Product-driven eucalypt-fibre selection for papermaking

by

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2nd Eucalypt Colloquium
Chile

24 – 26 May 2005

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Product-driven eucalypt-fibre selection for papermaking

Paul Kibblewhite
1. Bleached eucalypt market kraft fibres and end-use suitabilities

Paul Kibblewhite
Hardwood fibre types

Eucalypt
Acacia
Birch / Aspen / Poplar
Mixed hardwood
Hardwood market kraft types

- Eucalypt
- ‘Birch’
- Aspen
- Mixed hardwood

95 fibres
59 fibres
62 fibres
53 fibres
<table>
<thead>
<tr>
<th>Eucalypt fibres</th>
<th>Birch/Poplar fibres</th>
</tr>
</thead>
<tbody>
<tr>
<td>Short</td>
<td>Long</td>
</tr>
<tr>
<td>Slender</td>
<td>Broad</td>
</tr>
<tr>
<td>Thin to thick walls</td>
<td>Thin walls</td>
</tr>
<tr>
<td>Low coarseness</td>
<td>High coarseness</td>
</tr>
<tr>
<td>Large numbers</td>
<td>Small numbers</td>
</tr>
</tbody>
</table>

Kraft pulp component in papers

Mechanical pulp component in papers
No fixed rules to follow!!
Nothing set-in concrete!!

Exceptions to a rule always occur!!

For example

*Eucalyptus regnans* !!
For a eucalypt

*E. regnans*

Low density with broad and thin walled fibres

↓

Mediocre kraft pulp at mature age  Good CTMP pulp at young age
Globulus versus Regnans
Categories of eucalypt market kraft pulp

- High bulk (B)
- Intermediate bulk (A)
- *Eucalyptus regnans*
Eucalypt fibre types

Eucalypt Fibres

Regnans (A) (B)
Eucalypt market kraft “A” & “B” categories

![Graph showing the tensile index (N.m/g) vs. apparent density (kg/m³) for Pulp A and Pulp B. The graph is divided into high bulk and low bulk categories.](image_url)
Eucalypt market kraft pulps can have very different papermaking properties.
Regnans grouping

- Thin walled (relative to perimeter), collapsed fibres compared to “A” and “B” groupings

- Handsheets: High bonding, high light scattering coefficient and opacity. Low bulk, low stiffness and low porosity
Eucalypt “A” grouping

- Fibre properties intermediate
- Handsheet properties intermediate
Eucalypt “B” grouping

• Thick walled (relative to perimeter), uncollapsed fibres compared to “A” grouping

• Handsheets: Lower bonding, lower light scattering coefficient and opacity, higher bulk, higher stiffness, and higher porosity
Fibres in eucalypt market kraft pulps

- Short
- Narrow / slender
- Generally of low coarseness
- Present in very large numbers in highly uniform populations

Compared with birch, aspen and mixed hardwood fibres
References


2. Chemical and kraft fibre property variation within and among selected eucalypt trees and species

Paul Kibblewhite
For example

29 Eucalyptus nitens trees @ age 15

29 E. fastigata trees @ age 15
Property variation with height above ground

Model predicted means
Chip density and lignin content

Chip density

E. nitens

E. fastigata

Chip density kg/m³

0 2 4 6 8 10
(13 rings) (7 rings)
Tree age less mean-log ring No.

Chip lignin

E. fastigata

E. nitens

Chip lignin %

0 2 4 6 8 10
(13 rings) (7 rings)
Tree age less mean-log ring No.
Chip glucose and xylose content

**Glucose**

- **E. fastigata**

- **E. nitens**

**Xylose**

- **E. nitens**

- **E. fastigata**

Tree age less mean-log growth layer vs Chip glucose %

Tree age less mean-log growth layers vs Chip xylose %
Magnificent Variation within and among eucalypt trees and species

For example

Chip density and lignin content
Chip density

E. fastigata

E. nitens

Chip density kg/m³

Tree age less mean-log growth layer

Chip density kg/m³

Tree age less mean-log growth layers
Chip total lignin %

E. fastigata

E. nitens

Tree age less mean-log growth layer
Kraft fibre property interrelationships
(Fibres dried and rewetted from handsheets)

