Pulpwood Qualities of some Hardwood Species

Sven Lundgren
RISI - Wood Fibre Conference
15 February 2017
Da Nang
Vietnam

Content

- Introduction
- Cooking Yield
- Basic Wood Density
- Fibre Dimensions
- Pulp Quality Tests
- Wood Composition
- Summary
Pulpwood Qualities of some Hardwood Species
- Introduction

What is Pulpwood Qualities

- Propagation:
  - Growth rate
  - Wood density
  - Disease resistant, etc

- Kraft Pulping:
  - Viscosity
  - Brightness & reversion, etc

- Runnability:
  - Beating requirement
  - Wet web strength
  - Dewatering ability
  - Uniformity, etc

- Paper Product:
  - Opacity / Light scattering
  - Bulk / Density
  - Tensile & Tear index
  - Water absorption, etc
Pulpwood Qualities of some Hardwood Species
- Introduction

What affects pulp quality?

- Raw material
- Fibre processing
  - Chemistry
  - Mechanical
- The pulping process can at best preserve and maintain what goes in

20 - 30 %
70 – 80 %
Pulpwood Qualities of some Hardwood Species
- Introduction

General relation

- The Paper properties are related to the Physical wood fibre properties, such as:
  
  - Fibre length
  - Fibre coarseness

- Kraft Pulping performance are related to the Chemical composition of the wood, such as:
  
  - Lignin content
  - Lignin reactivity
Pulpwood Qualities of some Hardwood Species
- Introduction

Wood, Fiber & Paper Properties

- Raw Material
- Fibre Properties
- Paper Properties

- Fibre Length
- Coarseness
- Fibre Wall/Width
- Hemi-cellulose content

- Fibre Population
- Fibre Stiffness

- Formation
- Light Scattering/Opacity
- Drainage
- Bulk
- Refining Energy/Tensile
- Water Absorption
Pulpwood Qualities of some Hardwood Species
- Cooking Yield

Factors affecting Cooking Yield

- Wood Species
- Within a Wood Species
  - Type of clone
  - Growth area
  - Age of wood
- Cooking Process
Pulpwood Qualities of some Hardwood Species - Cooking Yield

Laboratory Cooking of E Globulus and E Nitens - Forico’s Tasmanian Plantations

Laboratory Cooking at Foricos Fibre Technology facility:
- Kappa 18 with fixed H-factor average of totally 135 samples up to late 2016

<table>
<thead>
<tr>
<th>Wood Specie</th>
<th>Samples</th>
<th>Wood Density kg BD/m3s wet</th>
<th>Total Yield %</th>
<th>AA Charge % NaOH</th>
</tr>
</thead>
<tbody>
<tr>
<td>E Globulus</td>
<td>35</td>
<td>546</td>
<td>56.4</td>
<td>16.0</td>
</tr>
<tr>
<td>E Nitens</td>
<td>100</td>
<td>476</td>
<td>54.0</td>
<td>16.9</td>
</tr>
</tbody>
</table>
Pulpwood Qualities of some Hardwood Species
- Cooking Yield

Laboratory Testing of Wood Samples
Laboratory Cooking at Forico’s Fibre Technology facility to Kappa 18 with fixed H-factor

<table>
<thead>
<tr>
<th>Wood Specie</th>
<th>Origin</th>
<th>Samples</th>
<th>Tree Age</th>
<th>Wood Density kg BD/m3s</th>
<th>Total Yield %</th>
<th>AA Charge % NaOH</th>
</tr>
</thead>
<tbody>
<tr>
<td>E Camaldulensis</td>
<td>Thailand</td>
<td>1</td>
<td>4</td>
<td>507</td>
<td>47.9</td>
<td>18.7</td>
</tr>
<tr>
<td>E Nitens</td>
<td>Chile</td>
<td>1</td>
<td>12</td>
<td>460</td>
<td>56.4</td>
<td>15.9</td>
</tr>
<tr>
<td>A Maernsii</td>
<td>Brazil</td>
<td>1</td>
<td>6</td>
<td>575</td>
<td>55.7</td>
<td>17.7</td>
</tr>
<tr>
<td>A Mangium Hybrid</td>
<td>Vietnam</td>
<td>1</td>
<td>4</td>
<td>489</td>
<td>53.3</td>
<td>18.3</td>
</tr>
</tbody>
</table>
Pulpwood Qualities of some Hardwood Species
- Cooking Yield & Basic Wood Density

