# Enhancement of Pulp Brightness And Whiteness Using TAED During Bleaching

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## ABSTRACT

Studies have been conducted with the use of TAED (Tetra Acetyle Ethylene Diamine) along with hydrogen peroxide to bleach the mixed hardwood bamboo pulp. Present paper describes the benefits of using TAED during oxygen delignification stage, after oxygen delignification and during oxidative extraction stage of pulp to improve the brightness and whiteness of mixed hardwood bamboo pulp.

Use of TAED along with $H_2O_2$ in ODL stage improved pulp brightness by 4-9% and reduced ODL pulp kappa number by 43-54%. Brightness of final bleached pulp was increased by 1.5-1.7% and CIE whiteness was increased by 1.8-1.9 points.

Use of TAED along with $H_2O_2$ after ODL stage results in significant improvement in pulp brightness i.e. 3-10% and reduction in kappa number by 8-19%. Final bleached pulp brightness was increased by 1.9-2.1% and CIE whiteness was increased by 2.2-2.4 points compared to control.

Use of TAED in $E_{OP}$ stage significantly improved $E_{OP}$ pulp brightness i.e. 2-3% and reduced kappa number to some extent. Final pulp brightness and whiteness of TAED treated pulp were improved by 1.1-1.8% and 1.8-2.0 units, respectively. With the use of TAED in $E_{OP}$ stage, chlorine dioxide dosage in $D_1$ stage was reduced by 3 kg/TP with comparable brightness and improved whiteness of the pulp.

***Key words:*** *TAED, hydrogen peroxide, bleaching, brightness and whiteness.*

## Introduction

In the last few years, interest in demand of high bright paper has forced paper manufacturers to think new ways to improve brightness/whiteness of paper. Improvement in final pulp brightness and whiteness with conventional techniques is a challenging task.

Hydrogen peroxide is a very effective bleaching chemical due to its high oxidation potential. It reduces the demand of other bleaching chemicals specifically chlorine dioxide and helps to boost the final brightness. Addition of an activator to the peroxide stage increases its efficiency further. Addition of TAED to peroxide stage generates a more powerful oxidative peracetic acid. Hydrogen peroxide and water react with TAED to form consecutively triacetylethylenediamine and diacetylethylenediamine with the release of two molecules of peracetic acid or acetic acid (Turner et al., 2004; Davies and Deary, 1991; Suchy and Argyropoulos, 2002). The compounds with O- or N- bounded acetyl groups have potential to react with the strongly nucleophilic hydroperoxy anion to yield peroxyacetic acid (Hofmann 1992).

Peracetic acid and Peroxyacetic acids are stronger bleaching agents than hydrogen peroxide due to higher redox potential than hydrogen peroxide (Hauthal et al 1990). Mill trial with Potlatch Corporation, Lewiston, Idaho, USA, evaluated the industrial application of peracetic acid generated by reacting TAED and peroxide; significant reduction of total chlorine dioxide consumption was achieved (Turner et al. 2004). Several plant scale trials were taken with per acetic acid but it is still not being used commercially due to high cost of manufacturing and handling hazards. These obstacles can be overcome with use of TAED with $H_2O_2$ due to insitu generation of peroxyacids. It is also reported that with the use of TAED some specific properties of the paper also get improved viz. brightness and bulk (Hsieh et al., 2006). Presently TAED is widely used in detergent and textile industry. It is odorless, colorless, storage stable solid and it is safe to handle. Reaction products of TAED are non toxic; it is biodegradable and generates ammonia, water, carbon dioxide and nitrate and does not generate ethylene diamine (Tompsett 1994). $H_2O_2$ / TAED bleaching system was also found more effective to decrease the carbonyl group content than $H_2O_2$ alone, which results in higher brightness and whiteness of final bleached pulp (Young Raymond 1998, Zhao et al 2010)

Present paper describes the benefits of using TAED (Tetra Acetyle Ethylene Diamine) during oxygen delignification stage, after oxygen delignification and during oxidative extraction stage of pulp to improve the brightness and whiteness of mixed hardwood bamboo pulp.

