Songklanakarin J. Sci. Technol.
41 (6), 1356-1359, Nov. - Dec. 2019

http://www.sjst.psu.ac.th

Original Article

Effect of beating on kraft pulp of *Sesbania grandiflora*

Boon Jia Geng[1, 2*], Sitti Fatimah Mhd. Ramle[1, 2], Nor Izaida Ibrahim[1, 2], Nurul Akmar Che Zaudin[1, 2], Liew Jeng Young[3], and Zulhazman Hamzah[4]

[1] *Faculty of Bioengineering and Technology, Universiti Malaysia Kelantan, Jeli, Kelantan, 17600 Malaysia*

[2] *Advanced Materials Research Cluster, Universiti Malaysia Kelantan, Jeli, Kelantan, 17600 Malaysia*

[3] *Faculty of Agro based Industry, Universiti Malayssia Kelantan, Jeli, Kelantan, 17600 Malaysia*

[4] *Faculty of Earth Science, Universiti Malaysia Kelantan, Jeli, Kelantan, 17600 Malaysia*

Received: 9 July 2017; Revised: 9 May 2018; Accepted: 14 August 2018

Abstract

Increasing global demands on pulp and paper necessitate fast-growing pulpwood. *Sesbania grandiflora* is one of the related species on which there is little scientific information. This research examines the potential of *S. grandiflora* as pulpwood by studying the effects of beating on pulp derived from *S. grandiflora.* Kraft pulp was prepared and beaten at 10000 and 20000 revolutions. Handsheets with the target grammage of 60 g/m^2 were produced. Pulp properties and physical and mechanical properties of handsheets were evaluated according to the TAPPI standard. Tensile index, tear index, bursting index, and folding endurance of handsheet made from *S. grandiflora* pulp increased with an increase in beating revolutions. Its moderate strength properties were due to its short fiber length. The study concludes that the pulp derived from *S. grandiflora* is not suitable to produce heavy duty paper.

Keywords: *Sesbania grandiflora*, beating, kraft pulp, pulpwood, handsheet

1. Introduction

There are 7.3 million hectares of forest that are harvested annually. Nearly 40% of the woods are for the pulping industry (Food and Agriculture Organization of the United Nations [FAO], 2015). World demand for paper, notwithstanding the contemporary digital era, is still increasing. E-commerce has led to growing demands for paper packaging such as corrugated boxes and security envelops (Technical Association of the Pulp and Paper Industry [TAPPI], 2016). The pulp and paper industry plays a prominent role in the economy of the world, in particular the Asian countries (Barr, 2001). The production and consumption of paper are steadily increasing in these countries. Pulpwood from natural forests is not a sustainable resource to support the increasing demands. Hence, forest plantation and recycled fiber were introduced as an alternative to replace the natural forest pulpwood.

Acacia mangium has been used as pulpwood in commercial forest plantation since the late 1970s (Mead & Miller, 1991). However, the species is vulnerable to root rot and heart rot fungal disease which decreases its pulp yield (Gafur, Nasution, Tarigan, & Tjahjono, 2012; Mohd Farid, Lee, Maziah, Rosli, & Norwati, 2005). Recent studies on pulp sources have focused on agricultural wastes such as oil palm and bagasse (Bissoon, Christov, & Singh, 2002; Hassan, Hassan, & Oksman, 2011; Sumanthi, Chai, & Mohamed, 20

*Corresponding author
Email address: jia.geng@umk.edu.my

08; Wanrosli, Zainuddin, Law, & Asro, 2007). However, their limited supplies, silica content and fungal decay are major challenges in using them as pulp sources. Even though recycling paper is one of the viable options, secondary fibers recovered from recycled paper have a limited lifespan. Therefore, secondary fibers are often mixed with virgin fibers to ensure the paper product meets strength properties. Among the existing pulp sources, pulpwood remains a reliable one in the pulping industries in coping with the world's insatiable paper demand. Hence, a new fast-growing pulpwood is needed to sustain the pulp and paper industries.

