Cellulose Valley

BY FONDATION GRENOBLE INP

REINVENTING PACKAGING

POSTERS POC 2026

Innovation for recyclable packaging with high barrier by tuning extruded cellulose foam with barrier papers

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Context and Objectives

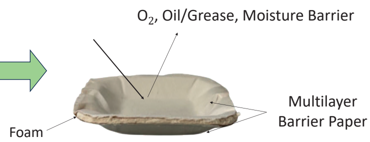
1950 — Industrial Revolution — Oil Everywhere: Packaging, Construction, Transport

2007 — Oil Production on Peak

Research Cellulose (Packaging)

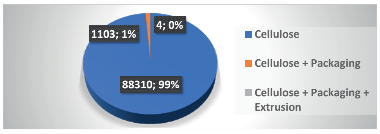
Nowadays 2026

Future 2030 — 3R, Sustainable, Lightweight, Banned single-use plastic



Extruded Polystyrene Packaging (XPS)

Extruded Cellulose Packaging (XCEL)

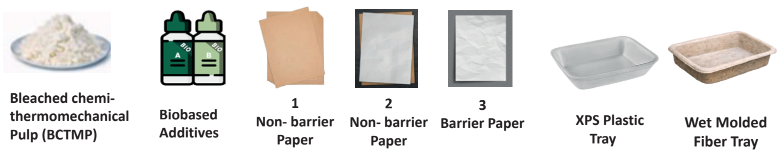


Objectives:
- Lightweight
- Barrier
- Recyclable
- High performance packaging

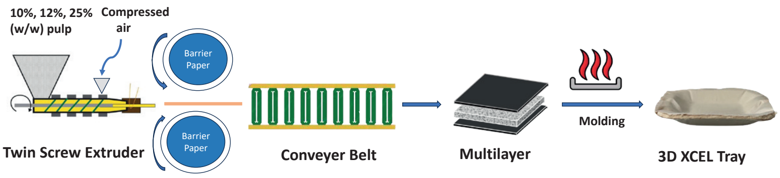
Materials & Methods

Raw Materials

Reference Materials

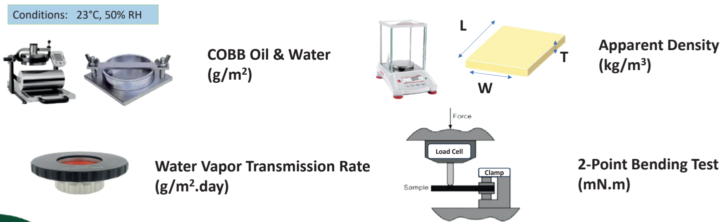


Methods



Characterizations

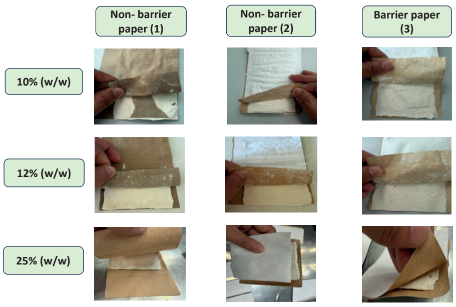
Conditions: 23°C, 50% RH



Results

Focus on Adhesion Properties

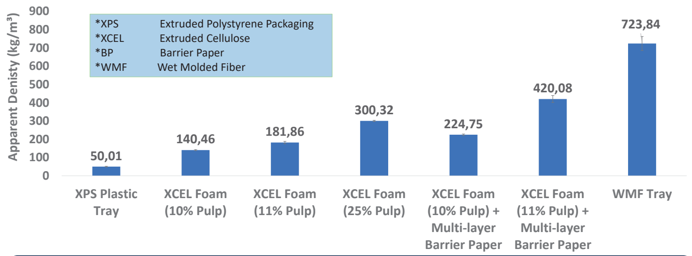
- 10% Pulp (w/w): Excellent adhesion between extruded cellulose foam (XCEL) with papers.
- 12% Pulp (w/w): Better adhesion between XCEL foam with papers.
- 25% Pulp (w/w): No adhesion between XCEL foam with papers because low water content in pulp.
- More drying time (48 hrs) in case of 10% and 12% pulp (w/w) because more water content in pulp.
- Less drying time (24 hrs) in case of 25% pulp (w/w) because low water content in pulp. .



Barrier Paper	
Cobb Water (g/m²)	3.30
Cobb Oil (g/m²)	3.41
WVTR (g/m².day)	18.40

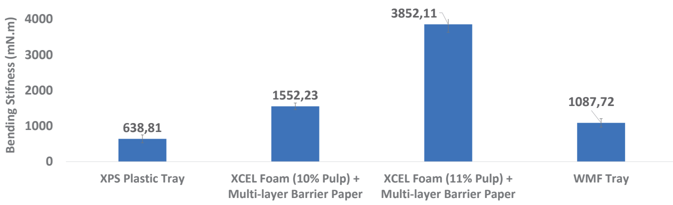
XPS < XCEL without BP < XCEL with BP < WMFT

Graph shows reference material (XPS) has low density. XCEL foam with barrier papers shows more apparent density.



XPS < XCEL with BP < WMFT

2-point bending stiffness depends on the thickness and density of the material, more the thickness and density more the bending stiffness value.



Conclusion and Perspectives

- The results confirm that while cellulose-based materials are a viable **sustainable alternative** for structural packaging
- Biobased packaging produce by wet extrusion process is **emerging process,** and can gain market in future
- Prototype shows more **better mechanical resistance** as compared to reference packaging
- High-performance bio-based coatings on classical papers or the selection of specialized food grade substrates is necessary to achieve the **functional barriers** required for the food packaging market

- Adherence & barrier tests should be performed on final packaging
- Recyclability test should be performed to compare better with other reference materials

H. Rigneault *et al.*, "Use of twin-screw extruder for innovative cellulose based packaging by injection and thermocompression," *Focus on Microscopy*, no. 1, p. 255, Nov. 2024
H. Najahi *et al.*, "Plastic pollution in food packaging systems: impact on human health, socioeconomic considerations and regulatory framework," *Journal of Hazardous Materials Advances*, vol. 18, p. 100667, May 2025
R. E. Abouzeid, R. Khiari, D. Beneventi, and A. Dufresne, "Novel technologies for producing tridimensional cellulosic materials for packaging: A review," *Carbohydr. Polym.*, vol. 342, no. 11, p. 122413, Oct. 2024

