Lignin Thermoplastic Products: En Route to Commercialization

NRC: Hongbo Li, Minh Tan Ton-That, Éric Patenaude, Karen Stoeffler and Nathalie Legros

Domtar: Shabnam Sanaei, Bruno Marcoccia and Michel Jean



Outline

- Introduction of NRC and lignin
- Roadmap of NRC's lignin technology
- NRC/Domtar innovative technology on fused lignin pellets
  - *Challenges*
  - *Process*
  - *Benefits*
- Examples of lignin blends for various industrial applications
- Commercialization activity: Demonstration plant at Domtar
- Summary

CANADA'S MAP



About NRC

- Government of Canada's premier **Research & Technology Organization**
- Over **3,700** full-time employees
- 5 divisions: **Transportation and Manufacturing**, Engineering, Emerging Technologies, Life Sciences, Industrial Research Assistance Program (IRAP)
- Provide innovation support to industry with a wide variety of services

Large Scale Processing Capabilities



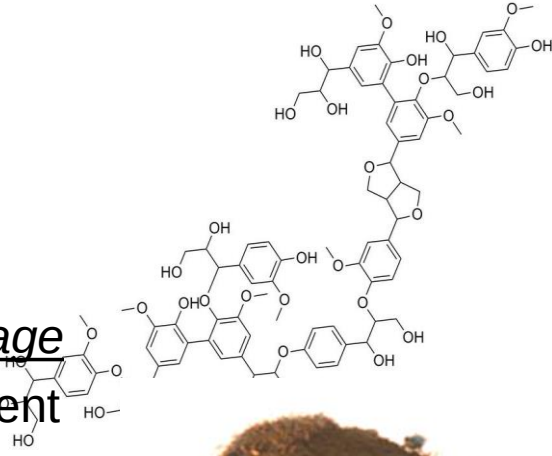
NRC's Industrial Biomaterials Vision

- Position Canada as a global player in industrial biomaterials
  - ⇨ Plentiful biomass in Canada from non-food sources: wood and agricultural derived **lignin** and fibres, agricultural and forestry **residues**
  - ⇨ Growing worldwide market for **lighter**, **low-cost** and **greener** plastics and composites
- Fill the gaps and support the development of the entire supply chain



Lignin Value Proposition for Industry

- Lignin:
  - A renewable thermoplastic → *green advantage*
  - Low density: → *weight reduction*
  - Co-product from industrial process and non-food grade source → *cost competitiveness and sustainable advantage*
  - A distinguish chemical structure with high aromatic content → *technical advantage*
  - Wide availability in Canada and USA all year long → *supply advantage*
  - Under exploitation, mainly for fuel → *a large room for innovation and business opportunity*







- Lignin thermoplastics blends:
  - Partially replace petroleum based thermoplastics
  - An attractive alternative green and rapid solution

