Chemical composition of jute (Corchorus capsularis) fibers used for paper pulp manufacturing

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Raw materials for papermaking

Wood
- Conifers (pine, spruce, etc.)
- Hardwoods (eucalypt, birch, aspen, etc.)

Herbaceous plants
- Flax crop (wheat straw, bagasse, etc.)

The main raw material for paper pulp manufacturing in developed countries

In developed countries are used for manufacturing specialty papers
Applications of nonwood fibers

Specialty papers include tea bags, filter papers, decorative papers, cigarette papers, bank notes, security papers…
Nonwood fibers from herbaceous plants

Flax (*Linum usitatissimum*)

Hemp (*Cannabis sativa*)

Kenaf (*Hibiscus cannabinus*)

Jute (*Corchorus capsularis*)

Sisal (*Agave sisalana*)

Abaca (*Musa textilis*)
Green jute stem

Jute (Corchorus capsularis)
Jute sticks

Jute fibers
Applications of jute fibers

carpets
ropes
bags
yarns
coasters
Applications of jute fibers

- carpets
- ropes
- bags
- yarns
- coasters
Due to its porosity, this material can be used for applications like special filters for tea bags or high porosity cigarette papers.
The aim of this work is the chemical characterization of jute (Corchorus capsularis) fibers used for manufacturing of high quality paper pulp, in order to improve the industrial processes in which they are used as raw materials...
Composition of lignocellulosic materials

- **Celullose**
- **Hemicelluloses**
- **Lignin**
- **Lipids**
with special emphasis in...

... the LIPIDS (responsible for pitch deposition) ...

... and LIGNIN (influences delignification and pulp yield) ...
Very low ash content, in contrast to other herbaceous fibers such as rice straw (18.2%) or wheat straw (6.9%).

According the general chemical composition, *a priori*, jute fibers seem suitable for paper pulp manufacturing.

### General composition of jute bast fibers

<table>
<thead>
<tr>
<th>Component</th>
<th>(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Holocellulose</td>
<td>81.6</td>
</tr>
<tr>
<td>α-cellulose</td>
<td>61.0</td>
</tr>
<tr>
<td>Hydrosolubles</td>
<td>1.0</td>
</tr>
<tr>
<td>Klason lignin</td>
<td>13.3</td>
</tr>
<tr>
<td>Acid-soluble lignin</td>
<td>2.8</td>
</tr>
<tr>
<td>Lipophilic Extractives</td>
<td>0.4</td>
</tr>
<tr>
<td>Ash</td>
<td>1.0</td>
</tr>
</tbody>
</table>

**Lignin structure**

**Composition of lipids**

High content on polysaccharides and low lignin and extractives content.

Very low ash content.
Lipid composition

Jute (Corchorus capsularis) fibers

GC/MS

Retention time (min)

Retention time (min)
Lipid composition

Jute (Corchorus capsularis) fibers

GC/MS

Retention time (min)

Campesterol

Stigmasterol

Sitosterol

Bauerenone

Isomultiflorenone

Epoxydammarane
Distribution of the main aliphatic series identified in the extracts of jute fibers

**n-Alkanes**

**Waxes**

**Free n-Fatty acids**

**Free n-Fatty alcohols**
## Composition and abundance of the lipophilics in the extracts of jute fibers

<table>
<thead>
<tr>
<th>Series of Compounds</th>
<th>Abundance (mg/Kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>n-Alkanes</td>
<td>48.5</td>
</tr>
<tr>
<td>n-Fatty acids</td>
<td>130.2</td>
</tr>
<tr>
<td>α-Hydroxyfatty acids</td>
<td>102.8</td>
</tr>
<tr>
<td>ω-Hydroxyfatty acids</td>
<td>34.5</td>
</tr>
<tr>
<td>n-Fatty alcohols</td>
<td>127.0</td>
</tr>
<tr>
<td>Steroid hydrocarbons</td>
<td>16.1</td>
</tr>
<tr>
<td>Sterols</td>
<td>43.4</td>
</tr>
<tr>
<td>Epoxydammarane-type triterpenoids</td>
<td>64.8</td>
</tr>
<tr>
<td>Tocopherols</td>
<td>3.1</td>
</tr>
<tr>
<td>Steroid/triterpenoid ketones</td>
<td>25.1</td>
</tr>
<tr>
<td>Steryl glycosides</td>
<td>8.4</td>
</tr>
<tr>
<td>Ester waxes</td>
<td>181.2</td>
</tr>
<tr>
<td>Monoglycerides</td>
<td>7.5</td>
</tr>
<tr>
<td>Diglycerides</td>
<td>13.5</td>
</tr>
</tbody>
</table>

