Lower-cost, ligther and greener polypropylene-based biocomposites for construction applications

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LOWER-COST, LIGTHER AND GREENER POLYPROPYLENE-BASED BIOCOMPOUNDS FOR CONSTRUCTION APPLICATIONS

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Canada

OUTLINE

- **About National Research Council Canada**
- **Polypropylene in industrial applications**
- **NRC green vision**
- **Materials, processes and characterization**
- **Bio-based PP compounds:**
  - **Low-cost** biocomposites
  - **Lighter** biocomposites
  - **Greener** bioblends and biocomposites
- **Summary of the achievements**

About NRC:

- The main Research & Technology Organization in Canada
- 2013-14 budget: **820 M$ and** Over **3,400** full-time employees
- 4 divisions: Emerging Technologies, **Engineering**, Life Sciences, Industrial Research Assistance Program (IRAP)
- Wide variety of disciplines, broad array of services and support to industry

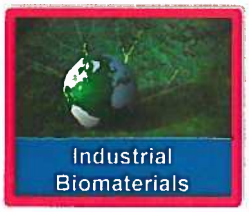
National Research Council Canada: A Research & Technology Organization

- Mission-oriented providers of innovation services to firms and governments (**R&D services, technical services, consortiums, Industrial Research Assistance Program**)
- **Bridges gap** between early stage R&D and technology deployment
- Builds **economic competitiveness** and improving **quality of life**

NRC: Market Driven Programs


Lightweighting


Vehicle Propulsion Technologies


Industrial Biomaterials


Advanced Manufacturing


Design Systems


Rail Vehicle Track Optimization


Fleet Forward 2020

NRC: Industrial Biomaterials Value Proposition

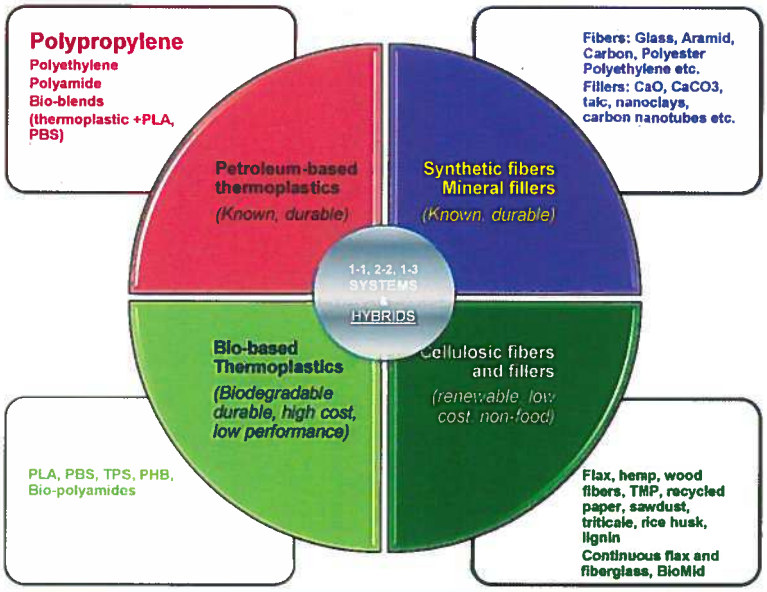
Stronger, tougher thermoplastic / biofiber materials for light-weight, lower-cost and eco-friendly applications:

- Forestry and agricultural cellulosic fibers;
- Sustainable biomaterials;
- Cellulosic biofiber contents up to 50%;
- Weight reduction up to 25%
- Reduction in material costs, energy cost = **Cost savings**
- Custom made formulations to meet industry requirements




NRC: background on bio-based compounds

Experience in biomass utilization in thermoplastics



NRC BACKGROUND:

Formulation
+
Processing:
Compounding
Injection molding
Foaming
Film cast
Film blown
Thermoforming
Compression
D-LFT
+
Characterization
Mechanical
Thermal
HDT
Fire resistance
Etc.

PP in building applications

- PP: the highest injection molded resin in 2013, with a demand estimated at 33 M tons;
- Growing demand for PP, at a CAGR 5% from 2014 to 2020, is expected to be a key driver for the market;

Examples of PP-based parts for construction industry

Window and door frames

Sidings

Trim and moldings

NRC green vision for PP

- Focus on replacement of PP, PP filled with minerals and PP-glass fiber composites with PP bio-compounds;
- The substitution of petroleum-based PP compounds and PP composites by biocomposites containing cellulosic fibers can allow weight and cost reductions;
- The use of injection foaming process allows to further reduce the weight and the cost of the parts;
- The substitution of a part of PP by a bioplastic is a way to increase renewable content.

