Formulation and Processing of Polypropylene – Flax Fiber Composites

Ton That, Minh Tan; Denault, Johanne; Patenaude, Éric; Leelapornpisit, W

Publisher's version / Version de l'éditeur:

BioPlastics 2006 [Proceedings], 2006-09-27

NRC·CNRC
Industrial Materials Institute

Formulation and Processing of PP- Flax Fiber Composites

M-T. Ton-That, J. Denault, E. Patenaude and W. Leelapornpisit

Bioplastics 2006
27th-29th September 2006
Montreal, Quebec, Canada

NRC·CNRC
Industrial Materials Institute

Outline

- Flax structure and properties
- PP composites from flax
  - Compression
  - Injection
  - Extrusion-Injection
- Conclusions









NRC·CNRC
Industrial Materials Institute

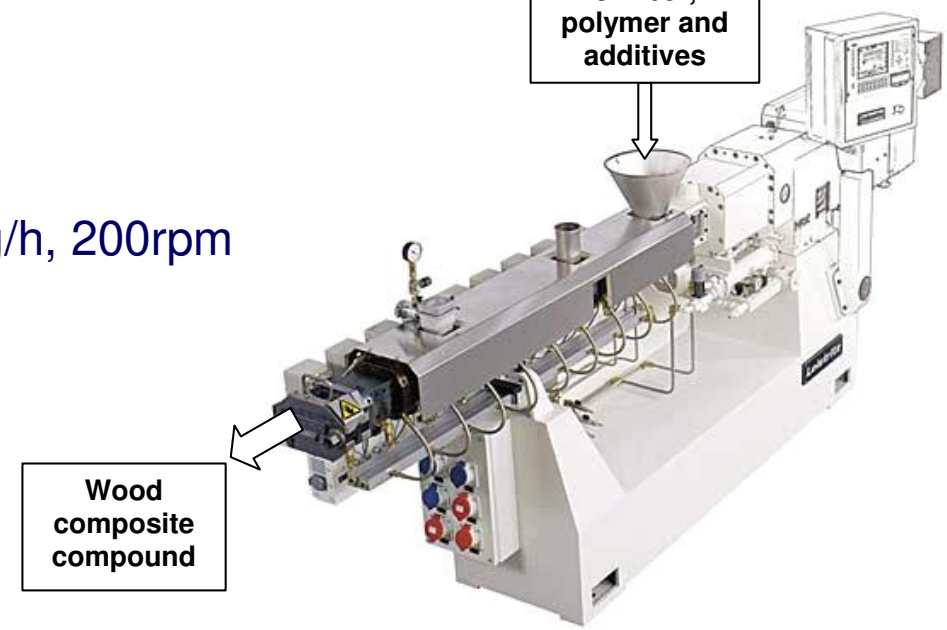
Flax types

- Flax
  - Fibers, Shives, Mix of shives & fibers, Dust (Biolin)
  - Fiber treatment: non, water, soap and NaOH 1% (50°C, 2 h)
- Polymer matrix
  - Injection grade PP Profax 1274 (Basell)
- Coupling agent: maleic anhydride (MA) grafted polypropylenes
  - Epolene-43 (Mn = 9,100; ~4.81 wt% of MA) (Eastman Chemical)
  - Epolene-3015 (Mn = 56,000; ~1.5 wt% of MA) (Eastman Chemical)
  - Polybond 3150 (Mn = 330,000; ~0.5 wt% of MA) (Chemtura)
- Additives: CaO

NRC·CNRC
Industrial Materials Institute

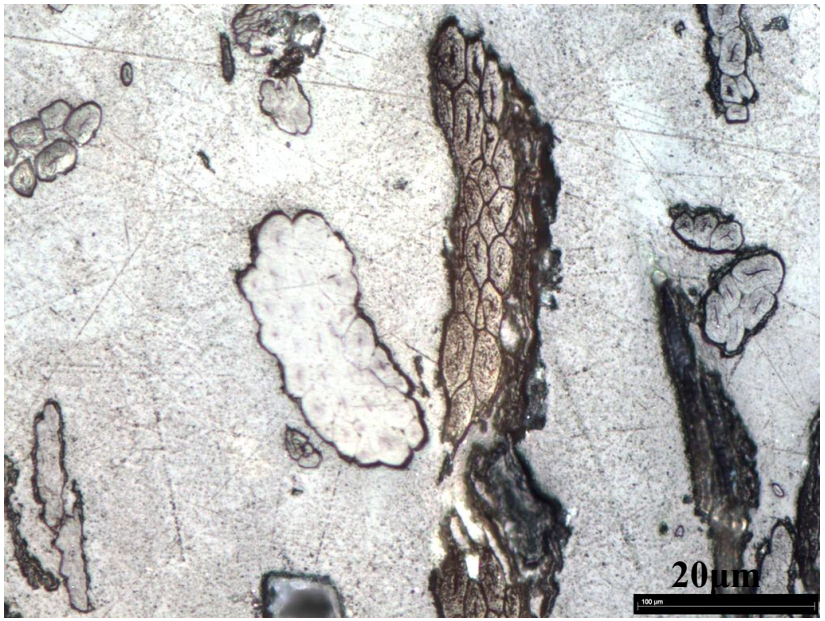
Processing

- Extrusion
  - Standard TSE, T=190°C, 10kg/h, 200rpm
- Injection molding; T=190°C



- Mat fabrication
- Compression molding

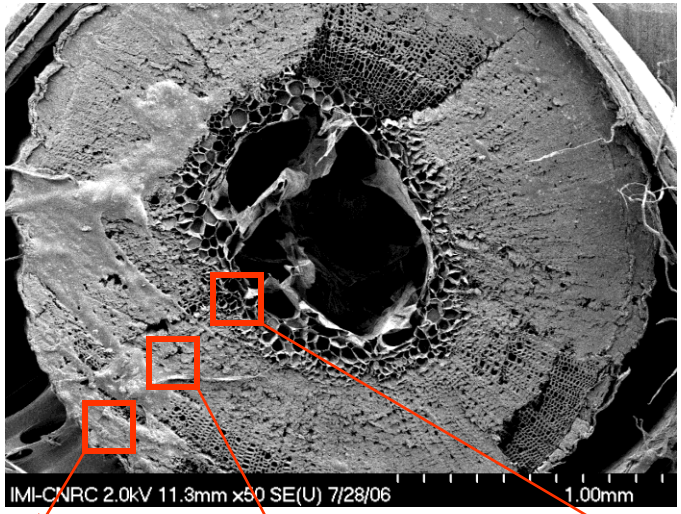
Flax fiber structure

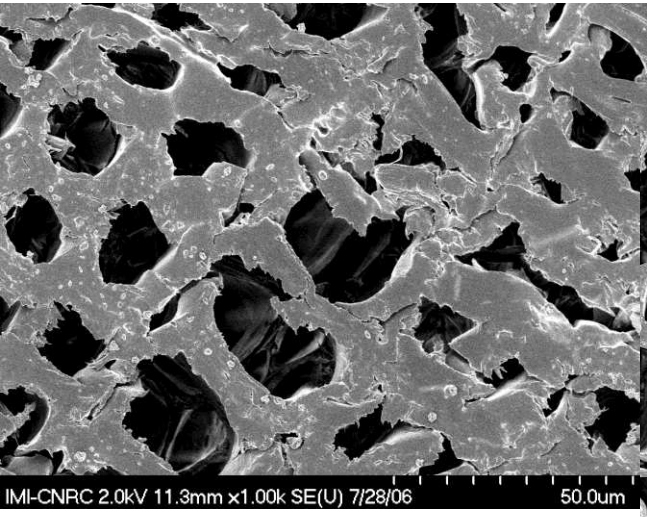


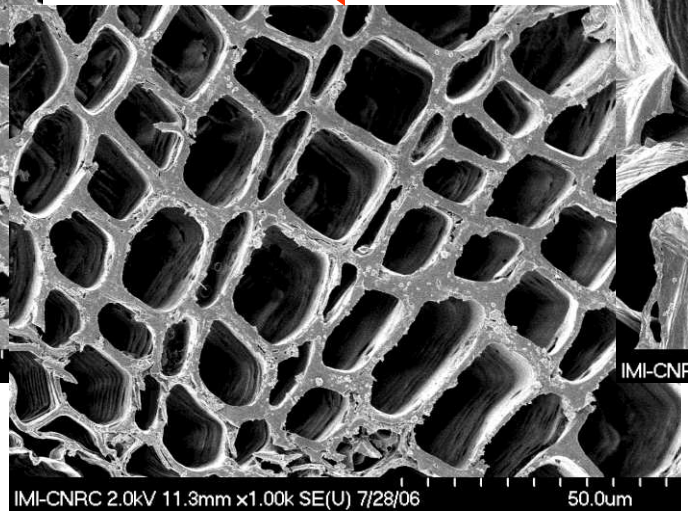
- Single fiber cells and multiple fiber-cell bundles at different sizes can be observed: very inhomogeneous
- Fiber cell cross-section is not a regular circle

