Mill Scale Implementation of Enzymes in Pulp Bleaching

Jeffrey S. Tolan

2002 TAPPI Bleaching Committee and SE Region
St. Augustine, Florida
Xylanase Enzymes

- Used to enhance the bleaching of pulp in 20 mills in North America
- Successful mill implementation takes into account:
  - Enzyme and pulp properties
  - Operating factors and assessment of benefits
Outline

1. Xylanase enzymes in bleaching
2. Benefits of xylanase treatment
3. Assessment of benefit
4. Yield Effects
5. Mill case studies
1. Xylanase Enzymes in Bleaching

- Xylanase enzymes made by microbes and used as a liquid solution
- Xylanase acts on the xylan in the pulp
  - Does not brighten or delignify pulp
  - Increases efficiency of the other bleaching chemicals
Enzyme Addition to Brownstock

Enzyme Addition System

- Enzyme
- Acid
- Water
- Mill TPD

Brownsstock Decker

Brownsstock Storage Tower

pH
T
L
Xylanase Operating Parameters

- pH
- Temperature
- time
- dosage
Figure 2: TEMPERATURE PROFILES

% Chemical Savings vs Temperature (°C)

- Xylanase 1
- Xylanase 2
Figure 3: TIME COURSES

% Chemical Savings

Time (hours)

Xylanase 1
Xylanase 2
Dosage Response of Two Enzymes

<table>
<thead>
<tr>
<th>Enzyme Dosage (litres/t pulp)</th>
<th>Brightness</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>90</td>
</tr>
<tr>
<td>0.2</td>
<td>89.5</td>
</tr>
<tr>
<td>0.4</td>
<td>89</td>
</tr>
<tr>
<td>0.6</td>
<td>88.5</td>
</tr>
<tr>
<td>0.8</td>
<td>88</td>
</tr>
<tr>
<td>1</td>
<td>87.5</td>
</tr>
<tr>
<td>1.2</td>
<td></td>
</tr>
<tr>
<td>1.4</td>
<td></td>
</tr>
</tbody>
</table>

Graph: Dosage Response of Two Enzymes
- Enzyme 1
- Enzyme 2

Y-axis: Brightness
X-axis: Enzyme Dosage (litres/t pulp)
2. Bleaching Benefit
Figure 4: BENEFIT OF XYLANASE IN BLEACHING

% ISO Brightness vs. ClO2 (kg/t)

- Untreated
- Xylanase 2
Other Benefits of Using Xylanase

- **Pulp Quality**
  - Increased viscosity
  - Decreased shives/TOX
  - Increased brightness ceiling

- **Mill Operations**
  - Maintain ECF
  - Decrease AOX
Versatility of Xylanase

- Furnish: Hardwood or Softwood
- Digester: Batch, Continuous, MCC
- Additives: AQ, Surfactant
- Brownstock: Conventional, O2-Delig
- Bleaching: Chlorine, ECF, TCF
- Stages: 3, 4, 5
- Extraction: E, Eo, Ep, Eop
- Brightness: Fully bleached, semi-bleached
Two Key Factors that Influence Bleaching Benefit

- Xylanase enzyme used
- Susceptibility of the pulp to xylanase
Figure 5: XYLOSE RELEASE BY THREE Xylanases

- Xylanase 1
- Xylanase 2
- Xylanase 3

Enzyme Dosage (ml/t) vs. Xylose Release (mg/g)
Figure 6: BLEACHING BENEFIT AND XYLOSE RELEASE

% Chemical Savings

Xylose Release (mg/g)

- Xylanase 1
- Xylanase 2
- Xylanase 3
Importance of the Enzyme

- Enzymes release different amounts of xylose from the pulp
- Bleaching benefit is proportional to xylose released (for many xylanases)
Figure 7: Xylan Susceptibility from Different Pulps

- Hardwood
- O2 Delig.
- Softwood

Xylose Release (mg/g) vs. Enzyme Dosage (ml/t)
Importance of Pulp Susceptibility

- Different amount of xylose released from pulps
- Leading cause of failed trials is low susceptibility pulp
3. Assessment of Benefit
Assessment of Benefit

• Before mill trial, carry out lab assessment
  • Ideal conditions
  • Mill conditions
• When done properly, this is a good prediction of mill results
Figure 8: LAB AND MILL Xylanase Results

- D2 Brightness (ISO)
- Total Kappa factor

- Lab Untreated
- Lab Treated
- Mill Untreated
- Mill Treated
Ongoing Assessment of Xylanase

- **On-site tests**
  - Enzyme activity, flow rate
  - Pulp pH, temperature
  - Stock retention time, by tracer
  - Enzyme action on pulp, by reactions with pulp filtrate after enzyme treatment
4. Yield Effects
New Developments in Xylanase Yield Effects

- Improved enzyme specificity for lower yield loss
  - In 1991, reports of 2% yield loss
  - In 1999, lab yield loss of 0.2-0.3%
    - Near limit of lab detection
    - Not measurable in mill
- Account for yield effects as with other chemicals
Effect of Xylanase on Pulp Yield

Yield loss related to bleaching benefit

```
<table>
<thead>
<tr>
<th>Yield Loss (%)</th>
<th>Enzyme 1</th>
<th>Enzyme 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.2</td>
<td>0.4</td>
</tr>
<tr>
<td>0.8</td>
<td>0.6</td>
<td>0.8</td>
</tr>
</tbody>
</table>
```

Brightness Gain (ISO):
- 2.5
- 2.0
- 1.5
- 1.0
- 0.5
- 0.0
5. Mill case studies
US Hardwood Mill

Total ClO2 versus K#

- 20.6% less Chlorine Dioxide is required to achieve target brightness, this compares to the expected 19.2% decrease.
- 11.2#/Ton less ClO2 required to achieve brightness target.
Softwood (500 ton/day)

Case History

- Chemical reduction/savings at all K#.
- Reduced ClO₂ 10 lb/ton, Net savings $3.00/ton.
US Southern Softwood Mill

Total ClO2 versus K#

- Less ClO2 required at any Kappa number
Northern Softwood with O2 Delign
(1000 ton/day)

Case History

Enzyme Treatment Increases Pulp Brightness and Lowers Chemical Usage.
Xylanase Enzymes

- Used to enhance the bleaching of pulp in 20 mills in North America

- Successful mill implementation takes into account:
  - Enzyme and pulp properties
  - Operating factors and assessment of benefits