Comparison of the Properties of Soda Straw Pulps 
Made from Taiwan & Indonesia Varieties

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ABSTRACT

The ash content is higher in both Indonesia straws, while Indonesia upland straw has higher lignin and holocellulose contents than those of Taiwan straw. The length/width ratios of these 3 straw samples are all over 130, which are greater than that of wood species. Indonesia upland rice straw has the highest pulp yield and K no. with the alkali charge range 13-17%. Before hypochlorite bleaching, the unbleached Indonesia paddy rice straw pulp gives the highest brightness (over 40% GE). The poor brightness stability of bleached Indonesia upland straw pulp is due to the greater extent of its brightness reversion after 5-year storage period.

KEYWORDS: Rice straw, Pulp, Bleaching, CIE L*a*b*, pc number.

INTRODUCTION

Rice is the most important food crop for Asian people, and is wildly planted in southern China, southeast Asia, India, and north Africa. Pulping of rice straw in solutions of sodium hydroxide was used in Taiwan for many years. Recently, due to the stringent rules against water pollution, the low-capital investors of straw pulp mills have no interest in the continuation of straw pulp making. However, because of the high ash content and slender fibers of straw pulp, a smoother and high-opacifying paper can be made. Once in a while, the price of straw pulp is three times higher than that of wood pulp in Taiwan. To overcome the increasing cost of straw pulp produced in Taiwan, some papermills try to move their straw pulp mills to Southeast Asia countries.

The purpose of this study is to compare the pulping characteristics and pulp strengths of Taiwan paddy rice straw with Indonesia paddy and upland rice straws, which can be used as an alternation guide to pulpmakers.

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MATERIAL and METHODS

Air-dried Taiwan rice straw (O. sativa L.), Indonesia paddy rice straw, and Indonesia upland rice straw were cut into 1-2 inch strips as the raw material for soda pulping. Partial straw samples were ground to powders that pass through between 40-60 mesh screen for the determination of chemical compositions, i.e., ash content, hot water, 1% NaOH and alcohol-benzene extractives, lignin, pentosan and holocellulose contents as specified in TAPPI standards. Each sample of 150g (od weight) was cooked indirectly in an electrically heated rotary digester, the sodium hydroxide dosage (based on dry straw) was in the range 13, 15, 17%, liquor-to-straw ratio of 4.5:1, time to 150°C :90 min and time at 150°C :120 min. Wash the cooked pulps in a 200-mesh screen, and separate the screenings from the low-vibrating flat screen. The pulp yield, permanganate number (abbreviated to K no., TAPPI T214) and fiber morphology were also examined. The freeness of unbeaten straw pulps is about 250-350 mL CSF that is able to form sheets directly on handsheet machine without beating (4).

The basis weight of 58g/m² sheets were made from one half of the unbeaten pulps using handsheet machine in laboratory. Hypochlorite bleaching was carried out batchwisely for the rest of unbeaten straw pulps in plastic bag under room temperature for 6 hrs., the pulp consistency used was 6%. the available chlorine added to the pulp was 6% and 8% (based on dry pulp), respectively.

After bleaching, same 58g/m² handsheets were prepared according to TAPPI T255. Brightness, tensile strength, bursting strength, Elmendorf tear strength and MIT folding endurance tests were run by using the methods described by TAPPI standards. The brightness of some paper samples were measured with brightness tester after 5-year storage, which provided the basis for the calculation of color reversion (expressed as pc no.).

RESULTS and DISCUSSION

Chemical composition

Table 1 shows the chemical composition of different rice straws. There are greater ash and lignin contents for Indonesia upland rice straw. Higher ash content of Indonesia paddy rice straw than that of Taiwan paddy rice straw was also found. There are not much differences for other constituents as showed in Table 1. Comparing to the fiber dimensions of pulp made from hardwoods, they are quite similar in length and much narrower in width, but a greater extent of L/W ratio 130 for rice straw fibers (Table 2). Generally speaking, Taiwan, rice straw fibers are longer and slenderer than Indonesia ones, and a considerable L/W ratio over 130 for these three rice straw species has been noticed. These composition and dimension data are parallel with previous reports (2, 6, 7).
Table 1. Chemical analysis of some rice straws (unextracted, dry straw basis).

<table>
<thead>
<tr>
<th>Species</th>
<th>Ash, %</th>
<th>Extractives, %</th>
<th>Holocellulose %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hot water</td>
<td>1% NaOH</td>
<td>Alcohol Benzene</td>
</tr>
<tr>
<td>T.P.</td>
<td>10.4</td>
<td>14.7</td>
<td>50.1</td>
</tr>
<tr>
<td>I.P.</td>
<td>14.6</td>
<td>15.2</td>
<td>51.3</td>
</tr>
<tr>
<td>I.U.</td>
<td>17.1</td>
<td>15.4</td>
<td>52.2</td>
</tr>
</tbody>
</table>

T.P. = Taiwan paddy rice straw  
I.P. = Indonesia paddy rice straw  
I.U. = Indonesia upland rice straw

Table 2. Fiber dimensions of rice straw pulps.

