CELLULOSE VALLEY CHAIR

Mid term report

PERIOD FROM JULY 1ST 2022
TO JULY 1ST 2024

Cellulose Valley

BY FONDATION GRENOBLE INP

REINVENTING PACKAGING

Cellulose Valley

BY FONDATION GRENOBLE INP

Contents

Note from
THE CHAIR HOLDER

"There's no longer any doubt that our society needs new packaging solutions to avoid pollution and reduce environmental impact. Cellulose science has come a long way since I took my first steps in the field 20 years ago. It is therefore one of the solutions for moving forward with developing high-performance materials derived from nature that are both recyclable and biodegradable. This challenge prompted me to launch this Chair of Excellence with 8 major industrial partners."

Julien Bras

Professor at Grenoble INP PAGORA, and chair Cellulose Valley holder.

Note from
THE DIRECTOR OF THE FOUNDATION GRENOBLE INP

"The Grenoble INP Foundation is proud to be able to support the Cellulose Valley Chair in its complex scientific challenges and its critical environmental impact on the future of our society. The presence of numerous partners representing the entire value chain from the upstream plastics/paper/cardboard industry, as well as downstream industrial users, also demonstrates the growing interest in the work carried out by the research teams. Our support for this Chair of Industrial Excellence is therefore a long-term commitment, spanning several years."

Benoit Giroud
Director of the Foundation Grenoble INP

Note from
THE STEERING COMMITTEE PRESIDENT

"Cellulose is the most abundant organic molecule on earth, and its potential is still far from being fully explored, developed and utilized. The aim of the Chair is to broaden its areas of application, particularly in packaging, with new solutions that replace other, less environmentally-friendly materials with the same or better levels of performance. I look forward to benefiting from the Chair's scientific power, its laboratory resources at LGP2 and its network of partners at different levels of the value chain, to bring virtuous solutions to market."

Vincent Renaudie

Steering committee president and R&D director at DS SMITH packaging group.

Note from
THE PRESIDENT OF THE SCIENTIFIC COUNCIL

"Packaging materials play a crucial role in our society. We use them en masse, which raises major environmental concerns. Plastic and aluminum packaging solutions still dominate the market thanks to their high properties and good cost/performance ratio. However, materials containing plastics present environmental challenges such as recyclability issues, the accumulation of microplastics in our environment and a high carbon footprint. Cellulose, a natural, renewable, biodegradable and recyclable substance, offers a promising ecological alternative to traditional plastics. Of course, the technical challenges of replacing plastics are considerable. The adage "He who seeks, finds" takes on its full meaning here. Investing in the research and development of cellulose and other biomaterials suitable for the circular economy is essential. To succeed, collaboration between researchers and industrial partners is crucial to discovering innovative, environmentally-friendly solutions."

Erkki Laiti

President of the scientific council, Ahltrom R&D , manager group product and technology development.


Cellulose
Valley

Cellulose Valley
PRESENTATION OF THE CHAIR

**The Cellulose Valley Chair is an excellence industrial chair supported by the Fondation Grenoble INP.
It was founded in November 2021 and started its activities in January 2022 with 5 industrial sponsors. Since its inception, the Cellulose Valley Chair has expanded to include 3 additional partners, bringing the total number of companies involved in the project to 8. The objective is to develop sustainable and recyclable highly performant cellulosic solutions for packaging.**

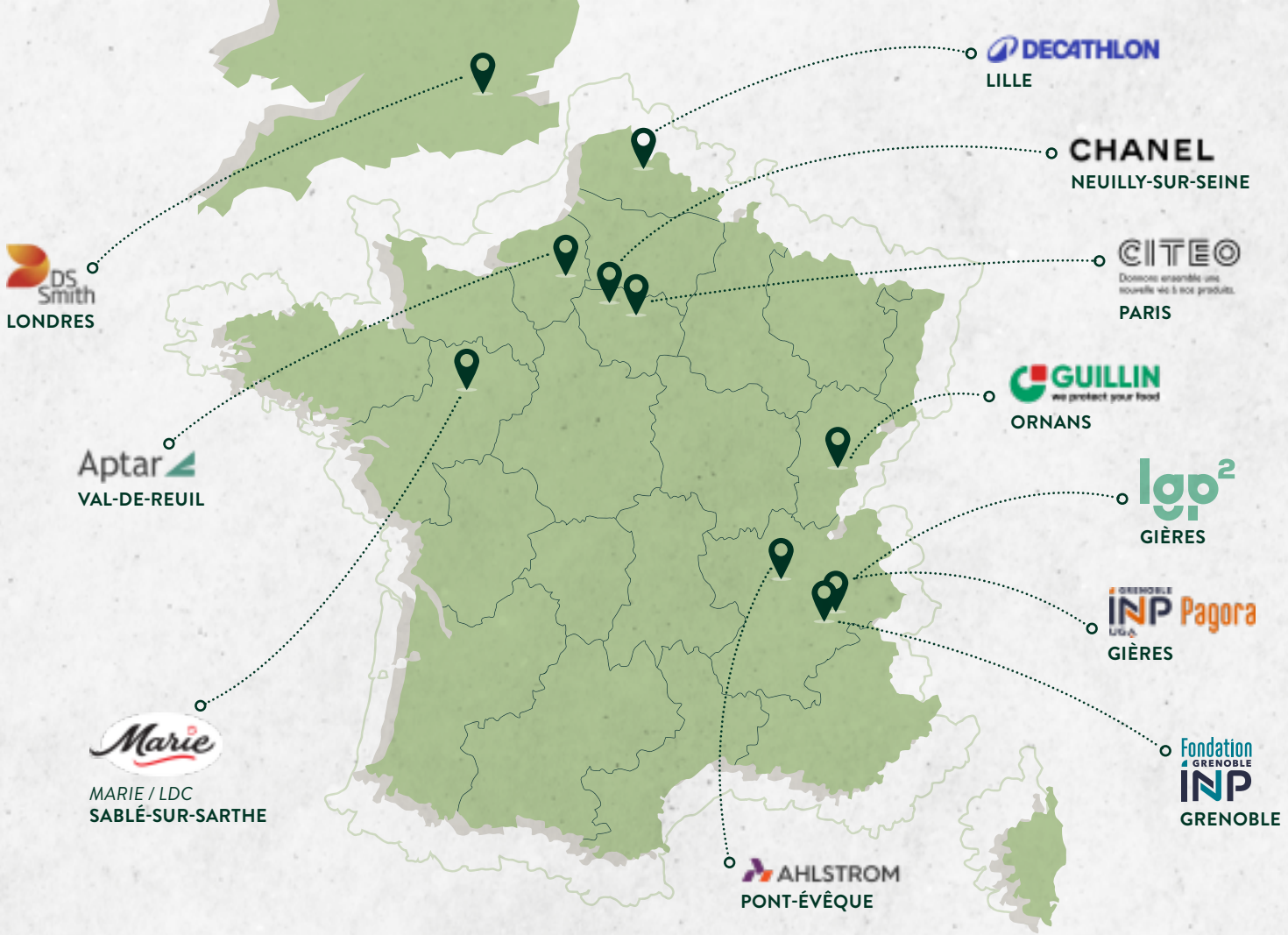
The Chair is designed to meet societal expectations and anticipate the scientific and technical challenges posed by the necessary environmental transition in packaging. A popularizing science video has been developed to explain the current issues facing Cellulose Valley. The objectives and motivations of the projects are clearly explained, so that everyone can understand what is at stake. An English version of this video is available since May 2023.