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Aknowledgements

This work is supported by the Fondation Grenoble INP in the framework of Cellulose Valley Chair. LGP2 is part of the LabEx Tec 21 (Investissements d'Avenir—Grant Agreement No. ANR-11-LABX-0030), of the PolyNat Carnot Institute (Investissements d'Avenir—Grant Agreement No. ANR-16-CARN-0025-01) and of the Cross disciplinary program Glyco@Alps (Investissements d'avenir – Grant agreement ANR-15-IDEX-02)

Self-healing and perforation resistant recyclable paper

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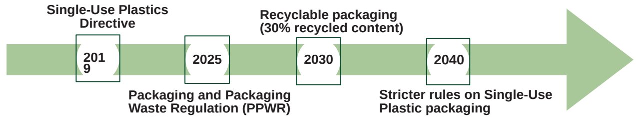
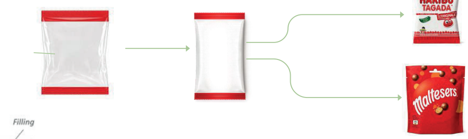
Cellulose Valley BY FONDATION GRENOBLE INP

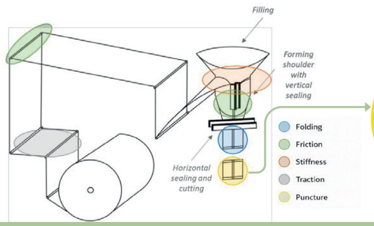
Context & Objectives



Paper-based alternative to conventional plastic packaging

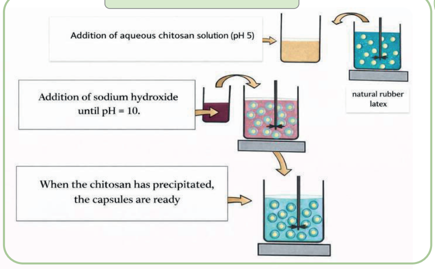


Paper-based materials are promising alternatives to plastic packaging. However, during converting, the material is exposed to traction, friction, folding, stiffness and puncture stresses that may damage the coating. To overcome this challenge, self-healing microcapsules containing natural rubber and protected by a chitosan shell will be incorporated into the coating. When a crack forms, the capsules break under stress, releasing natural rubber that fills the damaged area and heals the crack.
This project is part of the Cellulose Valley chair that aims to develop proof of concept of sustainable packaging.

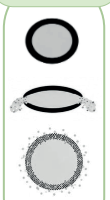


Methods

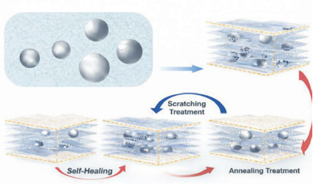
Microencapsulation



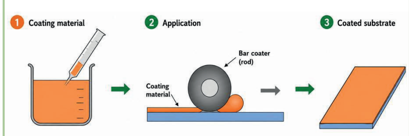
Crack-triggered release



Self-healing process



Bar coating Process (RK coater)

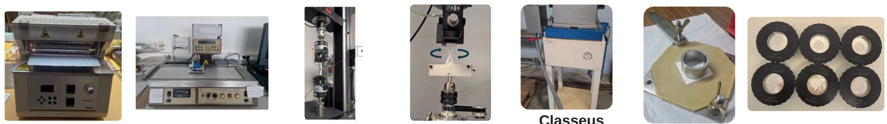


Drying

Raw materials

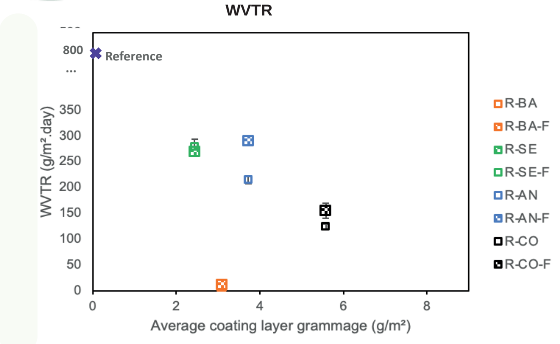
Converting resilience material | Antiabrasive coating | Sealant | Barrier coating | Rocalonde paper | Cristal paper

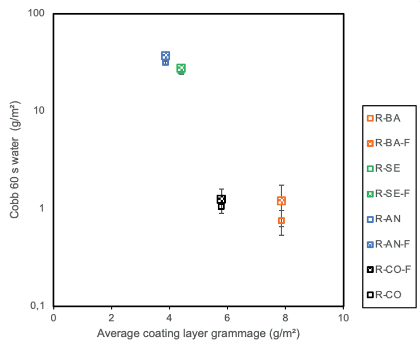
Characterizations

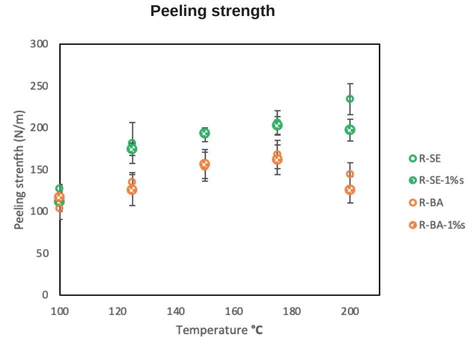


Thermal sealer (Param HST-H3) | Friction test | Tensile test (INSTRON 5965) | Twistability test (INSTRON 5965) | Classeus Somerville machine | Cobb test | WVTR (TAPPI 448)

Results







Conclusion and perspectives

Conclusion

Rocalonde paper (Fraise Tagada - Barrier Properties)

\+ Good sealing performance
Stable after twisting and 1% strain
Suitable candidate for barrier packaging
ood sealing performance

− Barrier properties decrease slightly after folding

Cristal paper (Maltesers - Transparency)

\+ High transparency
Good sealing performance
Natural rubber coating showed the best puncture resistance
Stable after twisting and 1% strain

− Cristal paper showed curling after natural rubber coating
Sealant-coated Cristal paper showed the highest stiffness

Perspectives

Develop self-healing coatings using natural rubber microcapsules

Evaluate recyclability to achieve Grade A

Study on linting and abrasion resistance of Dry Molded products

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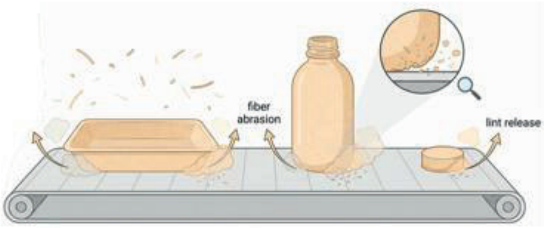
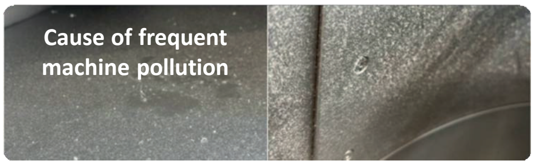
Context