## Experimental

For the study unbleached pulp was collected from a hard wood bamboo based pulp and paper mill situated in north India. Pulp

was squeezed and stored in polythene bag at temperature 5.0°C during the study period. Moisture was determined before study. Bleaching study was carried out in polythene bags in water bath of constant temperature. Solution of TAED was prepared prior to application on pulp. To prepare uniform solution of TAED, pH of the water was maintained at 8.0 and temperature at 20°C. TAED was dissolved uniformly to 2 g/l solution. For addition of TAED in pulp, required quantity of TAED and hydrogen peroxide was mixed thoroughly and kept for 10 minutes at normal temperature to activate the peroxide before addition to the pulp.

## Results and Discussion

***Application of TAED during oxygen delignification stage***

TAED was used in ODL stage with and without use of hydrogen peroxide. Marginal improvement in ODL pulp brightness and reduction in kappa number was obtained when TAED was used alone. When TAED was used along with $H_2O_2$ in ODL stage, significant improvement in ODL pulp brightness (4-9%) and reduction in ODL pulp kappa number (43-54%) was obtained. Detailed results on the effect of TAED in ODL stage with and without use of hydrogen peroxide are given in Table 1.

Table 1: Effect of TAED on pulp properties when used during ODL

| Particular | Without $H_2O_2$ | | | With $H_2O_2$ | | |
|---|---|---|---|---|---|---|
| | Control | TAED 0.5 | TAED 1.0 | Control | TAED 0.5 | TAED 1.0 |
| Initial kappa no. | 16.1 | | | | | |
| TAED dose (%) | -- | 0.5 | 1.0 | -- | 0.5 | 1.0 |
| $H_2O_2$ dose (%) | -- | -- | -- | 1.0 | 0.5 | 1.0 |
| NaOH dose (%) | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 | 1.8 |
| Initial pH | 12.5 | 12.4 | 12.3 | 12.2 | 12.0 | 12.2 |
| Final pH | 10.7 | 10.6 | 10.5 | 10.6 | 10.6 | 10.5 |
| Brightness (% ISO) | 36.1 | 37.9 (+1.8) | 37.8 (+1.7) | 40.2 (+4.1) | 40.5 (+4.4) | 44.8 (+8.7) |
| Kappa No. | 9.7 | 9.2 | 9.0 | 9.0 | 8.8 | 7.4 |
| Kappa reduction (%) | 39.8 | 42.9 | 44.1 | 44.1 | 45.3 | 54.0 |
| Bulk (cc/g) | 1.83 | 1.83 | 1.85 | 1.84 | 1.82 | 1.83 |
| Tensile Index | 27.6 | 27.2 | 26.9 | 27.9 | 27.3 | 26.9 |
| Tear Index | 4.9 | 4.8 | 4.9 | 4.8 | 4.9 | 4.9 |

TAED treated and control pulps were bleached with $C_DE_{OP}D_1D_2$ sequence to evaluate the effect of TAED treatment on final bleached pulp properties. Brightness of final bleached pulp was increased by 1.5 & 1.7% and CIE whiteness was increased by 1.8 & 1.9 points compare to control at TAED dose level of 0.5 & 1.0 %, respectively. Bulk, tear and tensile indices of TAED treated bleached pulps were found comparable with control. Detailed bleaching results on pulps produced after application of TAED in ODL stage are given in Table 2.

***Application of TAED after oxygen delignification stage***

The results on the effect of TAED after ODL stage are given in Table 3 and bleaching results of these pulps are given in Table 4. When combination of TAED and $H_2O_2$ was used on ODL pulp, significant improvement in pulp brightness (3-10%) and reduction in kappa number (8-19%) was achieved. TAED treated and control pulps were bleached with $C_DE_{OP}D_1D_2$ sequence to evaluate the effect of TAED treatment on final bleached pulp properties. Final bleached pulp brightness was increased by 1.9 & 2.1% and CIE whiteness was increased by 2.2 & 2.4 points compared to control at TAED dose level of 0.5 & 1.0%, respectively.