Chilean E Globulus - Cooked to Kappa 15-16

Source: M. Peredo
Pulpwood Qualities of some Hardwood Species
- Cooking Yield & Basic Wood Density

Yield and Basic Density due to Age

Source: Forico Pty Limited
Pulpwood Qualities of some Hardwood Species
- Basic Wood Density

![Fibre Coarseness & Population vs Basic Density](image)

Source: Celso-foelkel
Pulpwood Qualities of some Hardwood Species
- Cooking Yield & Basic Wood Density

Tree Age
- Increasing Tree Age gives:
  - increasing Basic Wood Density
  - higher Cooking Yield
  - higher Fibre Coarseness

Basic Wood Density
- Increasing Basic Wood Density gives:
  - higher Fibre Coarseness
  - reduced Fibre Population
Pulpwood Qualities of some Hardwood Species
- Fibre Dimensions

Fibre Dimensions
Pulpwood Qualities of some Hardwood Species - Fibre Dimensions

Fibre Dimensions

- There are variations of fibre dimensions within a Wood Species
- Those variations are due to:
  - Individual Trees
  - Location in the tree
  - Age of the tree
  - Growth location
  - Growth conditions
  - Climate
  - Soil

The sampling and testing curse

- Testing a Tree instead of Testing a Forest
Pulpwood Qualities of some Hardwood Species
- Fibre Dimensions

Fibre Measurement – Kajaani FS 200/300
- Fibre Length & Fibre Coarseness

- Average Fibre Length:
  - Arithmetic
  - Length weighted distribution
  - Weight weighted distribution

- Fibre Coarseness:
  - weight of Fibre per meter in µg/m (mg/100m)

- Fibre Population:
  - Length weighted Fibre Length and Coarseness

- Fibres / g:
  - Arithmetic calculation

- Fines definition:
  - Fibres with < 0.2 mm length

- Fines amount:
  - usually about 10 % of number of Fibres and about 2 % of total Fibre Length
Pulpwood Qualities of some Hardwood Species
- Fibre Dimensions

Fibre Wall Thickness – Fibre Coarseness

Low Coarseness
Thin-walled

High Coarseness
Thick-walled

Collapse susceptibility

Collapse resistance

More bonding
Higher Tensile Index
Less Bulk
Surface softness
Higher Light Scattering

Less bonding
Lower Tensile Index
More Bulk
Rougher
Lower Light Scattering
# Pulpwood Qualities of some Hardwood Species - Fibre Dimensions

## Comparison – Bleached Hardwood Pulp

<table>
<thead>
<tr>
<th>Wood Specie</th>
<th>Fibre Length mm</th>
<th>Fibre Coarseness µg / m</th>
<th>Fibre Population million / g pulp</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canadian Birch</td>
<td>1.11</td>
<td>124</td>
<td>7.3</td>
</tr>
<tr>
<td>US South HW</td>
<td>0.94</td>
<td>119</td>
<td>8.9</td>
</tr>
<tr>
<td>Scandinavian Birch</td>
<td>0.91</td>
<td>108</td>
<td>10.2</td>
</tr>
<tr>
<td>Canadian Aspen</td>
<td>0.75</td>
<td>103</td>
<td>12.9</td>
</tr>
<tr>
<td>Brazilian Eucalyptus</td>
<td>0.72</td>
<td>74.5</td>
<td>18.6</td>
</tr>
<tr>
<td>Acacia</td>
<td>0.66</td>
<td>70.8</td>
<td>21.4</td>
</tr>
</tbody>
</table>

Source: Cincinnati University
Pulpwood Qualities of some Hardwood Species
- Fibre Dimensions

- Comparison HW pulps

Fibre Population vs Fibre Coarseness

- Bulk & Stiffness improves

- Opacity & Formation improves

![Graph showing fibre population vs fibre coarseness for various species]

- Acacia
- Braz Euc
- Aspen
- Scan Birch
- US South HW
- Can Birch

Opacity & Formation improves as fibre coarseness increases.