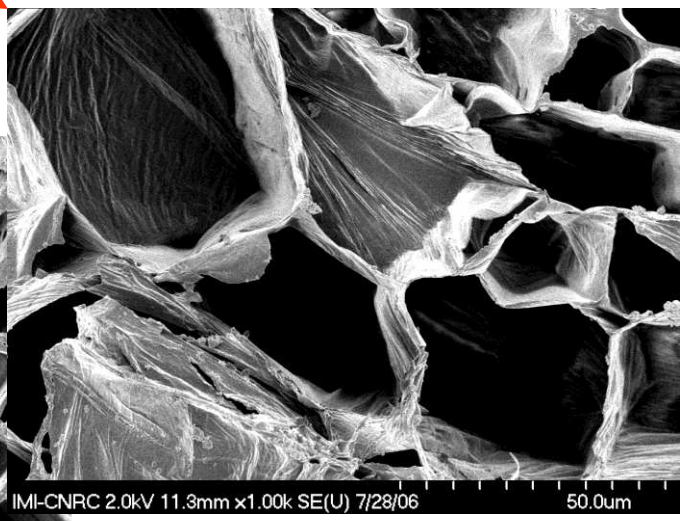
NRC·CNRC
Industrial Materials Institute

Flax fiber structure
Bottom of the stem



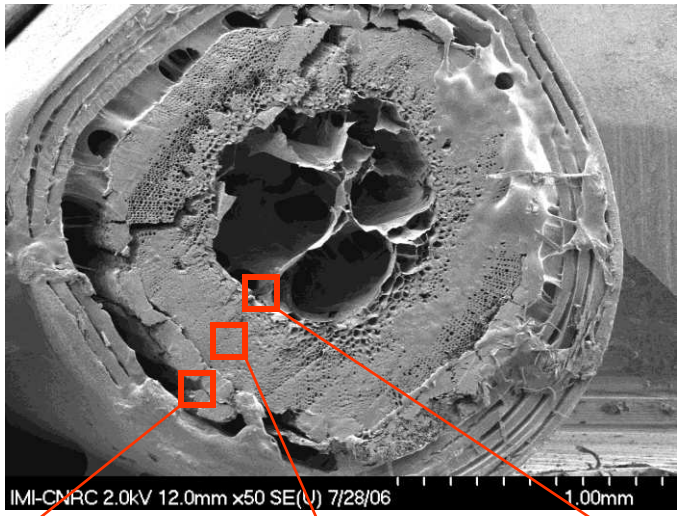


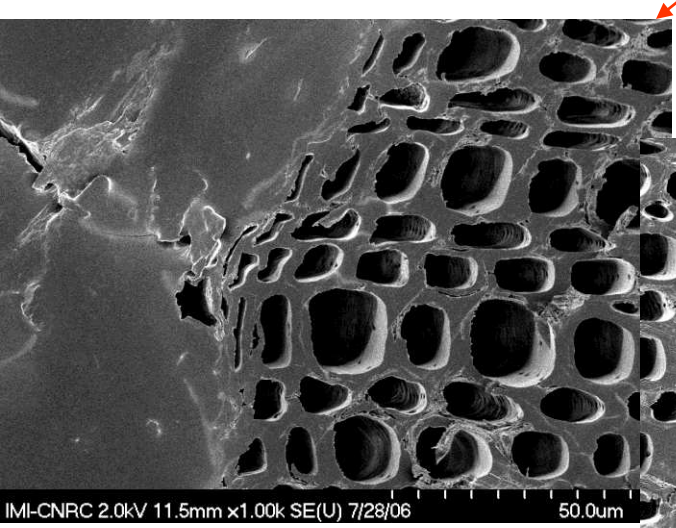


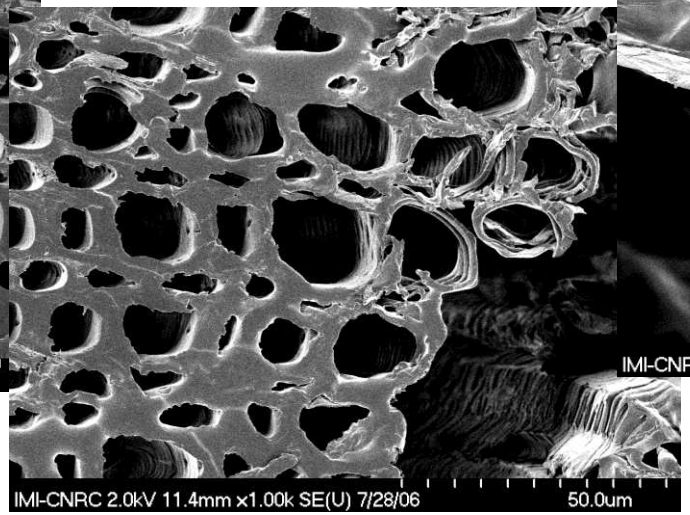


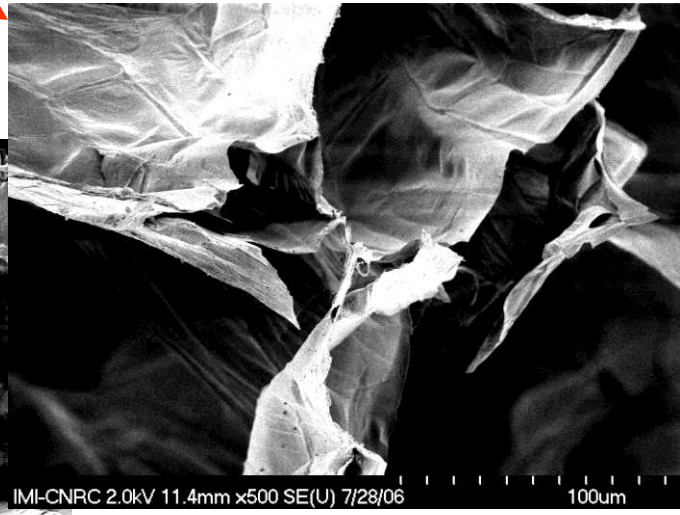
NRC·CNRC
Industrial Materials Institute

Flax fiber structure
Top of the stem



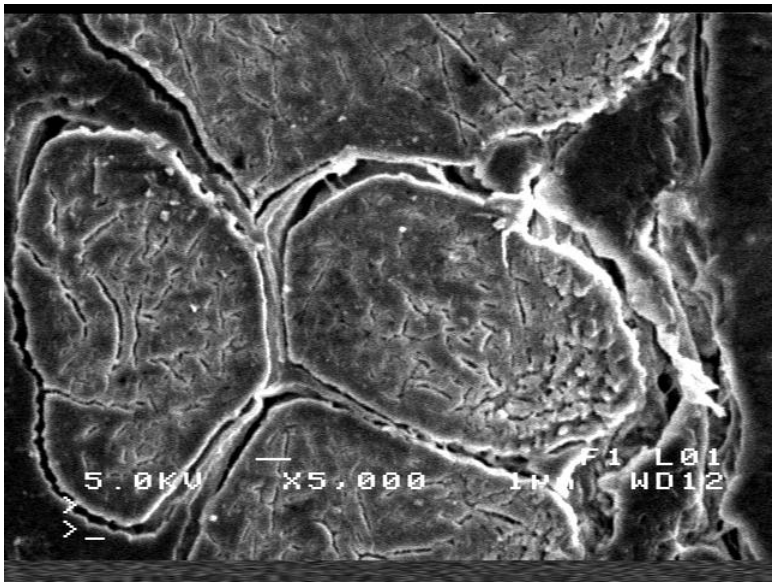


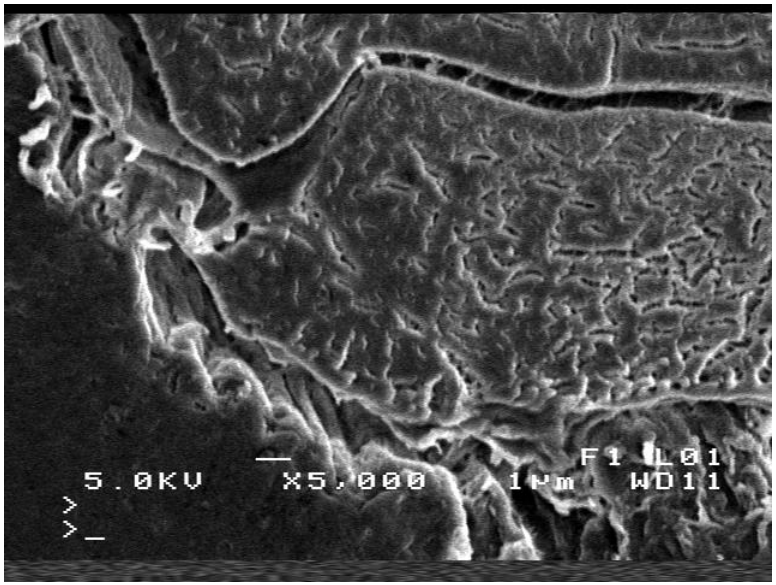




NRC·CNRC
Industrial Materials Institute

Flax fiber structure



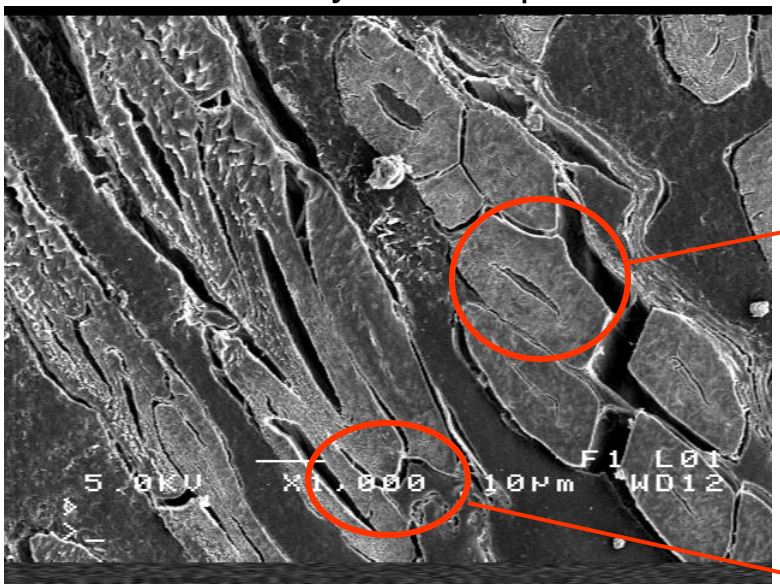


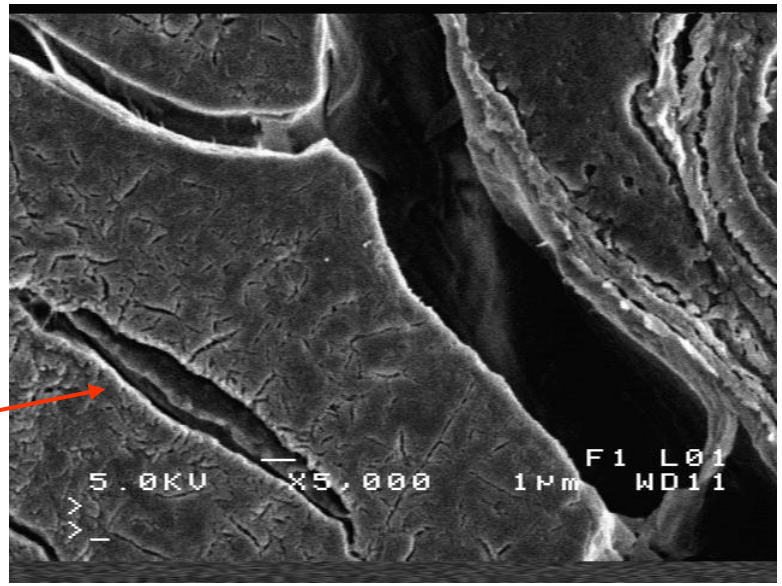
- Weak bonding between the fiber cells in the bundle
- Many deffects inside the fiber cell cross-section

