The Antibacterial Performance of Natural Bamboo Fiber and Its Influencing Factors

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Introduction

- **Chinese Bamboo Resource**
  More than 40 genus and 500 species in China.
  Bamboo forest area: 5.38 million ha.
  Bamboo annual yields: 20 million ton.
Introduction

● Textile fibers from bamboo

➢ Regenerated bamboo fiber (RBF)

Bamboo pulp → smashing → dipping → alkalization → sulfonation → dissolution → screening → spinning → plasticizing → washing → cut off → refining → drying
Introduction

- Textile fibers from bamboo

  - Natural bamboo fiber (NBF)

  bamboo splitting → alkali degumming → acid rinsing → water rinsing → dewatering → shaking → drying → combing
Introduction

● Advantages of natural bamboo fiber
  ➢ Saving cultivated land for cotton
  ➢ Natural and environmentally friendly
  ➢ Moisture absorption and comfortable
  ➢ Natural antibacterial function?

● The aim of this study
  To investigate the natural antibacterial property of natural bamboo fiber and its influencing factors.
Materials and Methods

- **Materials**
  - Natural bamboo fiber from *Neosinocalamus affinis*
  - Cotton, Jute, Flax, Ramie, Regenerated bamboo fiber
  - Bamboo bundle, bamboo powder
Materials and Methods

- Antibacterial test
  - Dynamic test (GB/T 20944.3-2008)

- Microorganisms
  - *Escherichia coli* (E. coli, 8099)
  - *Staphylococcus aureus* (S. aureus ATCC 6538)
  - *Candida albicans* (C. albicans, ATCC10231)
Materials and Methods

- **Hygroscopicity test**
  - Referring to GB/T 9995-1997 and GB 6529-86
  - Conditioned fiber to balance state at 20°C and 65% RH, and then dried them to constant weight at 105±2 °C.

\[
W = \frac{G - G_0}{G_0} \times 100
\]

- \(W\) is the moisture regain, %, \(G\) is the wet weight of the fiber, g, \(G_0\) is the dry weight, g.
Materials and Methods

- Extraction

  - Referring to the method used in papermaking process (GB/T 2677)
  - Extraction dissolvent: cold water, hot-water, ethanol, benzene, benzene/ethanol mixture, 1% NaOH.
## Result and Discussion

### Results of the antibacterial test

<table>
<thead>
<tr>
<th>Fiber type</th>
<th>Bacteriostatic rate(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>E. coli</td>
</tr>
<tr>
<td>Untreated cotton</td>
<td>0</td>
</tr>
<tr>
<td>NBF</td>
<td>0 (-68.9)</td>
</tr>
<tr>
<td>Jute</td>
<td>0 (-15.9)</td>
</tr>
<tr>
<td>Flax</td>
<td>0 (-45.0)</td>
</tr>
<tr>
<td>Ramie</td>
<td>24.3</td>
</tr>
<tr>
<td>RBF</td>
<td>41.4</td>
</tr>
<tr>
<td>Antibacterial cotton</td>
<td>&gt;99</td>
</tr>
</tbody>
</table>

Note: NBF=Natural bamboo fiber, RBF=Regenerated bamboo fiber
The bacterial population density on each sample after shaking 18h

- **Cotton**: E. coli 7.3, S. aureus 1.4, C. albicans 0.3
- **NBF**: E. coli 12, S. aureus 1.6, C. albicans 0.4
- **Jute**: E. coli 8.5, S. aureus 2.1, C. albicans 0.2
- **Flax**: E. coli 11, S. aureus 2.7, C. albicans 0.3
- **Ramble**: E. coli 5.6, S. aureus 0.14, C. albicans 0.1
- **RBF**: E. coli 4.3, S. aureus 0.35, C. albicans 0.3
## Antibacterial Efficiency of different extraction method

<table>
<thead>
<tr>
<th>Extraction solvent name</th>
<th>Escherichia coli</th>
<th>Staphylococcus aureus</th>
<th>Candida albicans</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cold-water</td>
<td>64.35</td>
<td>10.91</td>
<td>0</td>
</tr>
<tr>
<td>Hot-water</td>
<td>69.57</td>
<td>30.91</td>
<td>0</td>
</tr>
<tr>
<td>Ethanol</td>
<td>18.26</td>
<td>7.88</td>
<td>0</td>
</tr>
<tr>
<td>Benzene</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Benzene/ethanol</td>
<td>4.35</td>
<td>36.36</td>
<td>0</td>
</tr>
<tr>
<td>1% NaOH</td>
<td>58.26</td>
<td>67.88</td>
<td>0</td>
</tr>
</tbody>
</table>
The bacteriostatic rate on different shapes of bamboo

<table>
<thead>
<tr>
<th>Bamboo shape</th>
<th>Escherichia coli</th>
<th>Staphylococcus aureus</th>
<th>Candida albicans</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bundle</td>
<td>0(-69.0)</td>
<td>0(-75.0)</td>
<td>0(-45.5)</td>
</tr>
<tr>
<td>Fiber</td>
<td>0(-68.9)</td>
<td>0(-13.2)</td>
<td>0(-41.3)</td>
</tr>
<tr>
<td>Powder</td>
<td>0(-54.9)</td>
<td>0(-50.0)</td>
<td>0(-33.4)</td>
</tr>
</tbody>
</table>
The bacterial population density on different shapes of bamboo

Bacterial population density (10^6, CFU/ml)

- E. coli
- S. aureus bacteria
- C. albicans

- Bundle
- Fiber
- Powder
The relationship between moisture regain and bacteriostatic rate

<table>
<thead>
<tr>
<th>Fiber</th>
<th>Moisture regain (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NBF</td>
<td>9.80</td>
</tr>
<tr>
<td>Cotton</td>
<td>7.75</td>
</tr>
<tr>
<td>Flax</td>
<td>9.24</td>
</tr>
<tr>
<td>Ramie</td>
<td>6.81</td>
</tr>
<tr>
<td>RBF</td>
<td>12.09</td>
</tr>
</tbody>
</table>

$R^2 = 0.9938$

$R^2 = 0.7226$

$R^2 = 0.6162$

- E. coli
- S. aureus
- C. albicans

The graph shows the relationship between moisture regain and bacteriostatic rate for different fibers. The coefficients of determination ($R^2$) indicate the strength of the relationship, with higher values indicating a stronger correlation.
Conclusions

- Natural bamboo fiber has no antibacterial property compared with other textile fiber.
- The shape could not impact the antibacterial activity of natural bamboo fiber.
- The hygroscopicity may be a influencing factor in antibacterial performance of fiber.
- Extractives have influence on the antibacterial property of natural bamboo fiber.
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