Studies on Physical and Mechanical Properties by Soda-AQ Pulping of Napier Grass

Zawawi Daud¹,a, Mohd Zainuri Mohd Hatta¹,b, Mohd Baharudin Ridzuan¹,c, Halizah Awang²,d, Sharmiza Adnan³,e

¹Centre of Advanced Research for Integrated Solid Waste Management (CARISMA), Universiti Tun Hussein Onn Malaysia, 86400 Parit Raja, Batu Pahat, Johor, Malaysia
²Faculty of Technical and Vocational Education, Universiti Tun Hussein Onn Malaysia, 86400 Parit Raja, Batu Pahat, Johor, Malaysia
³Forest Research Institute Malaysia, Jalan FRIM, Kepong, 52109 Kuala Lumpur, Selangor, Malaysia

a.zawawidaud@uthm.edu.my, bmzainuri88@gmail.com, d.mdbahar@uthm.edu.my, chalizah@uthm.edu.my, dsharmizaadnan@frim.gov.my.

Keywords: Napier grass, pulp, agriculture, pulping and paper.

Abstract. Pulp and paper production from wood material as their main resources have a total capacity about more than one million tons per year. Malaysia has a high scale of deforestation based on the main resource for pulp and paper-based industry. Malaysia as its rate is accelerating faster than any other tropical countries in the world. This problem also affects the economic losses of some countries that face deforestation. To overcome this, Napier grass as a substitute material from non-wood material had been choose for pulp and papermaking industry. This study through the full fibre analysis and morphological characterization, pulpability at kappa number via soda-AQ pulping and the characteristic. These conclude that Napier grass had a high percentage of pulp yields; with a low screening rejects; good mechanical properties by TAPPI method. Thus, Napier grass has a potential to be substitute material for becoming waste-wealth product especially for Malaysia’s pulp and papermaking industry.

Introduction

Napier grass is also known as elephant grass. This grass has their scientific name, which is Pennisetum purpureum [9]. This plant is a perennial grass, where it can grow to 2-4.4 metres, with leaves 30-120 centimetres [7]. Like other non-wood material, Napier grass also contains hemicellulloses, cellulose and lignin content [13]. This plant species is a robust grass with perennial stems. The plant gives short, creeping rhizomes from 15 to 25 cm long with fine roots at the nodes [8,12]. Napier grass can grow in tropical and sub-tropical region. Napier grasses mostly use for forage for livestock and wildlife like other non-wood [4]. Alkaline cooking liquor of NaOH can give an effect to colour and fiber pulp yield by the observed on physical properties of pulp, measuring the yield of fiber, and changes in pulp colour where is dark color shows the lignin is still high on pulp [19]. Application of anthraquinone (AQ) as a catalyst for pulping has been documented in both way, scientific studies and mill production [15,17]. Anthraquinone has been known as to increase the rate of delignification, enabling the reduction pulping time, temperature, or chemical charge and increase the pulp yield [11]. Paper is mainly based on fibres from wood, renewable and recyclable raw materials [14]. The specific characteristics of these fibre materials are that the paper strength results from the hydrogen bonding between the individual fiber's [3,4]. The pulps produced in different ways have different properties, which make them suitable for particular products [5]. Napier grass can become a new design of material for pulp and papermaking industry for the whole world through the characteristic and the easy-growth production. Our environment can be slowly safe for other act of pollution [10,20].
Methodology

Preparation of material. Napier grass collected from Rusli Parit Sulong Farm, Batu pahat, Johor, Malaysia. The leaf and bast were cutted into 2cm pieces [19]. After that, Napier grass had been aired dry for 3 days (Fig.1). This step needed for free-water material where it can completely dry before undergo chemical pulping process.

Figures 1. (a) Napier grass before being dry (b) Bast and leaf were air dry for 3 days completely water free.

Soda-AQ pulping. Napier grass undergo the cooking process for Soda-AQ processes in digester autoclave were being done with anthraquinone (AQ) dosage 0.05% in Table 1. The material were weight and fill into digester autoclave [9]. The partially delignified pulps obtained were washed with water to neutralize the reaction. The form of paper from pulp followed TAPPI Method 205 om-8.

Table 1. Chemical cooking process of Napier grass Soda-AQ pulping.

