Using Optical Brightening Agents (OBA) for Improving the Optical Properties of HYP-Containing Paper Sheets

By: H. Zhang, Z. He, Y. Ni, H. Hu, and Y. Zhou

Abstract: High yield pulps (HYP) with different brightness levels were used to replace hardwood bleached kraft pulp to determine the influence of HYP substitution on the optical properties of paper products. The effects of OBA, PCC filler, and dyestuff on paper brightness, whiteness, and colour shade were investigated under various HYP substitution rates. The HYP substitution decreases the brightness and CIE whiteness of paper sheets, particularly at a high HYP substitution rate (e.g., 30%). The brightness loss due to the HYP substitution can be recovered by the addition of OBA and/or PCC.

High-yield pulps (HYP), also known as bleached chemi-thermo-mechanical pulps (BCTMP), can be used to replace bleached hardwood chemical pulp in the manufacturing of high-quality paper products, including printing and writing paper, due to their unique properties and lower cost [1-5]. Mechanical pulps have superior bulk and opacity compared with bleached chemical pulp, properties which are desirable for the production of printing and writing paper.

Brightness is one of the most important quality criteria for mechanical pulps. Aspen HYP pulp can be bleached to 85% ISO or even higher brightness, but it is relatively expensive to do so. The production cost of HYP increases exponentially with brightness levels. In the pulp and paper industry, optical brightening agents (OBAs) or fluorescent whitening agents (FWA) are commonly used to improve the brightness of paper products [6-11]. Essentially all of this literature refers to bleached chemical pulps. Very few references are available which refer to application of OBAs on mechanical pulps.

Since the substitution rate of HYP for hardwood chemical pulp in fine paper grades is usually at about 20% or lower, it was proposed that HYP with a brightness of a few units lower than 85% ISO might not affect the optical properties of final products if fillers, such as PCC, and optical brightening agents (OBA) are used. The production cost of HYP would decrease significantly if the brightness of HYP pulp can be lowered from 85% ISO to about 83% ISO without any sacrifice in the quality of final paper products.

The objective of this research project included: i) to investigate the influence of adding OBA on the brightness of HYP-containing paper sheets, and ii) to determine the feasibility of using a lower-brightness HYP (e.g., 83% ISO) instead of a high-brightness HYP (e.g., 85% ISO) for the production of printing and writing paper.

EXPERIMENTAL
A softwood (mainly spruce) bleached kraft pulp (SWBK), and a hardwood (eucalyptus) bleached kraft pulp (HWBK) were refined in a PFI mill to 470 and 490 ml CSF freeness, respectively. Three grades of commercial aspen high-yield pulp (325/85, 325/83, 250/80) were obtained from Tembec Inc., without further refining treatment. The properties of the pulp samples are listed in Table I.
TABLE I. Characteristics of the pulp samples used for the experiments.

<table>
<thead>
<tr>
<th></th>
<th>CSF (ml)</th>
<th>Brightness (%)</th>
<th>CIE Whiteness (%)</th>
<th>L*</th>
<th>a*</th>
<th>b*</th>
</tr>
</thead>
<tbody>
<tr>
<td>SWBKP</td>
<td>470</td>
<td>87.2</td>
<td>73.6</td>
<td>97.2</td>
<td>-0.72</td>
<td>4.28</td>
</tr>
<tr>
<td>HWBKP</td>
<td>490</td>
<td>88.4</td>
<td>76.2</td>
<td>97.4</td>
<td>-0.60</td>
<td>3.84</td>
</tr>
<tr>
<td>HYP(325/83)</td>
<td>510</td>
<td>85.5</td>
<td>66.7</td>
<td>97.2</td>
<td>-1.43</td>
<td>6.77</td>
</tr>
<tr>
<td>HYP(325/85)</td>
<td>540</td>
<td>83.7</td>
<td>61.7</td>
<td>96.9</td>
<td>-1.55</td>
<td>6.73</td>
</tr>
<tr>
<td>HYP(250/80)</td>
<td>450</td>
<td>81.2</td>
<td>55.0</td>
<td>96.6</td>
<td>-1.48</td>
<td>7.97</td>
</tr>
</tbody>
</table>

* Grade 325/83 HYP. **PCC filler retention was about 85% in all cases.

