chips are washed. To remove residual chemicals and solids, then the water content of the bamboo flakes is removed using a centrifugal dryer, and then the water content in the remaining bamboo flakes is calculated to facilitate further processing.

Stages of Cooking Bamboo Flakes

In cooking bamboo chips, the same equipment is used for the pre-hydrolysis stage, namely a rotary digester with 6 autoclaves, each of which has a capacity of 2 liters. The raw materials used in the cooking process consist of 2 raw materials: bamboo flakes that have undergone a pre-hydrolysis process and raw materials that have not undergone a pre-hydrolysis process.

There are 4 autoclaves used, 2 of which are for bamboo chips that have undergone a pre-hydrolysis process, and the other 2 are for bamboo chips that have not undergone a pre-hydrolysis process. Prepared bamboo flakes will be used for cooking, each autoclave containing 300 grams of sample in a dry state. The temperature in this process is 160^{o}C using H – Factor, which is 750. The concentration of active alkali used is 18% and 20% for each flake with a solution sulfidity of 25%. The ratio of cooking chemicals to bamboo flakes is 4: 1.

Bamboo Pulp Bleaching Stages

The stages of the bleaching process are the stages of the process that aim to remove the remaining lignin content contained in the bamboo pulp so that the brightness value of the bamboo pulp will increase. At this stage of the bleaching process using, the ECF (Elemental Chlorine Free) method, which is an environmentally friendly bleaching because it does not use Cl_2 compou this bleaching method uses ClO_2 comp

RESULTS AND DISCUSSION

The bamboo pulp, made from bamboo meat, and part of the bamboo skin are separated. The bamboo, which has been separated from the bamboo skin, is made into flakes with a size of 3x2 cm. This sample has characteristics that are not too different, which has the same brownish color, the surface is flat, and the mixture is homogeneous, as shown in Figure 1

Results of Prehydrolysis Process

The prehydrolysis process is the process of cooking bamboo chips using water at high temperatures. This prehydrolysis process aims to extract the hemicellulose in the bamboo chips. The results can be seen in Table 1.

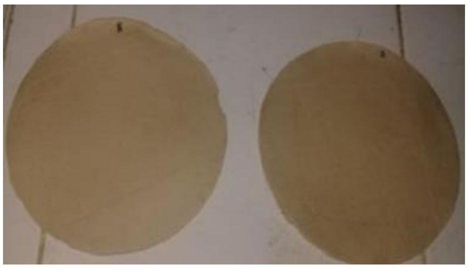

Figure 1. Sheets of green ampel bamboo pulp handsets

Table 1 Prehydrolysis Process Result Data

Autoclave	1	2	3
Bamboo Flakes Dry Weight Before Prehydrolysis (grams)	300	300	300
Bamboo Flakes Dry Weight After Prehydrolysis (grams)	261.87	265.89	270.63
Yields	87.29	88.63	90.21

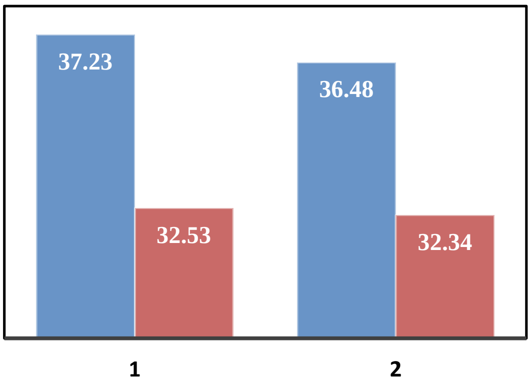

Figure 2. 1. alkaline active (18%) 2. alkaline active (20%)

Figure 2 explains the decrease in the kappa number in pre-hydrolyzed baboo chips (red) compared to bamboo chips that have not undergone the pre-hydrolyzed process. At an active alkaline concentration of 18%, the pulp produced from pre-hydrolyzed bamboo chips had a Yield UnSreened pulp value of 32.53%, while the pulp produced from bamboo chips that had not undergone a pre-hydrolyzed process had a Yield Un Sreened pulp value of 37.23%. Let's look at the active alkaline concentration of the 18% cooking solution. There is a decrease in the Yield UnSreened pulp value of 12,624% if the bamboo flakes used in the cooking process undergo a pre-hydrolyzed process first. At an active alkaline concentration of 20%, the pulp produced from pre-hydrolyzed bamboo chips has a Yield UnSreened pulp value of 32.34%. In comparison, the pulp produced from bamboo chips without a pre-hydrolyzed process has a Yield UnSreened pulp value of 36.48%. If we look at the active alkaline concentration of the 20% cooking solution. there is a decrease in the Yield Un S pulp value of 11.35% if the bambo used in the cooking process underg hydrolyzed process first.

