The Effect of Pulping Time and Alkali Concentration on the Efficiency of Soda Pulping Using Banana Stem

Nur Syafiqah Jusoh, PM Dr Junaidah Jai, and Amal Nadhirah Mohamad

Faculty of Chemical Engineering, Universiti Teknologi Mara

Abstract- The demand in pulp and paper industry has increased greatly as the world population using more and more papers every day. Since most papers are made from wood which makes the production hugely relies on the forest resources, huge areas of rainforest are getting destroyed every year. The main objectives of this research are to produce non-wood pulp from banana stem using soda pulping process and to analyze the efficiency of the soda pulping process by yield and also the kappa number of the resulting banana pulp. Pseudo stem are really suitable for pulping in paper industry. Banana fibers have great physical strength properties. The first step in this experiment is the preparation of the raw material. Then the soda pulping experiment is conducted with time and soda concentration as manipulated variable. The sample from the soda pulping is then dried to get the dried pulp. The dried pulp is characterized with yield, Kappa number. For cooking time, the shortest time at 60 min obtained the highest average yield at 39.47%. For the test of different concentration, the yield obtained the lowest yield at 16% concentration which is only 27.61%. The kappa number pattern for different concentration is decreasing with the increase of concentration. At 16% concentration the kappa number was 35.05 and at 20% the kappa number was 29.66%. Shorter cooking time and lower concentration of sodium hydroxide can give you higher yield, but it will also have higher bleachability and vice versa.

Keywords— concentration, kappa number, pulping time, soda pulping, yield

I. INTRODUCTION

Banana is one of the most cultivated tropical fruits that are currently grown in 129 countries around the world (1). Banana is crown as the second major fruit produced following behind citrus (1). The stem, which has high fiber content, can be used to make a lot of products for example paper board and tissue paper. Pseudo stem contain large quantity of holocellulose (72.71%) and with relatively small content of ash (8.20%) and lignin. Carrying this characteristics, pseudo stem are really suitable for pulping in paper industry (1).

Since the market demands for pulp and paper are keep growing, the technology used for making and producing pulp and paper undergo constant improvement (2). There are two types of pulping in the industry, which are chemical pulping and mechanical pulping. Chemical pulping have lots of advantages which include producing wood pulp that is of high quality that contain longer and stronger fibers with only a little impurities.

Soda pulping process is a chemical pulping process where the chemical pulp is produced by delignifying the sodium hydroxide. Soda pulping process is used for the production of pulp using annual plants as the raw materials such as sugar cane bagasse, flax and cereal straw. In soda pulping, there is a method that has been modified to decrease the carbohydrate degradation. The method is called soda-AQ pulping and the advantages of this method is it will have high pulp yield and also improved the mechanical strength properties of the yield. It is also environment friendly approach because it reduces active alkali consumption in the process (3). Thus, soda pulping was chosen to conduct this experiment to fulfill the objectives which are to produce non-wood pulp from banana stem using soda pulping process and to analyze the efficiency of the soda pulping process on the effect of pulping time and alkali concentration by observing the yield and kappa number of the resulting banana pulp.

II. METHODOLOGY

A. Materials

Banana stem from Musa Paradisiaca from species Musaceae was chosen as the raw material for this experiment. It is collected from Negeri Sembilan and also Kelantan. In previous study, it s shown that banana fibers have great physical strength properties and also high pentosan content together with gums may be a fitting source to produce paper (4).

B. Preparation of banana stem

First, the banana stem was separated layer by layer. Next, the separated layers were washed thoroughly to remove impurities. The layers were then cut into 3cm x 3cm size. Next, the cut banana stem was oven dried at temperature 105^{o}C to remove its moisture content. The banana stem was then grinded and sieved using sieve shaker to obtain particle size of 400µm to 300µm.

C. Soda Pulping of Banana Stem

The purpose of soda pulping is to remove lignin from banana stem using sodium hydroxide as the cooking material. The soda pulping experiment were carried out in lab digester, which 16% NaOH was mixed with sample at ratio 1:14 w/v and the experiment conditions were maintained at 105℃ for all trials. For the first set of experiment, concentration of NaOH was maintained at 16% but the pulping time was varied to 60 min, 90 min and 120 min. For the second set of experiment, the pulping time was maintained at 120 min but NaOH concentration was varied to 16%, 18% and 20%. After pulping was finished, to remove the black liquor, the pulp was washed with hot water and was dispersed with pulp disintegrator. The pulp was then screened to pass 0.25mm slit and was dried at 105℃ to produce dried pulp for characterization. The sample was then evaluated for yield and kappa number (5).

D. Characterization of banana stem

Yield

The percentage by oven dry weight of pulp, which the pulp was dried in the oven at 105℃ for 60 min, obtained from the original wood weight is the expression for the recovery from wood pulping.

Y = (DP/DW)*100
Where,
Y = Yield
DP= Weight after oven dried
DW= Weight before cooking

This calculation was taken from Forest Products Measurements and Conversion Factors (6).