NRC offers solutions for novel PP biocomposites and bioblends which:

- **Are cost competitive, greener and lighter;**
- **Have equivalent or higher performance compared to conventional materials.**

Materials

Polymers:

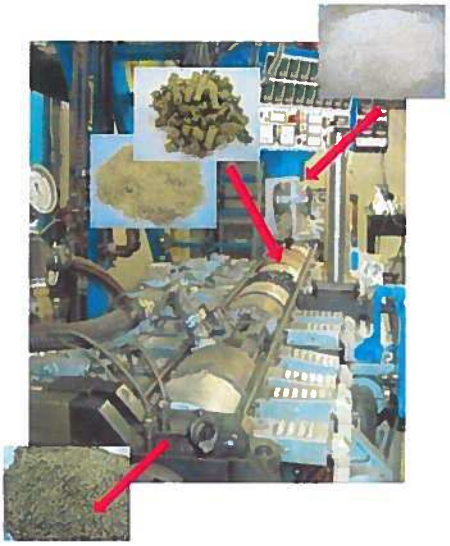
- PP: Pro-fax 6323 general purpose homopolymer for injection molding applications from Lyondell Basell.
- PLA: 8302D amorphous grade from Nature Works, was selected as the bio-sourced minor phase for the production of petro/bio hybrids;
- Coupling agents were used;
- Industrial PP grades used as references were:
  - PP 20% talc – Accutech 20L AND PP 40% talc – Accutech 40L
  - PP 20% GF – Polifil GFPP-20 AND PP 40% GF – Polifil GFPP-40

Bio-reinforcements and reinforcements :

- Cellulosic fibers contents: up to 40%wt;
- Short flax: was supplied by Schweitzer Mauduit Canada;
- Thermo-mechanical pulp (TMP): was supplied by SEC Papier Masson WB;
- Wood fibers (WF) in the form of dices (WoodForce) were supplied by Sonae Industria;
- Short glass fibers (GF), 3 cm in length, were a commercial grade;

Processing & Characterization

Compounding line:

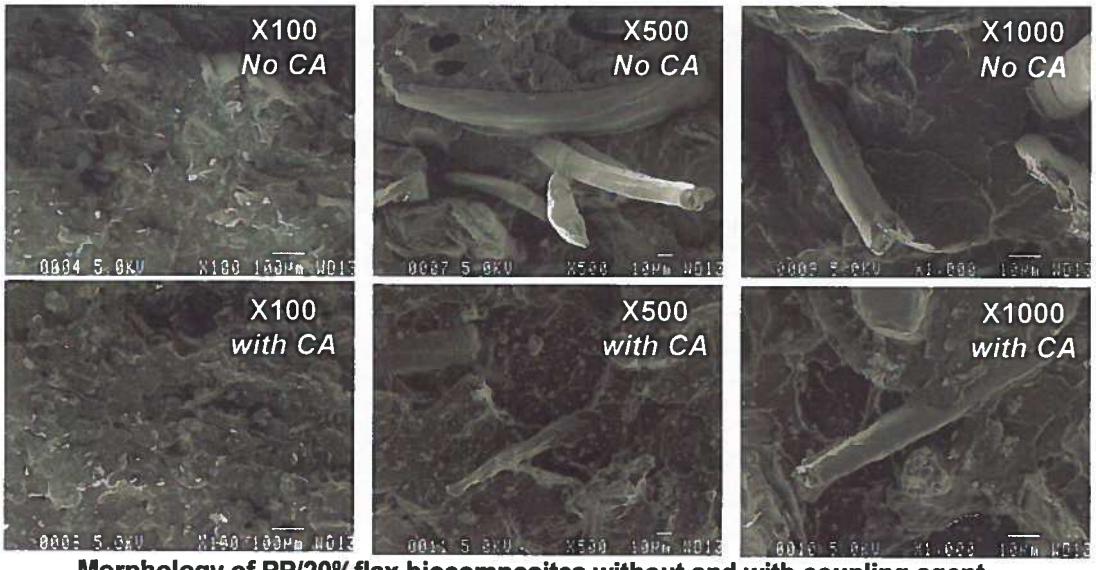


Testing:

