Effect of beating on kraft pulp of Sesbania grandiflora

<table>
<thead>
<tr>
<th>Journal:</th>
<th>Songklanakarin Journal of Science and Technology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manuscript ID</td>
<td>SJST-2017-0243.R2</td>
</tr>
<tr>
<td>Manuscript Type:</td>
<td>Original Article</td>
</tr>
<tr>
<td>Date Submitted by the Author:</td>
<td>09-May-2018</td>
</tr>
</tbody>
</table>
| Complete List of Authors:| Boon, Jia Geng; Universiti Malaysia Kelantan - Kampus Jeli, Faculty of Bioengineering and Technology
Mhd. Ramle, Sitti Fatimah; Universiti Malaysia Kelantan - Kampus Jeli, Faculty of Bioengineering and Technology
Ibrahim, Nor Izaida; Universiti Malaysia Kelantan - Kampus Jeli, Faculty of Bioengineering and Technology
Che Zaudin, Nurul Akmar; Universiti Malaysia Kelantan - Kampus Jeli, Faculty of Bioengineering and Technology
Liew, Jeng Young; Universiti Malaysia Kelantan - Kampus Jeli, Faculty of Agro Based Industry
Hamzah, Zulhazman; Universiti Malaysia Kelantan - Kampus Jeli, Faculty of Earth Science |
| Keyword:                 | Sesbania grandiflora, beating, kraft pulp, pulpwood, handsheet |
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$^3$, Zulhazman Hamzah$^4$

1. Faculty of Bioengineering and Technology, Universiti Malaysia Kelantan, Jeli, Kelantan, Malaysia
2. Advanced Materials Research Cluster, Universiti Malaysia Kelantan, Kelantan, Malaysia.
3. Faculty of Agro based Industry, Universiti Malaysia Kelantan, Jeli, Kelantan, Malaysia.
4. Faculty of Earth Science, Universiti Malaysia Kelantan, Jeli, Kelantan, Malaysia.

*Corresponding email: jia.geng@umk.edu.my, phone: +6099477000, fax: +6099477032*
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 potentiality of *Sesbania grandiflora* as pulpwood by studying the effects of beating on pulp derived from *Sesbania grandiflora*. Kraft pulp was prepared and beaten at 10000 and 20000 revolutions. Handsheets with the target grammage of 60 g/m² were produced. Pulp properties and physical and mechanical properties of handsheets were evaluated according to TAPPI standard. Tensile index, tear index, bursting index and folding endurance of handsheet made from *Sesbania grandiflora* pulp increased with an increase in beating revolution. Its moderate strength properties are because of its short fiber length. The study concludes that the pulp derived from *Sesbania 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 supplied for 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 envelopes (TAPPI, 2016). Pulp and paper industry play prominent roles 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 forest 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 late 1970s (Mead & Miller, 1991). However, the species is vulnerable to root rot and heart rot fungal which decreases its pulp yield (Mohd Farid, Lee, Maziah, Rosli & Norwati, 2005; Gafur, Nasution, Tarigan & Tjahjono, 2012). Recent studies on pulp sources have focused on agricultural wastes such as oil palm and bagasse (Bissoon, Christov & Singh, 2002; Wanrosli, Zainuddin, Law & Asro, 2007; Sumanthi, Chai & Mohamed, 2008; Hassan, Hassan & Oksman, 2011). 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, the secondary fibers recovered from recycled paper has a limited lifespan. Therefore, the secondary fiber is often mixed with virgin fiber to ensure the paper product meets strength properties. Among the existing pulp sources, pulpwood remains a reliable one for 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*, locally known as Turi, is one of the fast-growing and straight trees. It has short crops rotation 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 potentiality of its trunk has not been fully focused on yet. Few reports have focused on *Sesbania grandiflora* as a potential pulpwood (Bhat & Menon, 1971; Logan, Murphy, Philips & Higgins, 1977),
and there is no published scientific data on *Sesbania grandiflora* pulp. Hence, the present research is a timely attempt to examine the potentiality of *Sesbania grandiflora* as a new source of wood pulp, and in doing so help pulp industries and the environment to sustain.

This paper aims to identify the properties of pulp derived from *Sesbania grandiflora* and the paper made from it. The pulps were treated with different degrees of beating before forming into handsheet. Beating is a crucial mechanical treatment to improving 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, and result in an increase in fiber surface area and flexibility (Gulsoy, Hurfikir & Turgut, 2016). The physical changes, able to improve inter-fiber bonding, increase most of the paper strength properties. At the same time, reducing the fiber length and producing fine, they increase the drainage time of refined pulp (Gulsoy, 2014).

2. Materials and Methods

2.1 Pulp preparation

*Sesbania grandiflora* trunks were collected at Pasir mas Kelantan, Malaysia. Trunks were chipped into 2cm x 2cm x 0.5cm and air dried to moisture content of approximately 10%. The wood chips were performed with kraft pulping processes using the following pulping condition as shown in Table 1. Kraft pulping was used because the *Sesbania grandiflora* trunk contained rosin. The process was carried out in laboratory rotary stainless steel digester. The pulps were washed with tap water and screened at 0.15mm slits. The
obtained pulp was spun to remove excessive moisture to the moisture content of approximately 75%. The pulp was beaten using a PFI beater at 10000 and 20000 revolutions. Unbeaten pulp was used as blank.

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 60g/m² and with surface area of 100 cm² were made using unbeaten and beaten pulp. The handsheet specimens were conditioned according to TAPPI 402. Physical properties of 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 resistancy, 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 1kg tension. Results of mechanical strength were reported in index values, dividing the strength by its grammage. All results were expressed in mean.

