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Biocomposites and Bioplastics for Automotive
PA and ABS Based Biocomposites

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National Research Council of Canada
Automotive & Surface Transportation (AST)
Industrial Biomaterials Flagship Program (IBFP)
Polymer Bioproducts team

National Research Council Canada | Conseil national de recherches Canada

Canada

About National Research Council Canada (NRC)

- 2012-13 budget: **$774M;**
- Over **4,000** employees and 650 volunteer and independent visitors;
- 4 divisions: Emerging Technologies, Engineering, Life Sciences, Industrial Research Assistance Program (IRAP);
- Wide variety of disciplines and broad array of services and support to industry.

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Industrial Biomaterials Flagship Program (IBFP)

- Positions Canada as an international player in the field of industrial biomaterials: **formulation, product development and fabrication;**
- Engages industry and supports the development of the entire supply chain;
- Allows industry to **valorize products**:
  - Transformation of biomass in biomaterials for key industrial sectors;
- Supports the **road to sustainability**:
  - Substitution of petroleum-based resins, synthetic fibers and their composites by materials containing non food renewable resources

BIOMASS
Supply, selection, harvesting, standards

RAW MATERIALS TREATMENT
Characterization, fitness for use, handling

PROCESSING/ MANUFACTURING
Flexible platforms, high through-put, reliability, new markets

COMMERCIALIZATION
Cheaper, lighter, stronger materials for the construction and automotive industries

Automotive & Surface Transportation (AST) – Polymer Bioproducts Team (Boucherville, QC)

Summary

1- **Introduction**

2- **PA and ABS Based Biocomposites for Automotive:**

2.1- Biocomposites based on PA6 and PA6/PLA with short fibers
- Materials, Processing & Characterization Methods
- Results of characterization

2.2- Biocomposites based on ABS and ABS/PLA with short fibers
- Materials, Processing & Characterization Methods
- Results of characterization

2.3- PA6 with flax slivers, glass roving and hybrids (D-LFT)
- Materials, Processing & Characterization Methods
- Results of characterization

3- **Conclusions**

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1. Introduction: Greener Automotive Biomaterials

- The aim of this work is **to develop greener and cost competitive** engineering thermoplastic materials for automotive parts.
- 180 kg of thermoplastics are used in a car, i.e. 12 % from the car weight and 50% from the car volume. Most of these thermoplastics are used in fiberglass composites.
- Among those thermoplastics:
  - **9% are PA based parts** mostly used in under-the-hood applications. They represent **16.2 kg/vehicle**.
  - **8% are ABS and ABS/PC parts** used in B/C pillars, interior door assemblies, overhead consoles etc. and represents **14.4 kg/vehicle**
- The substitution of petroleum-based plastics and composites by biocomposites containing cellulosic fibers can allow **weight and cost reductions**.
- The substitution of a part of petroleum-based plastics by bioplastics is a **way to increase renewable content**.

In this presentation, focus is put on the **replacement of PA6 and ABS based components by greener equivalents**, while preserving thermal & mechanical performance, as well as durability.

DOOR CARRIER

Battery Trays, Tubs in floor

Front-end Carriers

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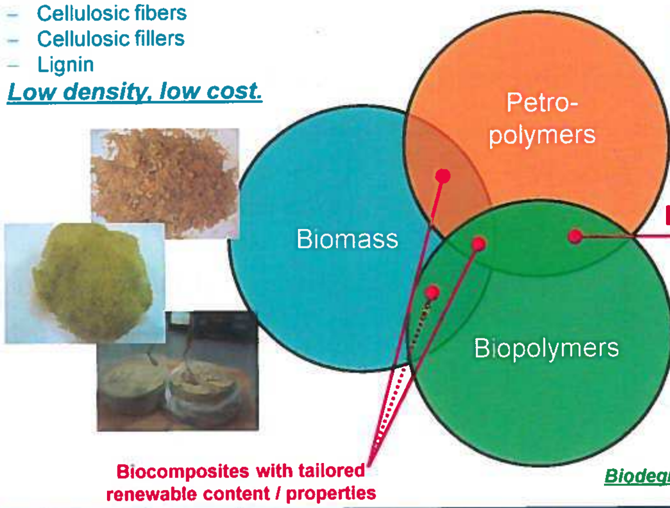
1. How can we increase renewable content in plastic materials?