Roadmap of NRC's Lignin Technologies

… en route to commercialization



Pulp mills & biorefiners



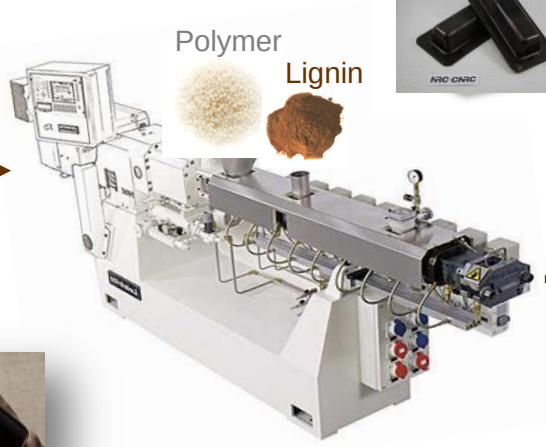


Lignin supply & lignin specialty





Biopolyols and Polyurethane biofoams
- Insulation foam
- Automotive seating



Moulded parts



Eco-fibres



Thermoplastic foam



Extruded construction profile



Industrial plastic films

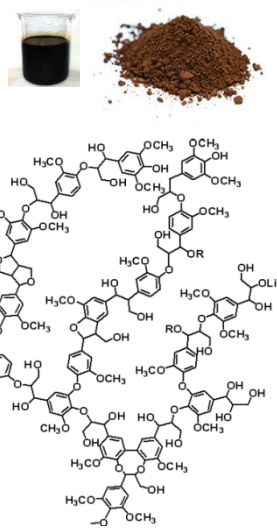
NRC's Lignin Upstream Technology

Forestry biomass residue: barks, saw dust

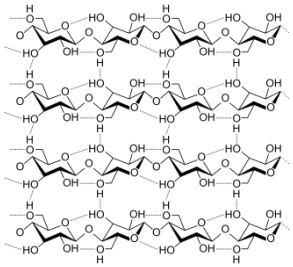












SiO_2 Na_2SiO_3 CaO

$Mg_3Si_4O_{10}(OH)_2$

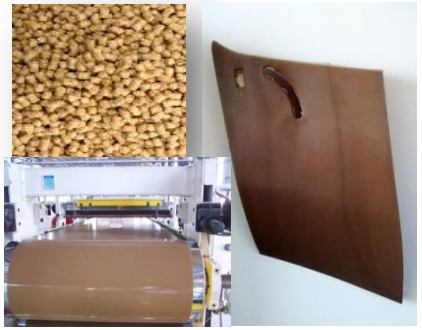
Tannin

Lignin

Slurry residue



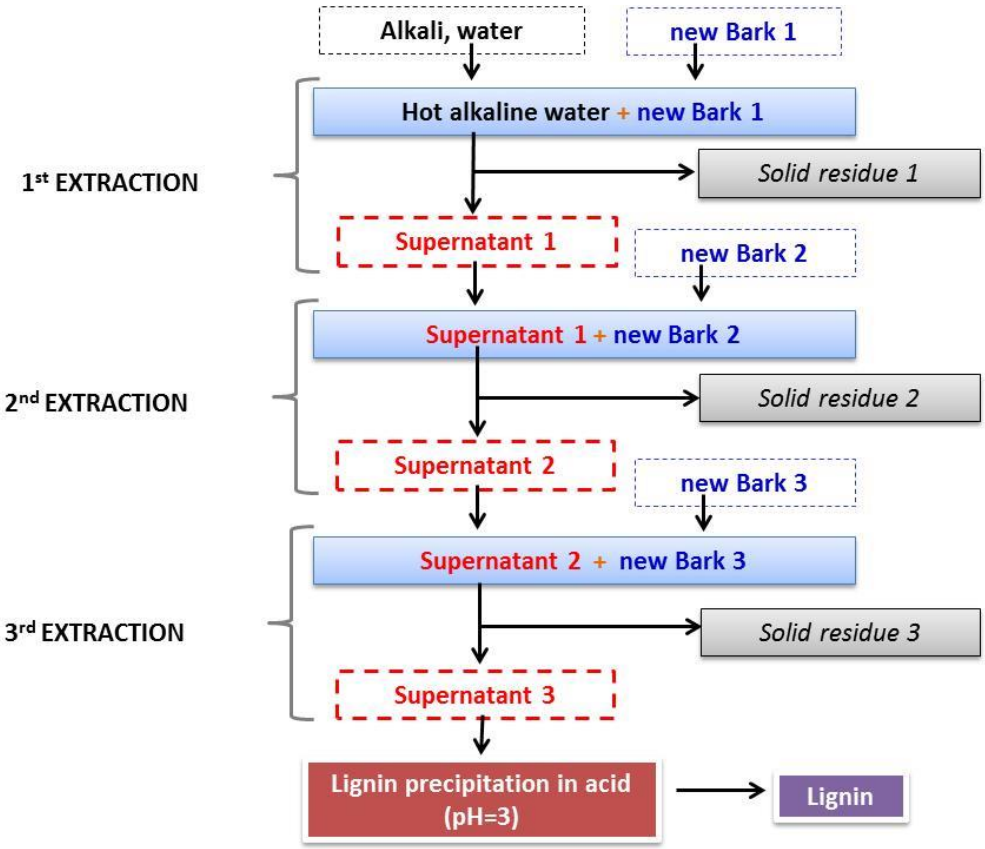
Flexible PU foam



Biocomposites

NRC's Lignin Upstream Technology

Bark is an abundant forest residue in Canada: ~ 17 million tons /year



NRC's innovative approach:

