Evaluation of ECF Bleached SW Kraft Pulps From Mature and Thinning Softwood Resources

Institute of Paper Science and Technology, Georgia Institute of Technology
Evaluation of ECF Bleached SW Kraft Pulps From Mature and Thinning Softwood Resources: Background

- Georgia has the highest collection of non-industrial private forest landowners (NIPF) in the nation
- NIPF are a primary source of wood for many of Georgia’s pulp mills.
- NIPF owners have begun to utilize short-rotation management options to improve the feasibility, profitability, and cash flow of production forestry enterprises.
- A valuable component in forestry management approaches is to cut immature trees to stimulate growth/yield of the remaining trees
- University of Georgia have demonstrated that thinning loblolly and slash pine stands increased internal rate of return for NIPF landowners by 1½% (slash) to 2% (loblolly) over unthinned stands.
- Hence economical factors will increase the availability of pine thinnings for kraft pulping operations
- Potential cost savings of 15 – 30%
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The physical performance of kraft pulps bleached/unbleached from thinnings vs. mature wood remains an issue of practical importance

- Zobel, McGovern, and Koch documented (1970 - 81) that southern softwoods from fast-grown plantations are different from that from older, natural stands of the same species because of age, tree form and quality

- Hatton et al. (1996) demonstrated that kraft pulps prepared from black, Norway, red and white spruce thinnings exhibited reduced tear properties, but excellent tensile properties which were attributed to the thinner cell walls from the juvenile wood.

- Drost et al. reported (2004) on variations in fiber characteristics from mature and juvenile wood from whole-log and sawmill chips pulps from juvenile wood had superior beatability resulting from their lower coarseness, while pulps from mature wood exhibited higher tear as a result of their greater fiber lengths.
Assess the impact of SW thinnings for the production of bleached kraft pulp for modern southern SW pulp mill operations.

Year 1: Examined SW kraft pulps
Year 2: Examined ECF SW kraft pulps
Evaluation of ECF Bleached SW Kraft Pulps From Mature and Thinning Softwood Resources: Research Objectives

Experimental:

- **Kraft Cooking Process**  
  Ratio of Thinnings:Mature Wood Employed
  - Conventional batch: 100:0, 80:20, 40:60, 0:100
  - Simulated ITC: 100:0, 60:40, 0:100

  The kraft pulps will be bleached to TAPPI brightness ~85 via two bleaching sequences:
  - OD(E+P+O)D
  - D(E+P+O)DED

- The partially bleached pulps will be analyzed for kappa number, viscosity, and TAPPI brightness
- The fully bleached pulps will be analyzed for optical, chemical, and physical strength properties
- Fully bleached pulps will also be PFI refined with 2000, and 4000 revs and the physical strength properties will be re-assessed at each point of refining
Evaluation of ECF Bleached SW Kraft Pulps From Mature and Thinning Softwood Resources: Wood Results

Wood Chips Properties for Thinning vs. Mature

<table>
<thead>
<tr>
<th></th>
<th>Density</th>
<th>Klason Lignin</th>
<th>Extractives</th>
<th>Earlywood:Latewood</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thinning</td>
<td>0.423</td>
<td>29.8</td>
<td>2.77</td>
<td>1.0:0.89</td>
</tr>
<tr>
<td>Mature</td>
<td>0.448</td>
<td>28.5</td>
<td>1.93</td>
<td>1.0:1.53</td>
</tr>
</tbody>
</table>

Carbohydrate Profile (%)

<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>Thinning</td>
<td>64.9</td>
<td>4.5</td>
<td>16.9</td>
<td>10.6</td>
<td>3.1</td>
</tr>
<tr>
<td>Mature</td>
<td>67.9</td>
<td>3.5</td>
<td>17.7</td>
<td>8.8</td>
<td>2.1</td>
</tr>
</tbody>
</table>
Evaluation of ECF Bleached SW Kraft Pulps From Mature and Thinning Softwood Resources: Pulping Results