TABLE II. Effect of HYP substitutions on the optical properties of handsheets

<table>
<thead>
<tr>
<th>Furnish composition (%)</th>
<th>0% PCC</th>
<th>0% OBA</th>
<th>0% PCC</th>
<th>0.2% OBA</th>
<th>0% PCC</th>
<th>0% OBA</th>
<th>30% PCC**</th>
<th>0% OBA</th>
<th>30% PCC**</th>
<th>0.2% OBA</th>
</tr>
</thead>
<tbody>
<tr>
<td>HYP *</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HWBKP</td>
<td>70</td>
<td>60</td>
<td>55</td>
<td>50</td>
<td>45</td>
<td>40</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SWBKP</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| Brightness (%ISO)      | 87.4   | 86.2   | 85.9   | 85.5    | 85.4   | 85.3   |
| CIE Whiteness (%)      | 74.3   | 71.7   | 70.6   | 69.1    | 68.7   | 68.3   |
| Scattering Coefficient (m²/g) | 27.8 | 29.2   | 29.7   | 30.7    | 30.9   | 31.5   |

| Brightness (%ISO)      | 92.2   | 90.9   | 90.6   | 90.0    | 89.5   | 88.9   |
| CIE Whiteness (%)      | 90.3   | 87.2   | 85.8   | 84.0    | 82.3   | 81.0   |
| Scattering Coefficient (m²/g) | 27.1 | 28.6   | 29.7   | 30.4    | 31.1   | 31.0   |

| Brightness (%ISO)      | 90.3   | 89.4   | 89.2   | 88.8    | 88.6   | 88.3   |
| CIE Whiteness (%)      | 81.8   | 79.3   | 78.9   | 78.1    | 77.4   | 76.7   |
| Scattering Coefficient (m²/g) | 60.8 | 62.9   | 64.1   | 64.2    | 64.9   | 65.3   |

A precipitated calcium carbonate filler (Albcar HO) was obtained from Specialty Minerals, one di-sulfonic and one tetra-sulfonic optical brightening agent from Ciba, a cationic polyacrylamide (CPAM, Percol 292) from Hydrocol, and a basic blue dye from Tri Tex Quebec.

Unless specified, the tetra-sulfonic OBA was used for all the experiments in this study, and its dosage was based on the liquid product (about 25% solid content). Weighed pulp samples (SWBKP, HWBKP, and HYP), were disintegrated for 15,000 revolutions in a standard disintegrator at 1.5% pulp consistency, and then diluted to 1% suspension. The pulp suspension was transferred to a 500 ml beaker, and a CaCl₂ solution was added to reach a Ca²⁺ concentration of 100 ppm (as CaO). The pH of the mixture was adjusted to about 7.0 followed by the OBA addition. Stirring was provided for 20 minutes under the room temperature. When needed, PCC (dispersed into a suspension) was then added, followed by the addition of CPAM (0.05%, on pulp). In some cases, a blue dye was added after the OBA addition and mixed for 10 minutes. The content of the beaker was then transferred to the cylinder of a handsheet machine which was pre-filled with 3 L deionized water that contained 100 ppm Ca²⁺ (as CaO), and a handsheet was prepared and tested according to the TAPPI methods.

RESULTS AND DISCUSSION

Effect of HYP Substitution Rate

We first investigated the effect of the substitution rate of HYP for hardwood bleached kraft pulp (HWBKP) on the optical properties of paper sheets. Table II, the percentage of HYP (grade 325/83) in the furnish composition was varied, from 0% to 30%, with softwood bleached kraft pulp (SWBKP) fixed at 30%. The HWBKP percentage changed accordingly from 70% to 40%. The results in Table II show that both the brightness and CIE whiteness decreased with the increase of HYP substitution rate, while the light scattering coefficient increased. The addition of OBA was very effective in recovering the loss of brightness and whiteness due to HYP substitution. With 0.2% OBA, the brightness and CIE whiteness of furnish which contained 30% HYP (88.9% ISO and 81.0%, respectively) were actually higher than those of the control furnish containing 100% bleached chemical pulps without OBA (87.4% and 74.3%, respectively). The PCC fillers were also effective in reducing the negative effects of the HYP substitution on brightness and CIE whiteness. When 0.2% OBA was used together with 30% PCC, at 20% HYP substitution rate, the brightness and CIE whiteness reached 92.3% ISO and 88.8%, respectively, which were compared to 87.4% ISO and 74.3% of the control. However, it should be noted that OBA is more effective with the bleached chemical pulp. As shown in Table II, if the same amount of OBA and PCC filler was applied to the control stock, higher brightness and whiteness were obtained (94.3% and 94.1%, respectively).

Table II further shows that the effectiveness of OBA decreases when more HYP is present in the furnish. For example, in the case of 0% PCC and 0% HYP, with 0.2% OBA the brightness increased from 87.4% to 92.2% ISO, an increase of 4.8 units. However, in the case of 30% HYP substitution, an increase of 3.6 units (from 85.3 to 88.9% ISO) was observed under otherwise the same conditions.