Bulk & Stiffness improves as fibre population decreases.
## Pulpwood Qualities of some Hardwood Species - Fibre Dimensions

### Comparison - Eucalyptus

<table>
<thead>
<tr>
<th></th>
<th>Unit</th>
<th>camal</th>
<th>dulenis</th>
<th>rudis</th>
<th>resini</th>
<th>fer</th>
<th>propi</th>
<th>nqua</th>
<th>siderox</th>
<th>ylan</th>
<th>botryo</th>
<th>dis</th>
<th>vimin</th>
<th>alis</th>
<th>macul</th>
<th>ata</th>
<th>saliga</th>
<th>grandis</th>
<th>ovata</th>
<th>globulus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>µm</td>
<td>569</td>
<td>626</td>
<td>629</td>
<td>614</td>
<td>568</td>
<td>719</td>
<td>598</td>
<td>748</td>
<td>708</td>
<td>759</td>
<td>608</td>
<td>727</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coarseness</td>
<td>µg/m</td>
<td>68</td>
<td>60</td>
<td>57</td>
<td>76</td>
<td>59</td>
<td>63</td>
<td>46</td>
<td>84</td>
<td>66</td>
<td>61</td>
<td>59</td>
<td>67</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fibre Population</td>
<td>Million/g</td>
<td>25.8</td>
<td>26.6</td>
<td>27.9</td>
<td>21.4</td>
<td>29.8</td>
<td>22.1</td>
<td>36.4</td>
<td>15.9</td>
<td>21.4</td>
<td>21.6</td>
<td>27.9</td>
<td>20.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Width</td>
<td>µm</td>
<td>19.7</td>
<td>19.2</td>
<td>19.3</td>
<td>18.8</td>
<td>16.8</td>
<td>19.6</td>
<td>18.8</td>
<td>18.0</td>
<td>19.6</td>
<td>18.9</td>
<td>19.4</td>
<td>18.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: D. Nevia
Pulpwood Qualities of some Hardwood Species
- Fibre Dimensions

Eucalyptus

Bulk & Stiffness improves

Opacity & Formation improves

Fibre Population vs Coarseness

Fibre Population million / g vs Fibre Coarseness µg / m

Sven Lundgren
# Pulpwood Qualities of some Hardwood Species
## - Fibre Dimensions

## E. Nitens Samples from Forico’s Tasmanian Plantations

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fibre Length</strong> mm</td>
<td>0.67</td>
<td>0.66</td>
<td>0.74</td>
<td>0.71</td>
<td>0.83</td>
<td>0.84</td>
<td>0.72</td>
<td>0.84</td>
<td>0.85</td>
<td>0.80</td>
<td>0.81</td>
<td>0.71</td>
</tr>
<tr>
<td><strong>Fibre Coarseness</strong> µm</td>
<td>62</td>
<td>64</td>
<td>68</td>
<td>68</td>
<td>55</td>
<td>54</td>
<td>60</td>
<td>64</td>
<td>57</td>
<td>57</td>
<td>71</td>
<td>65</td>
</tr>
<tr>
<td><strong>Fibre Population</strong> million/g</td>
<td>24.1</td>
<td>23.7</td>
<td>19.9</td>
<td>20.7</td>
<td>21.9</td>
<td>22.0</td>
<td>23.1</td>
<td>18.6</td>
<td>20.6</td>
<td>21.9</td>
<td>17.4</td>
<td>23.5</td>
</tr>
</tbody>
</table>

Source: Forico Pty Limited
Pulpwood Qualities of some Hardwood Species - Fibre Dimensions

E Globulus samples - Australia

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Fibre Lengths mm</td>
<td>0.80</td>
<td>0.9</td>
<td>0.85</td>
<td>0.87</td>
<td>0.88</td>
<td>0.88</td>
<td>0.91</td>
</tr>
<tr>
<td>Fibre Coarseness μg/m</td>
<td>74</td>
<td>80</td>
<td>76</td>
<td>76</td>
<td>70</td>
<td>70</td>
<td>75</td>
</tr>
<tr>
<td>Fibre Population million/g</td>
<td>16.9</td>
<td>13.9</td>
<td>15.5</td>
<td>15.1</td>
<td>16.2</td>
<td>16.2</td>
<td>15.3</td>
</tr>
</tbody>
</table>

Source: Forico Pty Limited
Pulpwood Qualities of some Hardwood Species
- Fibre Dimensions

