Preparation and study of food packaging composites based on nano-lignocellulose and PVA/Chitosan

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Introduction

The global demand on utilizing sustainable and ecologically friendly products based on raw materials has as result intense research on potential application of cellulose materials. **Cellulose Nano-Fibrils** (CNF), **Nano-Crystalline Cellulose** (NCC), purified or as **lignocellulose**, and **bacterial nanocellulose** (BNC) are intended to the development and application of high-performance industrial nanocomposites. Especially for lignocelluloses, the less energy/time consuming processes required to turn the biomass into the final nanostructured filler and the presence of lignin, which may be helpful for some applications, are key-factors that render these materials scientifically attractive. Focusing on the biodegradability and water solubility, Poly Vinyl Alcohol (PVA) and widely bioavailable Chitosan, have been used as polymeric matrices[1,2].

Targets

1. Composite wood products, as performance enhancers of ***adhesives*** and ***surface protective coatings***.
2. ***Food packaging materials*** as additives to enhance barrier properties
   a) ***development and characterization of nanocomposite materials*** based on nanocellulose (MFC, CNF, NFC, BNC)
   b) thorough study of the release of substances/particles from the composites to food simulants using certified methodologies and specially designed cells/devises.

Migration control *from food packaging materials*
Certified migration cells

Materials and Methods

- ***PVA*** *89-98kDa (S.Aldrich)*
- ***Chitosan*** *medium mol. weight (S.Aldrich)*
- ***Lignocellulose nanofibers*** *(API Europe)*
- ***Nanocrystalline cellulose, CNC*** *(Univ. Maine)*
- ***Bacterial nanocellulose, BC*** *(Agr. Uni. Athens)*

nanocomposite preparation

Good quality, homogenous films of both PVA and chitosan have been prepared by the film casting method from aqueous solutions (adding 1% acetic acid in the case of chitosan).

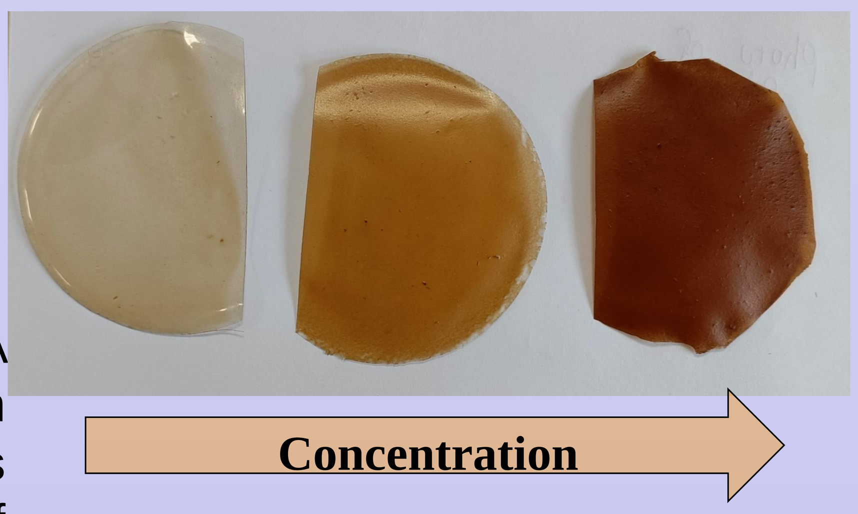


Image 1: PVA nanocomposites of ***1-5-10%*** lignocellulose loading (left to right)

Results & Discussion

Cellulosic inclusions' Characterization

✓**Molecular Spectroscopy (ATR-IR)** can differentiate the spectral contribution of each component in **lignocellulose** and **bacterial cellulose (BC)**