Non food biomass:
- Cellulosic fibers
- Cellulosic fillers
- Lignin

Low density, low cost.

Petro-polymers:
- Polyolefins (PP, TPO)
- PC, ABS, alloys
- PA6, PA66
- Etc.

Durable, well-known.



Biopolymers:
- PLA
- PBS
- Bio-polyamides
- Bio-polyolefins
- Etc.

Biodegradable or durable, high cost, limited performance.

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2. PA and ABS Based Biocomposites with short fibers:

2.1 based on PA6, PA6/PLA

2.2 based on ABS, ABS/PLA

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2. Materials

❑ **Polymers:**

- PA6: injection molding / extrusion grade, PA – Ultramid B27 from BASF.
- ABS: injection molding grade, Lustran Elite 1827 for high-heat application in automotive market. Typical applications: door panels, A&B pillars, consoles trims etc.
- PLA: an amorphous grade, 8302D from Nature Works was selected as the bio-sourced minor phase for the production of petro/bio hybrids.
- Coupling agents were used.
- Fiber concentrations in polymers: 10% up to 40%wt.

❑ **Bio-reinforcements:**

- Flax: was supplied by Schweitzer Mauduit Canada.
- Thermo-mechanical pulp (TMP) – was supplied by a Canadian producer.
- Wood fibers (WF) in the form of dices (WoodForce) were supplied by Sonae Industria.
- Glass fibers, 3 cm in length.

Flax

TMP

Woodforce

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2. Processing & Characterization

❑ **Processing:**

- Compounding was performed on a Leistritz 34mm twin screw extruder. All materials were dried before extrusion.
- Specimens for mechanical testing and foaming were injection-molded using a Boy 34t injection-molding machine.

❑ **Characterization:**

All materials were dried under vacuum for 24 h before testing:

- Tensile properties (TS, TM, ε%) were determined according to ASTM D638 using type I specimens and a crosshead speed of 5 mm/min.
- Impact strength (iS_{Izod}) was determined according to ASTM D256 (Izod) using notched samples and a 2 ft.lb pendulum.
- Heat deflection temperature (HDT) was determined according to ASTM D648 (method B: 0.45 MPa).
- Morphology: Jeol scanning electron microscopy.

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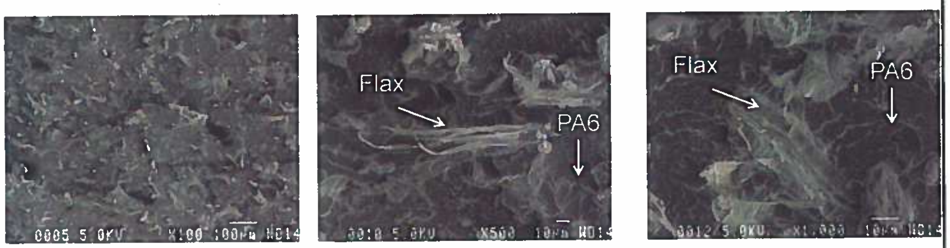
2.1 Biocomposites based on PA6: Morphology of PA6/20%flax biocomposites:



x100 x500 x1000

- Very good fiber distribution/dispersion (screw configuration was specifically designed to compound biocomposites).
- PA6 (hydrophilic polymer) and the hydrophilic cellulosic fibers present a good interfacial adhesion (fracture was produced throughout the cellulosic fiber).
- Using an adequate coupling agent allows to further increase interfacial adhesion.