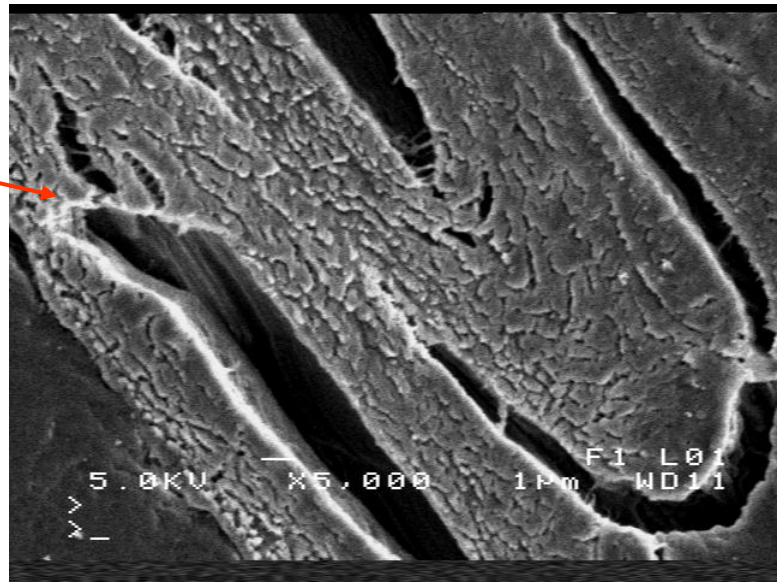
NRC·CNRC
Industrial Materials Institute

Flax fiber structure

Outer layer of the plant





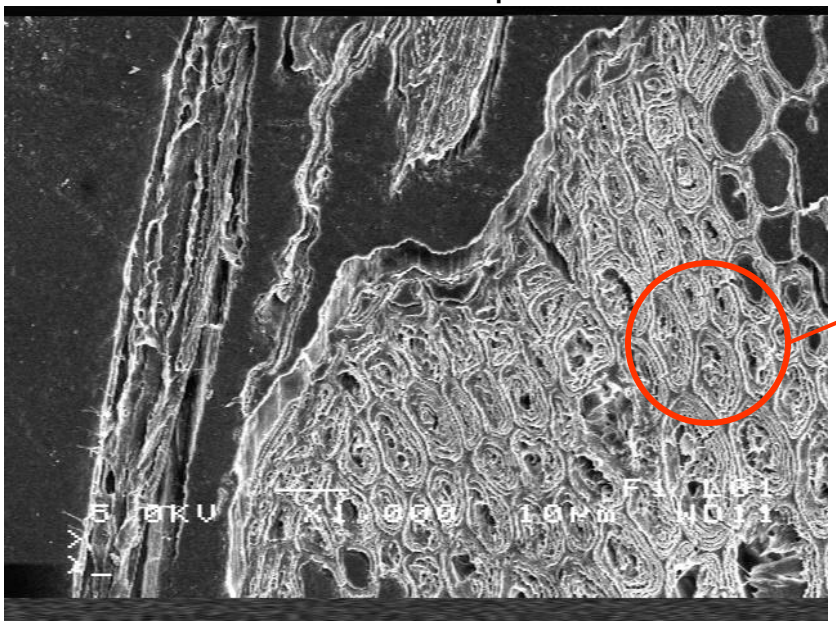


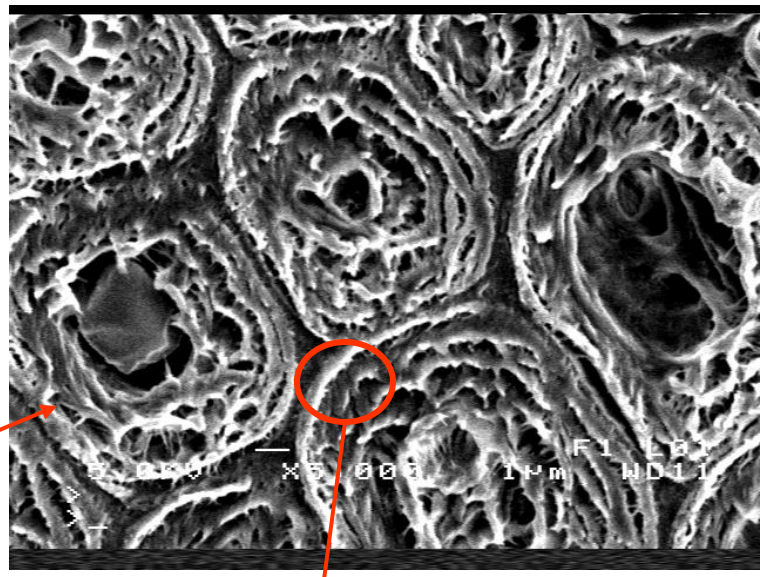
- Hollow and porous structure can also be observed

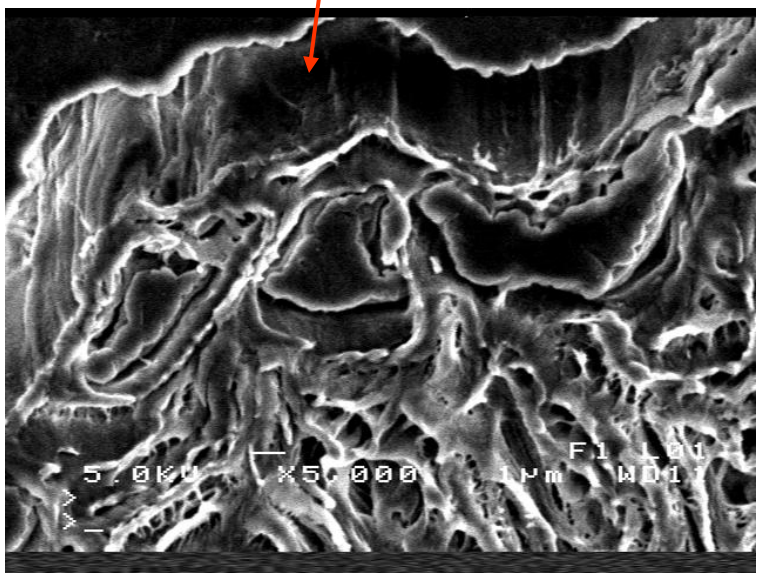
NRC·CNRC
Industrial Materials Institute

Flax fiber structure

Center of the plant





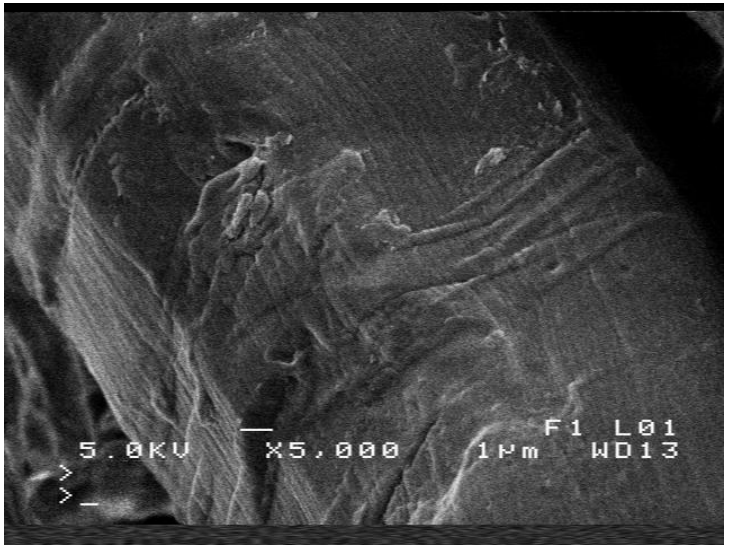


- Hollow and porous structure

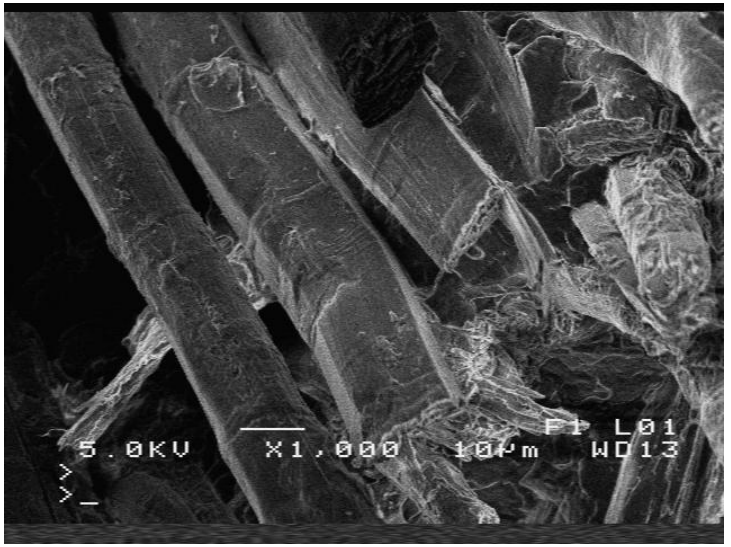
NRC·CNRC
Industrial Materials Institute

Flax fiber structure

- Splitting of elementary fiber and the meso structure in the secondary cell wall
- Fiber with intercellular bonding