DMF PROCESS

- Lower emissions by 70% (CO_2)
- Uses 80% less energy
- No water added



Reduces number of possible **H bonds**



Added water or MFC suspension sprayed before the thermopressing stage

30 - 40 - 50%wt

- Only water added
- 0,75%wt MFC
- 1,5%wt MFC

Parameters optimization to account for changes due to the water addition

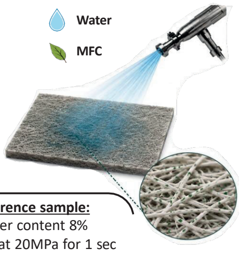
+ Pump to take out steam generated inside the mold

Temperature
Pressure
Press duration

Final objective:

Evaluation of the **surface improvement** of added water and MFC on the product's **resistance to linting and abrasion**

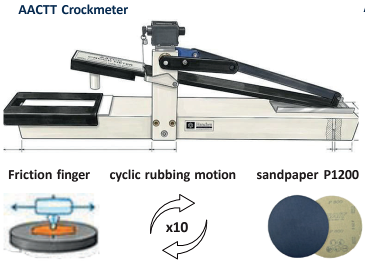
Methods - Results



Reference sample:
Water content 8%
pressed at 20MPa for 1 sec
(industrial conditions)

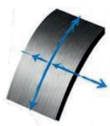
CROCKMETER ABRASION TEST

AACTT Crockmeter



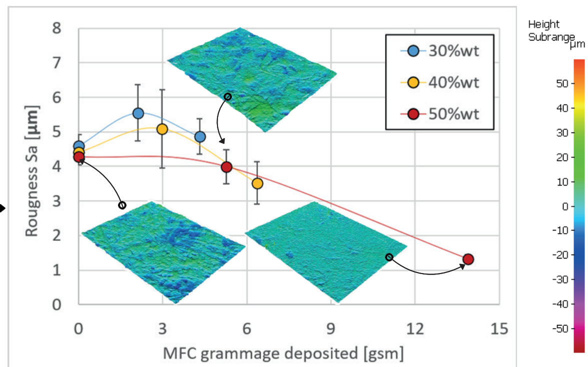
SURFACE MORPHOLOGY

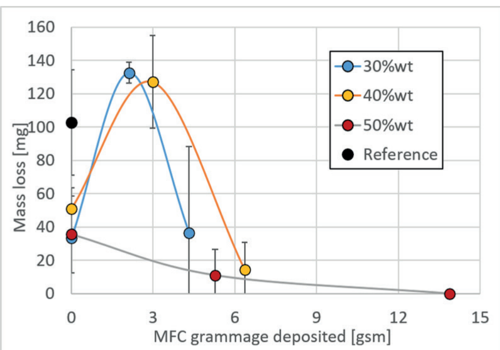
Alicona Infinite Focus system

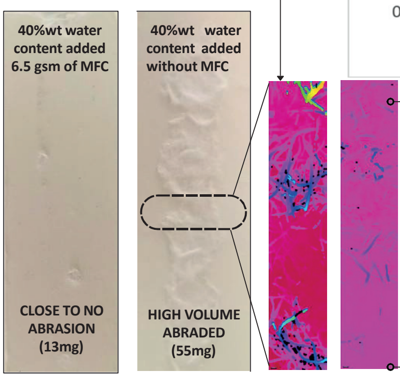


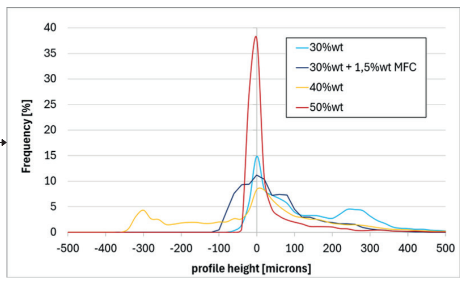
Clean surface roughness measures

Post-wear analysis









Conclusions and perspectives

Increased water content over 30% creates a **denser product** with **improved resistance to abrasion and higher bulk modulus**

Addition of **MFC sprayed** before thermopressing is able to create a **film** of top of the product that **completely stop the linting** before a certain **stress threshold**

Can be noted that spcimens with less than 5 gsm of MFC, there is higher mass loss after film rupture

Carrying out the crockmeter abrasion test with varying number of cycles: aimed to identify the threshold below which there is no abrasion

Testing other dry strenght additives to investigate improvement

Identify the best formulation to improve mechanical properties without compromiising the energy cost of the process

Aknowledgements

This work is supported by the Fondation Grenoble INP in the framework of Cellulose Valley Chair. LGP2 is part of the LabEx Tec 21 (Investissements d'Avenir—Grant Agreement No. ANR-11-LABX-0030), of the PolyNat Carnot Institute (Investissements d'Avenir—Grant Agreement No. ANR-16-CARN-0025-01) and of the Cross disciplinary program Glyco@Alps (Investissements d'avenir – Grant agreement ANR-15-IDEX-02)

Innovative Low Impact Food-Contact Cellulosic Trays by Valorizing Wastes From Agro and Protein Industry

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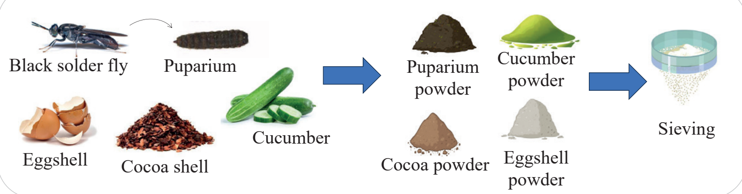
Context and objectives