- Morphology: Scanning Electron Microscopy (SEM)
- Tensile properties (TS, TM, e%) - ASTM D638
- Impact strength (IS_{Izod}) - ASTM D256
- Heat Deflection Temperature (HDT) - ASTM D648

Low-cost PP-based biocomposites
Partial replacement of PP with cellulosics

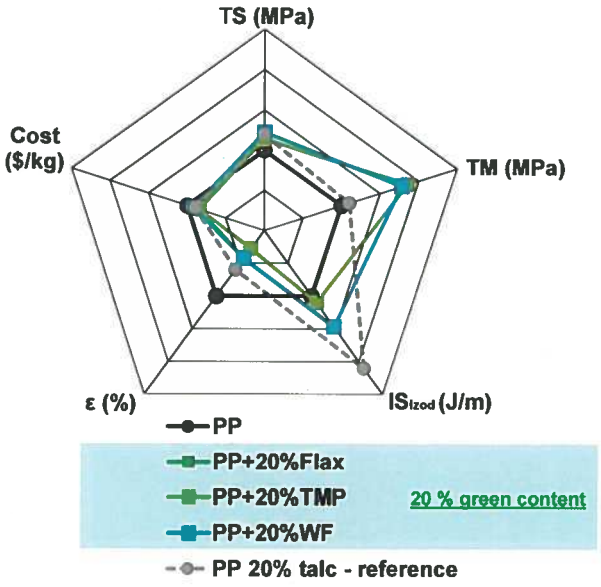
Excellent interfacial adhesion



Morphology of PP/20%flax biocomposites without and with coupling agent

Low-cost PP-based biocomposites
Partial replacement of PP with cellulosics

Excellent tensile properties equivalent with PP and PP/20% minerals



Approximate prices ($/kg) on the market :

PP Medium price	Flax	TMP	WF	PP 20% talc
2.8	0.7	0.5	1.5	3

Cost reduction

Cellulosic contents:	20%	40%
Cost ($/kg) – PP/Flax	2.4	2.0
Cost ($/kg) – PP/TMP	2.6	2.3
Cost ($/kg) – PP/WF	2.4	2.0

When replacing up to 40% of the matrix by cellulosic fibers:

- The mechanical properties are comparable with the references or higher;
- The cost is reduced by 10-30% due to lower price of the cellulosics comparing with the price of PP.

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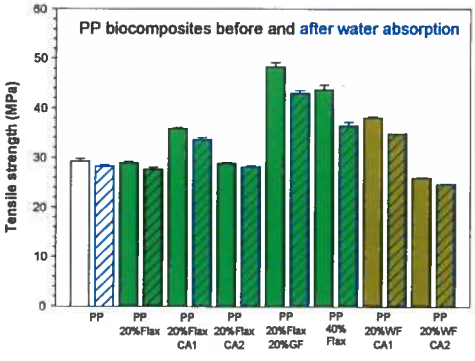
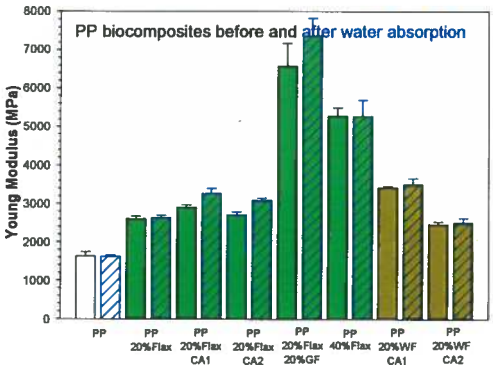
Low-cost PP-based biocomposites
Water absorption – mechanical properties

The mechanical properties of PP biocomposites were preserved after 2 months of water immersion at ambient temperature





The samples absorbed 2.5 to a maximum of 4% of water after two months

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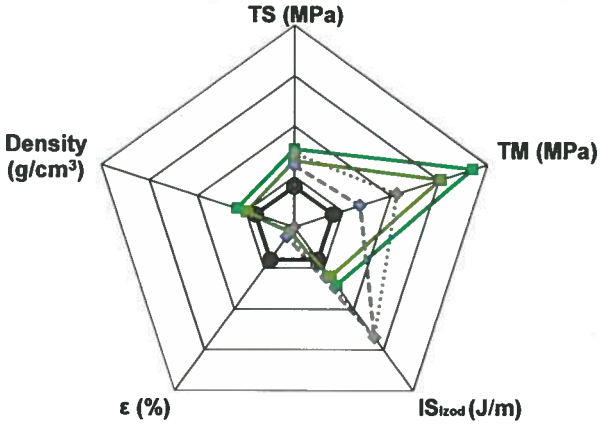
Low-weight PP-based biocomposites
Glass fiber replacement by cellulosic fibers

PP hybrids with excellent mechanical properties



- PP
- PP+20%WF+20%GF
- PP+40%WF
- PP+20%GF reference
- PP+40%GF reference

20 to 40% green content

Density of WF is 1.4 g/cm^3 comparing with the GF density of 2.55 g/cm^3.