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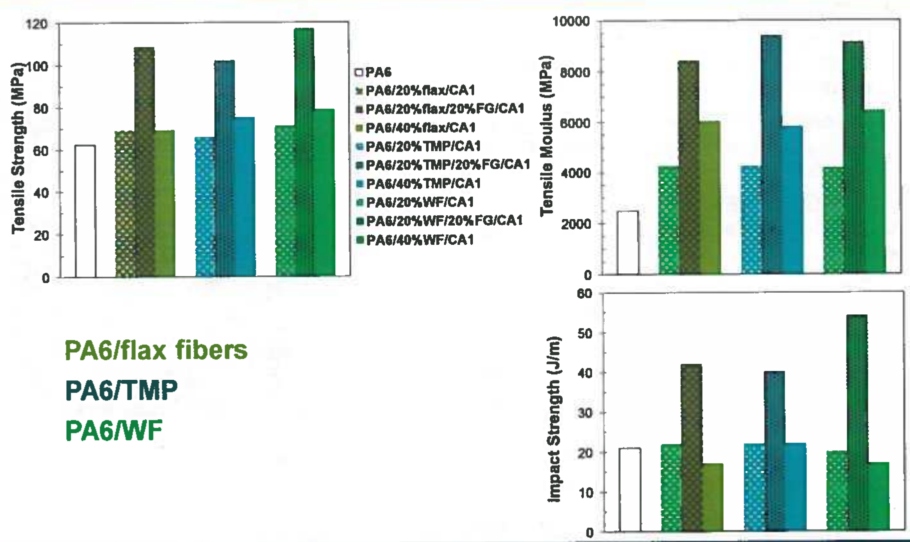
2.1 Biocomposites based on PA6: Tensile properties



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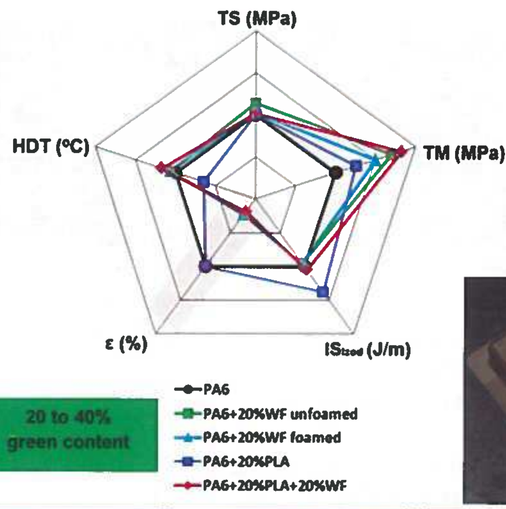
2.1 Biocomposites based on PA6/PLA blends

❑ **Properties of PA6/PLA biocomposites with 20% cellulosic fibers:**



20 to 40% green content

- HDT increased from 160°C to 189°C for PA6/PLA/20%WF
- Foamed biocomposites maintained very good mechanical properties compared to their unfoamed counterparts
- ε% decreased as expected for biocomposites
- All other mechanical properties are higher than for PA6 alone

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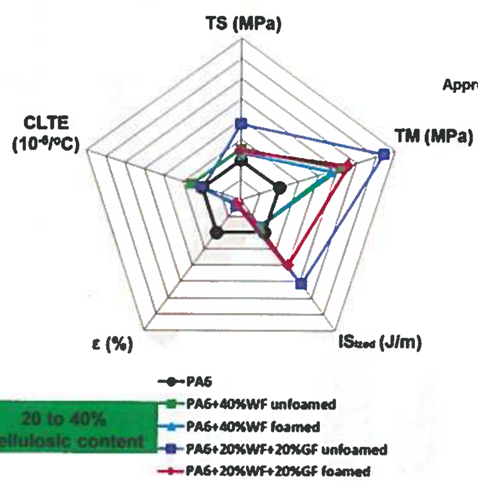
2.1 Biocomposites based on PA6

❑ **Properties of PA6 biocomposites with 40% fibers: unfoamed and foamed**



20 to 40% Cellulosic content

Cost and weight reduction

Approximate prices ($/kg) on the market of polymers and cellulosics:

PA6	PA 30%GF	WF
4.9	5.4	1.5

WF contents:	20%	40%
Cost ($/kg) – PA6/WF	4.3	3.6

Replacing 20 to 40% of PA6 with cellulosics results is a 28-35% cost reduction.