3. Results and Discussion

3.1 Pulp properties

Results of beating effect on Sesbania grandiflora pulp properties are tabulated in Table 2. The unbleached Sesbania 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) that 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 *Sesbania grandiflora* pulp is compatible with the common agricultural by-products that are used as potential pulp sources.

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

### 3.2 Handsheet physical properties

Physical properties of handsheet made from *Sesbania grandiflora* pulp are tabulated in Table 3. The thickness of the handsheet paper made from the beaten pulp is approximately 50% less than the unbeaten pulp. This is because the beaten pulp was delaminated, and the occurred inter-fiber void became less with the improvement of contact area among pulps. In other words, improvement in density of the beaten pulp handsheet has led to a reduction in its thickness. Density is an important indicator for structural properties of paper. High density paper shows a better inter-fiber bonding.

Opacity of a paper decreases by an increase in the beating revolution. Opacity is contingent on thickness of the paper. Thin layer paper has lower opacity than a thick layer one with the same grammage because the light can easily pass through it.

### 3.3 Mechanical properties
The mechanical properties of handsheet made from *Sesbania grandiflora* pulp are tabulated in Table 4. The results show that the mechanical properties of handsheet increased by an increase in the beating revolution. The mechanical strength of the beaten pulp handsheet significantly rose as the beaten fiber has a larger contact surface area (CSA) and a better contact quality. The tensile index of handsheet made from the pulp beaten at 20000 revolutions was recorded at 40.13 N m/g. In a similar report by Gulsoy et al. (2016), tensile index of handsheet made from low-beaten European aspen pulp was recorded at approximately 40 Nm/g. This is even lower than the tensile index of handsheet made from *Acacia mangium* which was recorded at approximately 100 Nm/g by Wan Rosli, Mazlan and Law (2011). The moderate tensile index of *Sesbania grandiflora* pulp could be due to its short fiber length (Hunsigi, 1989).

Similar findings were recorded on tear resistance index of handsheet made from *Sesbania grandiflora* pulp. Tear resistance index of *Sesbania grandiflora* handsheet increased with an increase in beating revolution. The results show that handsheet specimens made from unbeaten *Sesbania grandiflora* pulp have a rather low resistance to tearing. Beating pulps considerably boosted the mechanical properties of handsheet specimens. The good inter-fibre contact, resulted from the beating process, allows the handsheets to receive more stress before tearing.

Burst index is highly correlated with tensile index. An increase in the beating revolution increased the burst index of handsheet made from *Sesbania grandiflora* pulp and the tensile index of 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 revolution.

Folding endurance is also highly correlated with tensile strength and handsheet flexibility. Before rupture folding count of handsheet specimens made from Sesbania grandiflora pulp beaten at 20000 revolutions was recorded at 1255.2. Compatible burst index and folding endurance were found in handsheets made from oil palm empty fruit bunch by Tanaka et al. (2004).

**Conclusion**

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

**References**


List of Tables:

Table 1: *Sesbania grandiflora* kraft pulping condition

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

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

Table 4 Mechanical properties of handsheet made from unbeaten and beaten *Sesbania grandiflora* pulp
Table 1: 

*Sesbania grandiflora* kraft pulping condition

<table>
<thead>
<tr>
<th>Conditions</th>
<th>Parameter values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Active alkali, % (as Na₂O), AA</td>
<td>20%</td>
</tr>
<tr>
<td>Sulfidity, % (as Na₂O)</td>
<td>25%</td>
</tr>
<tr>
<td>Wood to liquor, W : L</td>
<td>1 : 8</td>
</tr>
<tr>
<td>Pulping temperature, T</td>
<td>170 °C</td>
</tr>
<tr>
<td>Heating to cooking time, t to T</td>
<td>60 minutes</td>
</tr>
<tr>
<td>cooking time, t</td>
<td>120 minutes</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Beating revolution</th>
<th>Kappa number</th>
<th>CSF, ml</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>13.02</td>
<td>630</td>
</tr>
<tr>
<td>10,000</td>
<td>13.97</td>
<td>260</td>
</tr>
<tr>
<td>20,000</td>
<td>13.56</td>
<td>180</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Beating revolution</th>
<th>Thickness, µm</th>
<th>Density, g/cm³</th>
<th>Grammage, g/m²</th>
<th>Opacity Tappi, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>245.5</td>
<td>0.246</td>
<td>60.44</td>
<td>99.76</td>
</tr>
<tr>
<td>10000</td>
<td>127.1</td>
<td>0.476</td>
<td>60.52</td>
<td>98.12</td>
</tr>
<tr>
<td>20000</td>
<td>107.6</td>
<td>0.559</td>
<td>60.10</td>
<td>97.47</td>
</tr>
</tbody>
</table>
Table 4 Mechanical properties of handsheet made from unbeaten and beaten *Sesbania grandiflora* pulp

<table>
<thead>
<tr>
<th>Beating revolution</th>
<th>Tensile index, (N m/g)</th>
<th>Tear resistant index, (mN m²/g)</th>
<th>Bursting index, (kPa m²/g)</th>
<th>Folding endurance (fold number at MIT. 1kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>3.16</td>
<td>1.86</td>
<td>0.25</td>
<td>2.6</td>
</tr>
<tr>
<td>10000</td>
<td>30.96</td>
<td>6.78</td>
<td>3.56</td>
<td>770.2</td>
</tr>
<tr>
<td>20000</td>
<td>40.13</td>
<td>10.53</td>
<td>5.81</td>
<td>1255.5</td>
</tr>
</tbody>
</table>