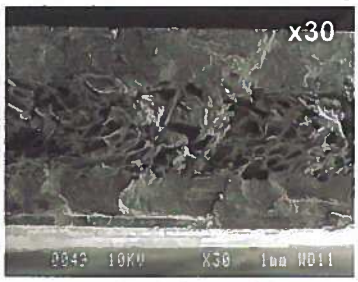
Therefore, 50% glass fiber replacement with cellulosic results in:

- **Up to 10% weight reduction;**
- **Equal or higher mechanical properties.**

Low-weight PP-based biocomposites
Processing means: Foaming in injection molding

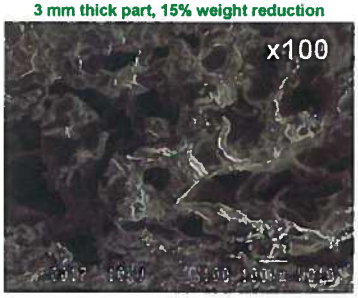
Morphology of PP/20%cellulosic biocomposites: FOAMED

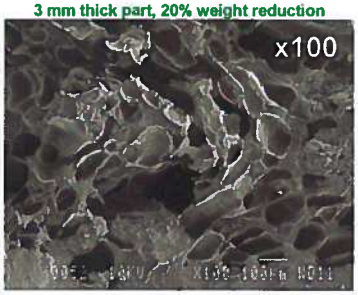
PP with 20 wt.% flax
3 mm thick part, 15% weight reduction

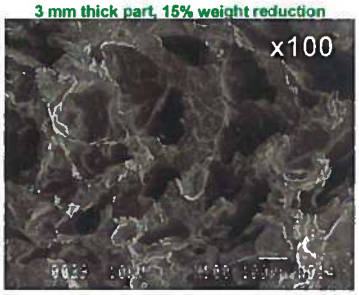


PP with 20 wt.% wood flour
3 mm thick part, 20% weight reduction

PP with 20 wt.% TMP
3 mm thick part, 15% weight reduction

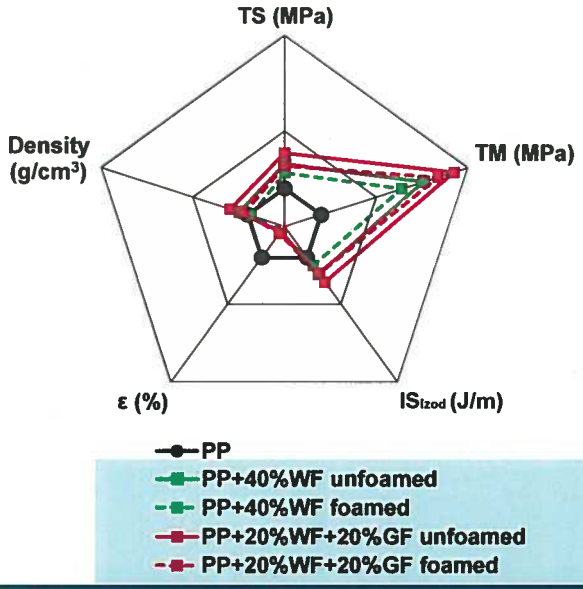






Low-weight PP-based biocomposites
Processing means: Foaming in injection molding

Excellent properties of foamed PP biocomposites



Replacing up to 40% of PP by cellulosic fibers results is a 10-30% cost reduction .

When these biocomposites are further processed by foaming in injection molding the weight reduction could be up to 25 %wt. This translates in up to 25% supplementary cost reduction.