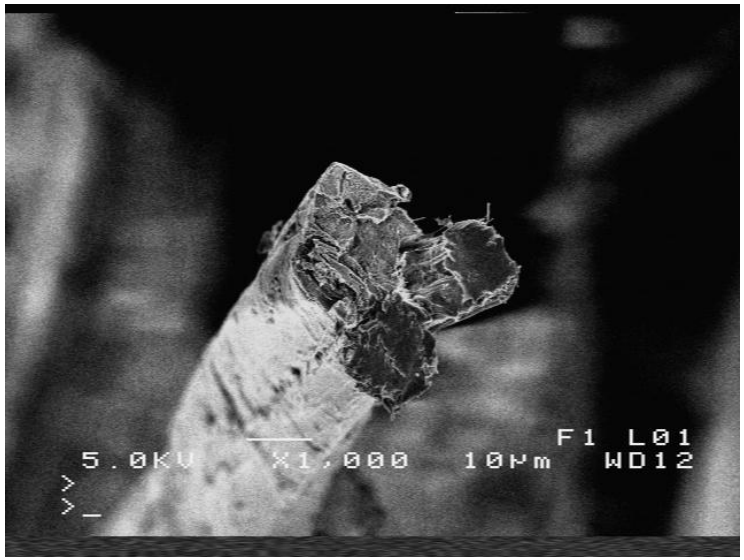


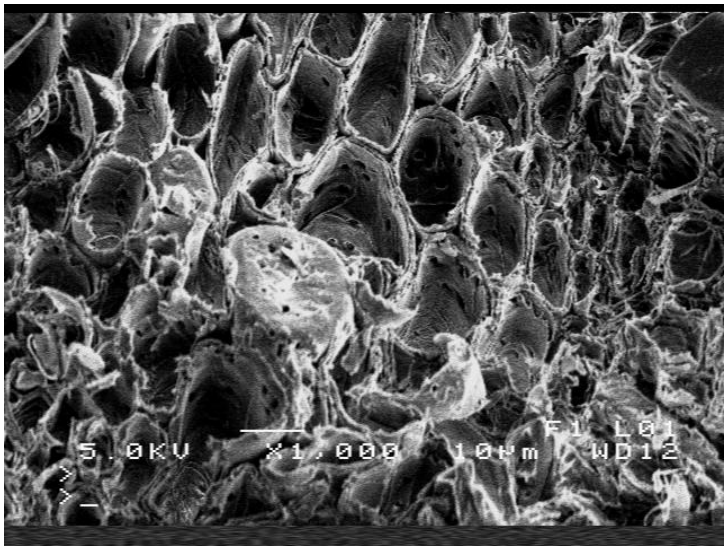
- Deformation and structural deffects



NRC·CNRC
Industrial Materials Institute

Flax fiber properties

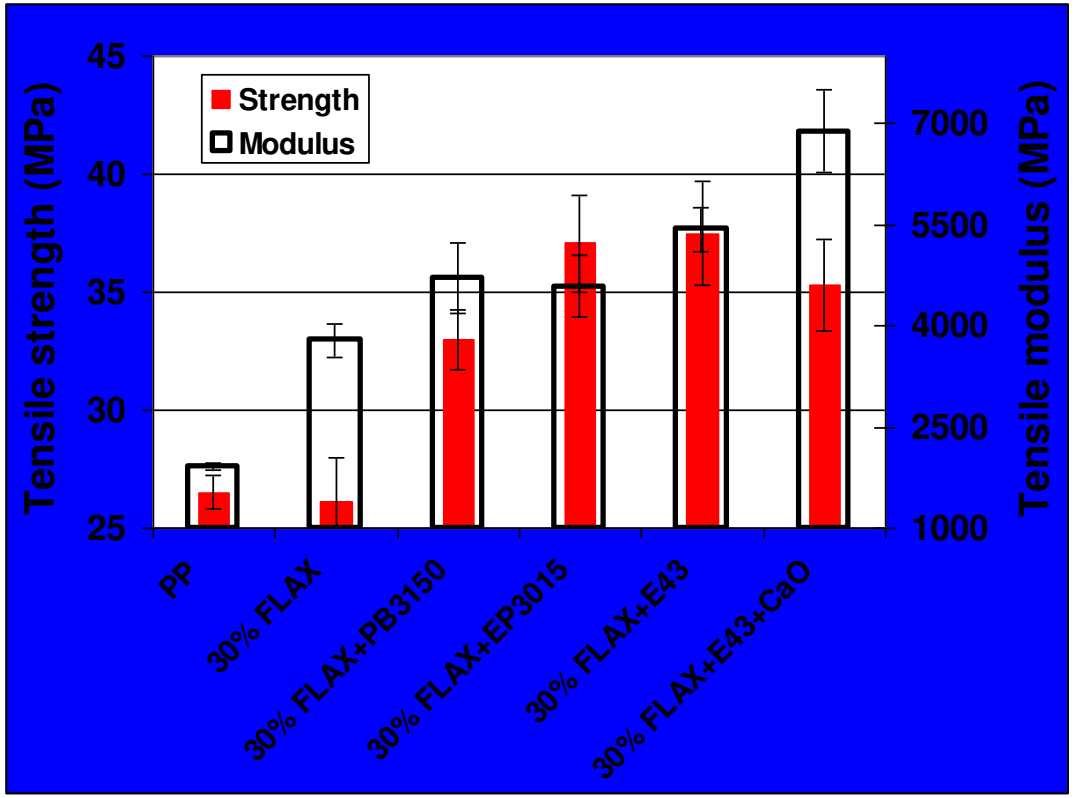




- Tensile strength: 280 ± 120 MPa
  expected: 780 MPa
- Tensile modulus: 15.8 ± 1.5 GPa
  expected: 27.5 GPa
- Diameter: 10-120 µm
- Rupture mode is very britle

NRC·CNRC
Industrial Materials Institute

Mechanical properties
Compression molding

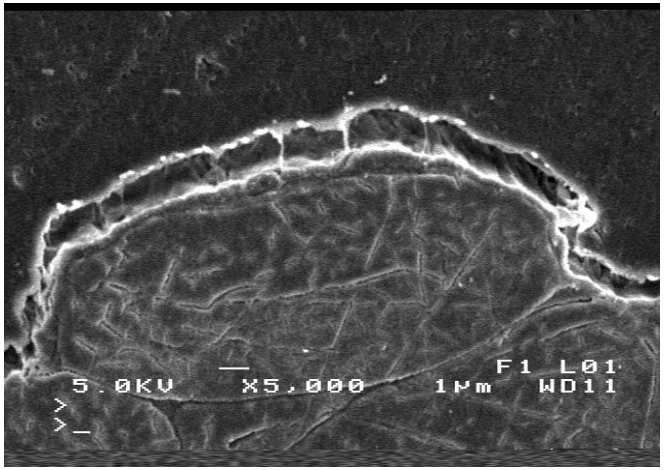


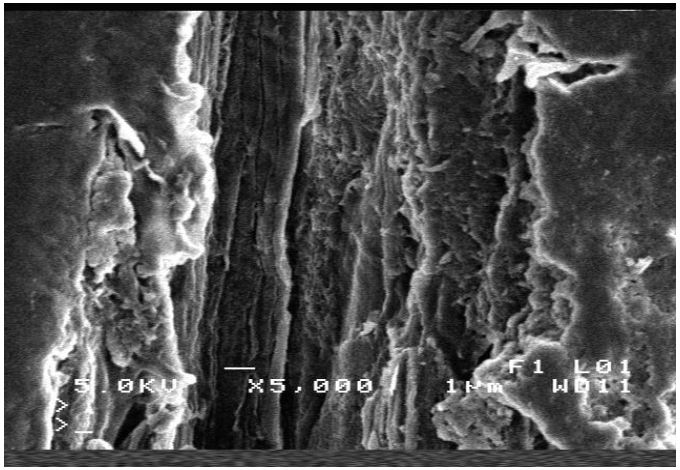
- Modulus and strength of the composites improve significantly with the presence of coupling agent
- Type of coupling agent also plays an important role
- The presence of CaO provide a great increase in modulus

