Journal of Tropical Resources and Sustainable Science

journal homepage: jtrss.org

# Effect of bleaching using sodium hydroxide on pulp derived from *Sesbania grandiflora*

Tan Shioa Wei[1], Boon Jia Geng[1,2,*], Low Hui Qi[1], Goh Kent Tiong[1], Kuek Sook Chi[1], Wong We Hoong[1]

[1]Faculty of Bioengineering and Technology, Universiti Malaysia Kelantan, Jeli, Kelantan, Malaysia
[2]Advanced Materials Research Cluster, Universiti Malaysia Kelantan, Kelantan, Malaysia

Received 10 November 2017
Accepted 24 November 2017
Online 6 June 2018

Keywords:
Sodium hydroxide, bleaching, *Sesbania grandiflora*, pulp, paper handsheet.

⌧*Corresponding author:
Dr. Boon Jia Geng,
Faculty of Bioengineering and Technology,
Universiti Malaysia Kelantan,
Kelantan, Malaysia.
Email: jia.geng@umk.edu.my

## Abstract

World demand for paper is increasing. Short rotation pulpwood is needed. *Sesbania grandiflora* also known as Turi, is a fast growing and straight log species. The scholarly information of Turi as pulpwood are still limited. This paper aims to provide information of sodium hydroxide effect on the paper made from pulp derived from Turi. Sodium hydroxide is a common chemical using as part of full stage chemical bleaching in pulp industrial. Kraft pulp that produced using Turi, was bleached with sodium hydroxide at 3%, 6% and 9% based on pulp weight, respectively. Unbleached pulp was served as blank test. The optical and mechanical properties of handsheet paper made from bleached kraft pulp were evaluated according to TAPPI standard. The brightness and opacity of handsheet made from bleached pulp were improved with increasing the concentration of sodium hydroxide. The mechanical properties of handsheet were improved with using 3% sodium hydroxide and gradually decreased after 3% sodium hydroxide. In conclusion, sodium hydroxide is potential to improve optical properties of Turi pulp and improve the mechanical properties of paper made from Turi pulp at certain level. Excessive usage of sodium hydroxide brings adverse effect to mechanical properties of paper made from Turi pulp.



## 1. INTRODUCTION

The paper production in worldwide is still increasing especially in Asia countries despite the paper industries in many western countries are going towards sunset industries. Besides from the industries shifting, the preference of paper application are also changing. E-commerce expanding rapidly in the decade and create the opportunity to paper packaging industries. In this past 10 years, more than 50% of the paper and paperboard production are using for paper packaging purposes (BIR, 2017).

Pulpwood is the main source of producing paper pulp. Practically, the pulp yield is approximately 40% of the pulpwood trunk weight. The consumption of pulpwood in pulp industries is extremely huge in order to withstand the global demands. The common pulpwood *Acacia mangium* that widely used by pulp industries are facing heart rotten disease (Gafur, Nasution, Tarigan & Tjahjono, 2012). To sustain the paper production that keep increasing, short rotation and diseases free pulpwood is needed. *Sesbania grandiflora* was previously reported as potential pulpwood （Bhat & Menon, 1971; Logan, Murphy, Philips & Higgins, 1977）. However, there are very limited scientific data to reveal its potential.

In the pulp industries, lignin removal is crucial. The lignin removal process also known as bleaching. In previous, chlorine based bleaching are common used in the industries. However, it is also bringing adverse effect to the industries. Total chlorine free (TCF) bleaching was introduced as the alternate. Sodium hydroxide treatment is one of the potential TCF bleaching. Sodium hydroxide well known with its ability in removing lignin (Boon et al, 2017). Other TCF bleaching that available are including oxygen treatment, ozone treatment, hydrogen peroxide treatment, and bio-enzyme treatment. Comparing to these TCF bleaching, sodium hydroxide treatment are more economical as the chemical can be recover and reuse (Kirwan, 2013).

Besides than removing lignin, sodium hydroxide also degrade the hemicelluloses from lignocellulosic. Hence, the concentration of applying sodium hydroxide as lignin removal agent of pulp are important. The author aims to study the effect of sodium hydroxide treatment to the pulp derived from *Sesbania grandiflora*. This research improve the scientific data potential of *Sesbania grandiflora* as pulpwood.