- ✓ **Green, low energy and cost effective**
- ✓ **Easy to scale up to industry**
- ✓ **Proven in the 20L reactor**



Challenges to Utilize Lignin Powders for Thermoplastic Industry

LIGNIN POWDERS





CONVENTIONAL METHOD

- **Drying lignin**
- **Grinding lignin**
- **Screening lignin**

→
- Capital investment
- Energy & labor cost
- Space
- Fire and health risk
- VOC & GHG emission

- **Compounding**

→
- Capital investment
- Energy & labor cost
- Space
- Plant contamination
- VOC & GHG emission

- **Processing into final products by injection, extrusion, etc.**

→
- Capital investment
- Energy & labor cost
- Space
- Water
- GHG

NRC METHOD

- **Pelletizing lignin**
- **Processing into final products by injection, extrusion, etc.**

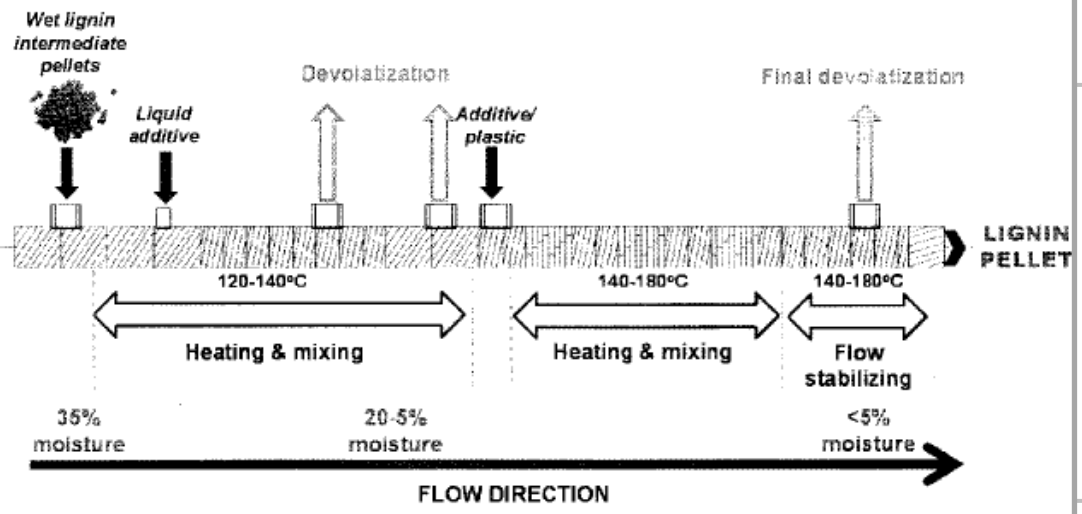
NRC/Domtar Innovative Extruded Fused Lignin Pellets/ Lignin MBs



Wet Lignin



Polymers + additives





Porous extruded pellets



Non porous extruded pellets
80-90% lignin



Non porous extruded lignin MB
50-60% lignin

- Nice extruded lignin pellets (1-5% moisture content) with controlled size and porosity
- 90% VOCs reduction compared with raw lignin powder
- Potential applications: thermosets and thermoplastics

NRC/Domtar Provisional Patent Filing (WO 2018/035598 A1)

TITLE

LIGNIN PELLETS AND PROCESS FOR PRODUCING SAME

FIELD

[0001] The present disclosure broadly relates to lignin pellets and a process for producing same. More specifically, but not exclusively, the present disclosure relates to lignin pellets comprising a fused lignin. The present disclosure also relates to a process for producing the lignin pellets and their use in the manufacture of lignin thermoplastic blend products, polyols, polyphenols, polyaromatics and polyurethanes.