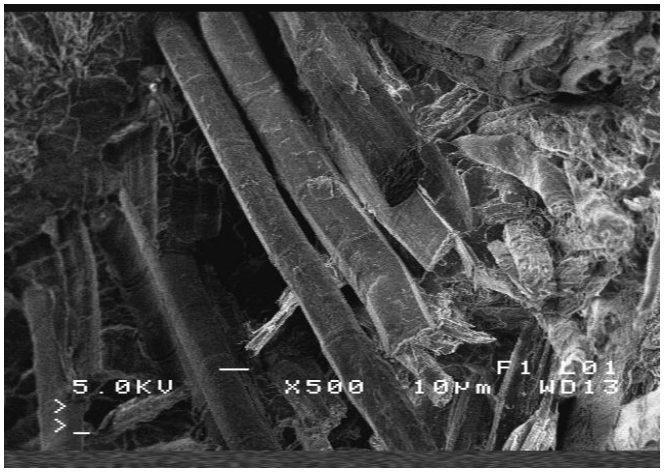
NRC·CNRC
Industrial Materials Institute

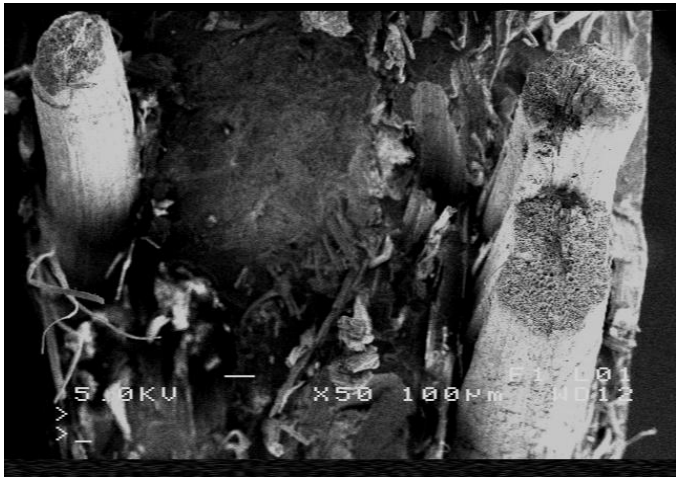
Interface
No coupling agent

- Very poor interaction between the fiber and the matrix





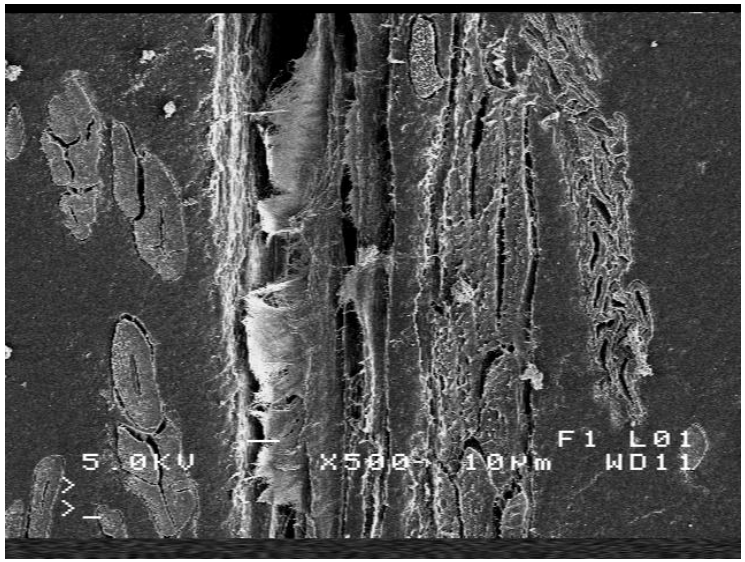


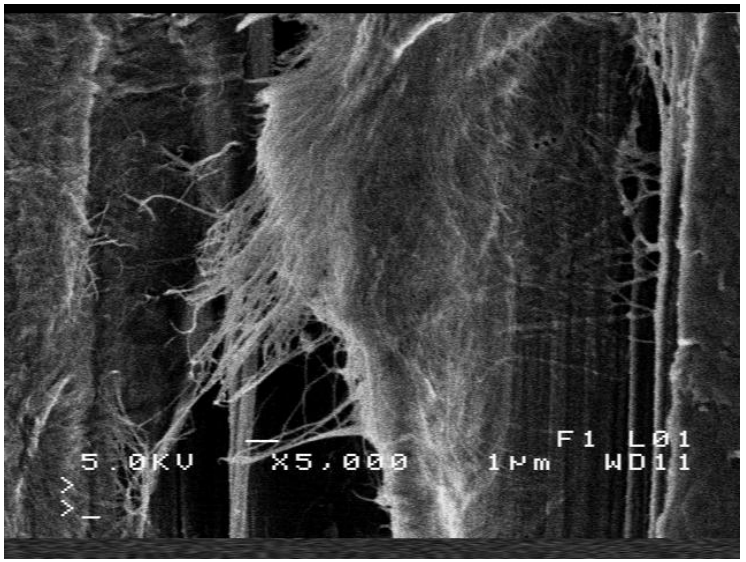


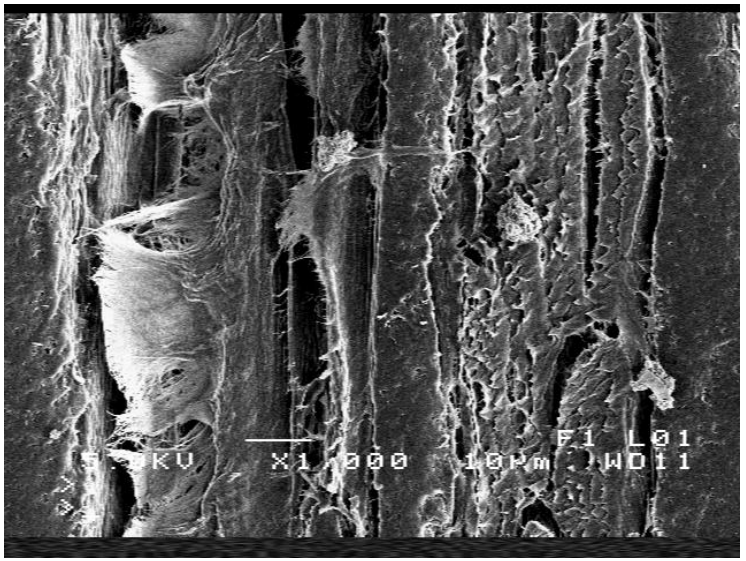
NRC·CNRC
Industrial Materials Institute

Interface
With coupling agent

- Great improvement at the interface



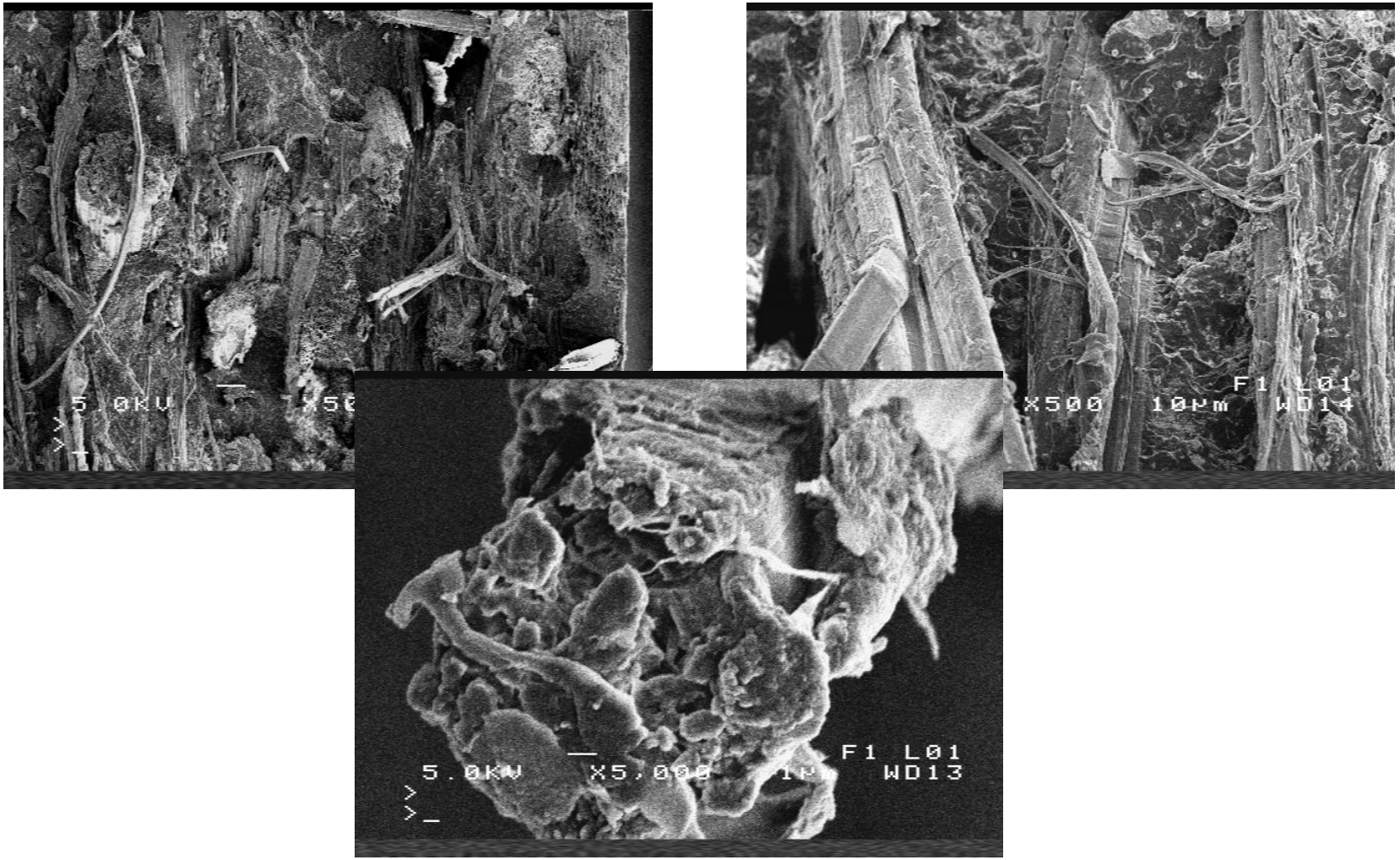




NRC·CNRC
Industrial Materials Institute

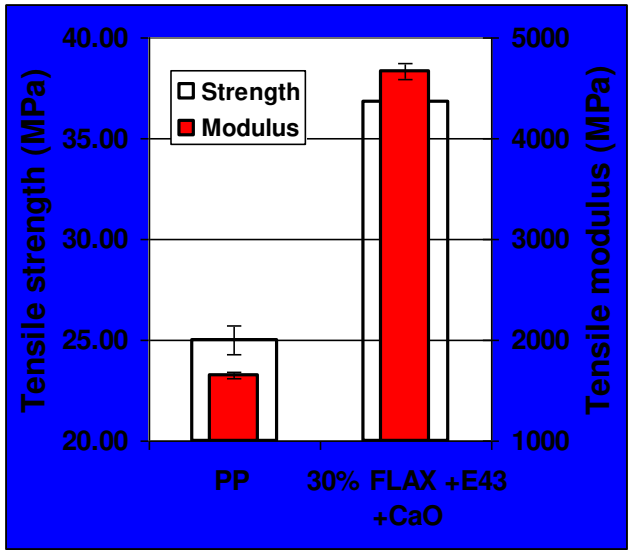
Interface
With coupling agent and CaO

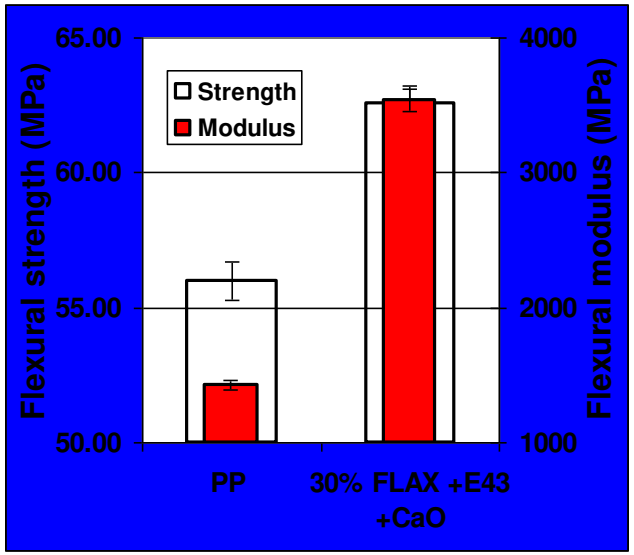
- Good interface

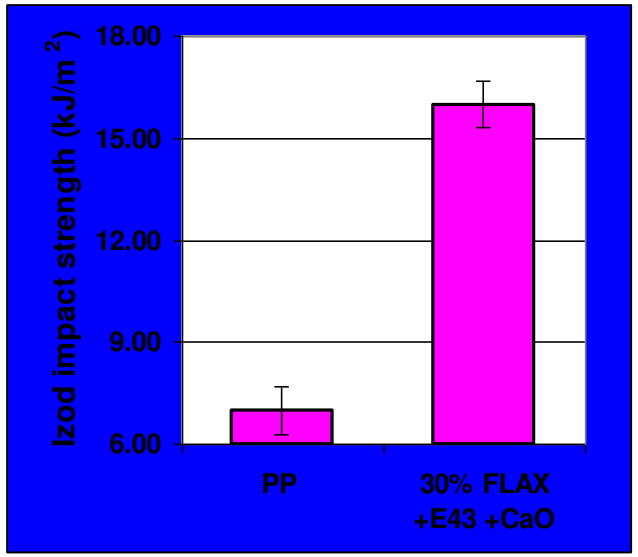


NRC·CNRC
Industrial Materials Institute

Mechanical properties – Injection molding



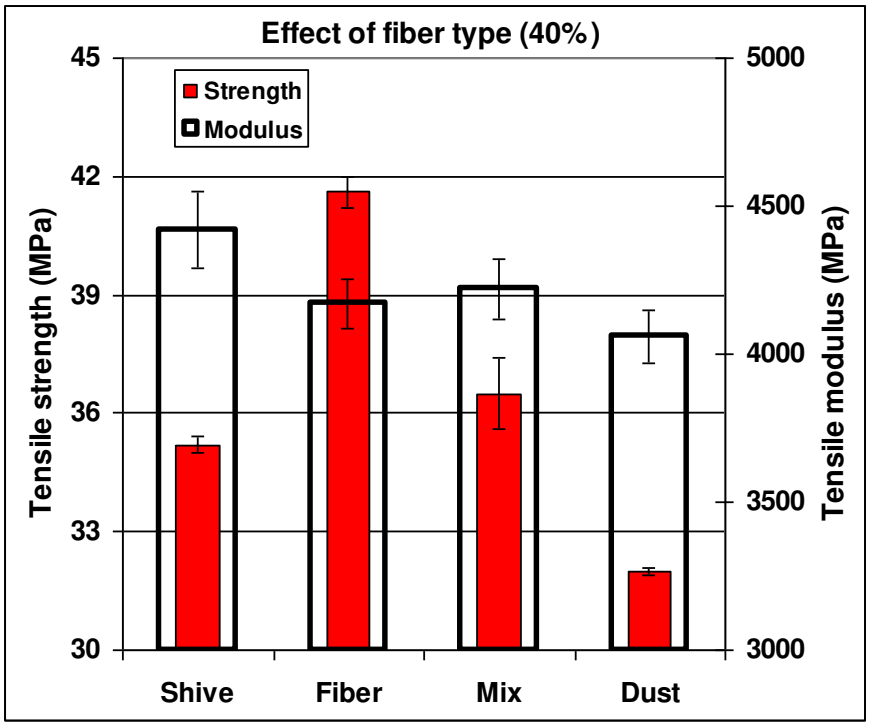


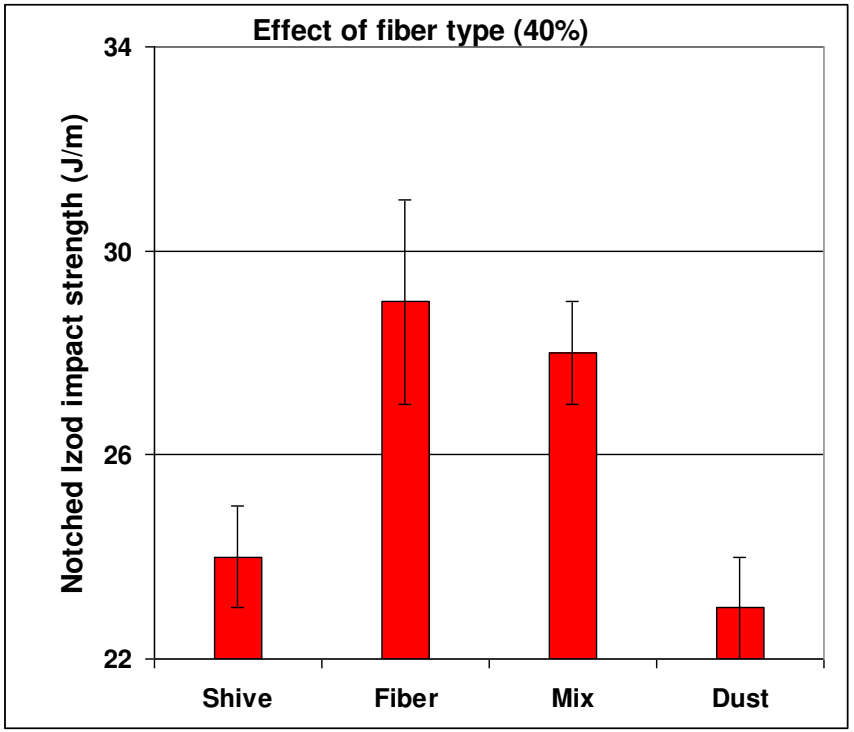


- Properties equivalent to wood-PP composites
- Process not optimized
  - ✓ Grinding
  - ✓ Extrusion