Fibre Coarseness & Population
- E Nitens & E Globulus - Forico Plantation

<table>
<thead>
<tr>
<th>Wood Specie:</th>
<th>E Globulus</th>
<th>E Nitens</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fibre Coarseness:</td>
<td>74.4</td>
<td>62.1 µg / m</td>
</tr>
<tr>
<td>Fibres:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Population:</td>
<td>15.6</td>
<td>20.9 million / g</td>
</tr>
</tbody>
</table>

E Nitens: + 33 % Fibre Population than E Globulus

better Light Scattering / Opacity
Pulpwood Qualities of some Hardwood Species
- Fibre Dimensions

**Fibre Coarseness & Fibre Length – Variation or Spread**

<table>
<thead>
<tr>
<th>Fibre Coarseness</th>
<th>Samples</th>
<th>Avg</th>
<th>Max Value</th>
<th>%</th>
<th>Min Value</th>
<th>%</th>
<th>+/- 10%</th>
</tr>
</thead>
<tbody>
<tr>
<td>E Nitens</td>
<td>12</td>
<td>62.1</td>
<td>71</td>
<td>+ 14.3%</td>
<td>54</td>
<td>- 13.0%</td>
<td>75%</td>
</tr>
<tr>
<td>E Globulus</td>
<td>7</td>
<td>74.4</td>
<td>80</td>
<td>+ 7.5%</td>
<td>70</td>
<td>- 5.6%</td>
<td>100%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Fibre Length</th>
<th>Samples</th>
<th>Avg</th>
<th>Max Value</th>
<th>%</th>
<th>Min Value</th>
<th>%</th>
<th>+/- 10%</th>
</tr>
</thead>
<tbody>
<tr>
<td>E Nitens</td>
<td>12</td>
<td>0.77</td>
<td>0.84</td>
<td>+ 9.1%</td>
<td>0.55</td>
<td>- 14.3%</td>
<td>83%</td>
</tr>
<tr>
<td>E Globulus</td>
<td>7</td>
<td>0.87</td>
<td>0.91</td>
<td>+ 4.6%</td>
<td>0.80</td>
<td>- 8.0%</td>
<td>100%</td>
</tr>
</tbody>
</table>
# Pulpwood Qualities of some Hardwood Species - Fibre Dimensions

**Fibre Measurement – Kajaani FS 200/300**

<table>
<thead>
<tr>
<th>Wood Species</th>
<th>Fines %</th>
<th>Fibre Length mm</th>
<th>Fibre Coarseness µg/m</th>
<th>Fibre Population million/g</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Numeric</td>
<td>Length Weighted</td>
<td>Arithmetic Weighted</td>
<td>Weighted</td>
</tr>
<tr>
<td>E Nitens Chile</td>
<td>8.31</td>
<td>1.23</td>
<td>0.70</td>
<td>0.87</td>
</tr>
<tr>
<td>E Camaldulensis</td>
<td>10.33</td>
<td>1.69</td>
<td>0.61</td>
<td>0.76</td>
</tr>
<tr>
<td>A Mearnsii</td>
<td>11.54</td>
<td>2.01</td>
<td>0.63</td>
<td>0.80</td>
</tr>
<tr>
<td>A Mangium Hybrid</td>
<td>8.75</td>
<td>1.55</td>
<td>0.66</td>
<td>0.83</td>
</tr>
</tbody>
</table>
Pulpwood Qualities of some Hardwood Species
- Fibre Dimensions

Comparison - Tested Wood Species

 opacity & formation improves

Bulk & Stiffness improves
# Pulpwood Qualities of some Hardwood Species
## Fibre Dimensions

### Comparison – Acacias

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Fibre Length</td>
<td>mm</td>
<td>0.67</td>
<td>0.65</td>
<td>0.77</td>
<td>0.83</td>
<td>0.66</td>
<td>0.65</td>
<td>0.60</td>
<td>0.80</td>
</tr>
<tr>
<td>Coarseness</td>
<td>µg/m</td>
<td>66</td>
<td>46</td>
<td>62</td>
<td>61</td>
<td>64</td>
<td>66</td>
<td>60</td>
<td>71.5</td>
</tr>
<tr>
<td>Fibre Population</td>
<td>Million/g</td>
<td>22.6</td>
<td>33.4</td>
<td>21.0</td>
<td>19.9</td>
<td>23.7</td>
<td>23.3</td>
<td>25.3</td>
<td>17.5</td>
</tr>
</tbody>
</table>