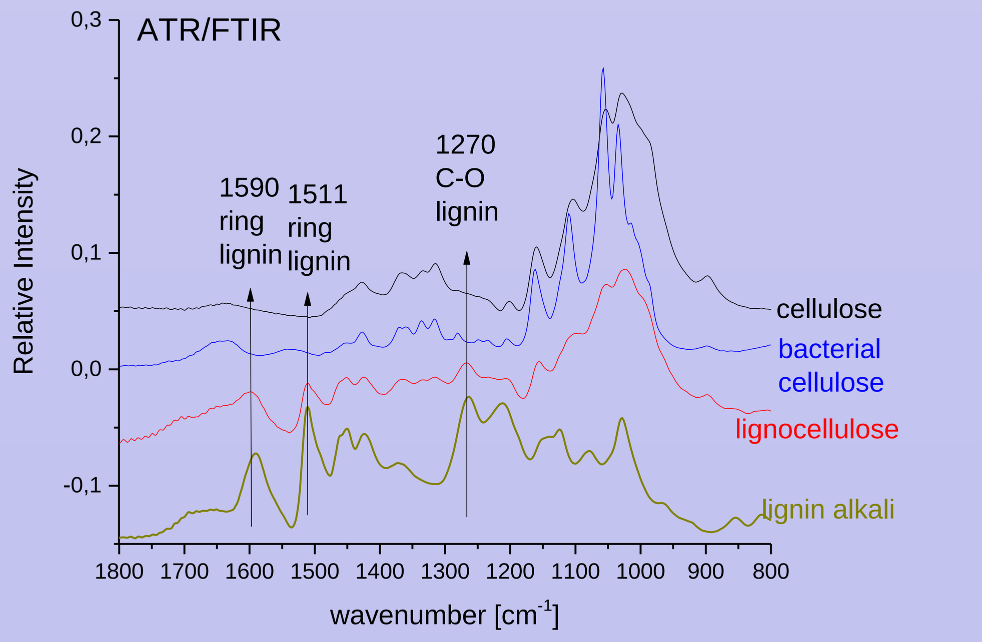


Figure 1: ATR/IR spectra of cellulose, BC, lignocellulose, lignin.

- **Lignocellulose** consists of **cellulose** and **lignin** (1270, 1511 and 1590cm-1)
- Sharp **BC** bands are attributed to increased crystallinity, especially compared to **lignocellulose**.

Thermal properties of PVA composites

✓**Differential Scanning Calorimetry (DSC)** indicates the effect of cellulose inclusions on the thermal properties of composites.

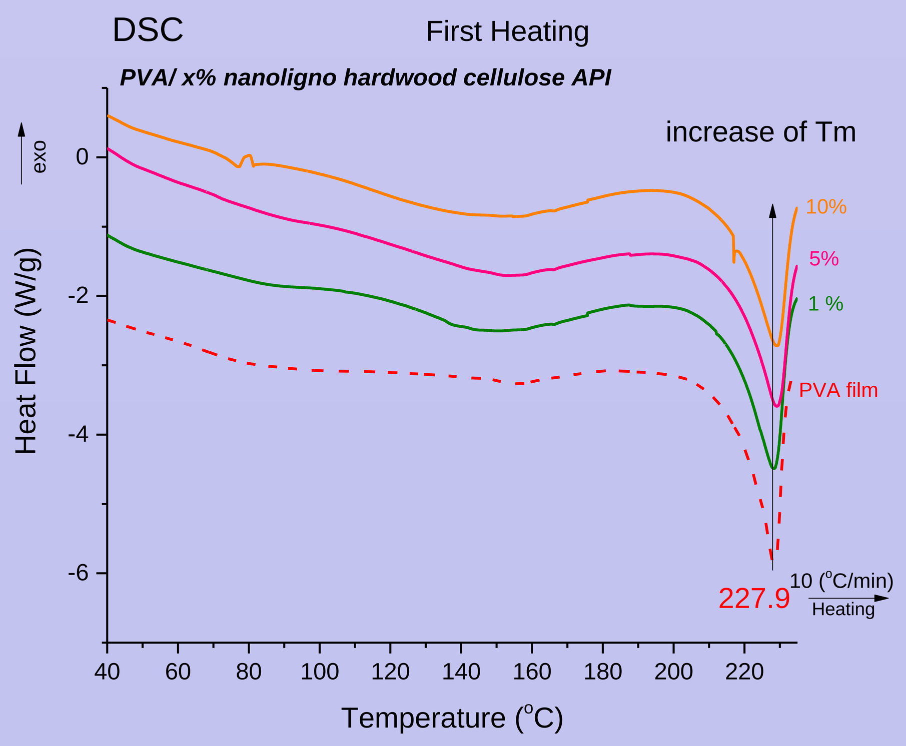
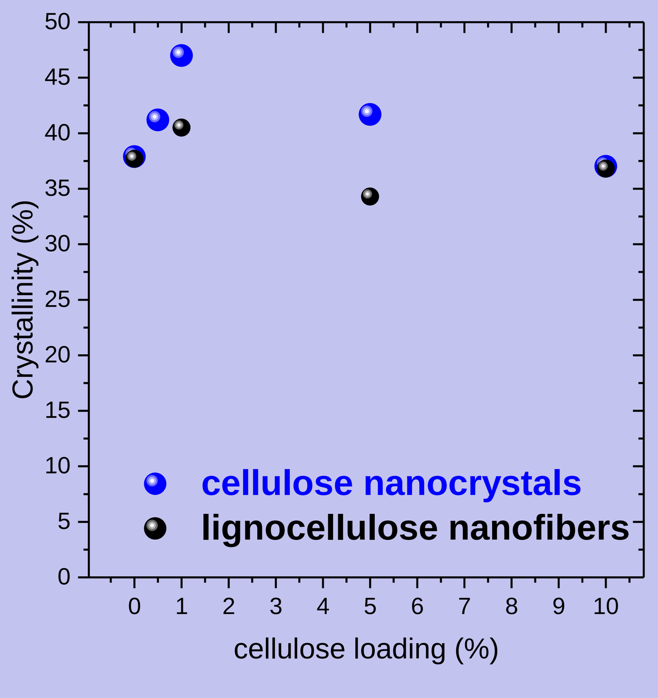