## 2. MATERIALS AND METHODS

### 2.1. Pulp preparation

*Sesbania grandiflora* trunk were collected at Pasir Mas, Kelantan. The trunk were debarked and chipped into 2.5 cm x 2.5 cm x 0.5 cm. The woodchip were left to air dry to approximately 10% moisture content. The woodchips were carried with kraft pulping using laboratory



eISSN Number: 2462-2389 

rotary stainless steel digester, at 170°C and cooking time 120 minutes with heating to cooking time 60 minutes. The white liquor was at 20% active alkali and 25% sulfidity with ratio to wood at 8:1. The pulp were washed with tap water to remove excessive black liquor and screened with mesh (0.15mm slits). The pulp was beaten with PFI beater at 5000 revolutions.

### 2.2. Sodium hydroxide treatment and handsheet formation

The beaten pulp were bleached with sodium hydroxide with 3%, 6% and 9% based on pulp weight with 15% consistency. The bleaching process was carried at 60°C for 60 minutes. The unbleached pulp serve as blank. The bleached pulp were rinse with distilled water to remove the excessive sodium hydroxide. Five handsheet at 60g/m$^2$ were formed with laboratory handsheet machine for each treatment condition, including blank.

### 2.3. Pulp and paper properties evaluation

The efficiency of sodium hydroxide in removing lignin of *Sesbania grandiflora* pulp was evaluated with TAPPI 236 by measuring the Kappa number of pulp. Physical properties of handsheet including thickness, density, grammage, opacity and brightness were conducted according to TAPPI 411, TAPPI 410, TAPPI 519, and TAPPI 452, respectively. Mechanical properties of handsheet specimen were conducted tensile strength, tear resistant, bursting strength, and folding endurance according to TAPPI 494, TAPPI 414, TAPPI 403 and TAPPI T511, respectively. The result of mechanical strength were reported in index, by dividing the strength with its grammage, respectively.

### 2.4. Statistical test

All the results were expressed in mean with standard deviation. The results were performed with ANOVA test at alpha level of 0.05. The results were performed with Tukey post hoc test for multiple comparison between treatments for each testing.

## 3. RESULTS AND DISCUSSION

Table 1 showed Kappa number of *Sesbania grandiflora* pulp with sodium hydroxide treatment. The Kappa number was significantly reduced with the increase of sodium hydroxide concentration. The lignin in the pulp was dissolved in sodium hydroxide solution and reducing the lignin content in the pulp (Zhai & Zhou, 2014). Overall, sodium hydroxide treatment able to reduce lignin content in the *Sesbania grandiflora* pulp. However, the degree of reduction in Kappa number was relatively low for 6% and 9% sodium hydroxide compare to 3% sodium hydroxide. Eventually, the Kappa number of the pulp were reduced for 51% from using 9% sodium hydroxide. Similar results was reported Vu, Pakkanen & Alen (2004) in their research using single stage oxygen bleaching on pulp derived from Bamboo. The Kappa number reduction of their research were ranged in 36-53%.

**Table 1**: Kappa number of *Sesbania grandiflora* pulp with sodium hydroxide treatment

| Sodium hydroxide Concentration,% | Kappa number |
|---|---|
| 0 | 14.34 ± 0.19 a |
| 3 | 9.91 ± 0.32 b |
| 6 | 8.27 ± 0.21 c |
| 9 | 7.00 ± 0.20 d |

The Kappa number with different letters within the same column is significantly different at alpha value of 0.05

The grammage of handsheets was range from 60.6 gm$^2$ to 64.7 gm$^2$ while the thickness of the handsheets was range from 0.1455mm to 0.2095mm. These handsheets were fulfil the specification according to TAPPI. Table 2 showed the opacity and brightness of the handsheets made from the *Sesbania grandiflora* pulp with sodium hydroxide treatment. The opacity was not statistical significantly affected by the sodium hydroxide. Opacity are highly correlate with the bulk density of paper. The pulp with less stiffness offer high density paper. Although lignin contribute the stiffness to pulp, however the pulp were beaten and the cell wall was ruptured and become flexible before lignin removal, the later effect of lignin removal on stiffness reduction were became insignificant.