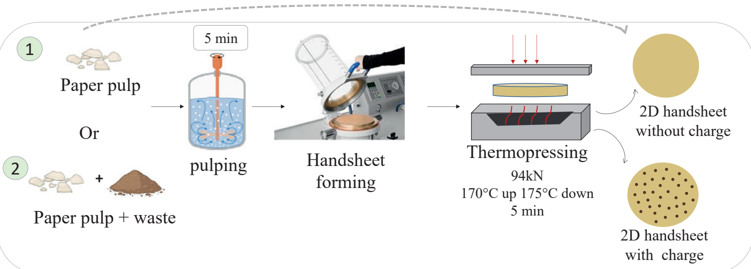
Context

Objectives

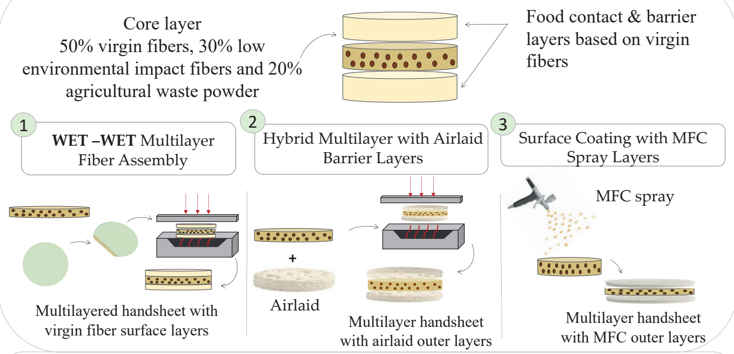
Materials and Methods

2D handsheets production 100% fibers or with charge



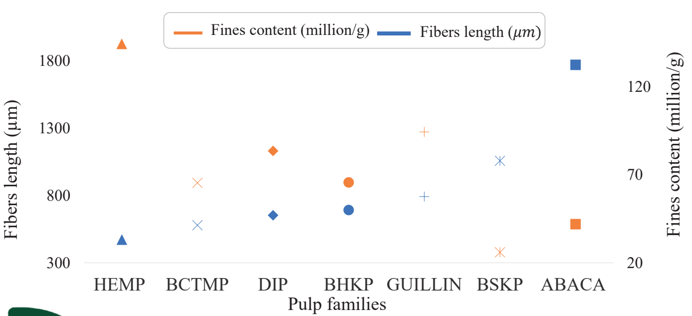


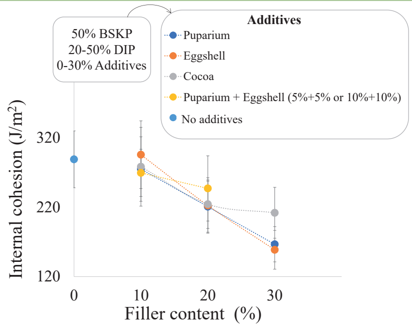
3 Innovative strategies for food safety application

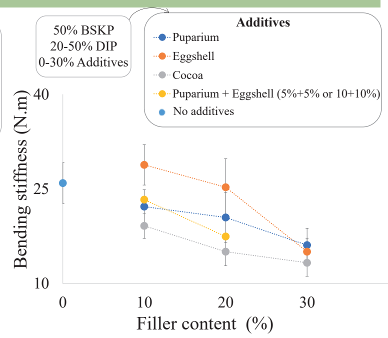


Characterization tests

Results







Conclusions and perspectives

Conclusion

- Recyclable cellulose-based food-contact trays were successfully developed using a **50% BSKP / 50% DIP** fiber blend, demonstrating the potential of incorporating bio-based residues into cellulose packaging.
- Eggshell at **10 wt.%** was identified as the optimum filler, providing the highest internal cohesion (~**296 J/m²**) and bending stiffness (~**28.8 N·m**).
- Puparium at 10 wt.% ranked as the second most promising filler, achieving high internal cohesion (~**275 J/m²**) and good bending stiffness (~**22.2 N·m**).

Perspectives

- Improve barrier performance.
- Reduce contaminant migration from the core layer into the food.
- Validate food-contact safety and migration behavior.
- Confirm industrial scale-up feasibility.

Acknowledgements

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GRENOBLE INP UGA Pagora lgp² Fibre Excellence AHLSTROM ANDRITZ Aptar CHANEL ctp CITEO DS Smith DECATHLON GUILLIN we protect your food Marie

Transparent and sustainable paper for packaging applications obtained by impregnation

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Cellulose Valley BY FONDATION GRENOBLE INP

Context and Objectives

Cellulose Valley: Chair of industrial excellence, 11 industrial partners

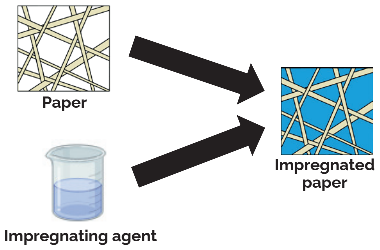
- Create innovative cellulosic packaging
- High performance packaging
- Biosourced; biodegradable and recyclable

Current transparent paper solutions:
- ❑ High cost
- ❑ Energie consuming

Main issue:
- ❑ light scattering and refraction.

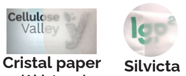
Objective:
Filling pores with a material whose refractive index is as close as possible to cellulose.

Strategy:



Materials and Methods

Reference:



Cristal paper (Ahlstrom)

Silvicta (Fedrigoni)

Fibers:

Softwood (Fibre excellence)

Grammage : 30-160 g/m²

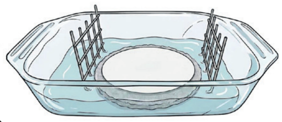
+

Impregnating agents

Chemicals (Polyvinyle Alcohol, (PVOH) , Kuraray)

Oils (siccative oil, Sigma Aldrich)

Impregnating bath



- 30 seconds of immersion,
- Excess liquid removal with blotting paper.

Impregnation control

$$filling\ rate = \frac{\varphi_f - \varphi_i}{\varphi_i}$$

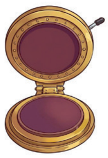
$$with: \quad \varphi_f = \frac{\frac{G_i}{1{,}54} + \frac{G_f - Gi}{\rho_{agent}}}{e_f}$$

Drying methods

Air drying (AD)

24h, conditioned room: 23°C and 50% relative humidity

Rapid Köthen dryer (RKD)

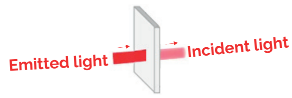


Pressure: ≈ 0,85 bar
Temperature: ≈ 93°C

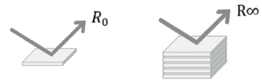
Characterizations

Transmittance at 550 nm

$$Transmittance = \frac{transmitted\ light\ (550nm)}{Total\ emitted\ light\ (550nm)}$$