During 4 years, Cellulose Valley is supported by 8 industrial sponsors and works as an ecosystem evolving between research and industrialization.

8 INDUSTRIAL *sponsors*

FOR ALL THE CHAIR DURATION *(2021-2026)*:

- *32 proofs of concept*
- *3 thesis*
- *2 one year research project (post doc & study engineer)*
- *1 research enginner*



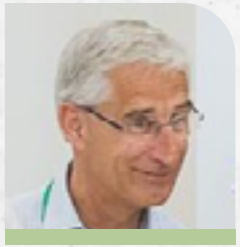
Cellulose Valley

BY FONDATION GRENOBLE INP

REINVENTING PACKAGING

PARTNERS MEMBERS

INDUSTRIAL PARTNERS



Thierry Maucotel

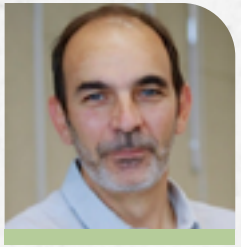
Innovation director at LDC group

"Marie and the LDC group are specialists in fresh, moist and health-sensitive products. To date, only plastic materials meet all the preservation constraints of our product ranges."

Christophe Peck

Packaging R&D manager, LDC group

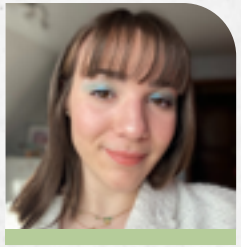
"As part of their packaging strategy, and in particular to reduce dependence on plastic materials, Marie and LDC have joined Cellulose Valley to undertake long-term research into cellulose materials, in which our products cannot currently be packaged."



Thierry Vallet

R&D director at Marie, LDC group

"We expect to identify the technological solutions that will improve the technical functionalities (water, grease and gas barrier) of 100% cellulose packaging materials."



Emma Camps

Packaging engineer at LDC group

AHLSTROM

Nicolas Tissier

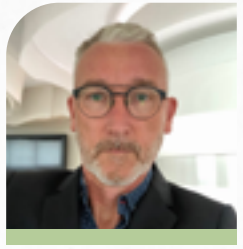
VP group innovation, Ahlstrom

Erkki Laiti

Manager group product and technology development, Ahlstrom

Charlène Reverdy

R&D scientist, Ahlstrom



Noël Cartier

Head of Global Science and Technology Development

CHANEL

Pascale Marciniak
Packaging R&D director

Virginie Recoura
Packaging and eco-design specialist

"The Cellulose Chair is an exceptional scientific initiative bringing together experts with a wide range of skills. As a representative of Chanel, I'm delighted to be contributing to this cutting-edge research into cellulose fibers, their transformation processes and the inherent barriers. This allows us to be at the heart of this research with enthusiastic partners."

Louna Vial
Packaging materials assistant engineer

CITEO

Donnons ensemble une nouvelle vie à nos produits.

Mélanie Eymas
Research and material innovation manager

Florine Rollin
Eco-design project manager

DS Smith

Vincent Renaudie
Group R&D packaging solutions director

Rémy Botalla-Gambetta
Packaging solutions project leader

Aptar

Christophe Marie
Product sustainability director

Patrice Leone
Material & science director

" Our expectations are to acquire scientific knowledge in the field of cellulose in order to offer our customers new, more sustainable solutions. Setting up collaborations with members of the Cellulose Chair Although there are still 2 years to go, we already consider the experiment to be conclusive. "

Randy Mujica
R&D engineer

GUILLIN
we protect your food

Margot Plée
R&D food packaging engineer

Franck Bournaud
Division director at Groupe Guillin

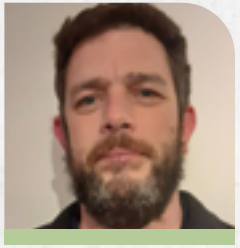
Thomas Vrignaud
Research & innovation manager

Julie Wutrich
Laboratory project manager

DECATHLON

Julien Lambert
Packaging innovation leader, Decathlon

" At Decathlon, our ambition is to eliminate all single-use plastics by favoring paper materials with a very high recyclability rate. Current materials don't always meet the latter expectation, so we needed a group of technical experts to help us invent them. "



Florent Maisch
Component and technology engineer, Decathlon

RESEARCHERS INVOLVED IN THE CHAIR

Isabelle Desloges

Associate professor, Grenoble INP PAGORA

Céline Martin

Associate professor, Grenoble INP PAGORA

Mohamed Naceur Belgacem

Professor, Grenoble INP PAGORA

Quentin Charlier

Associate professor, Grenoble INP PAGORA

Evelyne Mauret

Professor and PAGORA school director

Maxime Terrien

Study engineer, CNRS

Stéphane Dufreney

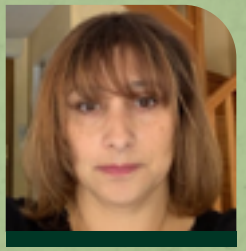
Engineer assistant, LGP2

Alain Dufresne

Professor (Grenoble INP PAGORA)