**Table 2**: Physical properties of *Sesbania grandiflora* pulp with sodium hydroxide treatment

| Sodium hydroxide Concentration,% | Opacity, % | Brightness, % |
|---|---|---|
| 0 | 97.81 ± 0.43 a | 32.90 ± 0.33 a |
| 3 | 96.56 ± 0.46 a | 38.18 ± 0.13 b |
| 6 | 97.00 ± 0.79 a | 39.23 ± 0.01c |
| 9 | 96.86 ± 0.17 a | 39.59 ± 0.03 c |

The opacity and brightness with different letters within the same column is significantly different at alpha value of 0.05.

The brightness was significantly improved by increasing the sodium hydroxide concentration. Sodium hydroxide is a common bleaching agent which solubilize the lignins (Dence & Reeve, 1996). The paper are brighter as more lignins are hydrolyzed and solubilized by increasing sodium hydroxide concentration. Lignin is the factor which causes the brown colour of paper. Brightness is inversely proportional to the kappa number. The lesser the kappa number, the brighter the handsheet. However, from the result, although lignin were significantly reduced when increasing the sodium hydroxide concentration from 6% to 9%, yet the brightness of handsheet made from pulp treated with 6% and 9% sodium hydroxide were showed insignificant different (sig. value 0.254). The effect of sodium hydroxide treatment on brightness of paper are optimized at 6% sodium hydroxide concentration.



eISSN Number: 2462-2389 

Table 3 showed the mechanical properties of the handsheet made from *Sesbania grandiflora* pulp with sodium hydroxide treatment. The folding endurance of the handsheets was decreased with the increased of sodium hydroxide. However, the effect of sodium hydroxide concentration on folding endurance was less significant than the effect of sodium hydroxide concentration on tensile index and tearing index. Sodium hydroxide causes swelling of the cellulose and even dissolution of the cellulose (Wang, 2008). When the concentration of sodium hydroxide increased, the cellulose fiber was also degraded too as the bleaching agent was not only attacked the lignin but also attacked cellulose (Dence & Reeve, 1996). The folding endurance was decreased due to the fiber degradation.

**Table 3**: Mechanical properties of *Sesbania grandiflora* pulp with sodium hydroxide treatment

| Sodium hydroxide Concentration ,% | Folding endurance (MIT. 1kg) | Tensile index (N m/g) | Tearing index (mN $m^2$/g) |
|---|---|---|---|
| 0 | 9.66 ± 2.08 a | 5.12 ± 0.61 a | 5.89 ± 0.61 a |
| 3 | 5.67 ±1.15 b | 8.16 ± 0.75 b | 7.16 ± 0.08 b |
| 6 | 5.00 ± 2.00 b | 5.60 ± 0.40 a | 5.88 ± 0.19 a |
| 9 | 3.67 ± 0.58 c | 3.93 ± 0.21 c | 5.05 ± 0.38 c |

The folding endurance, tensile index and tearing index with different letters within the same column is significantly different at alpha value of 0.05.

Tensile index and tearing index are influenced by fiber bonding, fiber strength and fiber length but tearing strength is more dependent on the individual fiber strength (Anonymous 2014). Tensile index and tearing index of handsheets were significantly affected by the sodium hydroxide concentration. Both tensile index and tearing index at 6% sodium hydroxide concentration were not much different with the unbleached paper. Besides that, both tensile index and tearing index were increased in 3% sodium hydroxide concentration. This was due to the decreased of lignin that reduced the modulus of elasticity of single fibers, hence reduced the stiffness of the pulp (Zhang, Fei, Yu, Cheng & Wang, 2013). The reduction of the stiffness indicates the individual fibers are more flexible and more easily to form fiber-fiber bonding (Johansson, 2011). Thus, this increased the tensile index and tearing index of the paper. However, both tensile strength and tearing strength decreased when the sodium hydroxide concentration beyond 3% due to the degradation of fibers