Inventors:

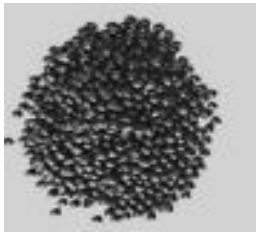
NRC: Minh Tan Ton-That, Hongbo Li and Éric Patenaude

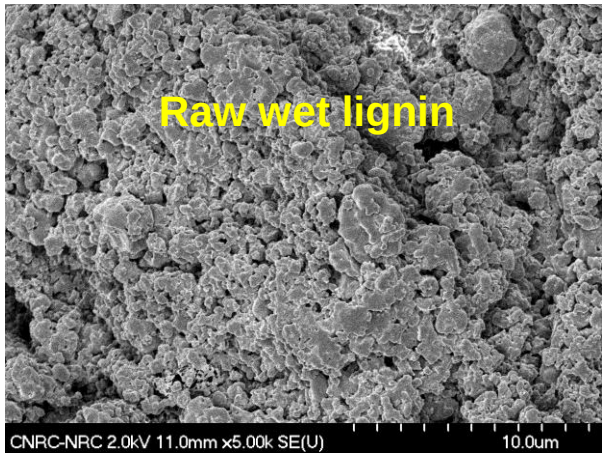
Domtar Inc.: Bruno Marcoccia and Shabnam Sanaei

Excellent Integrity and Homogeneity

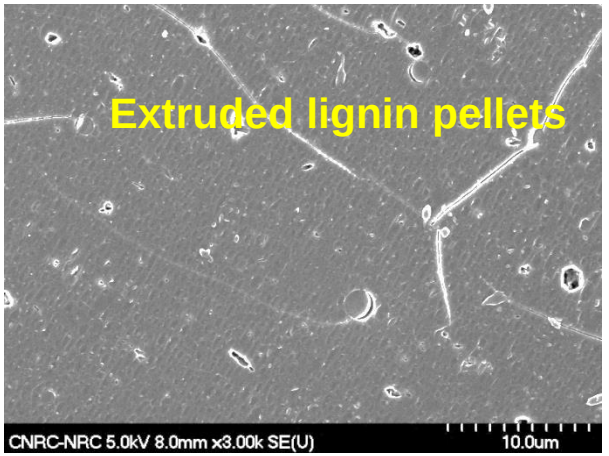












- Raw wet lignin powder: separated particles, agglomerates and lack of cohesive strength
- Extruded lignin pellets: good fusion, very homogeneous and very good cohesive strength

Benefits in Material Handling





- Removal fire & health risk and contamination associated with lignin powder in conventional plastic production plants