**Musi Pulp**

Source: * K Watanabe, Nippon Paper Ind.  
** U-B Mohlin, STFI, *** Valmet, **** A Santos
Pulpwood Qualities of some Hardwood Species
- Fibre Dimensions

- Comparison Acacias
Pulpwood Qualities of some Hardwood Species
- Fibre Dimensions
- Light Scattering Coef. vs Fibre Coarseness
  Un-refined Pulp

\[ y = -0.1932x + 47.344 \]
\[ R^2 = 0.7225 \]

Acacia Magium Hybrid
4 years
Pulpwood Qualities of some Hardwood Species
- Fibre Dimensions

- Bulk vs Fibre Coarseness – Un-refined Pulp

\[ y = 0.0224x + 0.1549 \]
\[ R^2 = 0.8608 \]
Pulpwood Qualities of some Hardwood Species
- Fibre Dimensions

- Light Scattering at Tensile Index 70 Nm/g vs Fibre Coarseness
- Bulk at Tensile Index 70 Nm/g vs Fibre Coarseness / Fibre width for 5 Eucalyptus species

Source: U Jansson, StoraEnso
Pulpwood Qualities of some Hardwood Species
- Pulp Quality Tests

Pulp Quality Tests
- Un-bleached Pulp
- Standardised Laboratory Procedure

The Paper Properties testing data from Forico’s Fibre Technology facility are used to create regression lines
Pulpwood Qualities of some Hardwood Species - Pulp Quality Tests

Tested Wood Species at Forico Fibre Technology Laboratory

<table>
<thead>
<tr>
<th>Wood Species</th>
<th>Samples</th>
<th>Origin</th>
<th>Tree Age</th>
</tr>
</thead>
<tbody>
<tr>
<td>E Nitens</td>
<td>~10</td>
<td>Australia / Tasmania</td>
<td>~15</td>
</tr>
<tr>
<td>E Globulus</td>
<td>~5</td>
<td>Australia</td>
<td>~13 -15</td>
</tr>
<tr>
<td>E Nitens</td>
<td>1</td>
<td>Chile</td>
<td>12</td>
</tr>
<tr>
<td>E Camaldulensis</td>
<td>1</td>
<td>Thailand</td>
<td>4</td>
</tr>
<tr>
<td>A Mearnsii</td>
<td>1</td>
<td>Brazil</td>
<td>6</td>
</tr>
<tr>
<td>A Mangium Hybrid</td>
<td>1</td>
<td>Vietnam</td>
<td>4</td>
</tr>
</tbody>
</table>
# Pulpwood Qualities of some Hardwood Species
- Pulp Quality Tests

## Paper Properties Comparisons - Un-bleached pulp

<table>
<thead>
<tr>
<th>Comparison</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wood Species</td>
<td>E Globulus vs E Nitens</td>
<td>E Nitens vs E Nitens Chile</td>
<td>E Globulus vs A Mangium Hybrid A Mearnsii E Camaldulensis</td>
</tr>
</tbody>
</table>

Sven Lundgren
Pulpwood Qualities of some Hardwood Species
- Pulp Quality Tests

Paper Properties - Hardwood Pulps

- The Tear-Tensile Index relation is not an important parameter for Hardwood pulps as it’s normal printing & writing applications are not too demanding on strength. However, always used.

- Light Scattering / Opacity and Bulk are more important parameters for Hardwood pulps in printing & writing paper applications

- Tensile Index development on Beating indicate refining behaviour

- Comparison usually made at a Tensile Index ~ 70 Nm/g. That is the level usually refined to at the Paper Machine
Pulpwood Qualities of some Hardwood Species

Tensile Index vs Beating

- E Nitens
- E Globulus

Tensile Index Nm/g

Beating revs/g
Pulpwood Qualities of some Hardwood Species

Tear Index vs Tensile Index

E Nitens  E Globulus

- Tear Index mNm^2/g
- Tensile Index Nm/g

Graph shows the relationship between Tear Index and Tensile Index for E Nitens and E Globulus, with peaks at different points for each species.
Pulpwood Qualities of some Hardwood Species

Bulk vs Tensile Index

- E Nitens
- E Globulus
Pulpwood Qualities of some Hardwood Species

**Light Scattering Coef. vs Tensile Index**

- Red line: E Nitens
- Blue line: E Globulus

<table>
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<th>Light Scattering Coef. m²/kg</th>
<th>Tensile Index Nm/g</th>
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</table>
Pulpwood Qualities of some Hardwood Species