Sesbania grandiflora, known locally as Turi, is a fast-growing and straight tree. It has short crop rotations of 3–4 years, and can reach 20 feet in height (Orwa, Mutua, Kindt, Jamnadass, & Anthony, 2009). Some researchers have reported on the medicinal value of its leaves (Das, Paul Das, & Velusamy, 2013). However, the potential of its trunk has not been fully focused on. Few reports have focused on *S. grandiflora* as a potential pulpwood (Bhat & Menon, 1971; Logan, Murphy, Philips, & Higgins, 1977), and there are no published scientific data on *S. grandiflora* pulp. Hence, the present research is a timely attempt to examine the potential of *S. grandiflora* as a new source of wood pulp which may help sustain the pulp industries and the environment.

This paper aims to identify the properties of pulp derived from *S. grandiflora* and the paper made from it. The pulps were treated with different degrees of beating before forming into a handsheet. Beating is a crucial mechanical treatment to improve the pulp by changing its fiber characteristics (Gharehkhani *et al.,* 2015). Unbeaten pulp often comes with poor inter-fiber contacts during paper formation and leads to poor paper properties. Defibrillation and delamination occur during the beating. The result is an increase in fiber surface area and flexibility (Gulsoy, Hurfikir, & Turgut, 2016). The physical changes are able to improve the inter-fiber bonding and increase most of the paper strength properties. At the same time, by reducing the fiber length and producing a fine diameter, the drainage time of the refined pulp is increased (Gulsoy, 2014).

2. Materials and Methods

2.1 Pulp preparation

S. grandiflora trunks were collected at Pasir mas Kelantan, Malaysia. Trunks were chipped into 2x2x0.5 cm pieces and air dried to a moisture content of approximately 10%. The wood chips were cooked by the kraft pulping process using the pulping conditions shown in Table 1. Kraft pulping was used because the *S. grandiflora* trunk contains resin. The process was carried out in a laboratory scale rotary stainless steel digester. The pulps were washed with tap water and screened with 0.15 mm slits. The obtained pulp was spun to remove the excessive moisture for a solids content of approximately 75%. The pulp was beaten using a PFI beater at 10000 and 20000 revolutions. Unbeaten pulp was used as a blank.

Table 1. *Sesbania grandiflora* kraft pulping condition.

Conditions	Parameter values
Active alkali, % (as Na_2O), AA	20%
Sulfidity, % (as Na_2O)	25%
Wood to liquor, W: L	1:8
Pulping temperature, T	170 °C
Heating to cooking time, t to T	60 min
Cooking time, t	120 min

2.2 Characterization of pulp and handsheet paper

The Kappa number and freeness of pulp were analyzed according to TAPPI T236 and TAPPI T227, respectively. Five handsheets at target grammage of 60 g/m^2 and with a surface area of 100 cm^2 were made using unbeaten and beaten pulp. The handsheet specimens were conditioned according to TAPPI 402. The physical properties of the handsheets such as thickness, density, grammage, and opacity were conducted according to TAPPI 411, TAPPI 410, and TAPPI 519. Mechanical properties of handsheet specimens such as tensile strength, tear resistance, bursting strength, folding endurance, and opacity were conducted according to TAPPI 494, TAPPI 414, TAPPI 403, and TAPPI T511. In addition, folding endurance was conducted at 1 kg tension. The results of the mechanical strength are reported in index values, dividing the strength by its grammage. All results are expressed in mean.

3. Results and Discussion

3.1 Pulp properties

Results of the beating effect on *S. grandiflora* pulp properties are tabulated in Table 2. The unbleached *S. grandiflora* pulp kappa number was observed in an approximate range of 13–17. Similar results were reported by Tanaka, Wan Rosli, Magara, Ikeda, and Hosoya (2004), i.e. the unbleached oil palm empty fruit bunch (OPEFB) pulp produced by kraft pulping was recorded at 14.9. Manimaran, Santhosh Kumar, and Permaul (2009) reported that the kappa number of pulp derived from bagasse was observed at 12.5 before bleaching. The kappa number of *S. grandiflora* pulp was comparable with common agricultural by-products used as potential pulp sources.

Water volume discharge from a Canadian Standard Freeness tester was much lower in the beaten pulp than in the unbeaten pulp. This is because the gap among the fibers was significantly reduced after beating. Delamination that occurred during the beating process reduced the stiffness of the fibers and increased the contact among them. Hence, the freeness of the specimen was reduced by increasing the beating revolution.

3.2 Handsheet physical properties

The physical properties of handsheet made from *S. grandiflora* pulp are tabulated in Table 3. The thickness of the

Table 2. Influence of beating on *Sesbania grandiflora* pulp properties.