  - ✓ Injection

NRC·CNRC
Industrial Materials Institute

Various Flax types
Extrusion-injection

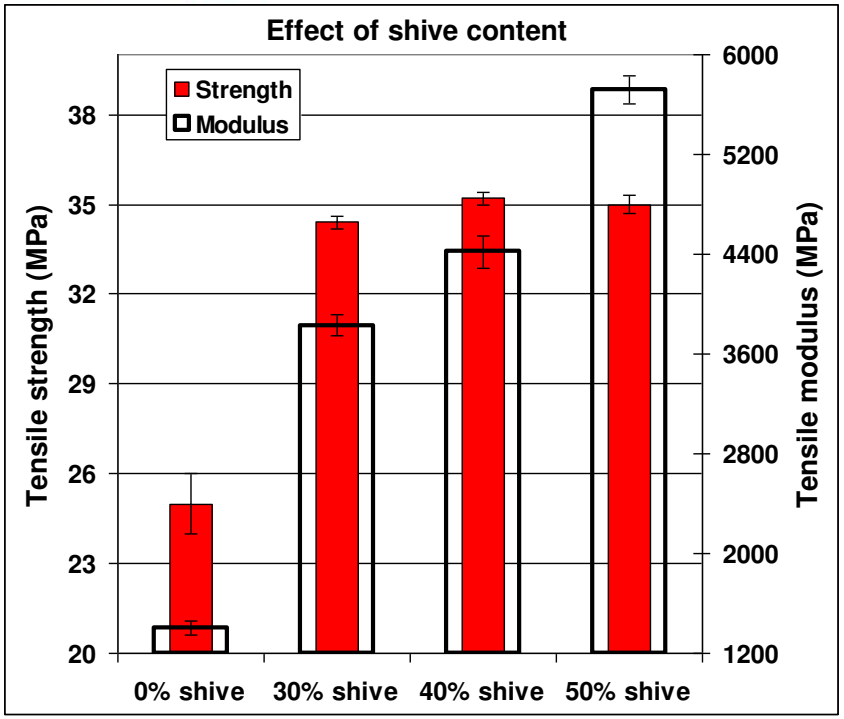


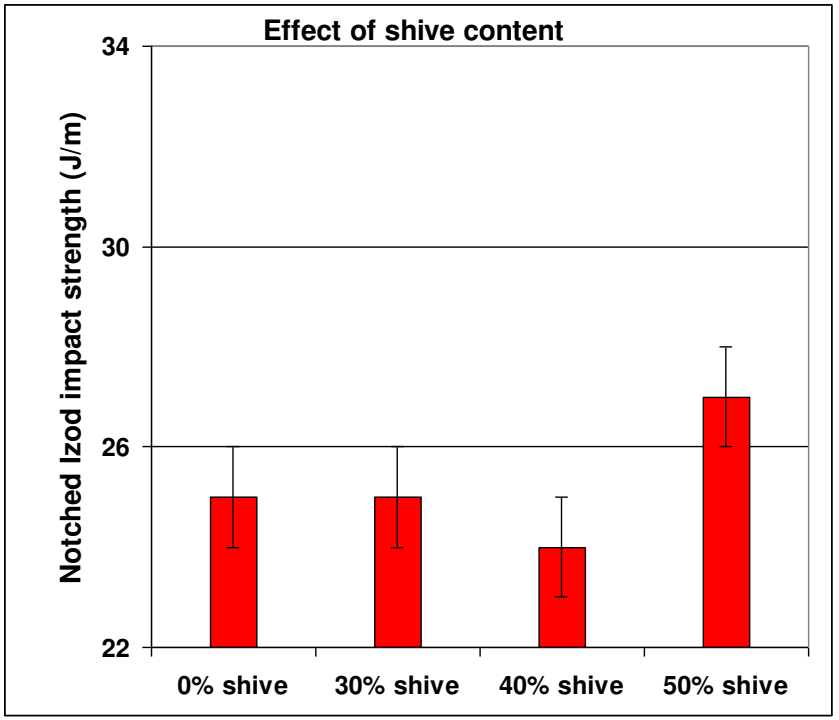


- ❑ All types of flax, even dust, provide a significant imporvement in strength and modulus (neat PP: 25MPa and 1400MPa, respectively) → **very positive!**
- ❑ The longer the reinforcement length, the greater the tensile strength and impact strength as the result of high aspect ratio (although fiber length has been reduced significantly during extrusion and injection)

NRC·CNRC
Industrial Materials Institute

Flax shive PP composites
Extrusion-injection

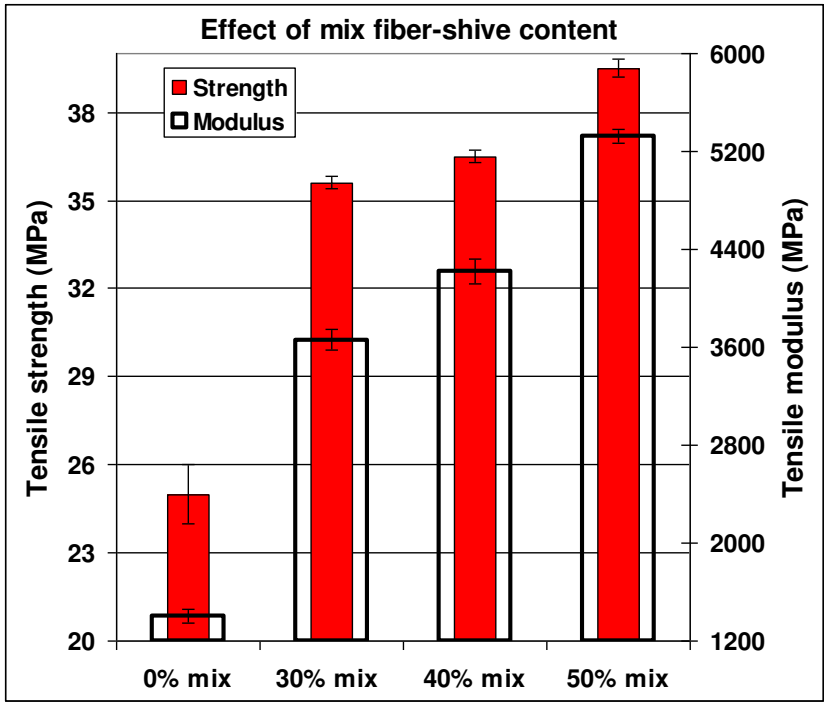


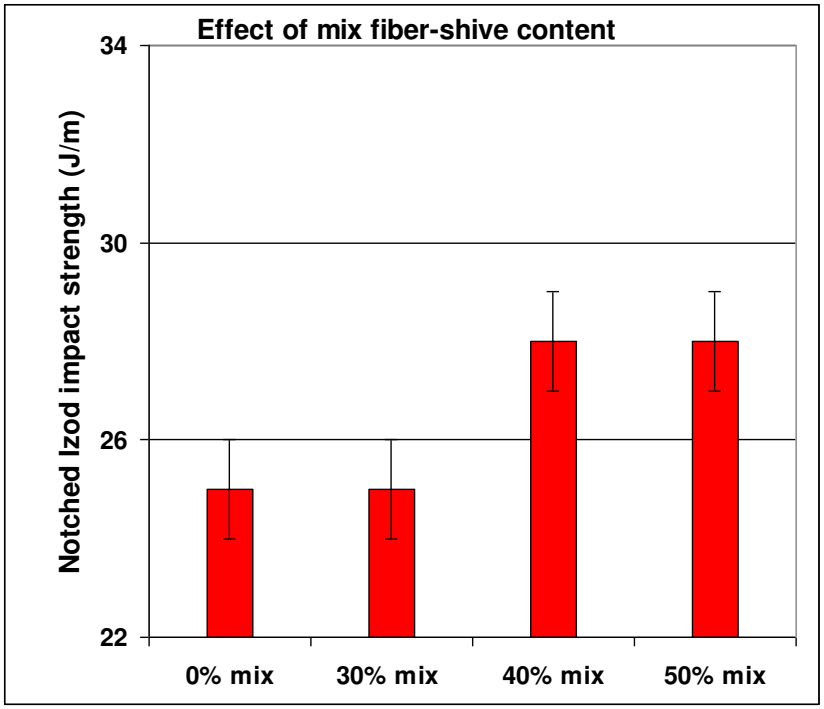


- The presence of shives increases significantly the tensile strength (>35%) and modulus (180-300%) without affecting the impact strength
- The increase of shive content in the composites also increases linearly the tensile modulus but not the tensile strength

