Hemp fibers for production of speciality paper and board grades

Janja Zule, Marjeta Černič, Matej Šuštaršič

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Papermaking fibers

Origin

- **Softwood** - spruce, fir, pine
- **Hardwood** - eucalyptus, aspen, birch
- **Annual plants** – hemp, flax, kenaf, bagasse, cotton, straw

Properties

- morphological
- chemical
- physical, mechanical
- optical
HEMP fibers in papermaking

• the oldest surviving piece of paper from hemp – China (140 – 87 B.C.)

• the first European papermaking in the 16th century

• until the 19th century - rags (hemp and flax fibers)

• growing need for paper - rag supply insufficient

• exploitation of wood – abundant and cheap

• today, only about 5% of world’s paper is made from annual plants (hemp, flax, …)
HEMP fibers in papermaking

- renewed interest in hemp – environmental reasons

- excessive deforestation
  (TREES - oxygen supply, CO$_2$ removal, natural balance)

- 1 t of PAPER – 3 t of WOOD - up to 17 TREES

- HEMP has about 4 times higher yield / hectare compared to TREES (20 years)

- TREES need 50-100 years to grow, HEMP can be cultivated in 100 days
# HEMP fibers in papermaking

<table>
<thead>
<tr>
<th></th>
<th>Hemp bast</th>
<th>Hemp core</th>
</tr>
</thead>
<tbody>
<tr>
<td>cellulose</td>
<td>70 %</td>
<td>35 %</td>
</tr>
<tr>
<td>hemicellulose</td>
<td>15 %</td>
<td>35 %</td>
</tr>
<tr>
<td>lignin</td>
<td>5 %</td>
<td>23 %</td>
</tr>
<tr>
<td>length, mm</td>
<td>5 - 40</td>
<td>0,5</td>
</tr>
<tr>
<td>diameter, µm</td>
<td>25 - 50</td>
<td>22</td>
</tr>
<tr>
<td>thickness, µm</td>
<td>10 - 25</td>
<td>1,4</td>
</tr>
</tbody>
</table>
HEMP fibers in papermaking

- hemp bast
- hemp core
- long fibers
- short fibers
# HEMP fibers – characteristics

<table>
<thead>
<tr>
<th></th>
<th>WOOD</th>
<th>HEMP</th>
</tr>
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<tbody>
<tr>
<td>cellulose</td>
<td>40 – 50 %</td>
<td>70 %</td>
</tr>
<tr>
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<td>25 – 35 %</td>
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<table>
<thead>
<tr>
<th>Fibers</th>
<th>SW</th>
<th>HW</th>
</tr>
</thead>
<tbody>
<tr>
<td>length, mm</td>
<td>3 - 6</td>
<td>(0,5 - 1,8)</td>
</tr>
<tr>
<td>diameter, µm</td>
<td>25 - 45</td>
<td>(10 - 36)</td>
</tr>
<tr>
<td>thickness, µm</td>
<td>2 - 5</td>
<td>(3 - 6)</td>
</tr>
</tbody>
</table>
HEMP fibers in papermaking

- **bleaching** possible by environmentally friendly procedures (ozone, hydrogen peroxyde, oxygen)
- **less energy** needed for paper production compared to wood
- **paper resistant against ageing** (no change of colour, mechanical and chemical properties over centuries)
- **1 t of HEMP paper preserves 12 TREES!!!**
HEMP fibers in papermaking

- hemp pulp mill 5000 t/year – wood pulp mill 250,000 t/year

- expensive production – small capacities

- hemp is harvested once a year
  (storage needed, manual work with bundles, high costs)
HEMP pulping technology

- long hemp bast fibers are processed

- bales → digester, water is added (5 to 10 times fiber weight), cooking chemicals (NaOH, Na$_2$SO$_3$, ...)

- digestion – up to 8 h, 175°C

- separation of fibers and washing → clean fibers

- beating (12 h) and bleaching → fibers ready for PAPERMAKING

- processing time (20 h) – costly equipment, expensive handling
Novel pulping techniques for annual plants

- pulp production without chemicals
  (high output, no pollution, low energy demand, low investment costs, cheap and easy to operate price)

- HEMP PULP (ultrasound technology)
  dr. Zsolt Nemeth – University of Budapest

- Pulp and Paper Institute Ljubljana
  (some preliminary tests were performed)
  - microscopy
  - mechanical testing (fiber characteristics)
  - chemical testing
Ultrasonic (or hydrodynamic) cavitation
Ultrasonic (or hydrodynamic) cavitation

- **cavitation** is formation of empty cavities in liquid and their subsequent implosion

- **implosion of cavities**
  - shock waves (100-300 m/s)
  - high temperature up to 5000 °C
  - high pressure > 500 atm
  - formation of OH radicals (chemical reactions)

**Practical use:** emulsification, catalysis, homogenization, disaggregation, dispersion, production of nano-particles, water treatment, cleaning of surfaces
“Shark” shearing technology

- efficient cutting of particles
- low energy demand
- no waste generated
- no polluting chemicals
- no toxic byproducts
- cheap and easy to operate
Microscopy - results
Mechanical properties - results

• laboratory sheets from pulp suspension (Rapid Köthen)
• mechanical tests
  (fiber length, tensile length, tensile strength, break index, burst index, folding strength, air permeability)

Results indicate - some characteristics similar or even better than usual papermaking fibers from wood!

Fiber screening and further refining needed - proper fiber characteristics for papermaking!
Chemical properties - results

- pH value of fiber suspension – neutral

- Viscosity - medium (degree of polymerisation of cellulose molecules quite high, long chains)

- ISO brightness (optical property) - low (lignin still present)

Further chemical analyses still needed - characterisation of surface properties of fibers
Bleaching needed - characterisation of mechanical, chemical and optical properties of fibers after bleaching

EVALUATION of papermaking potential of fibers in accordance with sustainability concept!!!
Conclusions

- hemp may be excellent substitute for wood cellulose fibers
- fiber quality highly depends on the pulping procedure
- “classical pulping processes” impact environment, expensive
- optimization of novel processes – good quality fibers, sustainable production
- small scale production of speciality papers – encouraged
- “hemp fibers” – durable and convenient for production of high quality archive, document and speciality art papers as well as security papers

- hemp fibers as papermaking raw material have potential, further research still needed – to produce durable paper at reasonable price
Thanks for your attention!

More information available from:

Dr. Zsolt Nemeth  nzt@gmx.de

Dr. Levente Csoka  lcsoka@fmk.nyme.hu