**Light Scattering Coef. vs Bulk**

- **E Nitens**
- **E Globulus**
Pulpwood Qualities of some Hardwood Species
Pulpwood Qualities of some Hardwood Species

Light Scattering Coef. vs Tensile Index

- E Nitens
- E Nitens Chile

![Graph showing Light Scattering Coef. vs Tensile Index for E Nitens and E Nitens Chile](image)
Pulpwood Qualities of some Hardwood Species
Pulpwood Qualities of some Hardwood Species

Tensile Index vs Beating

- E Globulus
- E Camaldulensis
- A Mearnsii
- A Mangium Hybrid

Tensile Index Nm/g vs Beatning rev/g
Pulpwood Qualities of some Hardwood Species

![Graph showing Tear Index vs Tensile Index](graph.png)
Pulpwood Qualities of some Hardwood Species

Bulk vs Tensile Index

- E Globulus
- E Camaldulensis
- A Mearnsii
- A Mangium Hybrid

Bulk cm³/g vs Tensile Index Nm/g
Pulpwood Qualities of some Hardwood Species

![Light Scattering Coef. vs Tensile Index Graph]

- **E Globulus**
- **E Camaldulensis**
- **A Mearnsii**
- **A Mangium Hybrid**

Sven Lundgren
Pulpwood Qualities of some Hardwood Species
- Pulp Quality Tests

Comments

- E Nitens develop Tensile Index fast – easy to refine
- E Globulus have better Bulk at given Tensile Index
- E Nitens have better Light Scattering Coefficient / Opacity at given Tensile Index and Bulk
- E Nitens and E Nitens Chile have the same Paper Properties
- A Mearnsii have lower Bulk than expected from it’s Fibre Coarseness
- A Mangium Hybrid and E Camaldulensis have good Light Scattering Coef. / Opacity probably due to very young wood (both 4 years) with low Fibre Coarseness
- Test your wood raw material and wood species
Pulpwood Qualities of some Hardwood Species
- Wood Composition

▶ **Wood Composition**
  - Cellulose
  - Hemi-cellulose
  - Lignin
  - Extractives

▶ The difference in Cooking Time, Cooking Temperature and AA charges can **not** be explained by the difference in Lignin content between different Hardwood species
Pulpwood Qualities of some Hardwood Species
- Wood Composition

**Lignin - Structural Units**

- All Lignin consist of mainly 3 Structural Units: H, G and S
- Eucalyptus Globulus:
  - Range S/G ratio: 4.4 – 7.1
  - Average S/G ratio: 5.5
- For Hardwood species the amount of the Structural Units in the Lignin vary considerably between the wood species
- For Softwood species the amount of the Structural Units in the Lignin vary little between the wood species

Source. J Colodette
Pulpwood Qualities of some Hardwood Species
- Wood Composition

Lignin Content & S/G Ratio - Eucalyptus

Source: J. Colodette
Pulpwood Qualities of some Hardwood Species
- Wood Composition

S/G Ratio, Lignin content & AA consumption
– some Hardwoods

► **Acacia** - Aucruliformis
   - Mearnsii
   - Mangium x 7
   - Hybrids x 6

► **Eucalyptus** - Camaldulensis x 2
   - Dunnii
   - Globulus x 2
   - Grandis x 3
   - Nitens x 2
   - Urophylla
   - Hybrid

**Definitions**

► Kappa number: an analytical measurement of remaining ‘Lignin’ content in pulps
► Klason Lignin: a measurement of Lignin content in wood that do not include Acid-soluble Lignin
► Total Lignin: Klason Lignin + Acid Soluble Lignin

Sven Lundgren
Pulpwood Qualities of some Hardwood Species
- Wood Composition

Source: Y. Matsumoto

Increasing S/G ratio

Source: Sven Lundgren
Pulpwood Qualities of some Hardwood Species - Wood Composition

Syringyl ratio vs acid soluble lignin (content)

Source: Y. Matsumoto
Pulpwood Qualities of some Hardwood Species - Wood Composition

**Syringyl ratio vs Lignin content**

- S/(S+G) = 0.67, S/G = 2
- S/(S+G) = 0.8, S/G = 4

Source: Y. Matsumoto

Sven Lundgren
Pulpwood Qualities of some Hardwood Species - Wood Composition

Source: Y. Matsumoto

S/V ratio vs pulpability (acacias and eucalyptus)