Total and Screened Yields for Conventional Kraft Pulping

<table>
<thead>
<tr>
<th>Cook Type</th>
<th>SW Chips</th>
<th>Final H-factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional Kraft</td>
<td>Thinning: Mature</td>
<td>100:0</td>
</tr>
<tr>
<td></td>
<td>0:100</td>
<td>1,445</td>
</tr>
<tr>
<td></td>
<td>80:20</td>
<td>1,438</td>
</tr>
<tr>
<td></td>
<td>60:40</td>
<td>1,434</td>
</tr>
<tr>
<td></td>
<td>40:60</td>
<td>1,433</td>
</tr>
</tbody>
</table>
Evaluation of ECF Bleached SW Kraft Pulps From Mature and Thinning Softwood Resources: Pulping Results

Kappa # for Conventional Kraft Pulps

![Bar Chart]

- Thinning (T)
- Mature (M)
- 80:20 T/M
- 60:40 T/M
- 40:60 T/M

Kappa #
**Evaluation of ECF Bleached SW Kraft Pulps From Mature and Thinning Softwood Resources: Background**

**Kappa Number for Lab-Simulated Continuous Kraft Cook**

<table>
<thead>
<tr>
<th>Cook Type</th>
<th>SW Chips</th>
<th>Final H-factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modified Continuous Kraft</td>
<td>100:0</td>
<td>1,717</td>
</tr>
<tr>
<td></td>
<td>0:100</td>
<td>1,713</td>
</tr>
<tr>
<td></td>
<td>60:40</td>
<td>1,709</td>
</tr>
<tr>
<td></td>
<td>Tear Index (mN\text{m}^2/\text{g})</td>
<td>Tensile Index (N/mm)</td>
</tr>
<tr>
<td>-------------------------</td>
<td>------------------------------------</td>
<td>----------------------</td>
</tr>
<tr>
<td><strong>Conventional Kraft</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>100% Thinning (T)</td>
<td>13.6</td>
<td>91.1</td>
</tr>
<tr>
<td>100% Mature (M)</td>
<td>16.8</td>
<td>88.2</td>
</tr>
<tr>
<td>80:20 (T:M)</td>
<td>14.6</td>
<td>92.2</td>
</tr>
<tr>
<td>60:40 (T:M)</td>
<td>14.4</td>
<td>88.7</td>
</tr>
<tr>
<td>40:60 (T:M)</td>
<td>15.7</td>
<td>90.1</td>
</tr>
<tr>
<td><strong>Modified continuous Kraft</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>100% Thinning (T)</td>
<td>15.6</td>
<td>85.4</td>
</tr>
<tr>
<td>100% Mature (M)</td>
<td>19.9</td>
<td>73.2</td>
</tr>
<tr>
<td>60:40 (T:M)</td>
<td>16.6</td>
<td>86.8</td>
</tr>
</tbody>
</table>
Evaluation of ECF Bleached SW Kraft Pulps From Mature and Thinning Softwood Resources: Experimental Protocol

OD(E+P+O)D

O-Stage (*Incoming brownstock kappa # 24-27*)
- 60 min, 100°C, 10% csc, 90 psig O₂
- Caustic charge varied 1.0 – 1.8
  - preferred value ~1.5% NaOH to yield post-O kraft pulps with kappa # ~ 10

- D₀-Stage
  - 45 min, 50°C, 3.5% csc, Kf 0.25, terminal pH 2.1 – 2.3

- (E+P+O)-Stage
  - 60 min, 75°C, 10% csc, 0.4% H₂O₂, initial O₂:65 psig 15 min; then vent12 psig/5 min, %NaOH 50% of Kf

- D₁-Stage
  - 180 min, 75°C, 10% csc, ClO₂ charge 0.5 – 2.0%, terminal pH 3
  - Final TAPPI Brightness Values ~ 87
Evaluation of ECF Bleached SW Kraft Pulps From Mature and Thinning Softwood Resources: Bleaching Results