Beating revolution	Kappa number	CSF, mL
0	13.02	630
10, 000	13.97	260
20, 000	13.56	180

Table 3. Physical properties of handsheet made from unbeaten and beaten *Sesbania grandiflora* pulp.

Beating revolution	Thickness, μm	Density, g/cm^3	Grammage, g/m^2	Opacity Tappi, %
0	245.5	0.246	60.44	99.76
10000	127.1	0.476	60.52	98.12
20000	107.6	0.559	60.10	97.47

handsheet paper made from the beaten pulp was approximately 50% less than the unbeaten pulp. This is because the beaten pulp was delaminated and the inter-fiber voids became less with the improvement of contact among the pulp fibers. In other words, improvement in the density of the beaten pulp handsheet led to a reduction in the thickness. Density is an important indicator for structural properties of paper. High density paper shows a better inter-fiber bonding.

The opacity of a paper decreased as the beating revolutions increased. Opacity is contingent on the thickness of the paper. Thin layer paper has lower opacity than thick layer paper with the same grammage because the light can pass easily through it.

3.3 Mechanical properties

The mechanical properties of handsheet made from *S. grandiflora* pulp are tabulated in Table 4. The mechanical properties of handsheet increased as the beating revolutions increased. The mechanical strength of the beaten pulp handsheet significantly rose because the beaten fiber has a larger contact surface area and better contact quality. The tensile index of handsheet made from the pulp beaten at 20000 revolutions was recorded as 40.13 N m/g. In a similar report by Gulsoy *et al.* (2016), the tensile index of handsheet made from low-beaten European aspen pulp was recorded as approximately 40 Nm/g. This is even lower than the tensile index of handsheet made from *Acacia mangium* which was recorded as approximately 100 Nm/g by Wan Rosli, Mazlan, and Law (20 11). The moderate tensile index of *S. grandiflora* pulp could be due to its short fiber length (Hunsigi, 1989).

The tear resistance index showed similar results of the handsheet made from *S. grandiflora* pulp. The tear resistance index of *S. grandiflora* handsheet increased as the beating revolutions increased. The results showed that the handsheet specimens made from unbeaten *S. grandiflora* pulp had a rather low resistance to tearing. Beating pulps considerably boosted the mechanical properties of handsheet specimens. The good inter-fiber contact, which resulted from the beating process, allowed the handsheets to receive more stress before tearing.

The burst index was highly correlated with tensile index. An increase in the beating revolutions increased the burst index of the handsheet made from *S. grandiflora* pulp and the tensile index of the handsheet specimens. The handsheet made from unbeaten pulps showed poor resistance to bursting. The specimens with low tensile strength were also unable to resist the force. The burst index of the specimens reached 5.81 kPa m^2/g at 20000 beating revolutions.

Folding endurance is also highly correlated with tensile strength and handsheet flexibility. Before rupture, the folding count of handsheet specimens made from *S. grandiflora* pulp beaten at 20000 revolutions was recorded as 12 55.2. Compatible burst index and folding endurance were found in handsheets made from oil palm empty fruit bunch by Tanaka *et al.* (2004).

Table 4. Mechanical properties of handsheet made from unbeaten and beaten *Sesbania grandiflora* pulp.

Beating revolution	Tensile index, (N m/g)	Tear resistant Index (mN m^2/g)	Bursting index, (kPa m^2/g)	Folding endurance (fold number at MIT. 1 kg)
0	3.16	1.86	0.25	2.6
10000	30.96	6.78	3.56	770.2
20000	40.13	10.53	5.81	1255.5

4. Conclusions

Handsheets produced from unbeaten *S. grandiflora* pulp showed poor properties. Thus, beating is crucial for *S. grandiflora* as a pulpwood. Beating *S. grandiflora* pulp improves mechanical strength of the produced handsheets. The mechanical strength of handsheet made from *S. grandiflora* beaten at 20000 revolutions is comparable with the properties of handsheets made from other potential pulp sources such as bagasse and oil palm empty fruit bunch. However, their overall strength is considered to be moderate. Therefore, the potential paper product made from *S. grandiflora* pulp is not suitable enough for heavy duty purposes.

References

Barr, C. (2001). *Profits on paper: The political-economy of fiber and finance in Indonesia's pulp and paper industries.* Center for International Forestry Research and WWF Macroeconomic Program Office, Washington, DC.