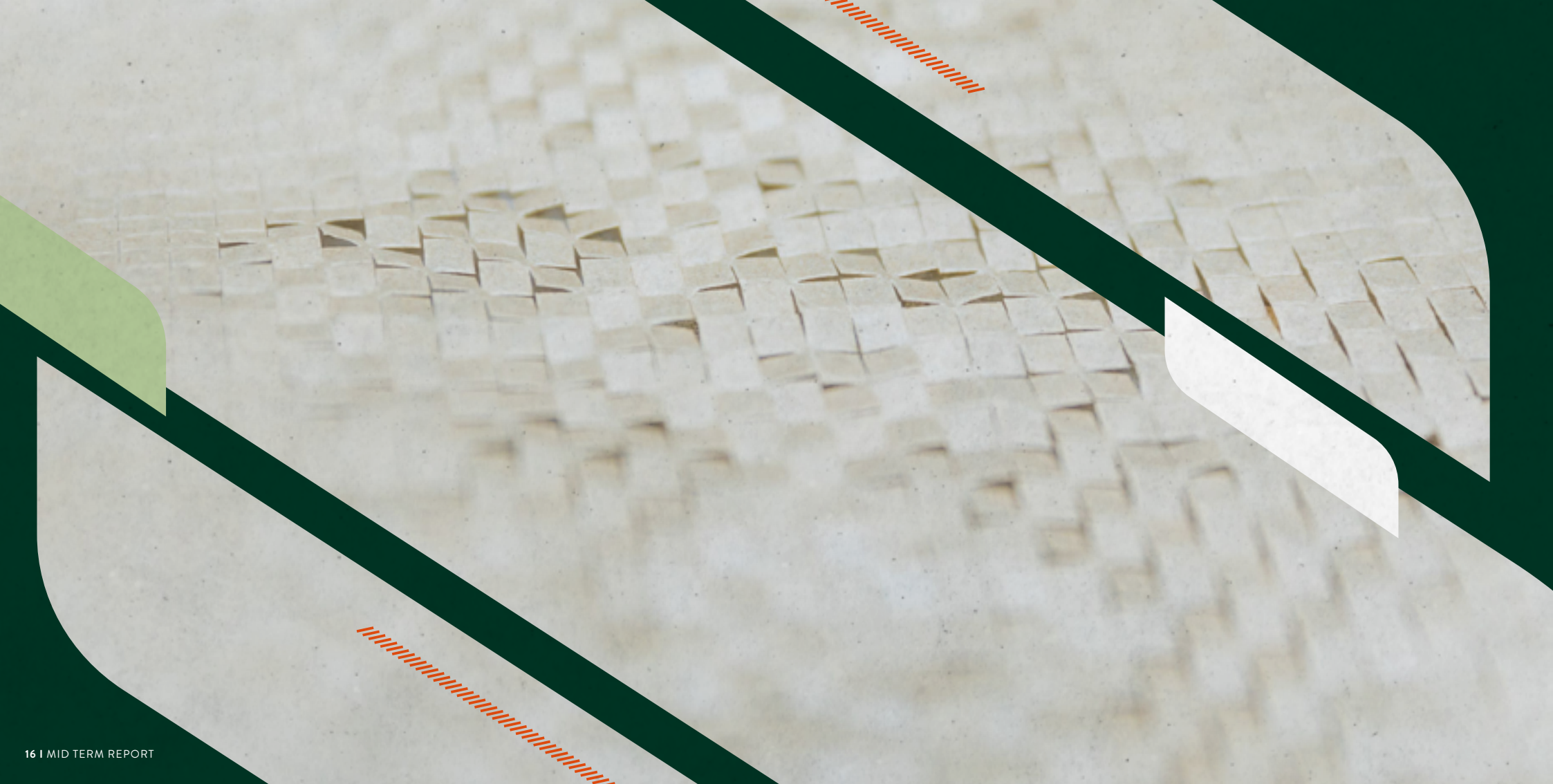
Jérémie Viguié

Research engineer, LGP2



Cécile Sillard

Study engineer, LGP2



The Chair Cellulose Valley
A KEY ACTOR IN THE ENVIRONMENTAL TRANSITION

Currently, plastic is one of the most widely used materials in the world. It is found in many everyday products, from food packaging to electronics, clothing, and sports equipment. Unfortunately, this widespread use of plastic has a significant impact on the environment. When they are not all well managed, plastic waste may pollutes oceans, rivers and soils, threatening wildlife, and plants. In particular, micro plastics, mainly resulting from the fragmentation of plastic, represent a danger for the environment and human health. In addition, the lack of fossil resources, the need to reduce carbon emissions and the accumulation of plastic waste are the main problematics that push the world today to find solutions to reduce the use of petroleum-based plastics.

Plastic have fantastic properties for packaging regarding processing, inertness, food contact transparency or barriers to liquid and gas. They have been extremely useful in our society to limit food waste among other advantages. However the pervasiveness of plastic packaging and its impact on the environment have ignited a global movement towards sustainable alternatives. This shift is particularly evident in the packaging industry.

It is estimated that between 25 and 30 million tons of plastic enter the oceans annually. This alarming trend has spurred the development of numerous laws and regulations aimed at curbing plastic packaging use and promoting environmentally friendly alternatives. Legislative bodies worldwide are implementing measures to reduce plastic waste and promote sustainable practices. For instance, a comprehensive waste reduction strategy has been outlined, encompassing the phasing out of single-use plastics, enhanced consumer information, waste generation mitigation, and reuse promotion. The specific laws and regulations enacted to achieve these objectives are detailed in subsequent sections.