<table>
<thead>
<tr>
<th></th>
<th>Conventional</th>
<th>ITC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mature</td>
<td>87.6</td>
<td>87.2</td>
</tr>
<tr>
<td>Thinning</td>
<td>87.2</td>
<td>87.5</td>
</tr>
<tr>
<td>60% Thin/40% Mature</td>
<td></td>
<td>87.4</td>
</tr>
<tr>
<td>40% Thin/60% Mature</td>
<td>87.3</td>
<td></td>
</tr>
<tr>
<td>80% Thin/20% Mature</td>
<td>87.7</td>
<td></td>
</tr>
</tbody>
</table>
Evaluation of ECF Bleached SW Kraft Pulps From Mature and Thinning Softwood Resources: Bleaching Results

OD(E+P+O)D Fiber Properties: Fiber Length

ITC

![Graph showing fiber length properties](image-url)
Evaluation of ECF Bleached SW Kraft Pulps From Mature and Thinning Softwood Resources: Bleaching Results

OD(E+P+O)D Fiber Properties: Fiber Length

Conventional

![Bar chart showing FQA Length (mm) for Thinning, 40% Thin, 80% Thin, and Mature with Weighted Length Weighted comparison]
Evaluation of ECF Bleached SW Kraft Pulps From Mature and Thinning Softwood Resources: Bleaching Results

OD(E+P+O)D Fiber Properties: Fines

% Fines (Arithmetic)
Evaluation of ECF Bleached SW Kraft Pulps From Mature and Thinning Softwood Resources: Bleaching Results

OD(E+P+O)D Fiber Properties: Fiber Charge
Evaluation of ECF Bleached SW Kraft Pulps From Mature and Thinning Softwood Resources: Bleaching Results

OD(E+P+O)D Sheet Properties
Evaluation of ECF Bleached SW Kraft Pulps From Mature and Thinning Softwood Resources: Bleaching Results

Sheet Properties: Conventional Kraft Pulps
Evaluation of ECF Bleached SW Kraft Pulps From Mature and Thinning Softwood Resources: Bleaching Results

Sheet Properties: Conventional Kraft Pulps
Evaluation of ECF Bleached SW Kraft Pulps From Mature and Thinning Softwood Resources: Bleaching Results

Sheet Properties: Conventional Kraft Pulps
Evaluation of ECF Bleached SW Kraft Pulps From Mature and Thinning Softwood Resources: Experimental Protocol

D(E+P+O)DED

• **D-Stage** *(Incoming brownstock kappa # 24-27)*
  – K.f.:0.20, 45 min, 50°C, 3.5% csc, terminal pH: 1.8

• **(E+P+O)-Stage**
  – 60 min, 90°C, 10% csc, 0.4% H₂O₂, initial O₂:35 psig 15 min; then vent 12 psig/5 min, 3.2 %NaOH

• **D₁-Stage**
  – 180 min, 75°C, 10% csc, 1.0% ClO₂, terminal pH 3

• **E-Stage**
  – 60 min, 75°C, 10% csc, 0.5% NaOH, terminal pH 12

• **D₁-Stage**
  – 180 min, 75°C, 10% csc, 0.2% ClO₂, terminal pH 3

• Final TAPPI Brightness Values ~ 88
Evaluation of ECF Bleached SW Kraft Pulps From Mature and Thinning Softwood Resources: Bleaching Results

D(E+P+O)DED TAPPI Brightness Properties

<table>
<thead>
<tr>
<th></th>
<th>Conventional</th>
<th>ITC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mature</td>
<td>87.8</td>
<td>88.1</td>
</tr>
<tr>
<td>Thinning</td>
<td>87.8</td>
<td>88.9</td>
</tr>
<tr>
<td>60% Thin/40% Mature</td>
<td>88.4</td>
<td>88.3</td>
</tr>
<tr>
<td>40% Thin/60% Mature</td>
<td>88.3</td>
<td></td>
</tr>
<tr>
<td>80% Thin/20% Mature</td>
<td>88.4</td>
<td></td>
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Evaluation of ECF Bleached SW Kraft Pulps From Mature and Thinning Softwood Resources: Bleaching Results

Pulp Viscosity Properties (mPa.s)