Cost Saving by Direct Dry Mixing

NRC/Domtar Lignin Pellets and Lignin MBs

Lignin pellets



80-90% lignin

Lignin MB



50-60% lignin



~~Melt compounding~~

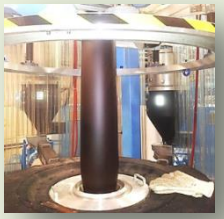


Dry Blending

Industrial Applications



Injection moulded parts



Industrial blown films



Thermoplastic foam



Industrial plastic cast films



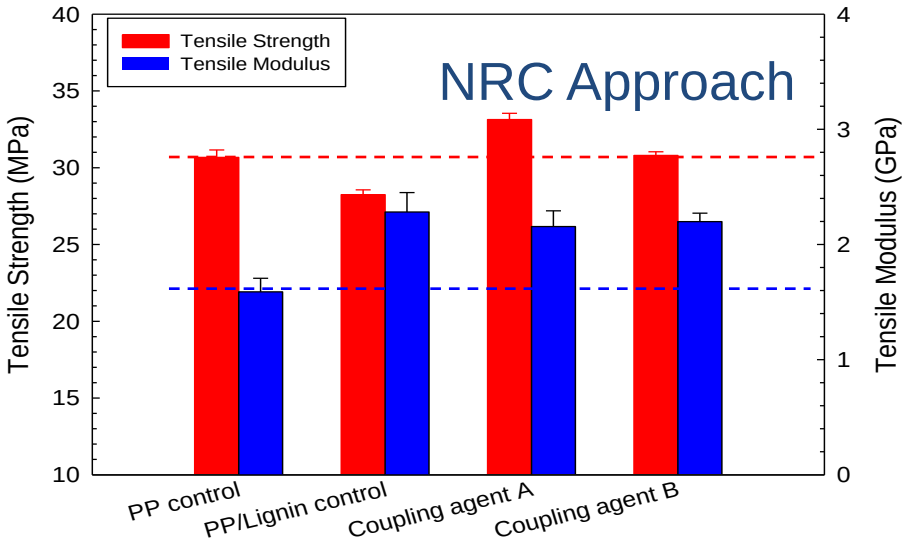
Extruded construction profile



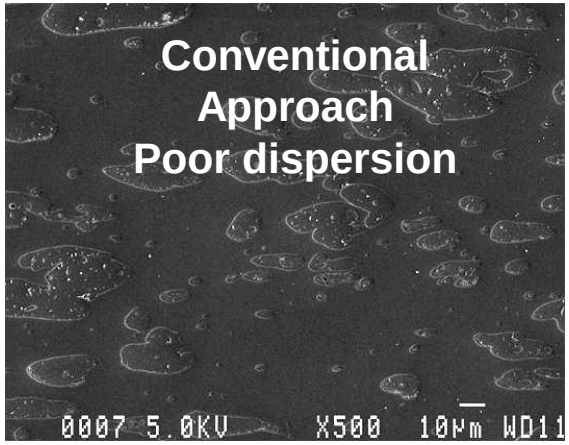
Industrial plastic sheet extrusion

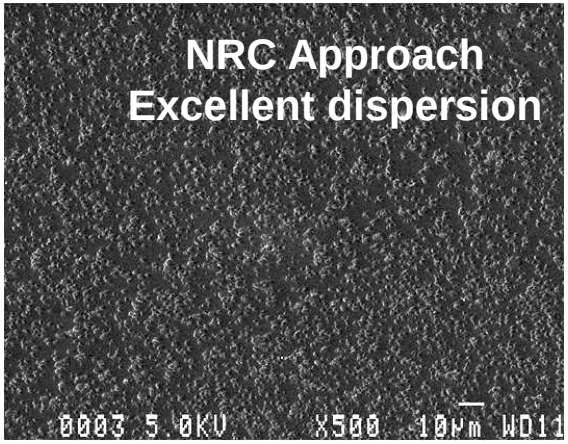
PP/ Lignin Blends for Injection Molding

- Even up to 40% lignin contents:
  - Excellent lignin dispersion (1 µm)
  - Maintained mechanical performance
  - Color of the lignin blends can be tuned









PVC/Lignin Sheet/Profile Extrusion

- ✓ Renewable content up to 40%
- ✓ Neutral cost on material
- ✓ Reduced processing temperature
- ✓ Higher strength and modulus than PVC → weight reduction
- ✓ Processable in conventional equipment

Material	Rigid PVC reference	PVC-1 + 30% Lignin 1	PVC-1 + 30% Lignin 2
Tensile Modulus (MPa)	3051 (176)	4102 (98)	4211 (48)
Tensile Strength (MPa)	47.2 (0.5)	46.0 (3.5)	52.3 (2.8)
Tensile Strength at Yield (0.2% deformation) (MPa)	28.0 (0.6)	37.6 (1.4)	47.8 (1.3)