Reflectance at 555nm

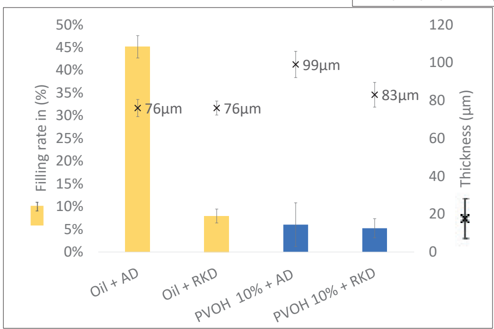


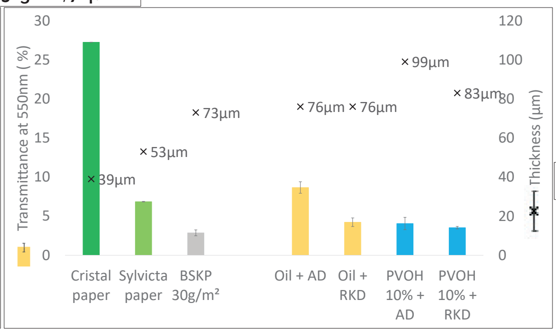
Opacity standards ISO 2471:

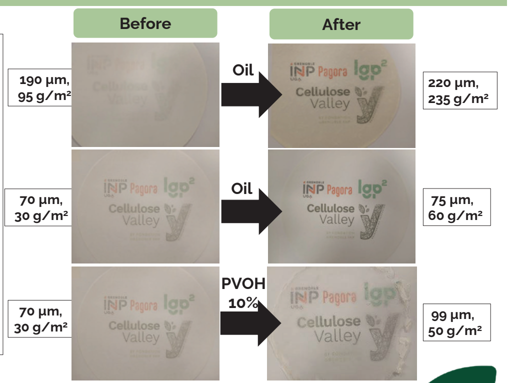
$$Opacity = \frac{R_0}{R\infty} * 100$$

Results

Initial handsheet: 30g/m², 70µm







Conclusions and perspectives

Conclusions

- ✓ Oils show a better effect on transparency than PVOH due to a higher filling rate than PVOH.
- ✓ The bath allows a wide diversity of impregnating solutions with a wide concentration range (compare to conventional method).
- ✓ The drying method shows a significant impact on the transparency: Air drying brings higher transmittance rate.
- ✓ Impregnating agent with a similar refractive index of cellulose brings transparency.

Perspectives

- Some other impregnating agents should be tested.
- Recyclability and LCA analysis should still be performed to measure the environmental impact and compare to the industrial references.

Aknowledgements

This work is supported by the Fondation Grenoble INP in the framework of Cellulose Valley Chair. LGP2 is part of the LabEx Tec 21 (Investissements d'Avenir—Grant Agreement No. ANR-11-LABX-0030), of the PolyNat Carnot Institute (Investissements d'Avenir—Grant Agreement No. ANR-16-CARN-0025-01) and of the Cross disciplinary program Glyco@Alps (Investissements d'avenir – Grant agreement ANR-15-IDEX-02)

GRENOBLE INP UGA Pagora lgp² Fibre Excellence AHLSTROM ANDRITZ Aptar CHANEL ctp CITEO DS Smith DECATHLON GUILLIN we protect your food Marie

Link Between Cellulosic Pulp Quality, Dewatering Behaviour and Product Performance in Wet-Moulded Cellulose Materials

Ami Hasan Jamil[1], Candice REY[2], Jérémie VIGUIE[2], Julien BRAS[2]

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Cellulose Valley BY FONDATION GRENOBLE INP

Context

Plastic packaging pressure

430.9 Mt global plastics production in 2024

31% / 40% packaging share of plastics use / plastic waste

1.8 Gt CO_2-eq 3.4% of global GHG emissions in 2019

Policy-driven transition

EU policy driver
Single-Use Plastics Directive + PPWR 2025/40

Pressure to reduce single-use plastics and make packaging recyclable by 2030

Wet-moulding research gap

Wet-moulded cellulose
renewable fibres; 3D packaging route

Main bottleneck
slow dewatering increases drying demand, energy use and product variability

Cellulose Valley BY FONDATION GRENOBLE INP — This work was carried out within the Cellulose Valley Chair, which aims to develop sustainable, high-performance cellulose based packaging materials as alternatives to conventional plastic packaging.

Objective: To link pulp quality with wet-moulding processability and final product performance, and to develop a Pulp Quality Index for comparing pulp suitability.

Materials & Methods

Raw material

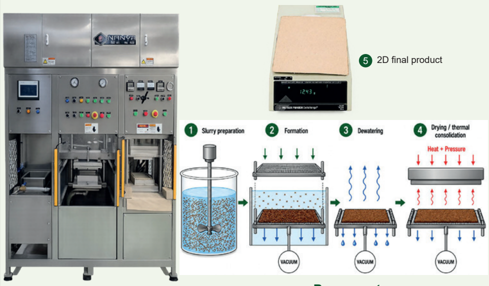
BSKP Bleached softwood kraft Fibre Excellence

BHKP Bleached hardwood kraft Fibre Excellence

USKP Unbleached softwood kraft Fibre Excellence

BCTMP Bleached chemi-thermomechanical M-Real

Processes



Nanya Model GY3030
formation-time (2–6 s) & equal-grammage (~420 g/m²)

Process steps

Characterizations

Physical :grammage · density · thickness · bulk · porosity

✣ **Pulp Quality Index (PQI)**

Results & Discussions

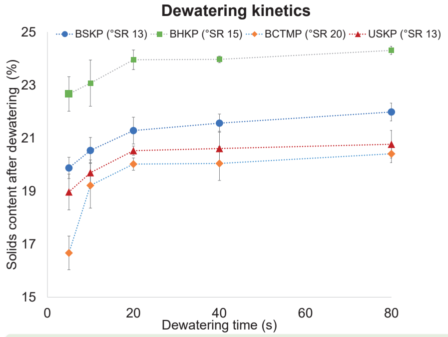


Fig. 1: Dewatering kinetics. Solids content after forming vs vacuum-suction time. BCTMP retains the most water (lowest solids); BHKP dewaters most effectively.

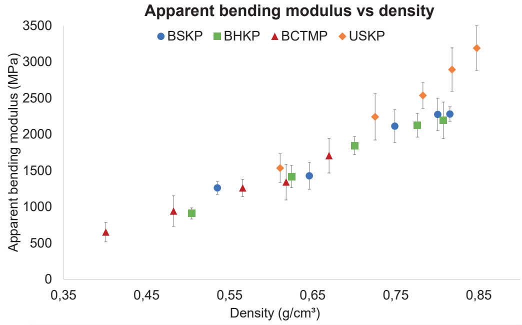


Fig. 2: Stiffness is density-driven. Apparent bending modulus rises steeply with density; USKP reaches the highest modulus and density.