PA6 biocomposites foaming allows a further 10% weight reduction which translates in a supplementary 10% material cost reduction.

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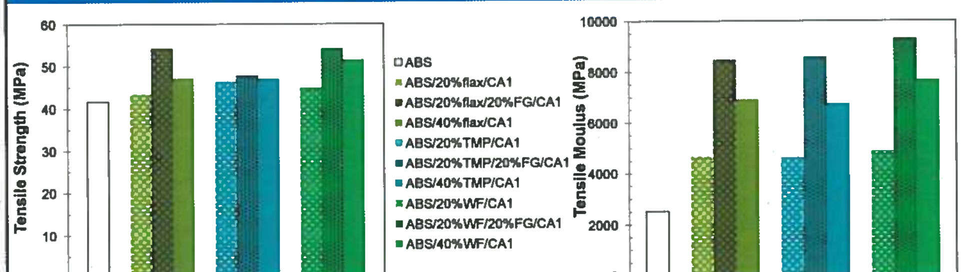
2.2 Biocomposites based on ABS: Morphology of ABS/20%WF biocomposites

X500, no CA **X500, with CA** **X1000, with CA**

- Very good fiber distribution/dispersion (special design for screw configuration).
- There is no adhesion between the ABS, hydrophobic polymer, and the hydrophilic cellulosic fibers in the absence of the coupling agent.
- The fracture was produced throughout the cellulosic fiber in the presence of the coupling agent.
- Therefore, the use of an adequate coupling agent will allow to increase this adhesion and the mechanical properties of the biocomposites.

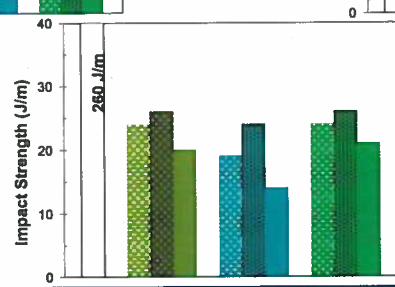
2.2 Biocomposites based on ABS: Mechanical properties



PA6/flax fibers

PA6/TMP

PA6/WF



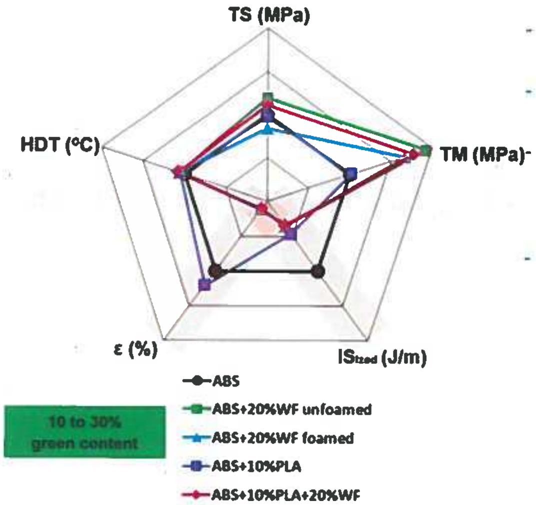
Challenge:

The impact properties of ABS are lost after the cellulosic adhesion.