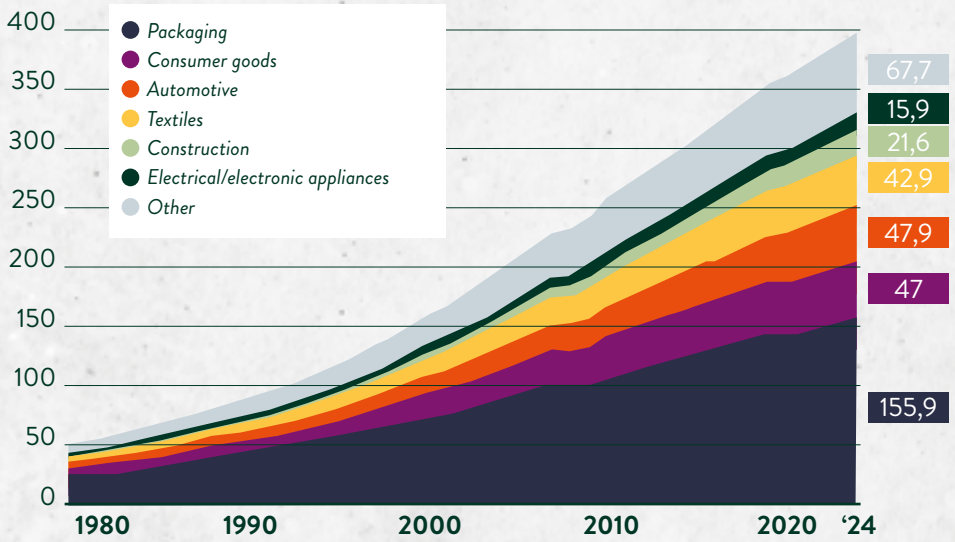
SUP
SINGLE-USE PLASTICS DIRECTIVE

LOI ANTI-GASPILLAGE pour une économie circulaire

PPWR

Some numbers
TO KEEP IN MIND

Global plastic waste production by type
(in millions of tons)*



** Forecasts from 2020 onwards*
Source OECD

In the space of two decades, the annual production of plastic waste worldwide has almost doubled, according to OECD data. Plastic waste is expected to almost triple worldwide by 2060: half of all plastic waste will still be landfilled, and less than a fifth will be recycled, according to the report.

460
MILLION TONS
= PLASTICS PRODUCTION IN 2019

Only 9% RECYCLED
REST IS INCINERATED OR LEAKS IN NATURE

MORE THAN 78 MILLION TONS
OF PLASTIC WASTE GENERATED IN 2018

Sources: *www.nationalgeographic.fr/le-plastique-en-10-chiffres*
www.nationalgeographic.fr/environnement/91-des-dechets-plastiques-ne-sont-pas-recycles
www.ellenmacarthurfoundation.org

In recent years, awareness of the scale and dangers of plastic pollution has paved the way for greater political intervention. As Euronews reported last year, more than 100 countries already ban single-use plastic bags in full or in part, and many are also banning other disposable items made from the material *(cutlery, straws, etc.)*.

Reducing and recycling is a priority in the fight against plastic pollution. According to an Ipsos survey of over 24,000 people, 85% of respondents in 32 countries worldwide agree that there should be international standards banning single-use plastics.

70,5%

CURRENT PAPER RECYCLING RATE IN EUROPE IN 2021

still places Europe well ahead of the rest of the world, with an average ***GLOBAL RECYCLING RATE OF 59,9%*** *in 2021.*

CELLULOSE

appears to be a promising solution thanks to its numerous advantages:

- *Most abundant polymer on planet earth*
- *Biodegradability*
- *Renewability*
- *Recyclability*

To further increase how much and how efficiently we recycle, the value chain actively works on achieving several 'qualitative targets' outlined in the new EPRC report. These include guidance documents on how to implement separate collection of Paper for Recycling which would be the best way to improve recycling, ecodesign projects to enhance paper products' recyclability, and educational campaigns for the public.

The creation of the chair Cellulose Valley is part of this environmental context.

Source: www.cepi.org/press-release-the-paper-value-chain-reached-a-705-recycling-rate-in-2022

A path FOR A SUSTAINABLE WORLD

In order to provide more environmentally-friendly alternatives, the various collaborations with our industrial partners will enable us to propose new solutions for high-performance packaging that meets the following criteria:

- **Made from bio-sourced origin, mostly cellulosic *(at least 80%)***
- **Preferably recyclable**
- **If not, biodegradable**
- **Guaranteeing mechanical resistance required for the application**
- **Providing barrier performances needed as a packaging.**

This work will enable us to meet the numerous commitments made by end-user companies, who are announcing the use of 100% recyclable, reusable or biodegradable packaging by 2025 or 2030.

SOME NUMBER FROM 2021 TO NOW:

3 PhDs STUDENTS

1 STUDY ENGINEER

1 RESEARCH ENGINEER

4 INTERNATIONAL PHDS STUDENTS COLLABORATION

23 CASES STUDY WITH PROOF OF CONCEPT

1 POST DOCTORAL RESEARCHER

Research ROADMAP OF THE CHAIR

The Chair is also dedicated to increasing and consolidating the excellence of partner companies and Grenoble INP by organizing a structuring activity of reflection and research on an international scale around the theme of cellulose materials in the packaging field.

80%
RESEARCH ACTIVITIES

20%
EDUCATION ACTIONS

To meet societal and political expectations and the commitments of the sector's manufacturers over the next few years, it is important to move quickly and have a sustained annual rate of results acquisition, as well as a longer timeframe for the development of innovative breakthrough solutions.

This is why the chair will simultaneously offers:

[A LONG TERM INNOVATION TEAM:]

3 PhDs STUDENTS

1 POST DOCTORAL RESEARCHER

BREAKTHROUGH RESEARCH IN THE FIELD OF CELLULOSE.

[A SHORT TERM INNOVATION TEAM:]

8 MASTER'S DEGREE LEVEL RESEARCHERS PER YEAR
DEDICATED TO **PROOFS OF CONCEPT**

1 RESEARCH ENGINEER TO COORDINATE RESEARCH AND INDUSTRY

The Chair is structured around these two levels of research, with a common research point: ***CELLULOSE IN ALL ITS STATE.***

Partners relationship AND DISCUSSIONS

Each year several scientific exchange meeting are organized. These meetings provide an opportunity to exchange scientific viewpoints and problems encountered on the industrial side, so as to better orientate the lines of investigation for each project. These 3 meetings also enable us to better understand the expectations of each partner and of our company.

More specific meeting for each Proof of Concept is organized regularly between the students on placement and the industrial partners involved in each project *(the sponsor)* to share results and progress. Visit of partners facilities have also been organized.

Visit at Guillin Emballage plant

Visit at Marie plant

Moreover, twice a year, a steering committee is organized in one partner facility with more focus on their research roadmap and facilities. This event is important for internal communications and allows all the partner members to set up potential collaborations.

Steering committee Ahlstrom

Steering committee Chanel

Steering committee Citeo

The Cellulose Valley team
ALONG THE YEARS

Since the creation of the chaire, the number of projects and persons involved increased. This marks the rise of interest in sustainable packaging and the needs of informations and proofs of concept in the aim of an industrial transition.