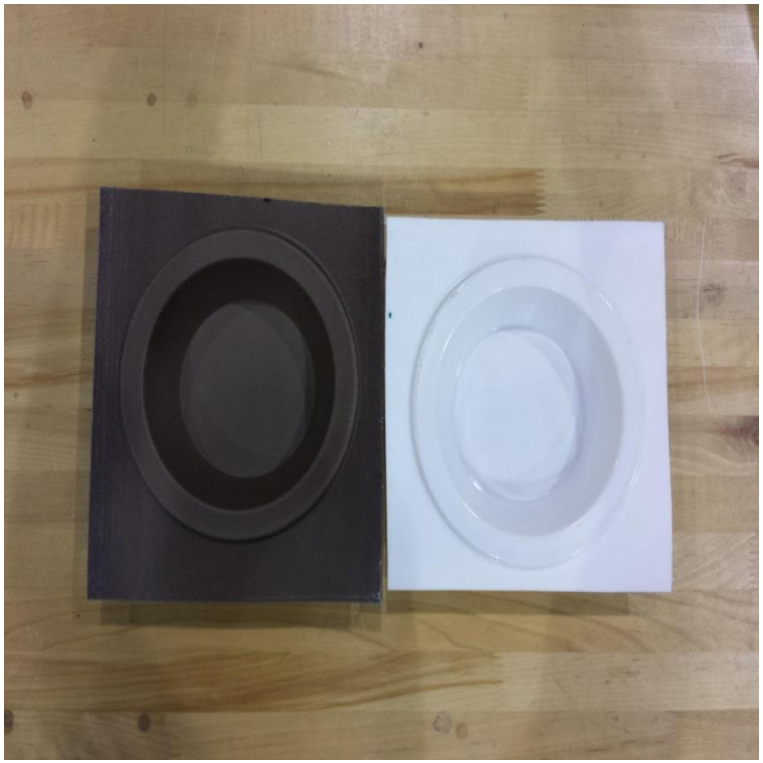




PERD IND01
Project 3C01.001



PLA/Lignin Blends for Thermoforming



- ✓ Renewable content up to 40%
- ✓ Lower material cost
- ✓ Reduced cycled time
- ✓ Decreased processing temperature
- ✓ Processable in conventional equipment



PS/Lignin Foam Extrusion







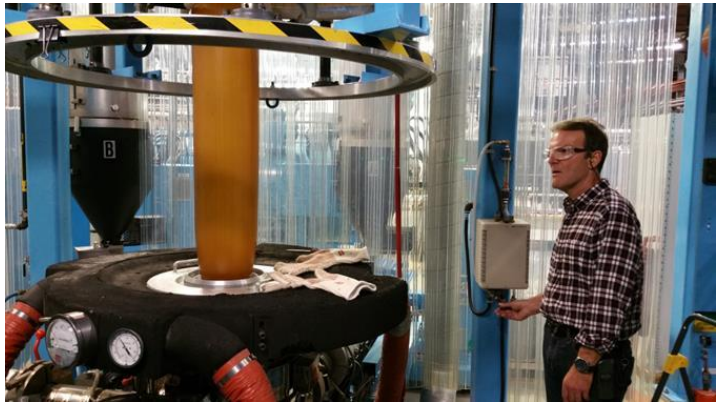
Potential industrial applications

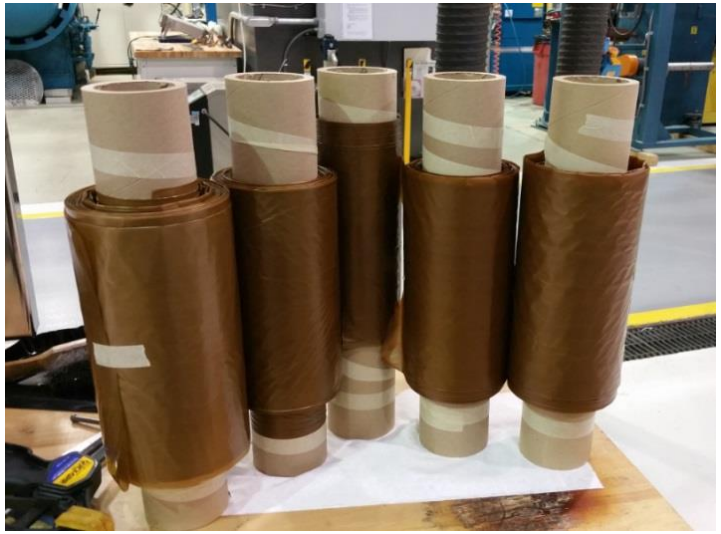
- ***Protective packaging***
- ***Insulation***
- ***etc.***