Figure 3: DSC thermographs of PVA nanocomposites with various lignocellulose loading (up). Comparison of PVA crystallinity vs loading for CNC and lignocellulose based composites (down).



- **Both CNC and lignocellulose** exhibit a maximum Xc% at ~1% loading.
- In all studied loadings **CNC** composites exhibit higher Xc% than pristine PVA.
- **Lignocellulose** loading *does not* seem to have similar trend on Xc% as CNC.

Cellulosic inclusion uptake identification

✓**X-Ray Diffraction (XRD)** can verify & monitor cellulosic species in **PVA** composites.

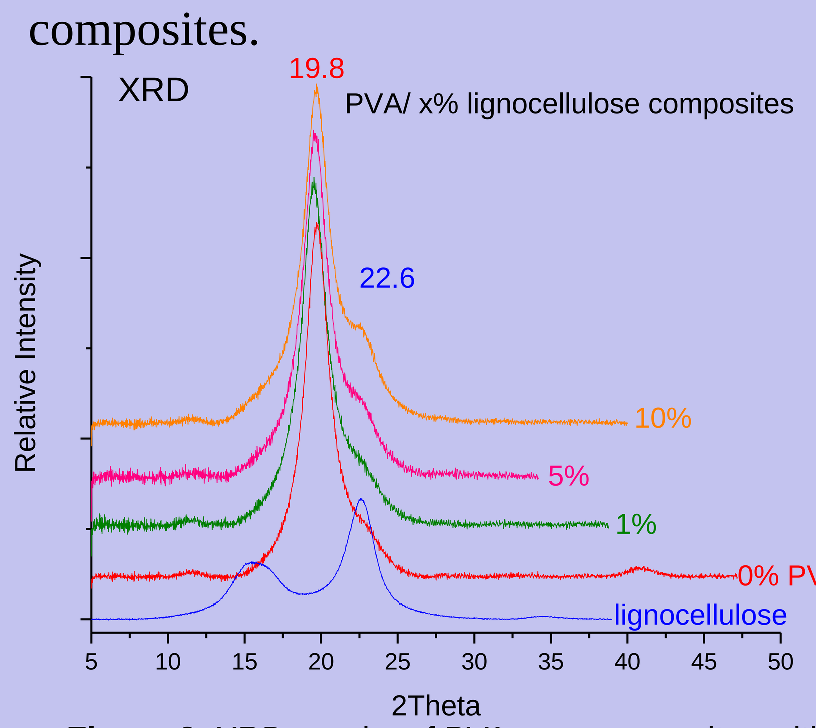


Figure 2: XRD graphs of PVA nanocomposites with various lignocellulose loading.