Kappa number

The pulp was weighed using estimation with the targeted kappa number. The sample was blended in a beaker that contained 500 mL of distilled water. After that, the solution was transferred into a 2000 mL beaker. The previous beaker was rinsed with 300 mL of water. The beaker was placed in a water bath to make sure that the temperature was maintained at 25℃. 100 mL of potassium permanganate and 100 mL of sulphuric acid was added into a beaker, and the solution was immediately poured into the 2000 mL beaker. The stopwatch was started right away after the solution was mixed. After 10 min, 20 mL of potassium iodide solution was added into the beaker to stop the reaction. Free iodine together with sodium thiosulphate was titrated into the 2000 mL beaker. Starch indicator was added towards the end of the reaction. For blank determination, the exact same step was carried out only the pulp was not added in the first place (Tappi T 236 om-99)

III. RESULTS AND DISCUSSION

A. The effect of Cooking Time on Yield

Table 4.1 shows the result of the effect of cooking time on recovery percentage of the pulp. The lowest recovery of pulp was obtained in the longest cooking time of the pulp which is at 120 min. The lowest value of yield is 23.57% in the first run of the experiment at 120 min cooking time. The average yield for cooking time 120 min is maintained as the lowest out of the three different cooking times of the pulp at 27.61% yield. Low pulp yield is undesirable for the production of pulp and paper.

The shorter the time taken to cook the pulp will help to decrease the degradation effects of temperature on the sample. This will be the main factor that can increase the yield of the pulp produced. Cooking the banana stem at longer time will cause the stem to lose more weight caused by the loss of bigger amounts of cellulose and also hemicellulose content together with lignin (7).

Table 4.1: Result of the effect of cooking time on pulp yield

Time (min)	Run	Yield (%)	Average yield for each cooking time (%)
60	1	48.04	39.47
	2	34.39	
	3	35.98	
90	1	27.34	35.97
	2	44.49	
	3	36.09	
120	1	23.57	27.61
	2	24.84	
	3	34.41	

B. The effect of Cooking Time on Kappa Number

Based from the result obtained, the average of the kappa number shows an inversely proportional pattern. The kappa number decreases with the increase of cooking time for the pulp. At minute 60, the average kappa number obtained was 35.05. The kappa number decreased when the pulp was cooked at 90 min to 32.06. The lowest kappa number obtained for this set of experiment was 30.53 when the pulp was cooked in sodium hydroxide for 120 min. From the result obtained from previous study by (7) it is shown that with the increasing of H-factor (cooking time, cooking temperature) the kappa number will decrease. It is tested for different concentration of alkali too but the pattern remains the same, the kappa number will decreased with the increase of H-factor. It can be explained by the longer cooking time will give time for the dissolution of lignin fragments from the fibers (8).

Table 4.2: Result of the effect of cooking time on kappa number

Time (min)	Run	Kappa number	Average kappa number for each cooking time
60	1	36.31	35.05
	2	36.27	
	3	32.57	
90	1	33.17	32.06
	2	27.00	
	3	36.00	
120	1	35.03	30.53
	2	31.56	
	3	25.00	

C. The effect of Concentration of Sodium Hydroxide on Yield

Supposedly, the concentration of alkali need to be low for pulp cooking as the high concentration of alkali can increase the degradation of cellulose in the banana stem. The usage of high concentration alkali will also consume alkali unnecessarily. With the increasing of the alkali, it will have similar effect with longer cooking time, which will decrease the yield and it is totally undesirable for the pulp and paper industry.

Table 4.2: Result of different concentrations of sodium hydroxide on the yield of the pulp

Concentration (%)	Run	Yield (%)	Average yield for each cooking time (%)
16	1	23.57477	27.61
	2	24.836	
	3	34.40822	
18	1	45.82925	45.20
	2	44.56222	
20	1	36.83569	36.71
	2	36.59068	

As we can see from the table above, the yield for 18% sodium hydroxide is higher compared to the yield of pulp when 20% sodium hydroxide was used for cooking. It shows a huge yield difference, 45.20% at 18% sodium hydroxide to 36.71% at 20% sodium hydroxide.

However, the average yield of the pulp when 16% sodium hydroxide was used during cooking showed a really low number

compared to 18% and 20% sodium hydroxide. This result is against the statement above which the lower the concentration of the alkali used for soda pulping will provide higher yield for the pulp. There are various reasons on why this situation has occurred. From the study conducted by (9), similar pattern of graph was found. It is explained that for any sodium hydroxide concentration, the yield will constantly increased until it reached the optimum temperature at 105℃ and will decreased at temperature higher than that. The temperature for cooking the pulp in 16% sodium hydroxide was at 110℃ which exceed the optimum temperature thus explaining on why it has the lowest yield compared to 18% and 20% sodium hydroxide concentration and go against the pattern that was supposedly to be directly proportional.