Perimeter = 2(width + thickness)
Wall area ∝ Coarseness
Width/thickness = Collapse
Perimeter/wall thickness ∝ 1/Density ∝ Collapse
Number ∝ 1/(Length x Wall area)
Fibre collapse and length

Fibre collapse

Kraft fibre width/thickness µm

Tree age less mean-log growth layer

E. nitens

E. fastigata

Fibre length

Kraft fibre length mm

Tree age less mean-log growth layers

E. nitens

E. fastigata

E. nitens

E. fastigata
Fibre perimeter and wall area (coarseness)

Fibre perimeter

Kraft fibre perimeter µm

E. fastigata

E. nitens

Tree age less mean-log growth layer

Fibre wall area

Kraft fibre wall area µm²

E. nitens

E. fastigata

Tree age less mean-log growth layer
Fibre wall thickness

![Graph showing fibre wall thickness for E. nitens and E. fastigata over tree age and mean growth layer number.](image)
E. nitens versus E. fastigata

For *E. nitens* with increasing tree height
- Fibre perimeter decreases rapidly
- Wall thickness increases

Thus for *E. nitens*

Chip density increases and fibre collapse decreases

(minimal change with tree height for *E. fastigata*)
Kraft fibre property variation with length the example

**E. fastigata**

**E. nitens**
Chemical and kraft-fibre property patterns of change with tree-height

Very different for E. nitens and E. fastigata
• Wood lignin, glucose and xylose
• Kraft fibre length, perimeter, wall thickness and collapse
• Chip density

Similar for fibre wall area (coarseness)
References


3. Selection of *Eucalyptus nitens* trees for different paper and pulp grades

Paul Kibblewhite
29 *Eucalyptus nitens* trees

- 15-year-old from same site
- Selection - basic density @ 1.4 m
- Kraft pulps @ kappa 20±2
Tensile index versus sheet density

“29 E. nitens trees”

\[ r^2 = 0.61 \]
Unrefined versus refined
“29 E. nitens trees”

$29 \ E. \ nitens$

$r^2 = 0.61$

29 E. nitens

$29 \ E. \ nitens$

$29 \ E. \ nitens$
29 *E. nitens* trees

Individual-tree kraft pulps ordered

⇓⇓

Increasing sheet density

Decreasing sheet bulk
Provided sufficient bulk, tensile index can be developed with refining but not vice versa!

**Trees 1 - 7**

![Graph](image1)

**Trees 22 - 29**

![Graph](image2)
Suggested end uses for some individual-tree fibre types

Eucalyptus nitens
# Trees 1-7 (high bulk)

**Sheet density ≤ 650 kg/m³ @ 500 rev**

<table>
<thead>
<tr>
<th>Fibres relatively</th>
<th>Tree 1 – 4</th>
<th>Excellent</th>
<th>Wood-free</th>
</tr>
</thead>
<tbody>
<tr>
<td>Short</td>
<td></td>
<td>• Bulk</td>
<td>Printings and writings</td>
</tr>
<tr>
<td>Slender</td>
<td></td>
<td>• Stiffness</td>
<td>Tissue</td>
</tr>
<tr>
<td>Thick-walled</td>
<td></td>
<td>• Formation</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Fibres relatively</th>
<th>Tree 5 – 7</th>
<th>Excellent</th>
<th>Wood-free</th>
</tr>
</thead>
<tbody>
<tr>
<td>Long</td>
<td></td>
<td>• Bulk</td>
<td>Printings and writings</td>
</tr>
<tr>
<td>Slender</td>
<td></td>
<td>• Stiffness</td>
<td>Tissue</td>
</tr>
<tr>
<td>Thick-walled</td>
<td></td>
<td>• &lt;Formation</td>
<td></td>
</tr>
<tr>
<td>Fibres relatively</td>
<td>Trees 11 – 16</td>
<td>Low bulk</td>
<td>Wood-free Glassine papers Soft tissue – Low bulk component</td>
</tr>
<tr>
<td>-------------------</td>
<td>---------------</td>
<td>----------</td>
<td>-----------------------------------------------------------</td>
</tr>
<tr>
<td>Broad</td>
<td>Trees 24 – 29</td>
<td>Extreme low bulk</td>
<td>Extreme high density papers</td>
</tr>
<tr>
<td>Thin-walled</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High collapse</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Broad</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thin-walled</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt; Collapse</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Trees 11-29 (low bulk) Sheet density > 660 kg/m³ @ 500 rev
4. Eucalypt-fibre selection for papermaking: *E. nitens*, *E. globulus* & *E. maidenii* at ages 8 and 11 years