- Cellulose loading in PVA composites is justified by the intensity of the 22.6º cellulose peak.

Thermo-Mechanical properties of PVA composites

✓**Dynamic Mechanical Analysis (DMA)** highlights the effect of loading in the stiffness for all studied composites.

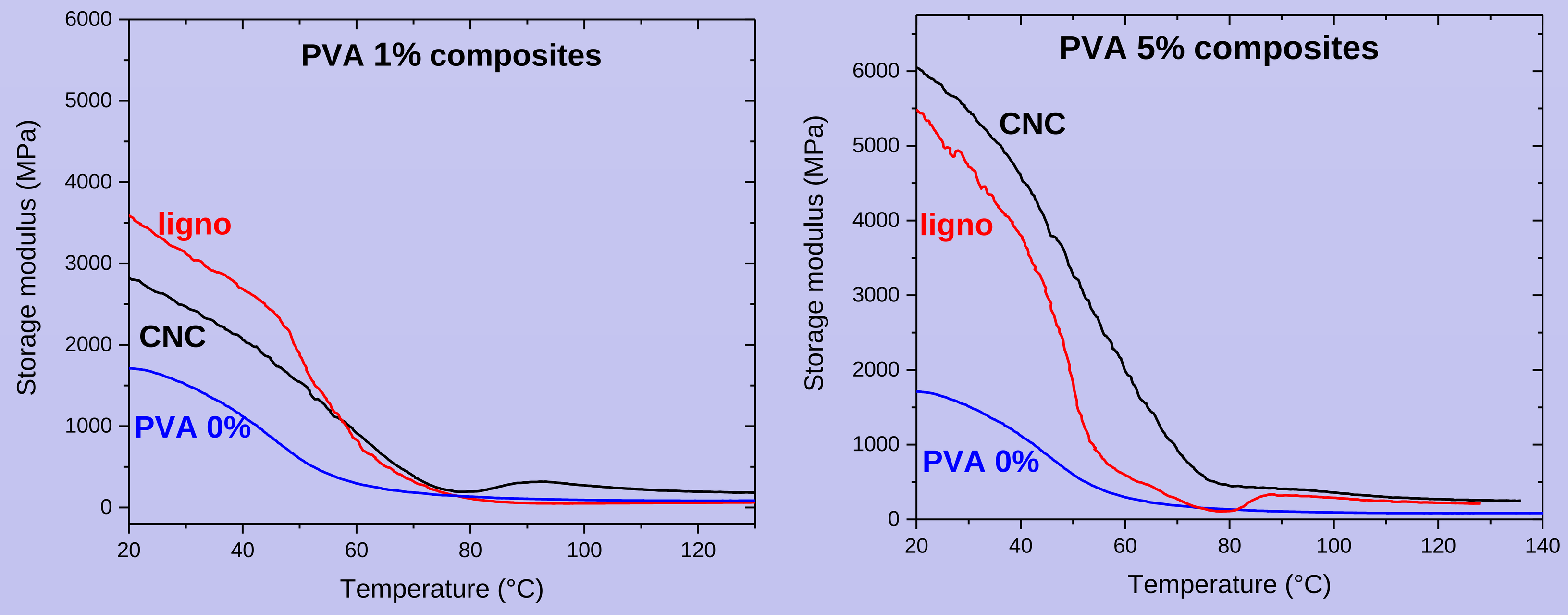


Figure 4:Comparative DMA graphs of PVA composites with loading of 1% (left) and 5% (right) on CNC and lignocellulose.