Table 2: Bleaching results of TAED treated pulp (during ODL)

| Particular | Without $H_2O_2$ | | | With $H_2O_2$ | | |
|---|---|---|---|---|---|---|
| | Control | TAED-0.5 | TAED-1.0 | Control | TAED-0.5 | TAED-1.0 |
| Kappa no. | 9.7 | 9.2 | 9.0 | 9.0 | 8.8 | 7.4 |
| **$C_D$ stage** (Kappa factor - *0.22*, consistency – 4.0%, *temp. – 75 °C, time – 120 min.)* | | | | | | |
| $Cl_2/ClO_2$ added (%) | 1.92/0.08 | 1.82/0.08 | 1.78/0.08 | 1.78/0.08 | 1.74/0.07 | 1.47/0.06 |
| End pH | 2.1 | 2.0 | 2.1 | 2.1. | 2.2 | 2.1 |
| **$E_{OP}$ stage** (Consistency – 10.0%, *temp. – 75 °C, time – 120 min., $O_2$ pres. 3.0 kg/cm²)* | | | | | | |
| NaOH/ $H_2O_2$ (%) | 1.17/0.5 | 1.1/0.5 | 1.2/0.5 | 1.0/0.5 | 1.1/0.5 | 1.0/0.5 |
| Brightness (% ISO) | 68.9 | 69.1 | 69.4 | 71.0 | 72.4 | 72.6 |
| CE Kappa no. | 2.0 | 1.8 | 1.9 | 1.9 | 1.8 | 1.8 |
| **$D_1$ stage** (Consistency – 10.0%, $ClO_2$ added – 0.7%, *temp. – 75 °C, time – 180 min.)* | | | | | | |
| Final pH | 3.4 | 3.5 | 3.5 | 3.4 | 3.4 | 3.4 |
| Brightness (% ISO) | 83.2 | 84.0 | 84.2 | 84.8 | 85.6 | 85.4 |
| **$D_2$ stage** (Consistency – 10.0%, $ClO_2$ added – 0.3%, *temp. – 75 °C, time – 180 min.)* | | | | | | |
| Final pH | 3.4 | 3.5 | 3.4 | 3.4 | 3.4 | 3.4 |
| Brightness (% ISO) | 87.7 | 88.3 | 88.2 | 88.0 | 89.2 | 89.4 |
| CIE whiteness | 74.3 | 74.9 | 75.1 | 75.3 | 76.1 | 76.2 |

***Application of TAED in oxidative extraction stage***

Detailed results on the effect of TAED in $E_{OP}$ stage are given in Table 5. Use of TAED in $E_{OP}$ stage was significantly improved $E_{OP}$ pulp brightness (2-3%) and reduced kappa number. Final pulp brightness and whiteness of TAED treated pulp was improved by 1.1-1.8% and 1.8-2.0%, respectively. With

Table 3: Effect of TAED on pulp properties when used after ODL

| Particular | Control | $H_2O_2$ | TAED 0.5 | TAED 1.0 |
|---|---|---|---|---|
| Initial kappa no. | 9.7 | | | |
| TAED dose % | -- | -- | 0.5 | 1.0 |
| $H_2O_2$ dose % | -- | 1.0 | 0.5 | 1.0 |
| NaOH dose % | 0.3 | 0.3 | 0.3 | 0.3 |
| Initial pH | 9.9 | 9.8 | 9.9 | 9.5 |
| Brightness % | 38.0 | 41.2 (+3.2) | 44.7 (+6.7) | 47.7 (+9.7) |
| Kappa No. | 9.3 | 8.9 | 8.3 | 7.9 |
| Reduction in kappa no. (%) | 4.1 | 8.2 | 14.4 | 18.6 |

Constant conditions: Consistency - 10%, time 60 min., temp. 60 °C,

Table 4: Bleaching results of TAED treated pulp (after ODL)

| Particular | Control | $H_2O_2$ | TAED 0.5 | TAED 1.0 |
|---|---|---|---|---|
| Kappa no. | 9.3 | 8.9 | 8.3 | 7.9 |
| **$C_D$ stage** *(*Kappa factor - *0.22*, consistency – 4.0%, *temp. – 75 °C, time – 120 min.)* | | | | |
| $Cl_2$ added (%) | 1.84 | 1.76 | 1.64 | 1.56 |
| $ClO_2$ added (%) | 0.08 | 0.07 | 0.07 | 0.07 |
| End pH | 2.2 | 2.2 | 2.1 | 2.2 |
| **$E_{OP}$ stage** *(*consistency – 10%, $H_2O_2$ – 0.5%, *temp. – 75 °C, time – 120 min., $O_2$ pres. 3.0 kg/cm$^2$)* | | | | |
| NaOH/ (%) | 1.03 | 0.98 | 0.92 | 0.90 |
| Final pH | 10.8 | 10.7 | 10.5 | 10.7 |
| Brightness (% ISO) | 68.0 | 69.8 | 71.6 | 71.8 |
| CE Kappa no. | 2.0 | 1.9 | 1.8 | 1.8 |
| **$D_1$ stage** *(*$ClO_2$ - 0.7%, consistency – 10%, *temp. – 75 °C, time – 180 min.)* | | | | |
| $ClO_2$ added (%) | 0.7 | 0.7 | 0.7 | 0.7 |
| Final pH | 3.4 | 3.5 | 3.6 | 3.5 |
| Brightness (% ISO) | 83.5 | 84.9 | 85.6 | 85.4 |
| **$D_2$ stage** *(*$ClO_2$ - 0.3%, consistency – 10%, *temp. – 75 °C, time – 180 min.)* | | | | |
| Final pH | 3.4 | 3.5 | 3.6 | 3.4 |
| Brightness (% ISO) | 87.7 | 88.2 | 89.6 | 89.8 |
| CIE whiteness | 74.4 | 75.3 | 76.6 | 76.8 |