<table>
<thead>
<tr>
<th></th>
<th>Conventional D(EPO)DED</th>
<th>ITC D(EPO)DED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mature</td>
<td>18.7</td>
<td>33.0</td>
</tr>
<tr>
<td>Thinning</td>
<td>23.0</td>
<td>21.3</td>
</tr>
<tr>
<td>60% Thin/40% Mature</td>
<td>22.1</td>
<td>24.7</td>
</tr>
<tr>
<td>40% Thin/60% Mature</td>
<td>21.6</td>
<td></td>
</tr>
<tr>
<td>80% Thin/20% Mature</td>
<td>23.1</td>
<td></td>
</tr>
</tbody>
</table>

*Physical Strength Properties Evaluated After 0, 2000, and 4000 revs PFI refining*
Evaluation of ECF Bleached SW Kraft Pulps From Mature and Thinning Softwood Resources: Bleaching Results

D(E+P+O)DED Fiber Properties: Fiber Length

![Fiber Length Graph]

- 100% Thinning
- 100% Mature
- 80% Thinning/20% Mature
- 60% Thinning/40% Mature
- 40% Thinning/60% Mature
- 100% Thinning/ITC Cooks
- 100% Mature/ITC Cooks
- Blend of Mature/Thinning/ITC Cooks

FQA Fiber Length/mm

ITC Pulps

Weight-Weighted
Length-Weighted
Evaluation of ECF Bleached SW Kraft Pulps From Mature and Thinning Softwood Resources: Bleaching Results

D(E+P+O)DED Fiber Properties: Tensile Index

- 100% Thinning
  - 0 revs.
  - 2,000 revs.
  - 4,000 revs.

- 100% Mature
  - 0 revs.
  - 2,000 revs.
  - 4,000 revs.

- 80% Thinning/20% Mature
  - 0 revs.
  - 2,000 revs.
  - 4,000 revs.

- 60% Thinning/40% Mature
  - 0 revs.
  - 2,000 revs.
  - 4,000 revs.

- 40% Thinning/60% Mature
  - 0 revs.
  - 2,000 revs.
  - 4,000 revs.

- 100% Thinning - ITC
  - 0 revs.
  - 2,000 revs.
  - 4,000 revs.

- 100% Mature - ITC
  - 0 revs.
  - 2,000 revs.
  - 4,000 revs.

- 60% Thin/40% Mature ITC
  - 0 revs.
  - 2,000 revs.
  - 4,000 revs.
Optimizing the Bleaching of Georgia’s SW Thinning Wood Resource: Results

D(E+P+O)DED Fiber Properties: Burst Index

![Bar chart showing Burst Index for different combinations of Thinning and Mature wood.]

- 100% Thinning
- 100% Mature
- 80% Thinning/20% Mature
- 60% Thinning/40% Mature
- 40% Thinning/60% Mature
- 100% Thinning-ITC
- 100% Mature-ITC
- 60% Thinning/40% Mature ITC

ITC Pulps
Optimizing the Bleaching of Georgia’s SW Thinning Wood Resource: Results

D(E+P+O)DED Fiber Properties: Tear Index

![Graph showing Tear Index for different thinning and maturity levels.]
Optimizing the Bleaching of Georgia’s SW Thinning Wood Resource: Results

D(E+P+O)DED Fiber Properties: Dry Zero Span
Optimizing the Bleaching of Georgia’s SW Thinning Wood Resource: Results

D(E+P+O)DED Fiber Properties: Wet Zero Span
Evaluation of ECF Bleached SW Kraft Pulps From Mature and Thinning Softwood Resources: Bleaching Results

Conclusions:

• Observe differences in Thin. vs. Mature wood and kraft pulp samples are maintained in fully bleached pulps

• Trends observed for conventional kraft pulps observed in continuous kraft

• Differences in tensile vs. tear less than some northern species
Conclusions:

• Experimental results between 40:60 and 60:40 blends of Thinning and Mature are very small and would most likely not be observed in commercial practice.

• Depending on product grade thinnings will provide distinct cost saving with little impact on product performance.
Evaluation of ECF Bleached SW Kraft Pulps From Mature and Thinning Softwood Resources

Acknowledgements

GA TIP3
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