Effect of HYP Brightness

The brightness of the three grades of HYP used in this study varied from 80 to 85% ISO. In Fig. 1, the effect of HYP brightness on the final sheet brightness was compared under the same HYP substitution rate (20%). The results show that the brightness of final sheets is sensitive to the brightness level of HYP. The brightness difference in final sheets between Grades...
325/85 and 325/83 was about 0.5 units. A slightly higher OBA dosage may be able to eliminate the difference, which may represent a more economical way to produce similar-brightness paper with HYP, since it is very costly in a HYP manufacturing process to increase the brightness of HYP from 83% to 85% ISO.

Effect of OBA Charge
As discussed above, the brightness and CIE whiteness of final sheets are sensitive to the brightness levels of HYP and its substitution rate. A question arises as to whether the brightness and whiteness loss due to using a lower-brightness HYP can be recovered by increasing OBA dosages. In Table III, the OBA dosage was varied from 0 to 0.6%, the HYP substitution rate was fixed at 10%, and no filler was added in this series of experiments. In all the four cases (the control furnish and furnishes containing different grades of HYP), both brightness and CIE whiteness increased significantly with the increase of OBA dosages, while b* decreased dramatically. Table III further shows that the brightness increment was smaller for furnishes with lower-brightness HYP. These results support the conclusion that HYP decreases the effectiveness of OBA, with the effect more pronounced when the HYP brightness is lower.

The effectiveness of OBA decreased when its charge exceeded 0.2%, regardless of the furnish composition. Nevertheless, the results in Table III clearly show that the brightness deficiency of the HYP containing furnishes can be compensated for by increasing the OBA charge. For example, for a given brightness target of 90% ISO, the OBA charge was 0.05-0.1% for the control furnish, and 0.1-0.2%, 0.2% and 0.4% respectively, for the three HYP-containing furnishes. Moreover, the yellow colour shade of HYP can be eliminated by OBA addition, as indicated by the significant decrease of b*.

Similar results were obtained when 30% PCC was applied, although the baselines of brightness and CIE whiteness were at much higher levels. As shown in Fig. 2, a brightness of 94% ISO was achieved for the control furnish with 0.1-0.2% OBA. To reach the same brightness target, the OBA charge had to be increased to 0.3-0.4%, 0.4-0.5% and 0.6-0.7% respectively for the three HYP-containing furnishes. Figure 3 shows the fluorescent composition as a function of OBA charge for different grades of HYP. At a given OBA charge, the brightness increase was higher for the control furnish than for the HYP-containing furnish. Also, the brightness of HYP affected the effectiveness of OBA. The lower the brightness of HYP, the
The effect is more pronounced when the
These results again confirm that HYP
degrees the effectiveness of OBA, and
Effect of OBAs on the Optical Properties of Paper Sheets

Some OBAs were claimed to be more
effectiveness of two types of OBA was com-
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CIE whiteness represents the visual appearance better
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Effect of Dyestuff on CIE Whiteness on
CONCLUSIONS

A low HYP substitution for hardwood

Effect of OBAs on the Optical Properties of Paper Sheets

It is well recognized that the CIE whiten-
ness represents the visual appearance better
than brightness. A recent trend in the pulp
and paper industry is to use both optical
brightening agents and dyes simultane-
ously, in order to improve whiteness more
The CIE whiteness increased dramatically
with the addition of the blue dye, while
the change in brightness was small. At
4.43 ppm blue dye dosage, the CIE white-
ness reached 94.6% and 100.9%, at 0.2%
and 0.6% OBA charges, respectively. The
change in brightness was small. At
the addition of blue dye also changed the val-
ues of L*, a* and b* mainly from yellow hue
improved significantly in all cases when 20-30% PCC was added.

However, the presence of PCC decreased the brightening efficiency of OBA. In Fig.
4, the fluorescent efficiency of filled and un-filled sheets was compared at various
The presence of PCC fillers has much higher specific
surface area and light reflectance than cellulose fibers, and therefore they can
improve the paper optical properties. As shown in Fig. 1, the brightness of the
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Effect of PCC Fillers

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ness represents the visual appearance better
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brightening agents and dyes simultane-
ously, in order to improve whiteness more
efficiently [10,11]. Blue dyes, such as
anionic direct dyes and basic dyes can give
an extra boost to the CIE whiteness [12].