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

Bissoon, S., Christov, L., & Singh, S. (2002). Bleach boosting effects of purified xylanase from *Thermomyces lanuginosus* SSBP on bagasse pulp. *Process Biochemistry, 37*(6), 567-572.

Das, J., Paul Das, M., & Velusamy, P. (2013). *Sesbania grandiflora* leaf extracts mediated green synthesis of antibacterial silver nanoparticles against selected human pathogens. *Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy, 104*, 265-270.

Food and Agriculture Organization of the United Nations (2015). Global Forest Resources Assessment 2015. Retrieved from http:// http://www.fao.org/3/a-i480 8e.pdf

Gafur, A., Nasution, A., Tarigan, M., & Tjahjono, B. (2012). Development of biological controls agents to protect plantation forests in Sumatra, Indonesia. In C. Mohammed, C. Beadle, J. Roux, & S. Rahayu (Eds.), *Proceeding of International Conference on the Impacts of Climate Change to Forest Pests and Diseases in the Tropics.*

Gharehkhani, S., Sadeghinezha, E., Kazi, S. N., Yarmand, H., Badarudin, A., Safaei, M. R., & Mohd Zubir, M. N. (2015). Basic effects of pulp refining on fiber properties-a review. *Carbohydrate Polymers, 115*, 785-803.

Gulsoy, S. K. (2014). Effects of cationic starch addition and pulp beating on strength properties of softwood kraft pulp. *Starke, 65*, 1-5.

Gulsoy, S. K., Hurfikir, Z., & Turgut, B. (2016). Effects of decresing grammage on the handsheet properties of unbeaten and beaten kraft pulps. *Turkish Journal of Forestry, 17*(1), 56-60.

Hassan, E. A., Hassan, M. L., & Oksman, K. (2011). Improving bagasse pulp paper sheet properties with microfibrillated cellulose isolated from xylanase-treated bagasse. *Wood and Fiber Science, 43*(1), 76-82.

Hunsigi, G. (1989). Agricultural fibres for paper pulp. *Outlook on Agricultural, 18*(3), 96-103.

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.

Manimaran, A., Santhosh Kumar, K., Permaul, K., & Singh, S. (2009). Hyper production of cellulase-free xylanase by *Thermomyces lanuginosus* SSBP on bagasse pulp and its application in biobleaching. *Applied Microbiology and Biotechnology, 81*, 887-893.

Mead, D. J. & Miller, R. R. (1991). The establishment and tending of *Acacia Mangium.* In J. W. Turnbull (Eds.), *Advances in Tropical Acacia Research* (pp. 114-122). Melbourne, Australia: Brown Prior Anderson.

Mohd Farid, A., Lee, S. S., Maziah, Z., Rosli, H., & Norwati, M. (2005). Basal root rot, a new disease of teak (*Tectona grandis*) in Malaysia caused by *Phellinus noxius*. *Malaysian Journal of Microbiology, 1*(2), 40-45.

Orwa, C., Mutua, A., Kindt, R., Jamnadass, R., & Anthony, S. (2009). Agroforestree database: A tree reference and selection guide. Retrieved from http:// http://www.worldagroforestry.org/output/agroforestree-database

Sumathi, S., Chai, S. P., & Mohamed, A. R. (2008). Utilization of oil palm as a source of renewable energy in Malaysia. *Renewable and Sustainable Energy Reviews, 12*(9), 2404-2421.

Tanaka, R., Wan Rosli, W. D., Magara, K., Ikeda, T., & Hosoya, S. (2004). Chlorine-Free bleaching of kraft pulp from oil palm empty fruit bunches. *Japan Agricultural Research Quarterly, 38*(4), 275-279.

Technical Association of the Pulp and Paper Industry. (2016). Global corrugated box market 2016-2020. Retrieved from http://www.naylornetwork.com/ppi-otw/articles/index-v2.asp?aid=359996&issueID=44680

Wan Rosli, W. D., Mazlan, I., & Law, K. N. (2011). Effect of Lignin on *Acacia mangium* kraft pulp refining behaviour. *Cellulose Chemistry and Technology, 45*(9-10), 643-648.

Wanrosli, W. D., Zainuddin, Z., Law, K. N., & Asro, R. (20 07). Pulp from oil palm fronds by chemical processes. *Industrial Crops and Products, 25*(1), 89-94.