Team photo - 2022

Team photo - 2023

Team photo - 2024

Cellulose Valley

BY FONDATION GRENOBLE INP

REINVENTING PACKAGING

EDUCATION ACTIONS IN THE CHAIR

COLLABORATION WITH GRENOBLE INP PAGORA STUDENTS

The Cellulose Valley Chair is hosted by the LGP2 laboratory and Grenoble INP - Pagora, UGA. This ensures a strong and privileged link between the Chair's research team and the students *(Engineers or masters)*. It also makes it possible to set up joint education projects that benefit all parties.

The expected results of the education actions at the beginning of the chair are listed below:

- *Joint projects between the Chair's research team and courses offered to students at Grenoble INP - Pagora, UGA.*
- *Enriching future engineers' expertise and understanding of cellulose.*
- *Drafting of technological and economic reports on topics related to the use of cellulose in packaging.*
- *Propose international webinar and student challenges every year on cellulose*
- *Favor dissemination of science of cellulose at all level of education*

All these actions are discussed in details during scientific council every semester and summarized during Steering committees.

The Cellulose Valley prize was presented to first-year students at Grenoble INP Pagora in recognition of the best scientific projects and the second-year students for the best technological watch presentation. Mr. Julien Bras provided supervision for all technological watches. The most suitable solutions are shared with our partners at Cellulose Valley.

STUDENTS DEMONSTRATOR PROJECT: REINVENTING VEGETABLE NETS

In 2023-2024, the chair has decided to support financially a demonstrator project called DEEP project. In this context, Grenoble INP - Pagora students have been involved in a several-month project linked to the chair Cellulose Valley.

AIM OF THE PROJECT

Design a prototype of bio-based vegetable net answering to these requests:

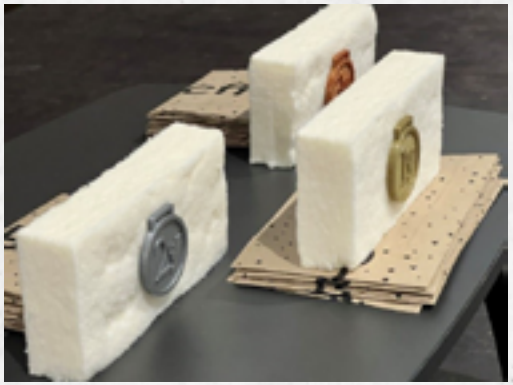
› bio-based, involving a minimum of 80% of cellulose
› recyclable
› allowing vegetables view
› supporting 2kg of vegetable
› resistant to humid conditions

This project has resulted in the examination of a number of papers and potential avenues for enhancing the packaging's extensibility on one hand and enabling the visualization of the inner product on the other. The team conducted a comparative analysis of the paper structure and humid resistance of four different papers. Based on this analysis, they designed slots with varying geometries and spaces to enable the stretchability of the packaging. A prototype of the packaging has been constructed, capable of supporting 1.5 kg of fruit or vegetables. It is entirely made from slotted paper and starch glue, as illustrated in the figure below.

STIMULATING CREATIVITY AND INNOVATION: CELLENGE CONTEST

The cellulose Valley launched a student contest CELLENGE in November 2023, for the first time. This competition aims to design a rigid cellulosic packaging to replace primary packaging, as a solution to the European directive against single-use plastics *(SUP)*. The award is 1000€ to be shared within the team member and the participation of the next steering committee.

This contest has been mixed with a teaching project from Grenoble INP Engineering School gathering more than 150 students. The title of the contest was the subject of an innovation project consisting of 25 hours of imagining a bio-sourced alternative to plastics daily products. The chair members have done videos, organized visits of the chair and spend time in classroom with students to give more details about Cellulose.



Actually 3 student teams from the teaching projects and one other team subscribed to the contest, the jury is composed of Julien Bras, chair director, Vincent Renaudie steering committee president, Erkki Laiti, scientific council president, and Candice Rey, research engineer in charge of the project.

The first prize of the jury is project called YOLOSE and presents an innovative process to produce 3D cellulosic packaging. This project was supported by Daniella SEMAAN, an engineering student at Grenoble INP PAGORA, and supervised by Emilien Freville, PhDs student at LGP2. She had the opportunity to present her innovation at the steering committee of the chair in July 2024, at CITEO.

A second jury's favorite prize was awarded to a group of 4 students from Grenoble INP PHELMA. They imagined a new design for refillable tooth past tube in order to manufacture it from cellulosic material and to reduce product waste.

LEARNING WHILE HAVING FUN:
CELLULOSE VALLEY - THE GAME

The serious game of the chair has been designed and tested this year with the POC students. The game will be deployed this year towards the partners of the chair. A video has been done and validated by the steering committee member in order to communicate on the serious game.

[THE SERIOUS GAME IS COMPOSED OF]

1 QUIZ PHASE FOR LEARNING | **8 DEBATE CARDS** TO RESTORE KNOWLEDGE

It is possible to flash this QR code to watch the video.

John Francis Kenwright

Serious game project involves 60 cards divided in two part of game: *1 part of quiz, 1 part of debate.* PerForm which is the innovation plateform for the teaching tools of Grenoble INP helped the chair members to build this project through a collaboration with John Francis Kenwright, English and educational innovation teacher, and SMART GAMES manager in Grenoble INP PAGORA. The challenges involved in the quiz phase and the debates proposed have been invented by the Chair member, as for the scenario and game play rules.

One promotion video and one tutorial video are currently recorded to help the setting of the game. The promotion video has been validated by the steering committee.

Visit to ATHANOR sorting center

The chair also organized a visit in a sorting center with all the short term and long term team member in order to give the opportunity to know better about recyclability.

Julien Bras, chair Holder, presented the chair and the challenges in the use of cellulose to produce packaging to highschools student at the occasion of the *"fête de la science"* in the LGP2 laboratory. This was the occasion to give some informations about cellulose, barrier paper and carboard, and the importance of designing recyclable packaging.

COMMUNICATION TOWARD SOCIETY

POPULARIZING ABOUT CELLULOSE AND ITS APPLICATIONS

20% of the time of the chair is dedicated to diffusing and exchange knowledge about cellulose as a raw material and its requirements to be used in packaging. Several actions has been done in this goal under different layout like, radio interview, webinar, conferences.

The chair members participate to some event in order to popularize cellulose and its advantages as being used in the packaging field of application.

The chair members participate to the *Tech&Fest event.* An exhibition mixing technology about every scientific field. The chair had a booth and presented some proof of concept. The CELLENGE contest was also introduced to some students. This event was organized for 3 days and a wide public type had the opportunity to attend. The chair members were present and could share discussions with students, families, academic and industry representatives.