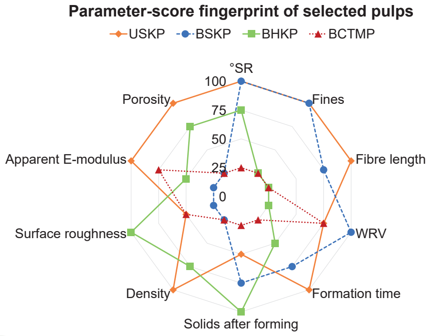


Fig. 3: Pulp property fingerprint. Ten properties scored 0–100 per pulp; a larger enclosed area indicates better overall suitability. USKP dominates most axes.

- ❑ Fibre length, fines, °SR & WRV govern forming and structure.
- ❑ **BCTMP** — highest fines & °SR, lowest solids after forming → poor dewatering.
- ❑ **BHKP** — highest solids after forming despite high fines/WRV → drainability alone isn't enough.
- ❑ Stiffness is density-driven; **USKP** reaches the highest modulus & density.
- ❑ **PQI ranking: USKP 86.9 > BSKP 65.4 > BHKP 59.2 > BCTMP 37.4**
- ❑ **Outlook** — validate the PQI with more pulps, 3D moulded shapes & drying-energy data.

Ami LinkedIn QR

References:

- Oecd. (2022). Global Plastics Outlook. In *OECD Publishing eBooks*. https://doi.org/10.1787/de747aef-en
- *Packaging waste*. (2026, April 29). Environment. https://environment.ec.europa.eu/topics/waste-and-recycling/packaging-waste_en
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Aknowledgements
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In operando barrier strategies for cellulosic packaging obtained by dry molded process

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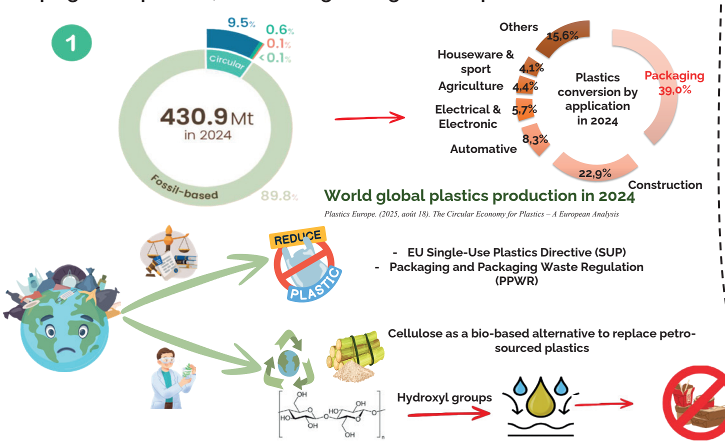
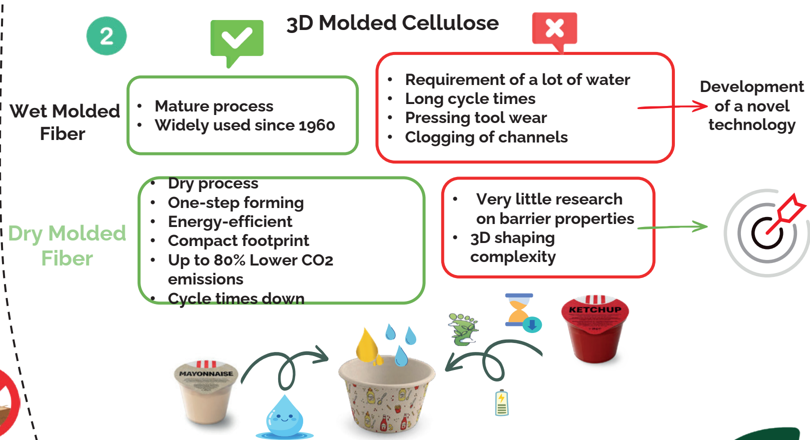
Cellulose Valley BY FONDATION GRENOBLE INP

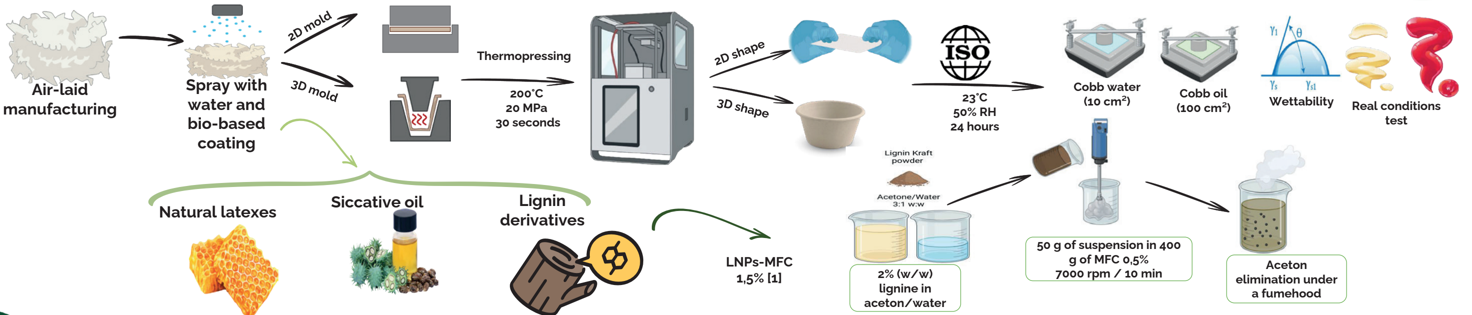
Context

The aim of this project is to develop 3D-shaped, cellulose-based packaging (>80% cellulosic content) for food applications. Food packaging is often in direct contact with moist or fatty products, which places strong demands on the material's barrier properties. The packaging must be recyclable, aesthetically appealing, and provide sufficient barrier properties against oil and water. The targeted application is a cup for ketchup and mayonnaise, aiming to reduce single-use plastic consumption. A key feature of this process lies its in operando nature: during dry molding, the aesthetic surface properties are generated simultaneously with the shaping of the product, within a single integrated step.