Consumption of active alkali at Kappa 19

S/G ratio

Cooperative research with Oji Paper Company
Pulpwood Qualities of some Hardwood Species
- Wood Composition

Lignin - Content and Reactivity

- S/G ratio correlates directly with Lignin Content and Lignin Reactivity for Eucalyptus and Acacias
  - Lower S/G ratio: 
    - higher Lignin Content
    - lower Reactivity
  - Higher S/G ratio: 
    - lower Lignin Content
    - higher Reactivity

- A Mangium consumes ~ 30% more Active Alkali than E Globulus / E Nitens during Kraft Cooking to reach Kappa 19

Source: Y. Matsumoto
Pulpwood Qualities of some Hardwood Species
- Wood Composition

S/G Ratio

- Lignin content, composition S, G, H and S/G ratio for the following Hardwood species:
  - E Globulus
  - E Camaldulensis
  - E Nitens
  - E Maidenii
  - E Grandis
  - E Dunnii
  - E Urograndis
  - E Pellita
  - A Mangium
  - A Mearnsii
  - A Auricuriformis
  - A Hybrid

- Limited references on some of the wood species

- Hardwood species ranked in falling average S/G ratio
### Pulpwood Qualities of some Hardwood Species - Wood Composition

<table>
<thead>
<tr>
<th>Wood Specie</th>
<th>Lignin %</th>
<th>S %</th>
<th>G %</th>
<th>H %</th>
<th>S/G</th>
<th>S/G Avg.</th>
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# Pulpwood Qualities of some Hardwood Species - Wood Composition

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<th>Wood Specie</th>
<th>Lignin %</th>
<th>S %</th>
<th>G %</th>
<th>H %</th>
<th>S/G</th>
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Pulpwood Qualities of some Hardwood Species  
- Wood Composition

Based on the S/G ratio the Hardwood species can be grouped as below

<table>
<thead>
<tr>
<th>S/G ratio</th>
<th>&lt; 2 Low S/G</th>
<th>2 – 4 Medium S/G</th>
<th>≥ 4 High S/G</th>
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<tr>
<td></td>
<td>A Auricuriformis</td>
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</table>
Pulpwood Qualities of some Hardwood Species - Wood Composition

Source: R. B. Santos

Delignification rate (1/min x 100) and S/G ratio

Delign. Rate
S/G ratio
FPulpwood Qualities of some Hardwood Species
- Wood Composition

**Delignification rate (1/min×100) vs S/G ratio**

\[ y = 0.7407x + 0.6254 \]

\[ R^2 = 0.9392 \]

Source: R. B. Santos
**Pulpwood Qualities of some Hardwood Species**

- **Wood Composition**

**S/G ratio importance**

- The S/G ratio defines the Lignin reactivity for Hardwood species which explains the difference in pulping conditions between the wood species

**High S/G ratio**

- Easy to de-lignify (Easy to Cook):  
  - Low Cooking Temperature
  - Short Retention Time
  - Low AA / EA charge

- Good Bleachability

- Very suitable for Dissolving pulping
Pulpwood Qualities of some Hardwood Species
- Wood Composition

Cooking of mixed Wood Species

- The S/G ratio should be not too far apart for the respective wood species

- S/G ratio correlates to the different cooking time and temperature to reach the desired Kappa number for the respective wood species

- Any given reaction rate doubles for every 8 - 10 °C temperature increase

- Similar S/G ratio is to avoid Over or Under - Cooking of the respectively wood species
Pulpwood Qualities of some Hardwood Species
- Summary

Summary

- Important Paper properties for Hardwoods
  - Light Scattering / Opacity and Bulk are contradictory

- Fibre Coarseness is a very informative parameter

- The Lignin chemical structure expressed as S/G ratio for Hardwoods defines the Lignin reactivity which influences:
  - Alkali consumption during cooking
  - Cooking time & temperature
  - Chemical consumption during bleaching

- Hardwoods with High S/G ratio are easy to de-lignify

- Test your wood raw material and get to know your wood species and how they interrelate
Pulpwood Qualities of some Hardwood Species

Thank you!

- Sven Lundgren
- Process & Project

- sven.a.lundgren@outlook.com
- +46 70 661 6978