The impact has to be improved by formulation means: impact modifiers

2.2 Biocomposites based on ABS/PLA blends

- Properties of ABS/PLA biocomposites with 20% fibers:



10 to 30% green content

- HDT increased from 85 up to 92°C for ABS/PLA/20%WF
- ε% and IS decreased as expected for biocomposites
- The foamed biocomposites preserved very good mechanical properties comparing with the unfoamed counterparts
- All other mechanical properties are higher than for PA6 alone

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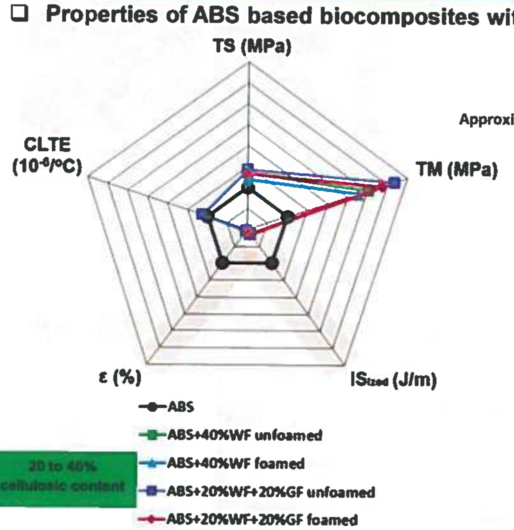
2.2 Biocomposites based on ABS

- Properties of ABS based biocomposites with 40% fibers: unfoamed and foamed



20 to 40% cellulosic content

Cost and weight reduction

Approximate prices ($/kg) on the market of polymers and cellulosics:

ABS	ABS/PC	WF
3.6	3.8	1.5

Cellulosic contents:	20%	40%
Price ($/kg) – ABS/WF	3.2	2.8

Replacing 20 to 40% of ABS with cellulosics results is a 11-35% cost reduction.

ABS biocomposites foaming allows a further 10% weight reduction which translates in a supplementary 10% material cost reduction.

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2.3 PA6 with flax slivers, glass roving and hybrids

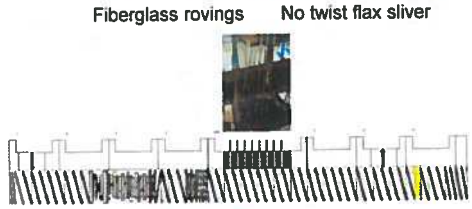
2.3 Materials and procedure: PA6 with flax slivers, glass roving and hybrids

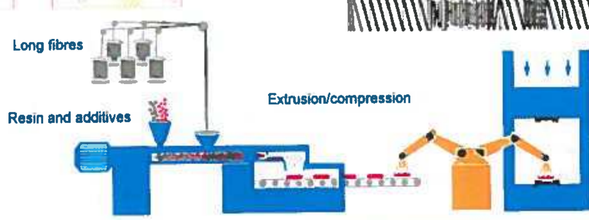
❑ **Processing:**

- PA6 B27E, general purpose extrusion grade, 130 cc/10 min (275 C/5 kg)
- Continuous fibre reinforcement (sliver):
- No twist flax sliver tex= 10,000
- Fiberglass tex= 2,500

Fiberglass rovings

No twist flax sliver





D-LFT industrial scale experimental line

2.3 Materials and procedure
PA6 with flax slivers, glass roving and hybrids

❑ **Obtained D-LFT parts:**

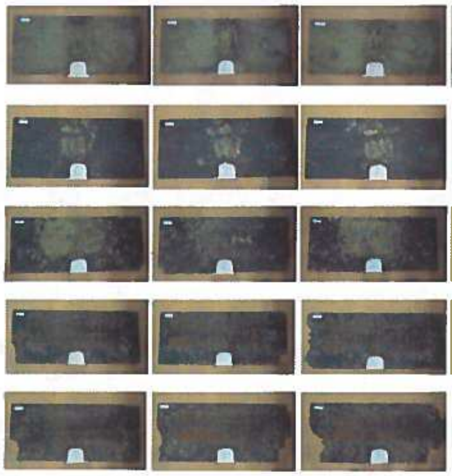
40%GF-0%Flax

30%GF-10%Flax

20%GF-20%Flax

10%GF-30%Flax

0%GF-40%Flax



- PA6/flax sliver/fiberglass molded plaques presented the short shots for the high flax content samples.
- This is a consequence of the alteration of the material rheology as the flax fibers are added.
- The flax fibers increase the compound viscosity which makes it more difficult to flow and reach the ends of the mold.