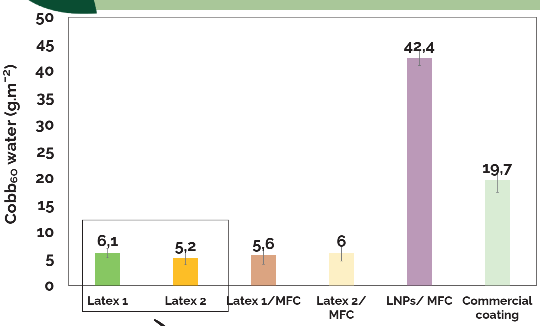


Methods



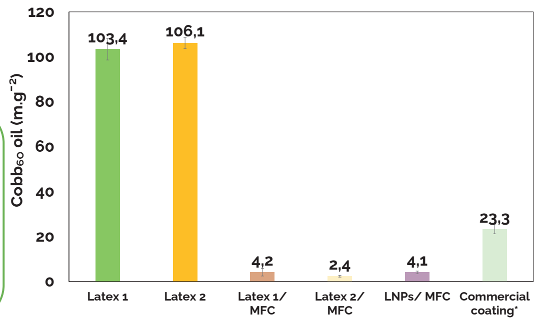
[1] Ruwoldt, J., Pasquier, E., & Dalheim, M. Ø. (2024d). Barrier coatings on dry-formed pulp with lignin, stearic acid, and combinations thereof. *Progress In Organic Coatings*, 197, 108804. https://doi.org/10.1016/j.porgcoat.2024.108804

Results and Conclusion

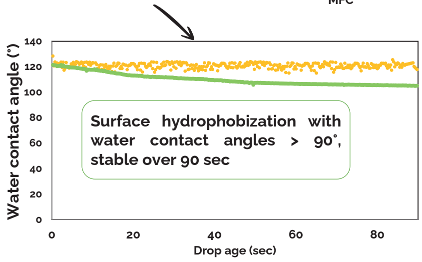


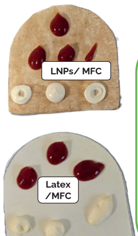
Reference
(Cellulose sprayed with only water)

Cobb$_{60}$ Water (g.m^{-2})	Cobb$_{60}$ Oil (g.m^{-2})
5440,9 ± 13,3	470,1 ± 7,8



- All coatings significantly decreased water and oil adsorption compared to the uncoated reference
- Natural latexes effectively reduced water adsorption (~99%), but proved less effective against oil.
- The addition of MFC markedly improved oil resistance fot both latex-based and lignin-derived coating.
- Compared to commercial coatings, latex-based coatings achieved the lowest Cobb water values, while all MFC-containing coatings demonstrated superior performance in oil adsorption resistance.





Perspectives

- Focus on natural latexes optimization
- ATICELCA test to evaluate the recyclability of the coated packagings
- Cobb test represents the worst-case scenario; track the migration kinetics of ketchup and mayonnaise over time
- Develop bilayer coatings: an MFC film followed by latex, either mixing them
- Combine two strategies (e.g., oil + lignin derivatives, or latex)

Aknowledgements

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Thermoformed Cardboard: application to refillable packaging

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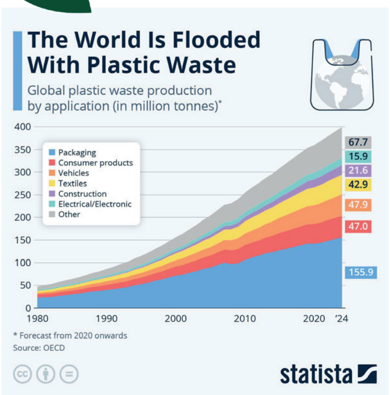
Cellulose Valley BY FONDATION GRENOBLE INP

Context and objectives



Plastic production has been on the rise over the years and the **annual production** is expected to reach 1.2 billion tons by 2060. The main source of plastic pollution is packaging, as **only 9 % is recycled**.

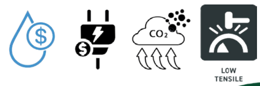
New approach

Using existing cardboard to create 3D objects by thermoforming

Forming 3D objects from cellulosic materials

The best known technics

Wet Molded Fiber & Dry Molded Fiber



Cardboard without coating

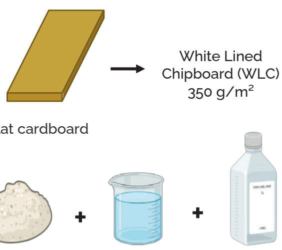
Thermoforming using shallow mold

Thermoforming using deep mold

- Cellulose fiber-based, renewable, biodegradable, recyclable
- Visible folds, craks and wrinkles
- Improve the mechanical properties of cardboard by impregnating it with starch, which will strengthen the material's fibrous structure

Materials and methods

Raw materials

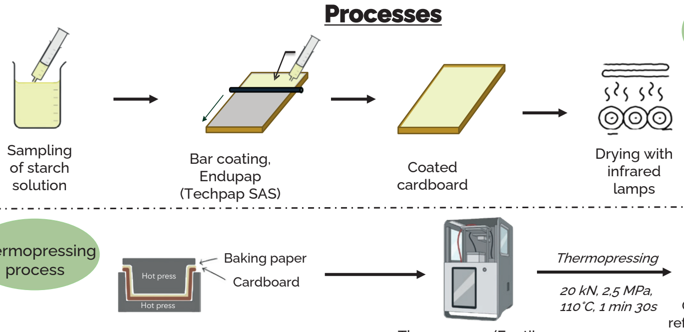


Flat cardboard → White Lined Chipboard (WLC) 350 g/m²

Starch + Water + Plasticizer

Processes

Coating process



Sampling of starch solution → Bar coating, Endupap (Techpap SAS) → Coated cardboard → Drying with infrared lamps

Thermopressing process

Mold with cardboard (Baking paper, Cardboard, Hot press) → Thermopress (Fontijne Press - LabEcon 600) → *Thermopressing* *20 kN, 2,5 MPa, 110°C, 1 min 30s* → Goal : obtain refillable cup for cosmetic face cream, made of cardboard

Characterizations

Structural properties

- Starch distribution in the structure after impregnation / thermopressing
- Structural integrity

Mechanical properties

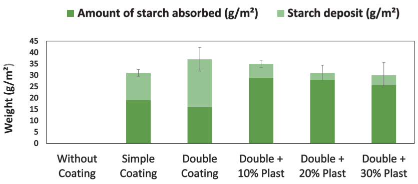
Tensile (Instron 5965) / bending tests (IDM tester) on plates & 3D

End Life

Recyclability test (ATICELCA)

Results and discussions

Starch penetration

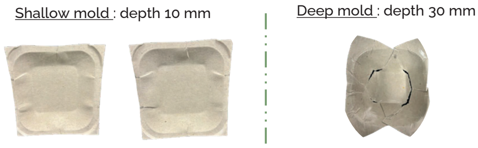


- Deposition of ~ 35 g/m² (10% of cardboard weight)
- Plasticizer improves starch penetration