<table>
<thead>
<tr>
<th>Species</th>
<th>Length, mm</th>
<th>Width, μm</th>
<th>L/W ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>T.P.</td>
<td>4.2</td>
<td>0.52</td>
<td>1.34</td>
</tr>
<tr>
<td>I.P.</td>
<td>4.4</td>
<td>0.44</td>
<td>1.12</td>
</tr>
<tr>
<td>I.U.</td>
<td>5.2</td>
<td>0.44</td>
<td>1.17</td>
</tr>
</tbody>
</table>

Pulping and bleaching results

Table 3 illustrates how the pulp yield and K no. vary with the alkali charge in the range 13-17%. Remarkably, because of higher lignin and holocellulose contents of Indonesia upland rice straw, larger straw culm and higher weight portion of leaves for Indonesia upland rice straw which give the highest yield and K no. (6).

Table 4 shows that the highest brightness of unbleached or bleached pulp will be achieved, with hypochlorite bleaching, for Indonesia paddy rice straw which has the lowest K no.. Approximately, the pulp yield and K no. of straw pulps decrease with increasing alkali charge.

The color of rice straw pulps may relate to the degree of bleaching, so we measured the color of these rice straw pulps which being expressed as CIE L*a*b*. Table 4 shows that Taiwan rice straw pulp appeared more red (a*) and yellow (b*) colors, i.e., higher a* and b* values. Although Indonesia upland rice straw pulp has nearly the similar shade as Taiwan rice straw pulp, a dull reddish brown tint for Indonesia upland rice straw pulp and light yellowish brown tint for Indonesia paddy rice straw pulp having the highest brightness and L* value had been found in this study. Bleaching Indonesia upland rice straw with hypochlorite (8% as available chlorine) that gives a comparable brightness to the other two straw pulps. The considerable decrease in brightness of Indonesia upland rice straw pulp (pe
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no. > 3), after 5 years’ exposure under office light, may be caused by the greater hypochlorite consumption in bleaching operation or could be related to its higher lignin content.

It seems that a higher hypochlorite consumption in bleaching process causes a detrimental effect on the improvement of brightness stability of straw pulps (1, 4, 9). The slightly greater tendency of color reversion of Indonesia paddy rice straw pulp than that of Taiwan paddy rice straw pulp was also found (Table 4).

Table 3. Soda pulping results of different rice straws.

<table>
<thead>
<tr>
<th>Species</th>
<th>Taiwan paddy rice straw</th>
<th>Indonesia paddy rice straw</th>
<th>Indonesia upland rice straw</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alkali charge, %</td>
<td>13</td>
<td>15</td>
<td>17</td>
</tr>
<tr>
<td>Yield, %</td>
<td>44.39</td>
<td>42.16</td>
<td>40.38</td>
</tr>
<tr>
<td>K number</td>
<td>7.21</td>
<td>4.10</td>
<td>7.02</td>
</tr>
</tbody>
</table>

Table 4. Optical properties of various straw pulps.

<table>
<thead>
<tr>
<th>Species</th>
<th>Taiwan paddy rice straw</th>
<th>Indonesia paddy rice straw</th>
<th>Indonesia upland rice straw</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alkali charge, %</td>
<td>13</td>
<td>15</td>
<td>17</td>
</tr>
<tr>
<td>CIE</td>
<td>L* 73.2</td>
<td>73.5</td>
<td>73.6</td>
</tr>
<tr>
<td>a* 6.6</td>
<td>6.4</td>
<td>6.4</td>
<td></td>
</tr>
<tr>
<td>b* 17.8</td>
<td>17.9</td>
<td>17.9</td>
<td></td>
</tr>
<tr>
<td>Brightness, %GF</td>
<td>UN 31.0</td>
<td>31.1</td>
<td>33.4</td>
</tr>
<tr>
<td>BL 73.5</td>
<td>74.2</td>
<td>75.1</td>
<td></td>
</tr>
<tr>
<td>5Y 72.8</td>
<td>72.9</td>
<td>73.2</td>
<td></td>
</tr>
<tr>
<td>pc number</td>
<td>0.30</td>
<td>0.55</td>
<td>0.78</td>
</tr>
</tbody>
</table>

UN = unbleached  BL = bleached  5Y = After 5 years’ storage  #. NaClO added, 6%  *. NaClO added, 8%

Pulp strength

Table 5 shows that the loss in pulp strength after hypochlorite bleaching is considerable, whereas Taiwan straw pulp has the highest pulp strength and Indonesia upland straw pulp the lowest.