Predominance of high molecular weight ester waxes! Predominance of fatty acids, including α- and ω-hydroxyfatty acids! Low content of free and conjugated sterols!
The low amounts of neutrals in jute fibers, particularly the low abundances of free and conjugated sterols, which have a high propensity to form pitch deposits, would point to a low pitch deposition tendency of the lipophilics from jute.
Lignin composition

Klason lignin content: 13.3%

Jute (Corchorus capsularis) fibers

Ball-milled fiber

Dioxane/water extraction

MWL lignin

\[ \text{Py-GC/MS (H:G:S)} \]

\[ \text{Björkman protocol} \]

2D-NMR (inter-unit linkages, H:G:S)

Thioacidolysis (linkages, units involved)
Lignin composition

Jute (Corchorus capsularis) fibers

carbohydrates

Py-GC/MS

% H 2
% G 32
% S 66
S/G 2.1

levogluicosane

jute lignin similar to a hardwood lignin!
(a) 

(b)
(a) 

(b) 

\[ S'_{2,6}, S''_{2,6}, S'_{2,6}, G_{2}, G_{5}, G_{6}, S' \]
Structural characteristics from integration of signals in the HSQC spectra of the MWL from jute (*C. capsularis*) fibers

<table>
<thead>
<tr>
<th>Linkage relative abundance (% of side-chains involved)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>β-O-4' linked units (A/A')</td>
<td>72</td>
</tr>
<tr>
<td>Resinols (B)</td>
<td>16</td>
</tr>
<tr>
<td>Phenylcoumarans (C)</td>
<td>4</td>
</tr>
<tr>
<td>Spirodieneones (D)</td>
<td>4</td>
</tr>
<tr>
<td>p-Hydroxycinnamyl alcohols (F)</td>
<td>4</td>
</tr>
</tbody>
</table>

**Erythro/threo ratio**

3.5

**Percentage of γ-acetylation**

4

**S/G ratio**

2.0

- High content of β-O-4′ aryl ether linkages
- High S/G ratio

Advantageous for delignification

Jute lignin very similar to that in eucalypt wood !!!
Thioacidolysis (followed by Raney Ni desulphurization)

Monomers

Dimers

Retention time (minutes)
Relative molar percentages of the different dimer types released after thioacidolysis and Raney-nickel desulphuration of jute MWL

<table>
<thead>
<tr>
<th></th>
<th>5-5'</th>
<th>4-O-5'</th>
<th>β-1'</th>
<th>β-5'</th>
<th>β-β'</th>
<th>β-1'/α-O-α'</th>
</tr>
</thead>
<tbody>
<tr>
<td>GG</td>
<td>GG</td>
<td>SG</td>
<td>GG</td>
<td>SG</td>
<td>SS</td>
<td>GG</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>4</td>
<td>8</td>
<td>2</td>
<td>4</td>
<td>9</td>
</tr>
<tr>
<td>GG</td>
<td>GG</td>
<td>SG</td>
<td>SS</td>
<td>GG</td>
<td>SG</td>
<td>SS</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>17</td>
<td>4</td>
<td>31</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>GG</td>
<td>SG</td>
<td>SS</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>1</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Resinol structures are made almost exclusively of syringaresinol, pinoresinol being completely absent!

(similar results found in eucalypt lignin, Rencoret et al. 2008 Holzforschung, 62:514)
Lignin trimers identified among the thioacidolysis products (after Raney Ni desulphurization)

S-β-β'-S'-4'-O-5''-G'' linkages

Reconstructed Ion Chromatogram (sum of ions at m/z 532 and m/z 696, from tetralin dimers and trimers)
Main Conclusions

- High content of holocellulose (and α-cellulose) and low content of ash, appropriate raw material for pulp and papermaking!

- Low lipid content, low content of neutrals, in particular free and conjugated sterols, low pitch deposition tendency!

- Low lignin content, with high S/G ratio, a high abundance of β-O-4 linkages and a low content of condensed structures, easily delignifiable!

Jute fiber is an excellent raw material for pulp and papermaking!
CONCLUDING REMARKS

The chemical characterization of these fibers offers valuable information for improving the cooking and bleaching processes. This knowledge will contribute to a better sustainable industrial utilization of this interesting lignocellulosic material of important socioeconomic interest.
PostDoc Position available

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