- Both CNC and lignocellulose composites possess elastic modulus values higher than that of PVA. These values increase with loading.[3]
- With respect to CNC, lignocellulose offers better mechanical properties at low loadings (~1%)
- At higher loadings, CNC composites exhibit higher Young Modulus.

Thermo-Mechanical properties of chitosan composites

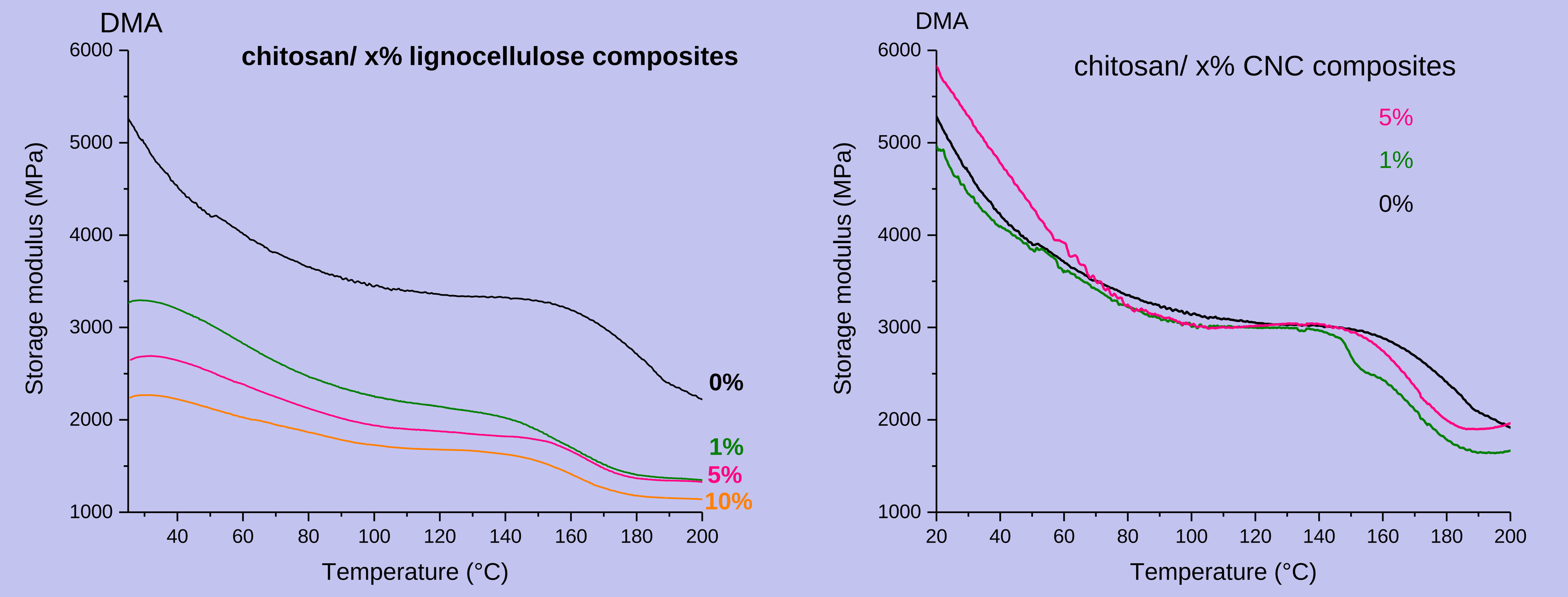


Figure 5: DMA graphs of chitosan composites with various loadings of lignocellulose (left) and CNC (right).

- CNC inclusions result in progressive enhancement of composite's Young Modulus as a function of loading.
- Lignocellulose inclusions on the other hand result in composites with lower Modulus that the pristine chitosan samples.

Conclusions

In order to develop biodegradable food packaging composites with enhanced barrier properties, both thermal and mechanical properties which are of prominent impotence have been examined.
Our first results indicate that lignocellulose may result in enhanced mechanical properties by affecting the crystalline structure of the host polymer (case of PVA). On the other hand, decrease of mechanical properties is observed in non-crystalline polymers (chitosan case). Initial experiments with Bacterial NanoCellulose inclusions shows similar behavior as CNC.

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