In Table V, a basic blue dye was used
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withgether with OBA to improve the CIE
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ues of L*, a* and b* mainly from yellow hue
to blue hue. The total reflectance of light
decreased with the addition of the blue dye
as indicated by the drop of L*.
bleached kraft pulp (10 - 20%) in the production of printing and writing paper grades resulted in a small decrease in brightness. However, the brightness and whiteness loss due to the HYP substitution can be recovered by increasing the OBA charge and the addition of PCC filler. The blue dye is very effective in improving the CIE whiteness when combined with OBA.

Technically it is feasible to use a 83% ISO grade HYP to replace a 85% ISO grade without affecting the optical properties of final paper sheets, provided that OBA charge is increased accordingly. At a 20% substitution for HWBKP, the brightness difference in final sheets when using 83% ISO HYP, instead of 85% ISO HYP was about 0.5 units, such a small difference can be compensated for by using a small amount of additional OBA in the paper making process.

**LITERATURE**


**TABLE V. Effect of blue dye on L*, a* and b* (20% HYP)**

<table>
<thead>
<tr>
<th>Blue dye dosage (ppm)</th>
<th>0</th>
<th>0.89</th>
<th>2.66</th>
<th>4.43</th>
<th>6.20</th>
<th>7.97</th>
<th>13.29</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brightness % ISO</td>
<td>89.44</td>
<td>89.44</td>
<td>89.43</td>
<td>89.33</td>
<td>89.21</td>
<td>89.16</td>
<td>88.68</td>
</tr>
<tr>
<td>CIE whiteness %</td>
<td>82.69</td>
<td>86.38</td>
<td>91.02</td>
<td>94.55</td>
<td>97.47</td>
<td>99.51</td>
<td>106.47</td>
</tr>
<tr>
<td>0.2% L*</td>
<td>96.8</td>
<td>96.0</td>
<td>95.2</td>
<td>94.5</td>
<td>93.9</td>
<td>93.4</td>
<td>92.1</td>
</tr>
<tr>
<td>OBA a*</td>
<td>0.33</td>
<td>0.44</td>
<td>0.74</td>
<td>0.99</td>
<td>1.33</td>
<td>1.59</td>
<td>2.15</td>
</tr>
<tr>
<td>b*</td>
<td>2.04</td>
<td>0.81</td>
<td>-0.63</td>
<td>-1.76</td>
<td>-2.68</td>
<td>-3.59</td>
<td>-5.46</td>
</tr>
<tr>
<td>Brightness % ISO</td>
<td>91.7</td>
<td>91.78</td>
<td>91.8</td>
<td>91.64</td>
<td>91.53</td>
<td>91.4</td>
<td>91.17</td>
</tr>
<tr>
<td>CIE whiteness %</td>
<td>89.61</td>
<td>92.63</td>
<td>97.43</td>
<td>100.86</td>
<td>104.01</td>
<td>106.67</td>
<td>113.63</td>
</tr>
<tr>
<td>0.6% l*</td>
<td>96.7</td>
<td>96.2</td>
<td>95.3</td>
<td>94.6</td>
<td>94.0</td>
<td>93.4</td>
<td>92.1</td>
</tr>
<tr>
<td>OBA a*</td>
<td>0.89</td>
<td>1.02</td>
<td>1.32</td>
<td>1.60</td>
<td>1.87</td>
<td>2.19</td>
<td>2.83</td>
</tr>
<tr>
<td>b*</td>
<td>0.47</td>
<td>-0.49</td>
<td>-2.00</td>
<td>-3.09</td>
<td>-4.08</td>
<td>-4.19</td>
<td>-7.00</td>
</tr>
</tbody>
</table>

Note: The furnish composition was 30% SWBKP, 50% HWBKP and 20% HYP (Grade 325/83).

**Résumé:** Des pâtes à haut rendement de divers degrés de blancheur ont été utilisées pour remplacer la pâte kraft blanche de feuillus afin d’évaluer l’influence de ce remplacement sur les propriétés optiques des produits du papier. Les effets des ABG, de la charge de PCC et des colorants sur la blancheur, la brillance et la teinte du papier ont été étudiés en fonction de divers taux de remplacement. La PHR utilisée en remplacement diminue la brillance et la blancheur CIE du papier, surtout lorsque le taux de remplacement est élevé (e.g. 30 %). La perte de brillance attribuable à ce remplacement peut être compensée par l’ajout d’un ABO et/ou de PCC.


**Keywords:** HIGH-YIELD PULP, HYP, FINE PAPER, OPTICAL BRIGHTENING AGENT, OBA, PCC, BRIGHTNESS, WHITENESS