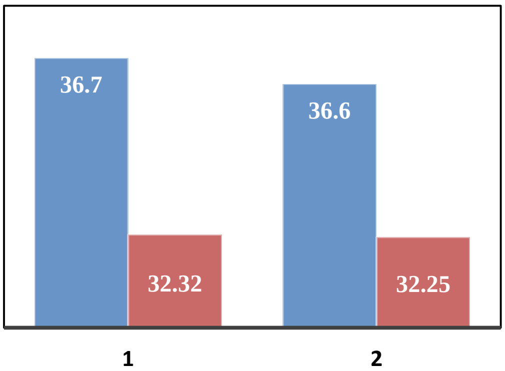

Figure 3. 1. alkaline active (18%) 2. alkaline active (20%)

At an active alkaline concentration of 18% (Figure 3), the pulp produced from bamboo chips that had undergone the pre-hydrolysis process had a Yield Sreened Pulp value of 32.32%. In comparison, the pulp produced from bamboo chips that had not undergone the pre-hydrolysis process had a Yield Sreened Pulp value of 36.70%. Let's look at the active alkaline concentration of the 18% cooking solution. There is a decrease in the Yield Sreened Pulp value of 11.935% if the bamboo flakes used in the cooking process undergo a pre-hydrolysis process first. At an active alkaline concentration of 20%, the pulp produced from pre-hydrolyzed bamboo chips has a Yield Sreened Pulp value of 32.25%, while the pulp produced from bamboo chips that have not undergone the pre-hydrolyzed process has a Yield Sreened Pulp value of 36.06%. Suppose we look at the active alkaline concentration of the 20% cooking solution. In that case, the Yield Sreened Pulp value decreases by 10.57% if the bamboo flakes used in the cooking process undergo a pre-hydrolysis process first.

Brightness is the degree of brightness that is owned by the pulp. From the data and graphs above, the authors can analyze an increase in the Brightness value of the pulp on the pre-hydrolyzed bamboo chips compared to the bamboo chips that have not undergone the pre-hydrolyzed process. At an active alkaline concentration of 18%, the pulp produced from pre-hydrolyzed bamboo chips had a Brightness value of 31.05. In contrast, the pulp produced from bamboo chips that had not undergone the pre-hydrolyzed process had a Brightness value of 30.79 (Figure 4). At an active alkaline concentration of 20%, the pulp produced from pre-hydrolyzed bamboo chips had a Brightness value of 33.74. In contrast, the pulp produced from bamboo chips that had not undergone the pre-hydrolyzed process had a Brightness value of 32.77.

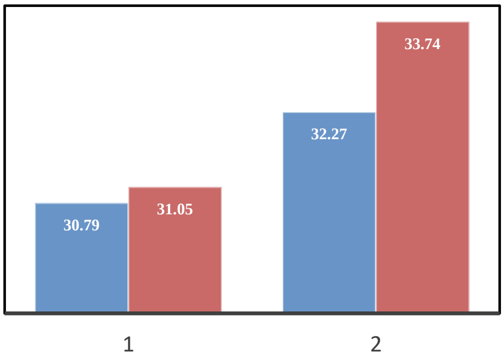

Figure 4. 1. alkaline active (18%) 2. alkaline active (20%)

It has been explained in the previous explanation that the concentration of the Active alkaline cooking solution influences the Kappa number Pulp value. The percentage of lignin content in the pulp is known by multiplying the Kappa number pulp value by the number 0.145, which is then expressed in percent units. The higher the Active alkaline concentration, the lower the pulp Kappa number. The research results prove evidence that the amount of lignin content affects the Brightness value. The relationship between the kappa number value of unbleached and unbleached pulp against the Brightness value shows it.