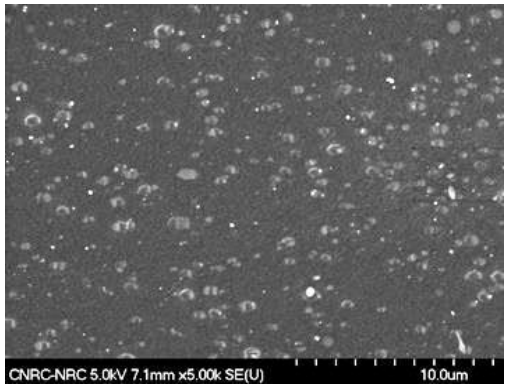


Pilot-scale Film Blowing
In Collaboration with Domtar









+ Verified PE/lignin film blowing at pilot scale
+ Very soft touch films with glossy surface
+ Higher modulus and puncture resistance
+ Film thickness (~40 µm) very consistent along MD and TD
+ Film with up to 20% lignin **using dry blend of MB**: **cost reduction**

Domtar Field Testing: Lignin Based Agricultural Films



Field testing results: Very Positive!

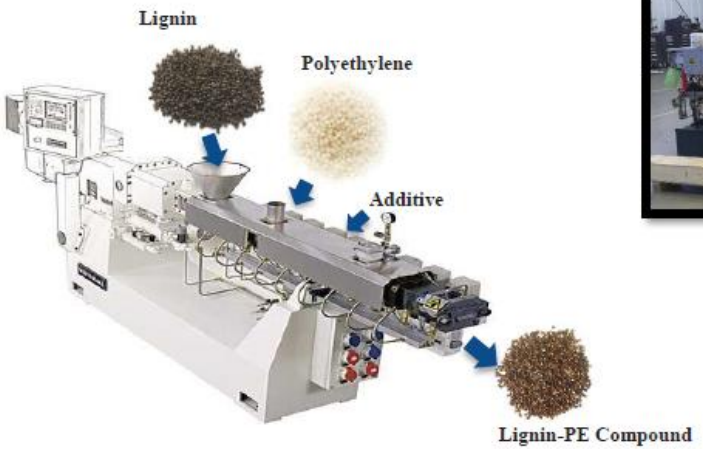


Potential benefits of lignin based films:

- ✓ **Partially biobased**
- ✓ **Dark color: no need for color MB and cost saving**

In Collaboration with U of Guelph

Process Scale Up at Domtar





Twin-Screw Extruder at NRC
(Lab and Pilot Scale: 25 kg/h)

Domtar's Twin-Screw Extruder
(Commercial Demonstration Scale, 0.75 ton/hr)

Dr. Shabnam Sanaei et al, Domtar's Biomaterials, Lignin Valorization into Thermoplastic Polymers, BIOFOR International 2018.

Summary

- NRC is actively committed to innovation in lignin thermoplastics to support Canadian industry
- The patent pending lignin pellets technology offers the following benefits:
  - *Reduced VOC and moisture content*
  - *Excellent homogeneity and integrity*
  - *Easy material handling*
  - *Cost saving and versatile for various industrial applications*
- NRC successfully developed lignin based platform for various large volume industrial applications
  - *Injection molding, film bowing, extrusion foaming, sheets and profile extrusion, thermoforming, etc.*
- **NRC** helped ***Domtar*** on the commercialization of their lignin for thermoplastic applications:
  - *0.75 ton/hr demonstration plant for lignin thermoplastics*

Acknowledgments

- NRCan **IFIT** (Investment in Forestry Industry Transformation)
- NRCan funding via the **PERD project 3A03.002**
- Technical contributions of NRC staff
  - *Éric Patenaude*
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  - *Éric Cloutier*
  - *Pierre-Marc Simard*
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Thank you!

Hongbo Li, Ph. D.

Research Officer
Polymer Bioproducts, Automotive & Surface Transportation

1-450-641-5439

Hongbo.Li@nrc-cnrc.gc.ca

www.nrc-cnrc.gc.ca



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