Table 5: Effect of TAED on pulp properties when used in $E_{OP}$ stage

| Particular | Control | | 1 | | 2 | | 3 | |
|---|---|---|---|---|---|---|---|---|
| Kappa no. | 16.1 | | | | | | | |
| **$C_D$ stage** *(Kappa factor - 0.25, $ClO_2$ - 0.14%, $Cl_2$ – 3.18%, temp. – ambient, time – 45 min.)* | | | | | | | | |
| End pH | 2.1 | | | | | | | |
| **$E_{OP}$ stage** *(NaOH added – 1.8%, $H_2O_2$ added – 0.5%, temp. – 75 °C, time – 120 min.)* | | | | | | | | |
| TAED (%) | -- | | 0.1 | | 0.5 | | 1.0 | |
| Final pH | 11 | | 10.6 | | 10.5 | | 10.5 | |
| Brightness (% ISO) | 60.5 | | 60.5 (--) | | 62.5 (+2.0) | | 63.2 (+2.7) | |
| CE Kappa no. | 2.4 | | 2.4 | | 2.1 | | 2.0 | |
| **$D_1$ stage** *(temp. – 75 °C, time – 180 min.)* | | | | | | | | |
| $ClO_2$ added (%) | 1.0 | 0.7 | 1.0 | 0.7 | 1.0 | 0.7 | 1.0 | 0.7 |
| Final pH | 3.0 | 3.1 | 3.0 | 3.1 | 3.1 | 3.2 | 3.1 | 3.2 |
| Brightness (% ISO) | 85.16 | 83.19 | 85.23 | 83.72 | 86.32 | 84.22 | 86.73 | 84.94 |
| **$D_2$ stage** *($ClO_2$ added – 0.3 %, temp. – 75 °C, time – 180 min.)* | | | | | | | | |
| Final pH | 3.2 | 3.1 | 3.2 | 3.0 | 3.0 | 3.1 | 3.0 | 3.0 |
| Brightness (% ISO) | 88.2 | 87.0 | 88.2 | 87.1 | 89.3 | 88.0 | 90.0 | 88.0 |
| Improvement (% ISO) | -- | -- | 0 | +0.1 | +1.1 | +1.0 | +1.8 | +1.0 |
| CIE whiteness | 72.83 | 70.43 | 74.14 | 71.44 | 74.63 | 71.94 | 74.81 | 72.25 |

the use of TAED in $E_{OP}$ stage, chlorine dioxide dosage in $D_1$ stage was reduced by 3 kg/ton of pulp with comparable brightness and improved whiteness of the pulp.

## Conclusions

- Use of TAED along with $H_2O_2$ in ODL stage can improve brightness of final bleached pulp by 1.5-1.7% and CIE whiteness by 1.8-1.9 points compared to control.
- Use of TAED along with $H_2O_2$ after ODL stage results in improved final bleached pulp brightness by 1.9-2.1% and CIE whiteness by 2.2-2.4 points compared to control.
- Use of TAED in $E_{OP}$ stage significantly improved final pulp brightness and whiteness by 1.1-1.8% and 1.8-2.0 units, respectively.
- With the use of TAED in $E_{OP}$ stage, chlorine dioxide dosage in $D_1$ stage was reduced by 3.0 kg/ton of pulp with comparable brightness and improved whiteness of the pulp.

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