Active alkaline 18% cooking solution with unbleached pulp samples or pulp that has not been bleached, the pulp kappa number value is 17.28 with a brightness value of 84.79. At an Active alkaline cooking solution concentration of 20%, the pulp kappa number value is 12.69 with a brightness value of 87.53. Then the pulp is subjected to a bleaching process to reduce the lignin content so that the pulp's kappa number value will decrease. At an Active alkaline concentration of 18% cooking solution with bleached or bleached pulp samples, the kappa number pulp value is 2.6848 with a brightness value of 89.18. At an Active alkaline cooking solution concentration of 20%, the pulp's kappa number value is 1.0838 with a brightness value of 90.32.

Figure 5 explains that there is a tendency to decrease the kappa number value of the pulp, which will increase the brightness value of the pulp. During the bleaching process, the lignin contained in the pulp is extracted out of the pulp so that the less lignin in the pulp, the brightness value of the pulp will increase. If the amount of lignin content in the pulp decreases, the amount of brightness value in the pulp will increase.

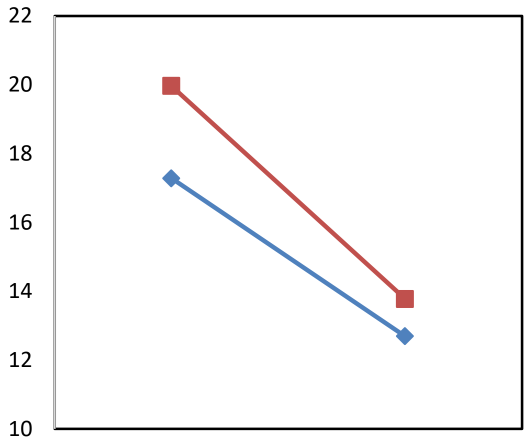

Figure 5. The Effect of Kappa Number on the Brightness value

Table 2. Research Results with Quality Standards

No	Parameter	Unit	SNI standards 938:2017	Yields	
				18 %	20%
1	Alpha Cellulose	%	Min.94	89.18	90.32
2	Extractive DCM	%	Maks. 0,2	0.06205	0.06222
3	*Viscosity*	mL/g	Min. 400	1116.67	1008.67
4	*Brightness*	% ISO	88	74.4	76.9
5	*Fiber Length*	mm	-	2.971	3.074
6	*Fiber Width*	µm	-	20.2	20.6
7	*Kappa Number*	-	-	2.695	1.084

Table 2 explains that the pulp products produced meet the SNI 938: 2017 standard, but several standard parameters have not met the target of the SNI 938: 2017 standard, namely the standard value of alpha-cellulose and the standard value of degrees of brightness. From the research results, the alpha value of cellulose at an active alkaline concentration of 18% cooking chemical solution was 89.18%, and at an active alkaline concentration of 20% cooking chemical solution was 90.32. The standard value of alpha-cellulose pulp is a minimum of 94%. Several factors caused the failure to achieve alpha-cellulose value above a predetermined standard. Alpha cellulose is a long-chain cellulose with a degree of polymerization above 600. If the degree of polymerization is below 600, it is classified into gamma and beta cellulose. In the fiber, there are 4 chemical components: cellulose, hemicellulose, lignin, and extractives. From the research results, the extractive value of the pulp product was obtained according to the standard, which is below 0.2%, so there are no problems with the extractive chemical content, which causes the alpha-cellulose value not to be included in the standard. So the possible factors that cause the alpha-cellulose value not to be included in the standard are the hemicellulose value contained in the pulp is still high, and a lot of cellulose is degraded, which causes the polymerization degree of cellulose to be below 600.

CONCLUSION

The pre-hydrolysis process can optimize the extraction of lignin from the bamboo chips during the cooking process so that the pulp produced has a lower lignin content of 4.63% - 14.52% and a higher brightness value of 0.844% - 2.96% when compared to pulp produced from bamboo chips which are not undergoing a prehydrolysis process. The Viscosity value influences the alpha-cellulose value. An increase in the Viscosity value will result in an increase in the alpha-cellulose value in the pulp. The Kappa number value influences the alpha-cellulose value; an increase in the Kappa number value will result in an increase in the alpha-cellulose value in the pulp. The Brightness value has an influence on the alpha-cellulose value. An increase in the Brightness value will result in an increase in the alpha-cellulose value in the pulp.

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