NRC·CNRC
Industrial Materials Institute

Mix shives-fibers
Extrusion-injection

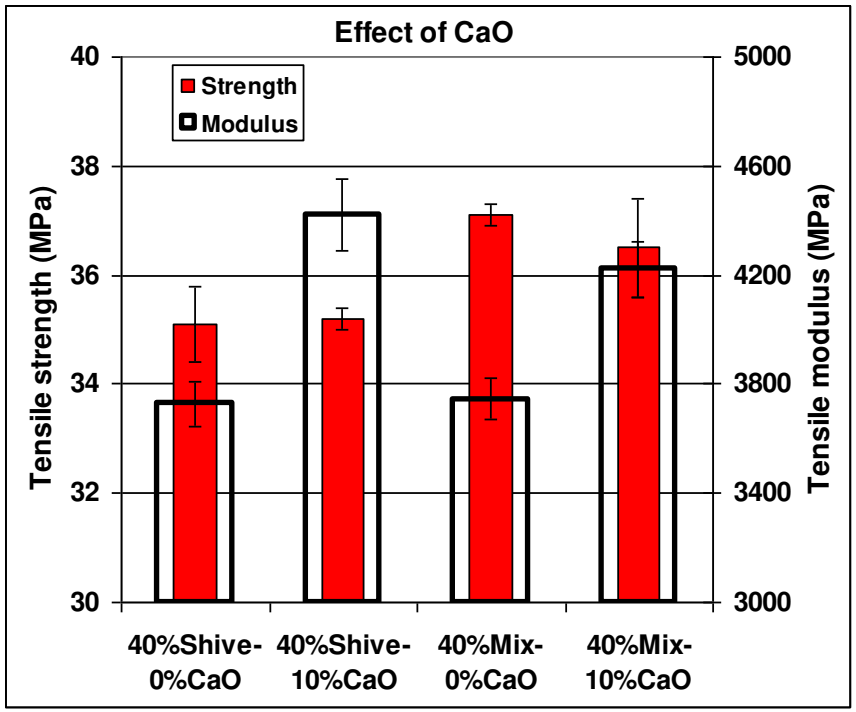


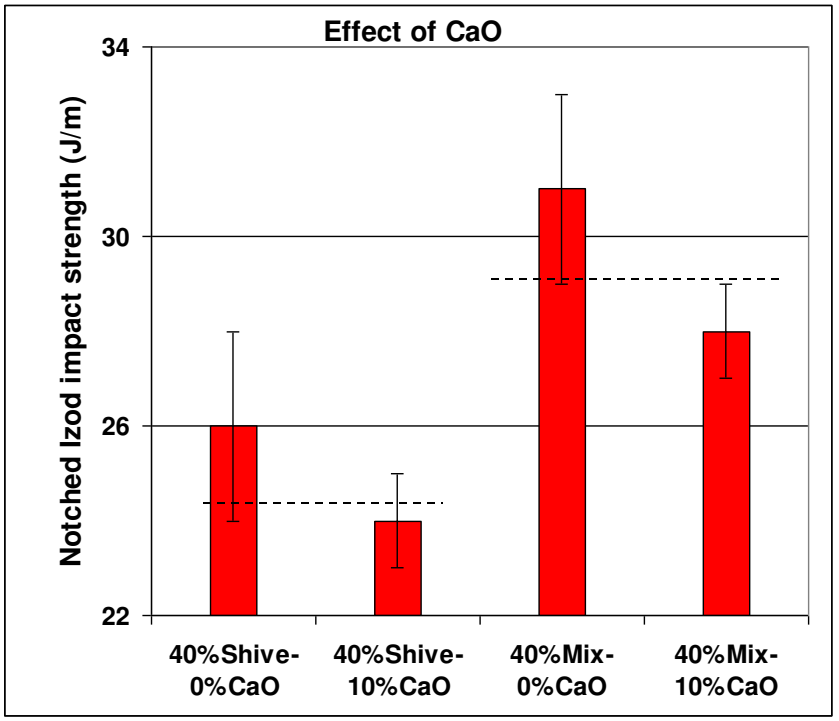


- The presence of mixture of shives and fibers increases significantly the tensile strength (>35%), tensile modulus (160-300%) and the impact strength (~12%)
- The increase of the content of mixture of shives and fibers in the composites also increases linearly the tensile modulus and the tensile strength

NRC·CNRC
Industrial Materials Institute

Effect of CaO
Extrusion-injection





- CaO improves more than 15% tensile modulus without sacrifying the tensile strength
- Impact strength was not affected by CaO (as standard deviation is taken into account) and remains the same as pure PP (25 J/m)

NRC·CNRC
Industrial Materials Institute

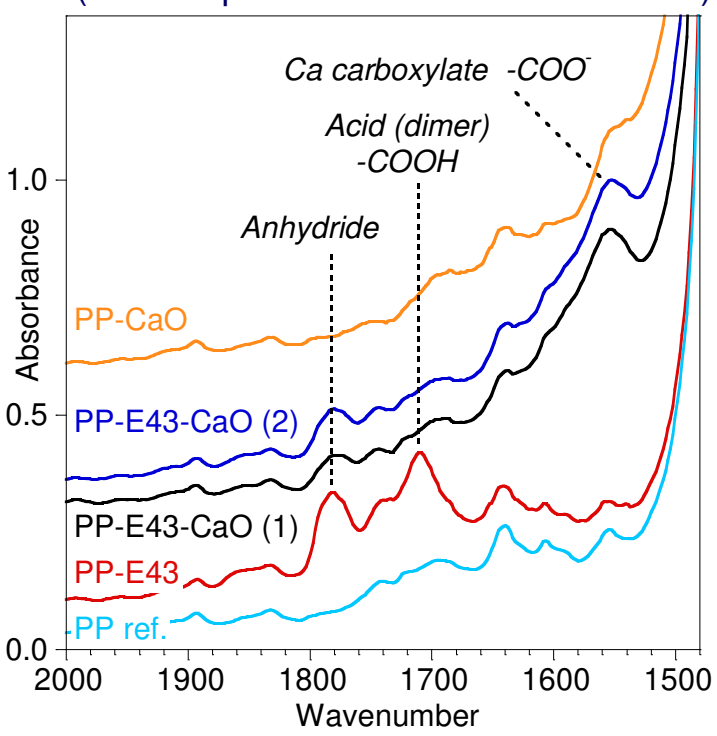
Roles of CaO

- CaO
  - Absorbs humidity in flax
  - Neutralizes acidity in flax
    - → minimize degradation during processing
  - Reacts with maleic anhydride group of coupling agent
    - →Improve interface between flax and PP matrix
    - →Increase molecular weight of coupling agent
    - →Limit a loss in toughness and impact

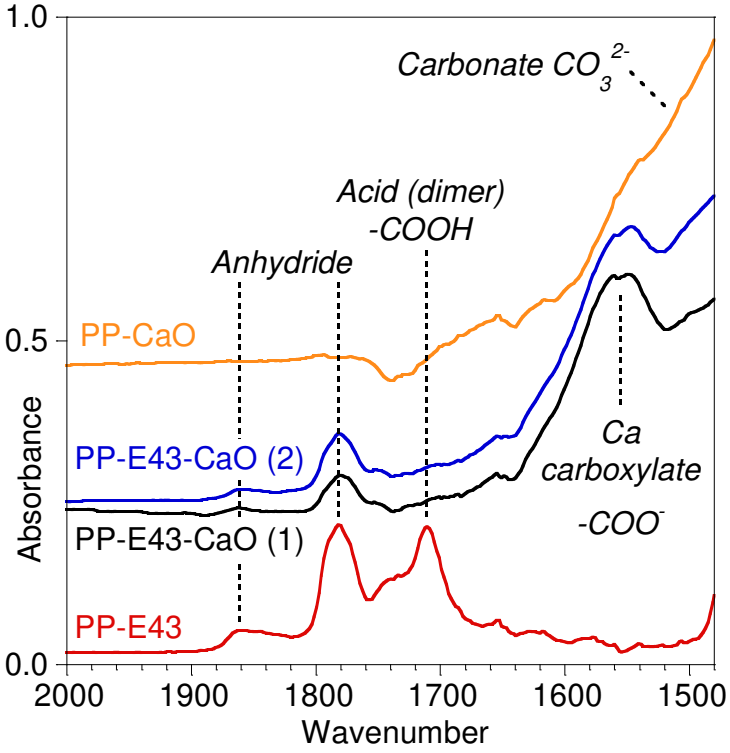
NRC·CNRC
Industrial Materials Institute

Interaction between CaO and coupling agent - FTIR study

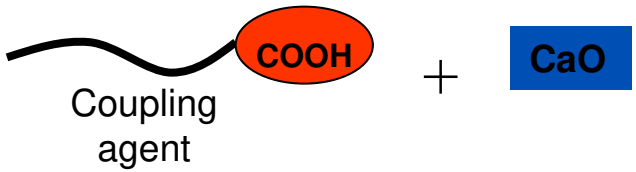
Spectra as measured
(thin hot-pressed films in transmission)



Difference spectra obtained by
subtracting PP ref.

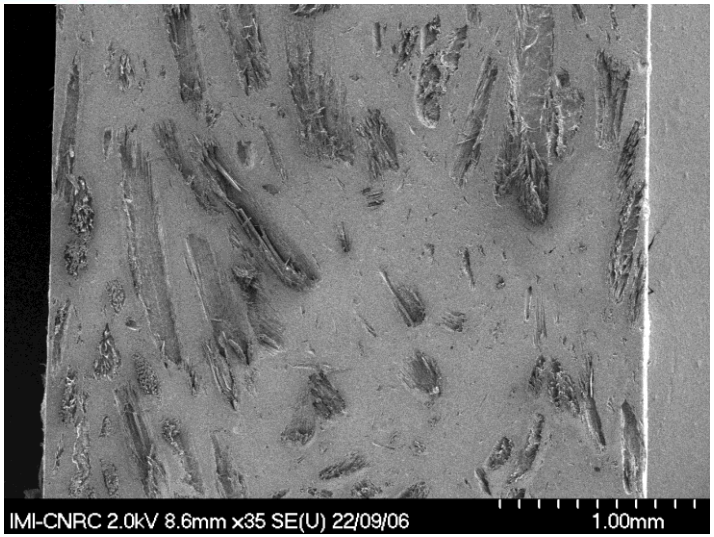


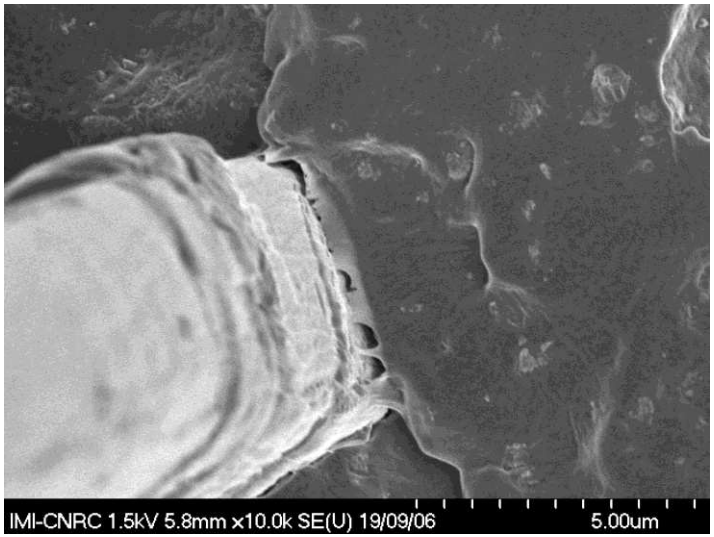
- Evidence of chemical reaction between coupling agent and CaO