D. The effect of Concentration of Sodium Hydroxide on Kappa Number

From the table, it can be observed that the average value of kappa number constantly declining with the increase of sodium hydroxide concentration used for cooking. This shows that with higher concentration of sodium hydroxide used, the lower the bleachabilty, which is a good result as lower bleachability means the pulp is easier to be bleached and less bleaching chemicals will be required.

Table 4.2: Result of the effect of sodium hydroxide concentration on kappa number

Concentration (%)	Run	Kappa number	Average kappa number for each cooking time
16	1	36.31	35.05
	2	36.27	
	3	32.57	
18	1	32.21	31.38
	2	30.55	
20	1	28.81	29.66
	2	30.50	

In previous study by (10), it is stated that with the higher concentration of the alkali and H-factor (cooking time) is remained constant, the kappa number will decreased. The result obtained from this experiment obeyed the statement from the study

IV. CONCLUSION

After conducting the experiment to check the best pulping time and concentration of sodium hydroxide to be used for soda pulping, it can be concluded that not one specific time and concentration can satisfy all the needs. While shorter cooking time can provide the higher yield compared to longer cooking time, longer cooking time can obtained the lowest kappa number for lower bleachability. The same case with concentration, the lowest concentration supposedly brings the highest number of yield because higher concentration of sodium hydroxide will decrease the yield of the pulp. However, lowest number of lignin can be obtained when higher concentration of sodium hydroxide was used. Both have pros and cons, if shorter cooking time and lower concentration of sodium hydroxide can give you higher yield, it will also have higher bleachability which means more bleach chemicals will be needed to bleach the pulp to certain brightness. Longer cooking time with higher soda concentration will provide you lower bleachability but also with lower pulp yield.

More sets of experiment should be conducted to get the optimum conditions which can favor both yield and kappa number. To find the optimum conditions, response surface method can be used which allow us to guesstimate the connections and quadratic effects (11).

This experiment only covered on yield and kappa number but not the physical properties which are also important in producing great pulp and paper for the industry, thus it is advisable to conduct all required tests to obtain the best conditions for soda pulping process.

ACKNOWLEDGMENT

Thank you to my supervisor and co-supervisor and Universiti Teknologi Mara.

References

[1] Jaya, B., Siram, M., & Anudeep, N. (2014). Production of Pulp from Banana Pseudo stem for Grease Proof Paper. *International Journal of Engineering Research and General Science*, 61-77

[2] Debabandya, M., Sabyasachi, M., & Namrata, U. (2010). Banana and its by-product utilisation: an overview. *Journal of Scientific & Industrial Research*, 323-329.

[3] Kurt, M., & Ewald, S. (1994). Biopulping: An overview of developments in an environmentally safe paper-making technology. *FEMS Microbiology Reviews 13*, 351-364.

[4] Ramadan, A., Salim, H., Mohamed, A., Hamad, A., Nader, D., & Ibrahim, M. (2015). Measurement of some properties of pulp and paper made from date palm midribs and wheat straw by soda-AQ pulping process. *Measurement*, 179-186.

[5] Manish, K., & Deepak, K. (2011). Comparative study of pulping of banana stem. *International Journal of Fiber and Textile Research*, 1-5.

[6] Tripathi, S., Singh, S., Gangwar, A., Mishra, O., Chakrabarti, S., Bhardwaj, N., & Varadhan, R. (2013). Blending of banana stem with wheat straw and bagasse to enhance physical strength properties of paper. *Indian Pulp & Paper Technical Association*, 121-126.

[7] Briggs, D. (1994). Chapter 8. Pulp and Paper . In D. Briggs, *Forest Products Measurements and Conversion Factors* (pp. 96-106). Washington: The College of Forest Resources.

[8] Larekeng, S., Sudarsono, S., & Purwito, A. (2015). Pollen Dispersal and Pollination Patterns Studies in Pati Kopyor Coconut using Molecular Markers. *International Journal on Coconut R&D*, 13-23.

[9] Vu, T. M., Pakkanen, H., & Alen, R. (2004). Delignification of bamboo (Bambusa procera acher)Part 1. Kraft pulping and the subsequent oxygendelignification to pulp with a low kappa number. *Industrial Crops and Products 19*, 49-57.

[10] Wutisatwongkul, J., Thavarungkul, N., Tiansuwan, J., & Termsuksawad, P. (2016). Influence of Soda Pulping Variables on Properties of Pineapple (Ananas comosus Merr.) Leaf Pulp and Paper Studied by Face-Centered Composite Experimental Design. *Advances in Materials Science and Engineering*, 11 pages.

[11] Sharma, M., & Shukla, R. (2013). Impact of Cooking Conditions on Pulp Viscosity and Kappa Number of Leucena Leucocephala Wood for Kraft Pulping. *International Journal of Engineering Research & Technology*, 1-8.

[12] *NIST/SEMATECH e-Handbook of Statistical Methods*, http://www.itl.nist.gov/div898/handbook/, 30 November 2013.