Tech&Fest

The chair was also present in the french event *Mondial des métiers* sharing a booth with Paper and Carboard Careers. It has been the occasion to present to schoolchildren and young student the wide applications of bio-based polymer.

In may 2023 Julia Pescheux Sergienko, PhD student 2nd year and Julien Bras the chair holder attended to the French edition of an international event named *Pint of Science.* Scientific talks are organized the same day in 54 cities of France, mostly in bars, in order to popularize science. They gave a talk about cellulose and the chair Cellulose Valley.

SUMMARY OF THE ACTIONS OF EXTERNAL COMMUNICATIONS DONE BY THE CHAIR MEMBERS DURING THE LAST YEAR.

DATE	MEMBERS NAME	EVENT NAME	EVENT TYPE
18-22 September 2023	Julien, René	European Polysaccharide network of excellence conference	Conference
12 October 2023	Julien, Candice	Fête de la science	Society Dissemination
19-20 October 2023	Julien	International conference packaging *(Slovenia)*	Conference
8 November 2023	Julien	Visite lyceen Argouge	Society Dissemination
December 2023	Candice	« Mondial des métiers »	Exhibition Society Dissemination
11 January 2024	Julien	Conference academie des sciences Paris	Conference
February 2024	Julien, Julia, Mathilde, René, Candice	Tech&Fest	Exhibition
6th of February 2024	Julien, Candice	Kaleidoscope Week, Grenoble INP	Society Dissemination
10 February 2024	Julien	Journée portes ouvertes de Grenoble INP	Society Dissemination
September 2023 to May 2024	Julien, René, Mathilde, Candice	Innovation project - Grenoble INP	Student challenge CELLENGE
9-12 April 2024	Julien	Pulp & Beyond *(Finland)*	Conference
22-26 April 2024	Julien	FB POL *(Brazil)*	Conference
May 2024	Julien	Polynat day	Conference
April 2024	Julien, Mathilde, René, Candice	LGP2 visit with the students of the innovation project – Grenoble INP	CELLENGE
June 2024	René, Candice	IAPRI *(Spain)*	Conference
June 2024	Julien	Seminar North Carolina State University	Conference
June 2024	Julien	Tappi Nano	Conference

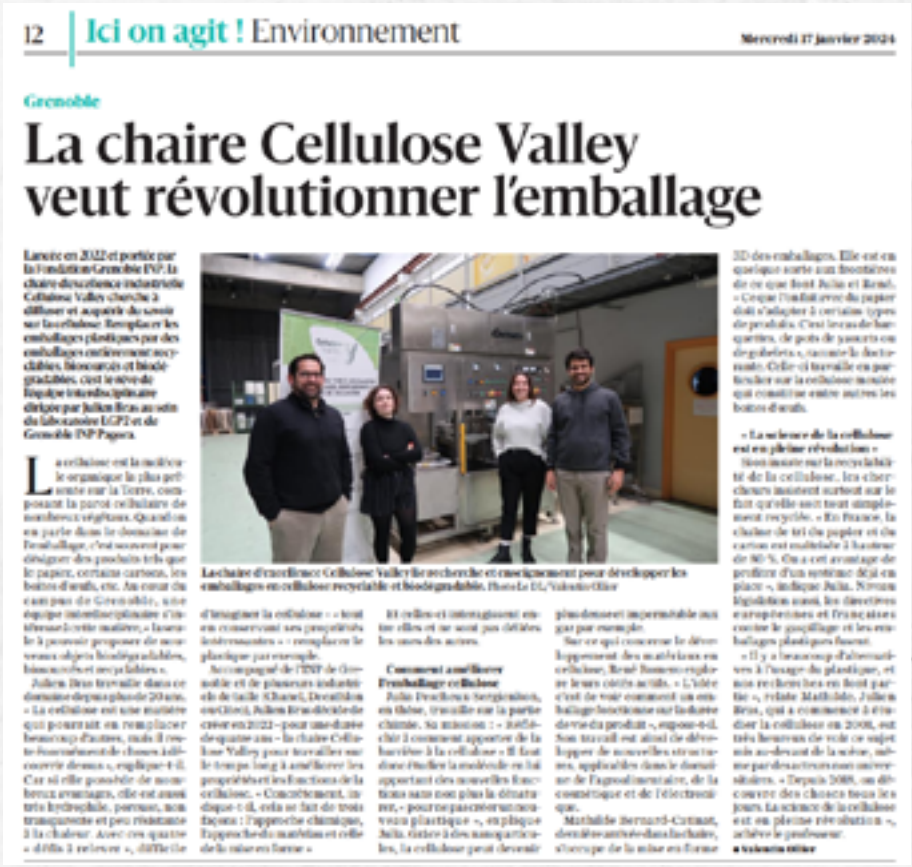
PRESS AND RADIO COMMUNICATIONS

To touch another type of public, the chair members participated to several interviews for specialized and non-specialized newspapers *(as well as two published articles)*. In addition, interviews on radio stations such as NRJ and RCF *(15-minute programs)* helped to publicize the Chair's themes.

A press release was also issued on January 6, 2022 to present the Chair, its objectives and the issues at stake in today's society. This press release is available on the Cellulose Valley website.

An article was also written in the French newspaper Emballage Magazine about Julien Bras and the Cellulose Valley in October 2022.

An article in the French newspaper Le Dauphiné has been written to present the chair, its challenges, and the importance of sustainability in the packaging application in January 2024.



12 | Ici on agit ! Environnement — Mercredi 17 janvier 2024

Grenoble

La chaire Cellulose Valley veut révolutionner l'emballage

Lancée en 2022 et portée par la Fondation Grenoble INP, la chaire de recherche industrielle Cellulose Valley cherche à diffuser et acquérir du savoir sur la cellulose. Remplacer les emballages plastiques par des emballages entièrement recyclables, biosourcés et biodégradables, c'est le rêve de l'équipe interdisciplinaire dirigée par Julien Bras au sein du laboratoire LGP2 de Grenoble INP-Pagora.

La cellulose est la molécule organique la plus présente sur la Terre, composant la paroi cellulaire de nombreux végétaux. Quand on en parle dans le domaine de l'emballage, c'est souvent pour désigner des produits tels que le papier, certains cartons, les boîtes d'œufs, etc. Au cœur du campus de Grenoble, une équipe interdisciplinaire s'intéresse à cette matière, « loin de la penser propice de nouveaux objets biodégradables, biosourcés et recyclables ».

