Novel Approaches to Process Bamboo Plants into Fibres and their UV-blocking Property

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Why Bamboo?

Serving daily need of mass people

Amazingly fast growth rate

Multifunctional and eco friendly

No or Low pesticides and irrigation

Outstanding Carbon neutral activity!

Medicine, construction, cosmetics...

Motivation: myth of bamboo textiles

Present non eco-friendly harmful production method. i.e. viscose method

Can the unique properties of bamboo be retained into fibres??

Green?

UV protection?

Antimicrobial?

My Research Question:

“To develop an eco-friendly manufacturing method to process bamboo plants into fibre without loosing the unique properties.”
Characterisation of Raw Bamboo

**Morphology:** Scanning Electron Microscope (SEM) and Confocal Microscope.

**Chemical constituents analysis:** Chinese standard: GB5889-86.

**Crystalline structures:** X-ray Diffraction (XRD).

**Chemical bonds analysis:** Fourier Transform Infrared Spectroscopy (FT-IR).

**Australian grown:** *Phyllostachys pubescens*
Morphology of raw bamboo (under SEM)
Under confocal microscope
Chemical constituents analysis

According to Standard: GB5889-86

- Cellulose: 53%
- Lignin: 28%
- Hemicelluloses: 15%
- Others: 4%
Functional chemical bonds in raw bamboo

FT-IR spectroscopy of raw bamboo

Lignin region: 1500-1750 cm⁻¹
(Yueping et al. 2010)

- Contracting vibration of O-H
- C-H stretching
- Conjugated carbonyl stretching
- Non conjugated carbonyl stretching
- Aromatic skeletal vibration
- Cellulose

Wave numbers (cm⁻¹)
According to Segal Method:

\[ X_c = \frac{I_{002} - I_{am}}{I_{002}} \times 100\% \]

Where, \( I_{002} \) is the peak intensity from the (002) lattice plane (2\( \theta \)=22.6\(^\circ\)) and \( I_{am} \) the peak intensity of amorphous phase (2\( \theta \)=19\(^\circ\)).

Calculated degree of crystallinity: 81-83\% (Segal Method)
Calculated crystal size: 31-40 Å (Scherrer Equation)
Fitted by HighScore plus software
Origin of the UV shielding Characteristic of Raw Bamboo

- **Polar**
  - Protic: Ethanol and water;
  - Aprotic: Acetone and Dimethyl Sulfoxide (DMSO)

- **Non-polar** (Hexane and Toluene)

- Mixture of non polar and polar (dioxane: water=9:1)/MWL extraction (Björkman, 1956)
Bamboo extractions

SEM: milled bamboo powder

Material: Liquor = 1:30

Time: 72 hours

Milled bamboo 10 gram + Solvents

Filtration

Centrifuged filtrate

Transparent solution
UV absorbance of raw bamboo extracts

- More than one UV responsible component (Afrin et al., 2011).

UVA: 315-400 nm
UVB: 280-315 nm
UVC: 100-280 nm
Relation between UV absorbance and chemical bonds of lignin

- Chemical components of lignin is contributing in UV blocking (Afrin et al., 2011).
Origin of the Antimicrobial Property of Raw Bamboo

Challenge Bacteria: Gram negative bacteria, *Escherichia coli* (E. coli): ATCC 25922 and gram positive bacteria *Staphylococcus aureus* (S. aureus): ATCC 25923

Test standard: AATCC 100-2004 (clause 10.2) with slight modification.

Samples:
- Bamboo Powder
- Bamboo extracts in water.
- Bamboo extracts in 90% aqueous dioxane (MWL). (after extraction dioxane is evaporated)
- Bamboo extracts in DMSO
Antimicrobial test results

- Antimicrobial component(s) is water insoluble and stemming out from the chemical components of lignin (Afrin et al. 2011)
Development strategy: manufacturing process

- Ultrasonic treatment
- Shaker milling
- New economic & eco-friendly approach
- Without loosing the unique properties
Ultrasonic treatment to process bamboo

Bamboo Culms → Crushed into powder~500μm

- Ultrasonic treatment for 1 hour at 60°C, 40kHz, 300W
- With NaOH
- With Enzymes
- With H₂O₂

M:L=1:30
Recipe: Solvents 10%

Washing using Centrifuge
SEM images after ultrasonic treatment

Roughly Milled bamboo

NaOH

H2O2

Enzyme
Processing of bamboo: shaker milling

- **Bamboo Culms**
- **Crushed into powder, 500μm**
- **NaOH**
- **Enzymes**
- **H₂O₂**
- **H₂O**
- **Washing using Centrifuge**

**Recipe:**
- Solvents= 10%
- M:L=1:40
- B:M= 1:80
- Sample: 0.5gm

**Shaker milling for 6 hours**
SEM images after shaker milling

Bamboo fibres can be processed without any chemical aid.
Processing of bamboo

Eco-friendly manufacturing process.

Thermo-mechanical treatment

Eco-friendly By-Product

Afрин et al., 2011, Australian provisional patent: 2011902451

Bamboo Culms

Salt wash and 2nd

M : L = 1:5

Washing and filtration

Eco-friendly manufacturing process.
Morphology: processed fibre

Long fibre
Comparison: UV absorbance

UV blocking ability is preserved after processing.

UV-Vis spectroscopy

Absorbance vs. Wavelength (nm)
Antimicrobial property of processed fibre

The processed fibres have shown outstanding antibacterial property against fatal and pathogenic bacteria.
FT-IR spectroscopy of the processed fibre

The functional bonds of lignin are retained into the processed fibre
Summary

Bamboo species used for this study is cellulose-I crystalline, micro porous lignocellulosic natural nano composite with 28% lignin.

In this bamboo species, more than one chemical components are responsible for UV shielding.

Eco-friendly and economic manufacturing processes have been developed preserving the unique properties.

Bamboo plant and processed fibres have shown distinctive antimicrobial activity but the antimicrobial component(s) is water insoluble.

Bamboo plant and processed fibres are much superior to cotton, cellulose and commercial bamboo fibres in UV protection.
Heading towards... Bamboo puts other in the shade

“OUCBDFJUFSMBNCPP It’s proven bamboo clothes reduce the risk of skin cancers!”

Multifunctional
Highly porous
and breathable
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