The decrease in straw pulp strength might be related to the appreciable amount of plenty degraded parenchyma cells of straws which still exist as debris in straw pulp (5). The other reason of this phenomenon would be the strong oxidation caused by hypochlorite. In addition, the pentosan-rich straw pulps are easily attacked by chemicals, so the desirable pulp strength and high brightness can not be attained (3, 4, 8). Therefore, it seems that
hypochlorite bleaching is not advisable to keep the pulp strength of unbleached straw pulps. Nevertheless, in order to minimize the loss in pulp strength, all variables in hypochlorite bleaching process must be carefully controlled.

Table 5. Physical properties of unbleached and bleached straw pulps.

<table>
<thead>
<tr>
<th>Species</th>
<th>Taiwan paddy rice straw</th>
<th>Indonesia paddy rice straw</th>
<th>Indonesia upland rice straw</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alkali charge, %</td>
<td>13</td>
<td>15</td>
<td>17</td>
</tr>
<tr>
<td>Basis weight, g/ m²</td>
<td>58.37</td>
<td>58.61</td>
<td>58.92</td>
</tr>
<tr>
<td>Break, Km</td>
<td>9.70</td>
<td>9.81</td>
<td>9.22</td>
</tr>
<tr>
<td>Burst factor</td>
<td>69.1</td>
<td>69.5</td>
<td>70.4</td>
</tr>
<tr>
<td>Tear factor</td>
<td>63.4</td>
<td>62.2</td>
<td>61.1</td>
</tr>
<tr>
<td>Fold. endur., MIT</td>
<td>325</td>
<td>360</td>
<td>378</td>
</tr>
<tr>
<td>BLEACHED</td>
<td>13</td>
<td>15</td>
<td>17</td>
</tr>
<tr>
<td>Basis weight, g/ m²</td>
<td>58.83</td>
<td>58.60</td>
<td>58.84</td>
</tr>
<tr>
<td>Break, Km</td>
<td>7.00</td>
<td>7.05</td>
<td>7.26</td>
</tr>
<tr>
<td>Burst factor</td>
<td>48.3</td>
<td>50.7</td>
<td>51.1</td>
</tr>
<tr>
<td>Tear factor</td>
<td>60.2</td>
<td>52.7</td>
<td>50.2</td>
</tr>
<tr>
<td>Fold. endur., MIT</td>
<td>51</td>
<td>57</td>
<td>57</td>
</tr>
</tbody>
</table>

CONCLUSIONS

Analyses of the chemical compositions of the three rice straw samples have shown that the ash content is higher in Indonesia straws, and Indonesia upland straw has higher lignin and holocellulose contents, while the rest constituents are quite similar among the varieties.

The fiber length of Taiwan rice straw is the longest. Besides, the length/width ratio of Taiwan rice straw is still the largest one. It is clearly shown that the length/width ratios of these three straw samples are all over 130, which is much greater than those of wood species.

The pulp yield and K no. from three different rice straws decrease with increasing alkali charge; the optimum of alkali charge is 15%. Indonesia upland rice straw has the highest pulp yield and K no.

In view of the optimum pulp yield and pulp strength, Indonesia upland rice straw is the most suitable raw material for the production of unbleached straw pulp, while Indonesia paddy rice straw is preferable for bleached-grade papermaking.

It is also found that the unbleached Indonesia paddy rice straw pulp has the highest
brightness (over 40% GE) which is substantially higher than those of the other samples (31-33% GE).

After 5-year storage period test of bleached straw pulps, it is shown that the brightness reversion of Indonesia upland rice straw pulp is considerably higher than others, which indicates the poor brightness stability.

ACKNOWLEDGEMENT

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[This paper was also presented by the second author at the 2nd. International Non-Wood Fiber Pulping & Papermaking Conference (1992 INWFPPC), Shanghai, April 6-9, 1992]

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臺灣與印尼稻草之製漿性比較

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摘要：稈米為亞洲人主食之一，以中國南方、中南半島、東南亞、南亞次大陸、北非為主產區。稻米收成後，稻草可採行蘇打法制成紙漿用於造紙。近來由於環保意識興盛及法規限制，臺灣稻草漿製造業者嘗試將工廠遷往南洋。本試驗以臺灣省產水稻、印尼水稻及早稻為試材，進行化學組成分析、製漿與漂白、紙張力學及光學性質之比較，期望能進一步瞭解其差異作為業者參考。試驗結果顯示印尼稻草灰分略高於臺灣稻草，印尼早稻則有較高的木質素含量，其它成分則差異不大；纖維形態三者相近，纖維長寬比皆大於130；在考量收率與紙力下，製漿條件均以15%為佳；印尼早稻紙漿較適用於未漂紙張之製造，印尼水稻紙漿則因有較高亮度而適合製造漂白紙張。各種未漂及漂白紙漿以實驗室手抄紙機抄造成標準紙樣，並將此等紙樣存放於室內五年後，側得印尼早稻漂白紙漿之回色最為嚴重，應注意其漂白條件及操作。

關鍵詞：稻草、紙漿、漂白、CIE L* A* B*、回色值。

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