20 to 40% green content

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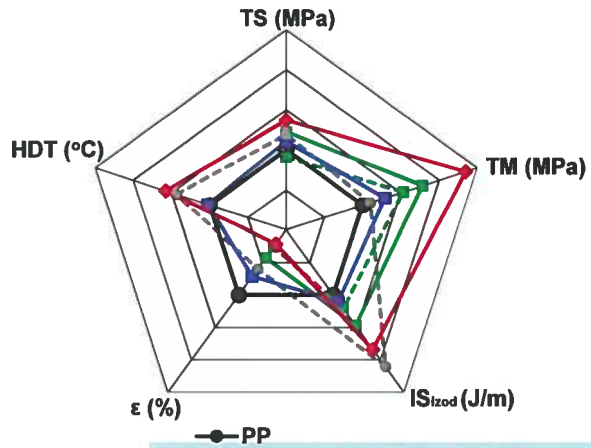
Greener PP/PLA :
Bioblends and biocomposites

Properties of PP/PLA bioblends and PP/PLA biocomposites



- HDT increased from 80°C to 126°C for PP/PLA/20%WF, that is higher comparing with PP/20% talc (115°C)
- ε% decreased as expected for biocomposites
- All other mechanical properties are at least equivalent than for PP alone and PP/20% talc.

20 - 50% green content

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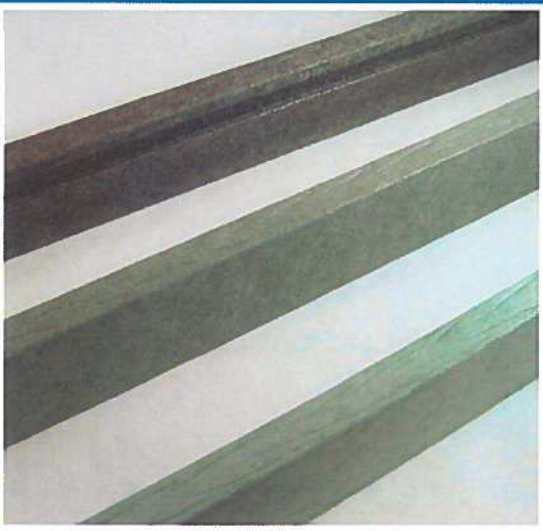
NRC demonstrators based on Polyolefins based biocomposites

Polyolefins / PLA / cellulosics: injected parts

NRC demonstrators based on Polyolefins based biocomposites

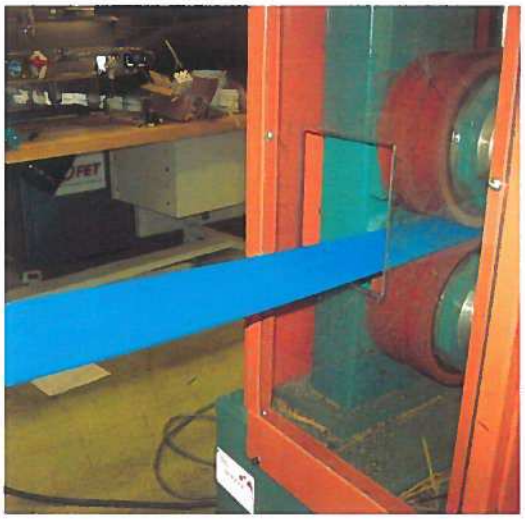
Recycled Polyolefins / 10-50% cellulosics: thermoformed sheets for trim and molding applications

NRC demonstrators based on Polyolefins based biocomposites



- Recycled Polyolefin / cellulosics: extruded foamed profiles.
- Up to 25% weight reduction comparing with the unfoamed profiles.
- Applications: decking, door and window profiles, others…

NRC demonstrators based on PO based biocomposites



Polyolefins / cellulosics biocomposites:
Sidings obtained in extrusion and extrusion foaming

Summary of the achievements

- NRC biocomposites based on PP and PP/PLA are:
  - **Equivalent in terms of mechanical and thermal properties than those of conventional PP-based materials currently used in industry;**
  - **Lower-cost due to a content up to 50 wt.% of renewable resources;**
  - **Lower-weight due to:**
    - **Partial or complete replacement of glass fibers by cellulosic fibers;**
    - **Foaming in injection molding;**
  - **Greener when a bioplastic / biofibers replace a part of the PP matrix.**
- We also developed:
  - PE and PE/PLA based biocomposites with cost and weight reductions;
  - PA6 and PA6/PLA based biocomposites with cost and weight reductions;
  - ABS and ABS/PLA based biocomposites with cost and weight reductions;
  - PP, ABS and PA6 based biocomposites with continuous cellulosic fibers by D-LFT process.
- NRC can help you formulate and process **lower-cost, lighter and greener PP-based biocomposites** according to the specifications of your products.

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Thank you!

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