Julien Bras travaille dans ce domaine depuis plus de 20 ans. « La cellulose est une matière qui pourrait en remplacer beaucoup d'autres, mais il reste beaucoup de choses à découvrir dessus », explique-t-il. Car si elle possède de nombreux avantages, elle est aussi très hydrophile, poreuse, non transparente et peu résistante à la chaleur. Avec ces quatre « défis à relever », difficile d'imaginer la cellulose – « tout en conservant ses propriétés intéressantes » – remplacer le plastique par exemple.

Accompagné de l'ESP de Grenoble et de plusieurs industriels de taille (Charal, Decathlon ou Clinti), Julien Bras décide de créer en 2022 – pour une durée de quatre ans – la chaire Cellulose Valley pour travailler sur le temps long à améliorer les propriétés et les fonctions de la cellulose. « Concrètement, on étudie : est-ce le fait de trois façons : l'approche chimique, l'approche matériau et celle de la mise en forme ».

Et celles-ci interagissent entre elles et ne sont pas définies les unes des autres.

Comment améliorer l'emballage cellulose

Julie Peuchot, ingénieure, en thèse, travaille sur la partie chimie. Sa mission : « mieux cibler l comment apporter de la barrière à la cellulose » Il faut donc étudier la molécule en lui appartient des nouvelles fonctions sans non plus la dénaturer, « pour ne pas créer un nouveau plastique », explique Julie. Grâce à des nanoparticules, la cellulose peut devenir plus demeurer imperméable aux gaz par exemple.

Sur ce qui concerne le développement des matériaux en cellulose, René Boumis explore les leurs coûts actifs. « L'idée c'est de voir comment un emballage fonctionne sur la durée de vie du produit », expose-t-il. Son travail est ainsi de développer de nouvelles structures, applicables dans le domaine de l'agroalimentaire, de la cosmétique et de l'électronique.

Mathilde Bernard-Cormat, doctorante entrée dans la chaire, s'occupe de la mise en forme 3D des emballages. Elle est en quelque sorte aux frontières de ce que font Julie et René. « Coupe l'imbattable du papier doit s'adapter à certains types de produits. C'est le cas de barquettes, de pots de yaourts en de gobelets », raconte la doctorante. Celle-ci travaille en particulier sur la cellulose moulée qui constitue entre autres les boîtes d'œufs.

« La science de la cellulose est en pleine révolution »

Son mantra sur la recyclabilité de la cellulose. Les chercheurs insistent surtout sur le fait qu'elle soit tout simplement recyclée. « En France, la chaîne de tri du papier et du carton est maîtrisée à hauteur de 80 %. On a cet avantage de profiter d'un système déjà en place », indique Julie. Nouvelle législation aussi, les directives européennes et françaises encore le plastique et les emballages plastiques fissent.

« Il y a beaucoup d'alternatives à l'usage du plastique, et nos recherches en font partie », relate Mathilde. Julien Bras, qui a commencé à étudier la cellulose en 2008, est très heureux de voir ce sujet mis au devant de la scène, même par des structures non universitaires. « Depuis 2008, on découvre des choses tous les jours. La science de la cellulose est en pleine révolution », achève le professeur.

■ Valentin Ollier

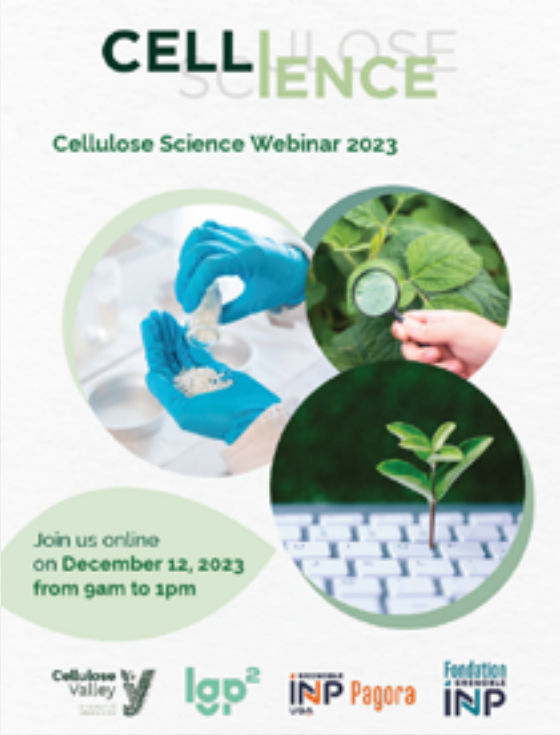
SCIENCE SHARE WITH SOCIETY

CELLIENCE webinar: diffusing the knowledge about cellulose wide world

Since the creation of the chair Cellulose Valley, a webinar called CELLIENCE is organized by the chair members. The first edition was in December 2022 and almost 300 people from all around the world subscribed to the event. Well-known researchers were invited to give a talk about cellulose, from characterization to application. This remote event brought together around 150 people connected at the same, with a common taste for knowing more about cellulose.

The 2nd edition of our webinar CELLIENCE was held on December 12th, 2023, enabling participants to interact with international speakers. The day was organized around three major cellulose-related themes, with over 480 registrants, and 250 participants connected at the same time.

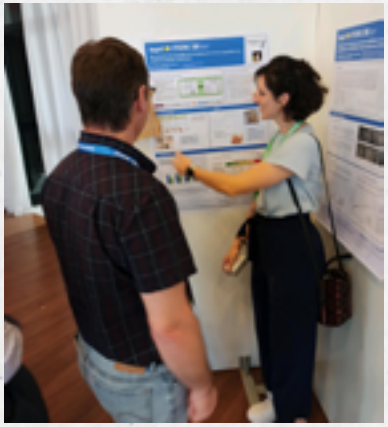
The chair will organize the 3rd edition of CELLIENCE in December 2024, and expect to see numerous registrations!