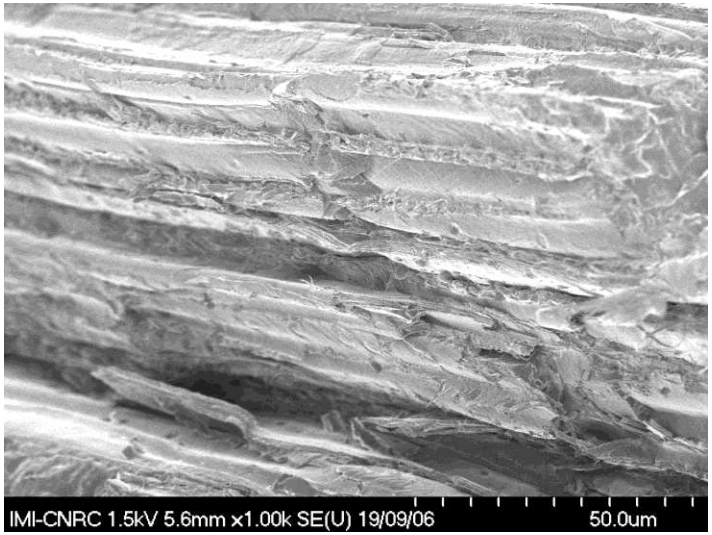
NRC·CNRC
Industrial Materials Institute

Dispersion and Interface
Fiber composites





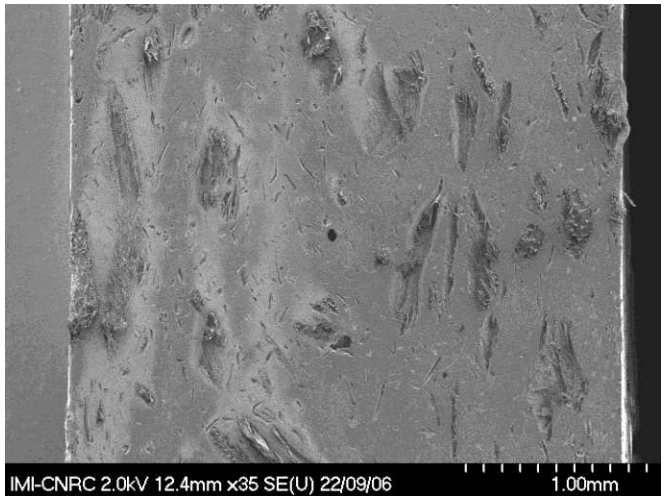
- Good dispersion and distribution of shives
- Good shive-matrix interface

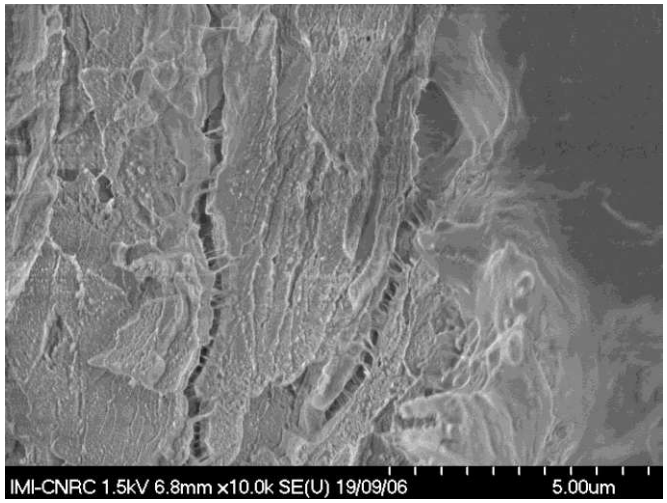


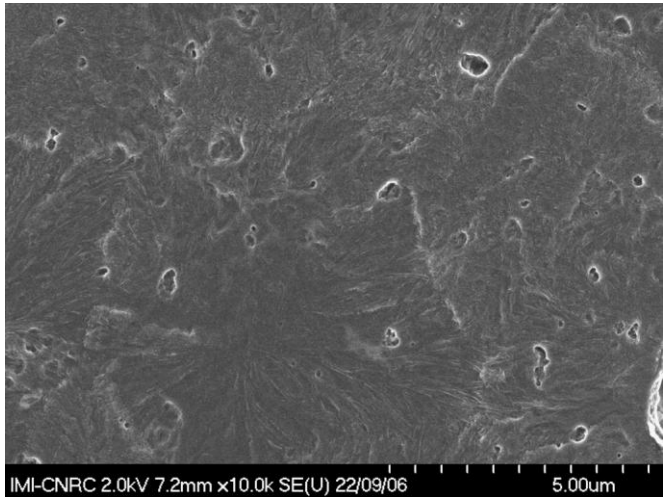
NRC·CNRC
Industrial Materials Institute

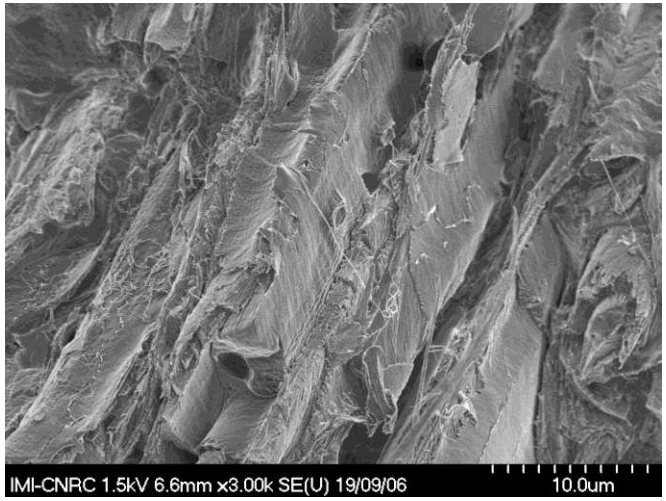
Dispersion and Interface
Mixed fiber-shive composites

- Very good dispersion of shives and fibers in the matrix and great reduction of fiber length can be observed
- Crystalline structure of PP matrix remains
- Very good fiber-matrix interface



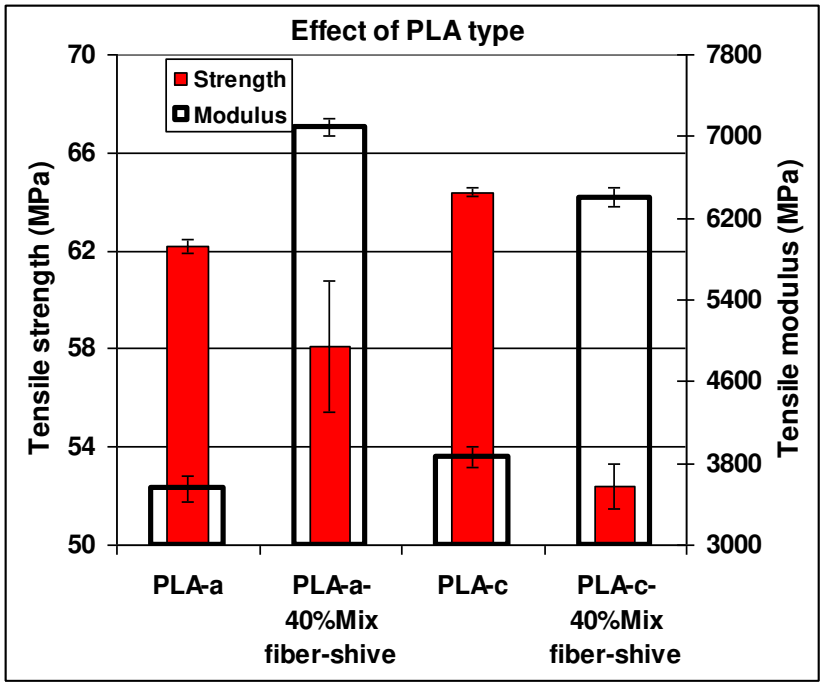


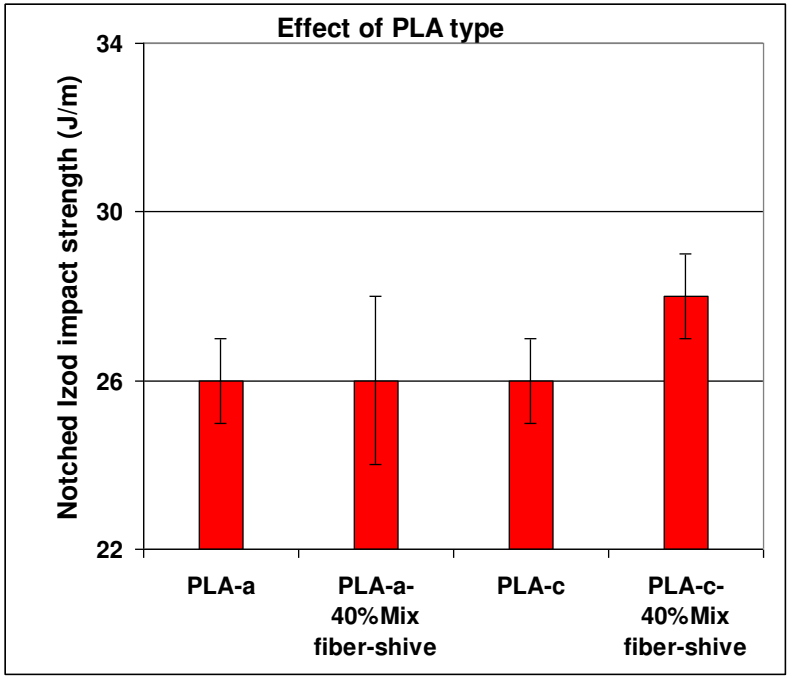




NRC·CNRC
Industrial Materials Institute

PLA-Flax Composites





- Great improvement in modulus for both crystalline (~70%) and amorphous (~100%) PLAs
- Noticable reduction in tensile strength
- No effect on impact strength

NRC·CNRC
Industrial Materials Institute

Conclusions

- Flax fibers and shives can improve significantly the polymer performance even without fiber surface treatment.
- The composite properties are determined by many different factors: flax types, formulation, and processing equipment and conditions.
- The incorporation of some selective mineral fillers can greatly improves the stiffness and the impact resistance without scarifying the strength.
- CaO is the most promising candidate for such purpose.
- PLA-flax composites also show great interest although more work on optimization of formulation and processing conditions must be done.

Acknowledgement

The Government of Canada for the funding via CBIN project