Thermopressing ability

Shallow mold : depth 10 mm

Deep mold : depth 30 mm

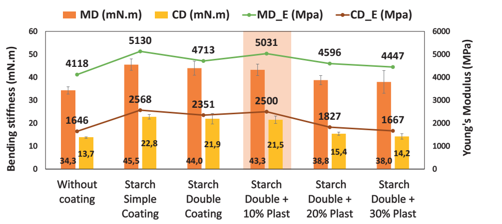


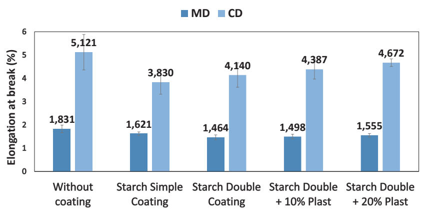
Cardboard with Starch double coating

Cardboard Starch double + 10% Plast

Cardboard WLC - CARGILL double + 10% Plast

Mechanical properties





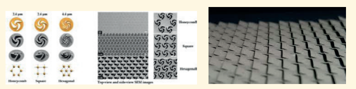
- Best formulation : with 10% of plasticizer
  → Increase in + 25% in machine direction (MD)
  → Increase in + 50% in cross direction (CD)
  For bending stiffness & Young's modulus

- No significant improvement of deformation after coating

Conclusion & Perspectives

- Mechanical properties improvement in stiffness after coating
- Thermoforming ability with shallow mold
- Material failure with deeper mold

↪ Testing of new approach : Kirigami Assisted Thermoforming →



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Single fluted corrugated cardboard reinforced with 3D-Printing

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[1]Université Paris Saclay, France - MSC Polymers and biomaterials
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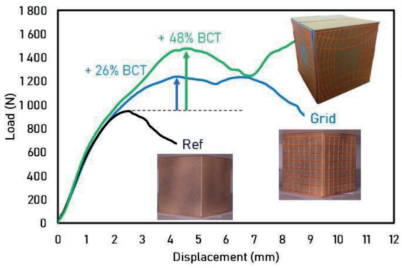
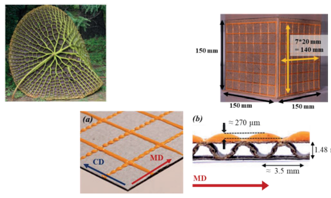
Cellulose Valley BY FONDATION GRENOBLE INP

Introduction and context

LOI ANTI-GASPILLAGE pour une économie circulaire

- E-commerce Boom: Surge in Demand for Logistics Packaging.
- Waste Alert: Massive Volume of Cardboard to Manage and Process.
- PPWR Emergency: Urgent Need to Lighten Packaging and Reduce Empty Space.
- Goal: reduction of the weight of packaging without losing performance



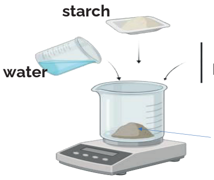


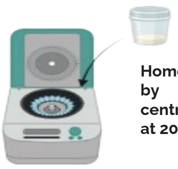
Inspired by biomimicry, the addition of 3D-printed PLA stiffeners enhances the mechanical performance of the cardboard. Optimizing their geometry maximizes this reinforcement

Objective: reduce the weight of double fluted corrugated cardboard boxes while maintaining good mechanical performance using 3D printing of biobased stiffener

Materials &Methods

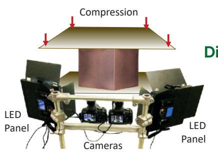
Formulation of bio-based stiffener





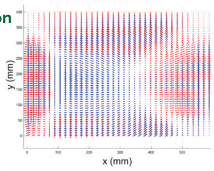
Homogenization by centrifugation at 2000rpm

Processes



Digital Image Correlation

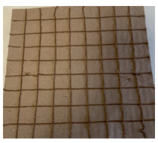
7D



- Tracking of the displacement
- Calculation of the displacement vectors
- Mapping of the the areas of significant deformation.

3D Impression

3D NEPTURE Printer

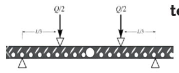


Bio-based paste extrusion printing technology assisted by pneumatic pressure (Direct Ink Writing, DIW).

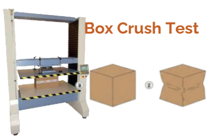
Characterization

Bending stiffness test

Lorentzen & Wettre 4-point bending stiffness test at 23°C and 50%RH



Box Crush Test, Standard method TAPPI T804

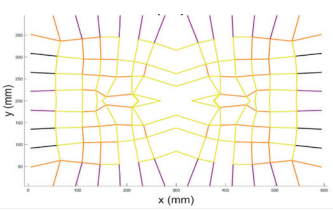


The test Is performe at 50% RH and 85% RH

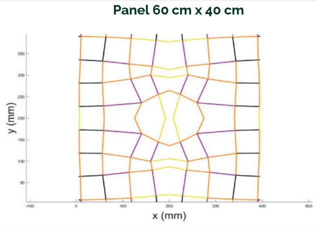
Characterization of the recyclability of printed cardboard boxes using the ATICELCA standard

Results

Optimal print pattern

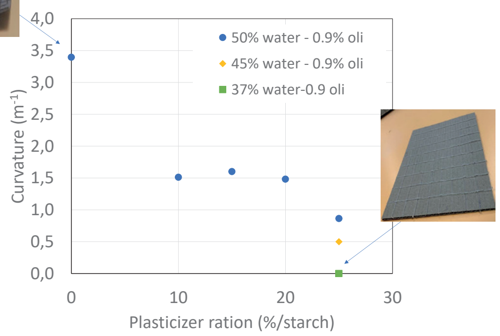


Panel 60 cm x 40 cm



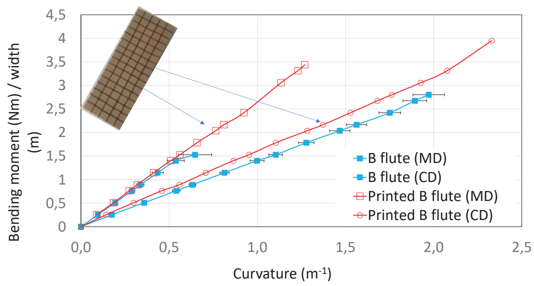
Panel 40 cm x 40 cm

Analysis of the cardboard warping based on curvature



Optimal formulation: 37% water / 25% plasticizer (% starch) / Additives
Formulation designed to ensure good dimensional stability of the cardboard

4 points bending test



Conclusions

- The use of bio-based pulp is fully in line with an eco-design approach by preserving the cardboard's recyclability,
- Good dimensional stability.

Perspectives

- BCT testing campaign with the optimal pattern
- End of life study

Aknowledgements

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Grenoble INP UGA, Pagora, lgp2, Fibre Excellence, AHLSTROM, Aptar, CHANEL, ctp, CITEO, DS Smith, DECATHLON, GUILLIN, Marie