## 4. CONCLUSION

As conclusion, the sodium hydroxide treatment able to reduce the lignin content in *Sesbania grandiflora* pulp with increasing the sodium hydroxide concentration. The brightness of the handsheet made from the pulp treated with sodium hydroxide showed improvement with increasing the sodium hydroxide treatment. The brightness were improved drastically at 3% sodium hydroxide concentration and the improvement were slow after 3% sodium hydroxide concentration. However, the mechanical strength especially tensile index and tearing index were improved in beginning and the mechanical strength gradually reduced after 3% concentration. Hence, 3% sodium hydroxide concentration were chosen as the most suitable treatment level for *Sesbania grandiflora* pulp.

## ACKNOWLEDGEMENT

This research was funded by Universiti Malaysia Kelantan Short Term Research Grant Scheme (R/SGJP/A08.00/01349A/001/2016/000343).

## REFERENCES

Anonymous. (2014). *Tensile Strength of Paper*. Retrieved October 8, 2017, from ttp://www.pulppapermill.com/tensile-strength-of-paper/

Bhat, A.S., & Menon, M.M. (1971). *Sesbania grandiflora* (A Potential Pulpwood). *Indian Forester*, 97, 128-144.

BIR. (2017). Paper Materials. Retrieved October 13, 2017, from http://www.bir.org/industry/paper/?locale=en_US

Boon, J.G., Hashim, R., Sulaiman, O., Sugimoto, T., Sato, M., Salim, N., Amini, M.H.M., Nor Izaida, I. & Sitti Fatimah, M.R. (2017). Important of Lignin on the Properties of Binderless Particleboard Made from Oil Palm Trunk. *ARPN Journal of Engineering and Applied Sciences*, 12 (1), 33-40

Dence, C. W. & Reeve, D. W. (Ed.). (1996). *Pulp Bleaching: Principles and Practice* (1st ed.). Tappi Pr. Retrieved on March 2, 2017.

Gafur, A., Nasution, A., Tarigan, M., & Tjahjono, B. (2012). Development of Biological Controls Agents to Protect Plantation Forests in Sumatra, Indonesia. In Mohammed, C., Beadle, C., Roux, J., & Rahayu, S. (Eds.), *Proceeding of International Conference on The Impacts of Climate Change to Forest Pests and Diseases in The Tropics*

Johansson, A. (2011). *Correletions Between Fibre Properties and Paper Properties*. Retrieved October 3, 2017, from https://www.diva-portal.org/smash/get/diva2:505453/FULLTEXT01.pdf

Kirwan, M.J. (2013). Handbook of Paper and Paperboard Packaging Technology. Wiley-Blackwell, 9-10.

Logan, A.F., Murphy, P.I., Philips, F.H., & Higgins, H.G. (1977). Possible Pulpwood Resources for Northern Australia: Pulping Characteristics of young *Anthocephalus chineses* and *Sesbania grandiflora*. *Appita*, 31, 121-127.

*TAPPI 236 om-99*. (1999). Kappa Number of Pulp: 1999. Atlanta: *Technical Association of the Pulp and Paper Industry.*

*Vu, T.H.M., Pakkanen, H., Alen, R., (2004). Delignification of Bamboo (Bambusa procera acher) Part 1. Kraft Pulping and the Subsequent Oxygen Delignification to Pulp with a Low Kappa Number. Industrial Crops and Products, 19, 49-57.*

Wang, Y., (2008). Cellulose Fiber Dissolution in Sodium Hydroxide Solution at Low Temperature: Dissolution Kinetics and Solubility Improvement. Ph.D Dissertation, Institute of Technology, Georgia.

Zhai, R., Zhou, X., (2014). Enhanced Effect of NaOH/Thiourea/Urea Aqueous Solution on Paper Strength of High Yield Pulp. *Bioresources*, 9(2), 2154-2166.

Zhang, S.Y., Fei, B.H., Yu, Y., Cheng, H.T., & Wang, C.G., (2013). Effect of The Amount of Lignin on Tensile properties of Single Wood Fibers. *Forest Science and Parctice, 15*(1), 56-60.



eISSN Number: 2462-2389 