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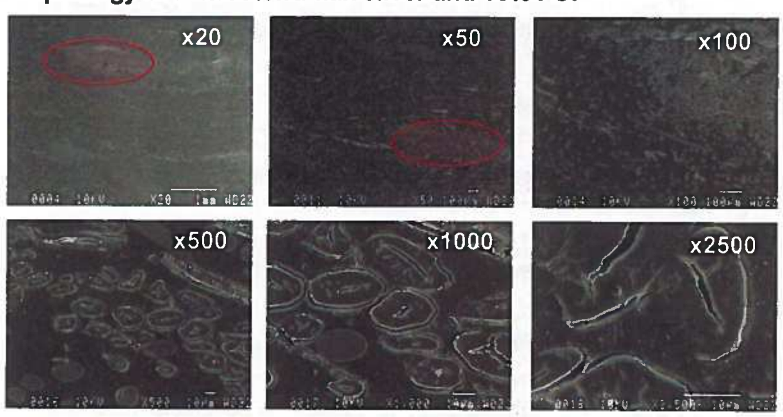
2.3 Materials and procedure:
PA6 with flax slivers, glass roving and hybrids

❑ **Morphology of PA6/30%wt. flax sliver and 10% FG:**



- Same distribution was observed in MD and TD for all plaques.
- Bundles of fibers can be observed.

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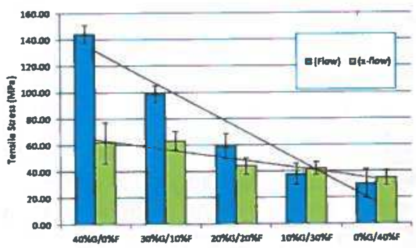
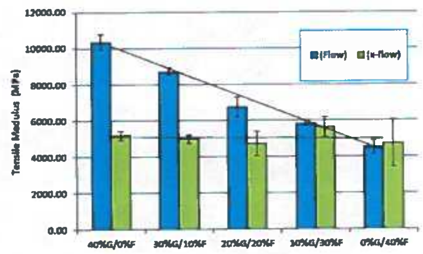
2.3 Materials and procedure: PA6 with flax slivers, glass roving and hybrids

❑ **Tensile properties:**





- The flow direction values of maximum tensile stress varied from 143 MPa for the 40 wt%. fiberglass sample to 36 MPa for the 40 wt%. flax sample
- The tensile modulus in the flow direction also showed a reduction as flax fibers were varied from 0% to 40%. This is evidence of the effect of glass fiber orientation on the part stiffness.
- The samples on the cross-flow direction showed no significant variation as the amount of flax fibers was gradually increased from 0% to 40% with a trend line almost perfectly horizontal.

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3. Conclusions

❑ NRC can help you formulate and process <u>biocomposites and bioplastics</u> with improved renewable content according to the specifications of your products.

❑ As an example:

- Our PA6 and PA6/PLA based biocomposites:
  - Contain up to 40 wt.% renewable resources,
  - Up to 40% lower weight and cost due to the incorporation of cellulosic fibers and chemical foaming in injection molding,
  - Offer mechanical and thermal properties comparable or higher than those of pure polymers classically used in automotive.

❑ We also develop:

- PA6, ABS and PP based biocomposites hybrids with flax and glass rovings
- PP/PLA and PP/PBS based biocomposites with cellulosic materials.

❑ We develop innovative green products for automotive under-bonnet and structural applications, as well as light products (ex: foamed components) for a variety of applications.

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Working with NRC

- Technical services
- R&D collaborative projects
- Consortiums (multi-clients projects)
- Industrial Research Assistance Program (IRAP)

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Thank you !

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