Paul Kibblewhite
Two stand ages
- 8 years
- 11 years

Three species
- *E. nitens*
- *E. maidenii*
- *E. globulus*
## Chip density and pulp yield

<table>
<thead>
<tr>
<th></th>
<th>Chip density kg/m³</th>
<th>Pulp yield %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>8 years</td>
<td>11 years</td>
</tr>
<tr>
<td>Nitens</td>
<td>447</td>
<td>448</td>
</tr>
<tr>
<td>Maidenii</td>
<td>569</td>
<td>576</td>
</tr>
<tr>
<td>Globulus</td>
<td>490</td>
<td>543</td>
</tr>
</tbody>
</table>
## Chip total lignin and pulp yield

<table>
<thead>
<tr>
<th></th>
<th>Pulp yield %</th>
<th></th>
<th>Total lignin %</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>8 years</td>
<td>11 years</td>
<td>8 years</td>
<td>11 years</td>
</tr>
<tr>
<td>Nitens</td>
<td>53.0</td>
<td>55.6</td>
<td>30.4</td>
<td>29.0</td>
</tr>
<tr>
<td>Maidenii</td>
<td>55.0</td>
<td>55.5</td>
<td>31.8</td>
<td>28.8</td>
</tr>
<tr>
<td>Globulus</td>
<td>56.2</td>
<td>“54.5”</td>
<td>31.9</td>
<td>27.4</td>
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</tbody>
</table>
## Chip carbohydrates and pulp yield

<table>
<thead>
<tr>
<th></th>
<th>Pulp yield %</th>
<th>% of total carbohydrates</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>8 yrs</td>
<td>11 yrs</td>
<td>Glucose</td>
<td>8 yrs</td>
<td>11 yrs</td>
</tr>
<tr>
<td>Nitens</td>
<td>53.0</td>
<td>55.6</td>
<td>69.9</td>
<td>70.2</td>
<td></td>
</tr>
<tr>
<td>Maidenii</td>
<td>55.0</td>
<td>55.5</td>
<td>73.9</td>
<td>73.6</td>
<td></td>
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<tr>
<td>Globulus</td>
<td>56.2</td>
<td>“54.5”</td>
<td>72.3</td>
<td>74.6</td>
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</table>
Handsheet bulk (or density)

"Critical eucalypt pulp quality determinant"
Acceptable handsheet density range for eucalypt laboratory pulps

~600 - ~650 kg/m³  
(@ 500 rev PFI mill)

Corresponding acceptable range for rewetted, bleached eucalypt market kraft

~560 - ~610 kg/m³  
(@ 500 rev PFI mill)
Tensile index versus sheet density

*E. globulus* aged 8 & 11 years

![Graph showing tensile index versus sheet density for *Eucalyptus globulus* aged 8 and 11 years.](image)
Tensile index versus sheet density

*E. globulus & E. nitens* aged 8 & 11 years

![Graph showing tensile index versus sheet density for *E. globulus* and *E. nitens* aged 8 and 11 years.](image)
Tensile index versus sheet density
**E. globulus** & **E. maidenii** aged 8 & 11 years

![Graph showing tensile index versus sheet density for **E. globulus** and **E. maidenii**.](image)
Eucalypt kraft pulps of premium quality

E. maidenii  aged 6 - 8 years

E. globulus aged 11+ years
Pulp quality
and
“Fibre dimensions”
Fibre property interrelationships
(Fibres dried and rewetted from handsheets)

Perimeter = 2 (width + thickness)
Wall area ∝ Coarseness
Width/thickness = Collapse
Perimeter/wall thickness ∝ 1/Density ∝ Collapse
## Important fibre property relationships