<table>
<thead>
<tr>
<th>Pulping Process</th>
<th>NaOH Concentration (%)</th>
<th>Anthraquinone Concentration (%)</th>
<th>Time (Minutes)</th>
<th>Temperature (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sodaᵃ (Control)</td>
<td>18</td>
<td>-</td>
<td>120</td>
<td>170</td>
</tr>
<tr>
<td>Soda-AQᵇ</td>
<td>18</td>
<td>0.5</td>
<td>120</td>
<td>170</td>
</tr>
</tbody>
</table>

Mechanical characterization. Paper from Napier grass soda-AQ pulping undergo the mechanical test by tensile, tear, fold and burst test. Set of paper-sheets (60g/m2) were made from the pulp of sample in one attempt according to Tappi T205 and keep overnight in a conditioning room in accordance with Tappi T402. The tensile and tear index were measured according to Tappi T494 and T414. The burst index of papers was also measured according Tappi T403. Besides that, Tappi T511 was used to measure the fold of the paper sample.

Result and Discussion

Pulp properties. The anthraquinone had maximises of Napier grass potential to becoming one of the alternative fibre in paper industry world [18]. From figure 1, Napier grass with the additive by anthraquinone in 0.05% shows a potential to use this additive for Napier grass in future. All analysis shows a high potential from Soda-AQ rather than Soda pulping itself.
From the graph, pulp yield (34.7%) from Soda-AQ shows a greater of pulp production than raw Napier grass. Anthraquinone make the cooking more efficiency to material and produce more pulp, besides the optimum of condition of process [3]. The rejected pulp also lower (4.0%) by Soda-AQ compared to raw Soda pulping. The lower of Kappa number index (15.73) and fibre length (8cm) give a better result and shown a good of pulp for paper testing. This can be seen on graph where is Soda-AQ have a lowest Kappa number index and fibre length. Lowest Kappa number index shows that the pulp has a low lignin, which related a minimum use of chemical for bleaching in future [6]. This differentiated of analysis by variables condition, which would give an optimize condition for cooking process for napier grass.

**Mechanical properties.** Table 2 shows the mechanical properties by Napier grass treat with soda-AQ being compared to previous studies. Result indicated that corn stalk has a high probability in becoming a good paper production due to high of certain mechanical properties (Tensile, Fold and Burst). From this study, a Napier grass soda-AQ paper has a tensile index of 3.69 Nm/g, compared oil palm leaf, 7.9 Nm/g between the Date Palm rachis (1.1 Nm/g). Besides that, Napier grass has a tear index (5.1 Nm²/g) compared oil palm leaf (1.8 Nm²/g) and Date Palm rachis (4.4 Nm²/g). High tensile strength given tear index lower because the behavior between both tear and tensile index is contrarily [19], where it respectively showed the inter-fibre bonding strength is high [1]. The strength of properties of the sheets of paper was correlated to inter-fibre bonding [16]. Napier grass soda-AQ gives a good of burst index about 2.8 kPa*m²/g compared Date palm rachis 1.32 kPa*m²/g; oil palm leaf shows low in burst strength (0.9 kPa*m²/g). The result from burst strength shows how strong the paper from corn stalk material. For folding test, Napier grass soda-AQ gives 4.7 Nm compared oil palm leaf shows 1.9 Nm where it show the strength of folding endurance to shows how the paper can have a maximum of fold where have an advantage to become a tissue paper with a tiny density [1, 2].

<table>
<thead>
<tr>
<th>Material</th>
<th>Tensile Index (Nm/g)</th>
<th>Tear Index (Nm²/g)</th>
<th>Burst Index (kPa*m²/g)</th>
<th>Folding Endurances (Nm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Napier grass</td>
<td>3.69</td>
<td>5.1</td>
<td>2.84</td>
<td>4.7</td>
</tr>
<tr>
<td>Soda-AQ*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Date Palm Rachi[11]</td>
<td>1.1</td>
<td>4.4</td>
<td>1.3</td>
<td>n.a.</td>
</tr>
<tr>
<td>Oil Palm Leaf[11]</td>
<td>7.9</td>
<td>1.8</td>
<td>0.9</td>
<td>1.9</td>
</tr>
</tbody>
</table>

*Material Napier grass that treat with anthraquinone.
Conclusion

Napier grass treat with anthraquinone (AQ) have potential to become fibre substitution to wood materials. From the pulpability properties, treated Napier grass shows remarkable properties (high pulp yield; lower rejected pulp; low kappa number and low fibre length) compared the previous study materials. Besides that, treated Napier grass shows a high of measurement of mechanical properties test (Tensile index, Tear index, Burst index and Fold test) where have a same property with wood material. Thus, this agro material can become an effective source and products for pulp and papermaking industry.

Acknowledgements

This research was supported by Ministry of Higher Education of Malaysia, scholarship from Universiti Tun Hussein Onn Malaysia (UTHM) and Fundamental Research Grant (FRGS) for vot 1457 and 1571 from ORICC, UTHM. The authors are thankful for this financial support.

References