<table>
<thead>
<tr>
<th></th>
<th>Nitens 8 yrs</th>
<th>Nitens 11 yrs</th>
<th>Maidenii 8 yrs</th>
<th>Maidenii 11 yrs</th>
<th>Globulus 8 yrs</th>
<th>Globulus 11 yrs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Perimeter</td>
<td>38.8</td>
<td>40.4</td>
<td>40.7</td>
<td>42.9</td>
<td>40.6</td>
<td>40.4</td>
</tr>
<tr>
<td>Wall thickness</td>
<td>2.10</td>
<td>2.16</td>
<td>2.59</td>
<td>2.80</td>
<td>2.16</td>
<td>2.48</td>
</tr>
<tr>
<td>Collapse</td>
<td>2.18</td>
<td>2.14</td>
<td>1.81</td>
<td>1.83</td>
<td>2.07</td>
<td>1.81</td>
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</tbody>
</table>
## Kraft pulp quality determinants

<table>
<thead>
<tr>
<th></th>
<th>Nitens 8 yrs</th>
<th>Nitens 11 yrs</th>
<th>Maidenii 8 yrs</th>
<th>Maidenii 11 yrs</th>
<th>Globulus 8 yrs</th>
<th>Globulus 11 yrs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>0.82</td>
<td>0.88</td>
<td>0.88</td>
<td>0.94</td>
<td>0.85</td>
<td>0.85</td>
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<tr>
<td>Wall area</td>
<td>50</td>
<td>56</td>
<td>64</td>
<td>73</td>
<td>57</td>
<td>62</td>
</tr>
<tr>
<td>Collapse</td>
<td>2.18</td>
<td>2.14</td>
<td>1.81</td>
<td>1.83</td>
<td>2.07</td>
<td>1.81</td>
</tr>
<tr>
<td>Sheet density</td>
<td>751</td>
<td>735</td>
<td>607</td>
<td>566</td>
<td>704</td>
<td>629</td>
</tr>
</tbody>
</table>
Premium eucalypt fibres

*E. globulus* (11+ years) & *E. maidenii* (~6-8 years)

- Nitens
- Maidenii
- Globulus
## Summary

<table>
<thead>
<tr>
<th></th>
<th>Nitens 8 yrs</th>
<th>Nitens 11 yrs</th>
<th>Maidenii 8 yrs</th>
<th>Maidenii 11 yrs</th>
<th>Globulus 8 yrs</th>
<th>Globulus 11 yrs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chip density</td>
<td>X</td>
<td>X</td>
<td>Best</td>
<td>Best</td>
<td>Good</td>
<td>Good</td>
</tr>
<tr>
<td>Pulp yield</td>
<td>X</td>
<td>Good</td>
<td>Good</td>
<td>Good</td>
<td>Good</td>
<td>Good</td>
</tr>
<tr>
<td>Fibre length</td>
<td>Good</td>
<td>Good</td>
<td>Good</td>
<td>Good</td>
<td>Good</td>
<td>Good</td>
</tr>
<tr>
<td>Fibre quality</td>
<td>X</td>
<td>X</td>
<td>Good</td>
<td>X</td>
<td>x</td>
<td>Good</td>
</tr>
<tr>
<td>Pulp quality</td>
<td>X</td>
<td>X</td>
<td>Good</td>
<td>X</td>
<td>X</td>
<td>Good</td>
</tr>
</tbody>
</table>
Eucalypt kraft quality requirements for laboratory-made pulps

Sheet density range
≈600 - ≈650 kg/m³
(@ 500 rev PFI mill)

- Fibre length: ≈0.8 - ≈0.9 mm
- Fibre collapse: ≈1.8 - ≈1.9
- Appropriate fibre perimeter, wall thickness & wall area (coarseness) combination
Eucalypt kraft quality requirements for rewetted bleached market dry-lap

Sheet density range
~560 - ~610 kg/m³
(@ 500 rev PFI mill)

- Fibre length: ~0.65 - ~0.75 mm
- Fibre collapse: ~1.8 - ~1.9
- Appropriate fibre perimeter, wall thickness & wall area (coarseness) combination
Reference