THE CHAIR IS PRESENT IN CONFERENCE

Cellulose Valley members are presents at international and national conferences, with participation in the following congresses among others:

› FinnCeres, Finland - May 2022
› Nanocellulose day, Norway - October 2023
› ACS Cellulose division, USA - March 2023
› Tappi Nano, Canada - June 2023
› EPNOE, Austria – September 2023
› Carnot Polynat day, Grenoble – May 2023
› Pulp&Beyond, Finland – Avril 2024
› FB POL, Brazil – June 2024
› Tappi Nano, USA - June 2024
› IAPRI, Spain – June 2024



THE CELLULOSE VALLEY
IN THE ACADEMIE DES SCIENCES

A highlight of the year 2023 was the chair Cellulose Valley presentation at the *Académie des Sciences.* On October 17, Julien Bras was awarded the Arkema / Académie des Sciences Prize for Innovation in Chemistry for Sustainable Materials 2023. He had the opportunity to give a talk to present his research projects and took advantage of this moment to introduce the chair Cellulose Valley and the hosted projects.

This prestigious prize rewards his high-level work in chemistry, paving the way for innovative solutions for sustainable and responsible development. This research - which has given rise to 195 publications and 22 patents - is a perfect illustration of the prospects offered by the use of structures derived from the plant world, in particular cellulose at all its scales. By chemically modifying nanocelluloses to endow them with new properties, the researcher and his team are demonstrating that it is possible to replace fossil-based polymers in numerous applications ranging from packaging to composites.

A senior member of the Institut Universitaire de France, Julien Bras is a scientist who is convinced of the need for technology transfer of scientific activities, as demonstrated by his regular collaborations with industry, the creation in 2022 of the Cellulose Valley Chair of Industrial Excellence and his contribution to the emergence of several start-ups.

SCIENTIFIC PUBLICATIONS

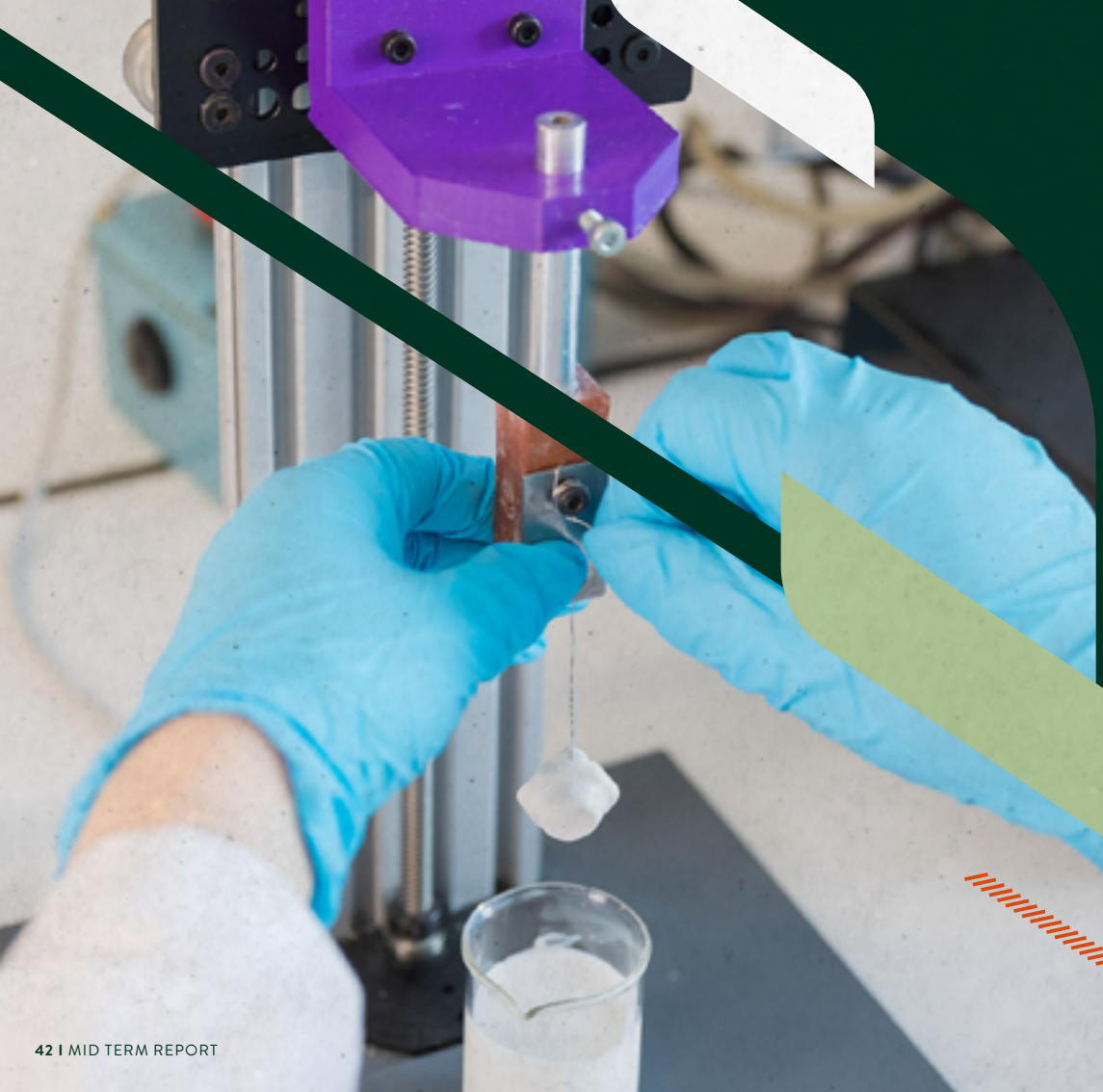
Some members of the chair *(Julien Bras, Julia Pescheux-Sergienko and Candice Rey)* had the chance to join other researchers from the LGP2 laboratory to write a review article about tridimensional cellulosic material, published in October 2024. This is the first review summarizing the novel and common processes to design 3D cellulosic packaging.

Julia Pescheux Sergienko and René Rafael Romero Lezama had the chance to present scientific posters in conference in France and abroad.

› GdR DUMBIO in Grenoble *(France)*, May 2022
Cellulose Valley: Reinventing Packaging. Engineering of new highly performant cellulose based materials.
› Tappi Nano in Helsinki *(Finland)*, June 2022
Nano-cellulose based coating to obtain high performance sustainable packaging solutions
› ACS in Indianapolis *(USA)*, March 2023
Development of new high-performance recyclable packaging within Cellulose Valley
› EPNOE conference *(Austria)*, September 2023
Development of a multilayer cellulosic material based on cellulose foam and paper for water vapor barrier shift concept in packaging.


Carbohydrate Polymers

Novel technologies for producing tridimensional cellulosic materials for packaging: A review



Long-term research :

FOCUS ON OPTIMIZING CELLULOSE MATERIALS THROUGH SPECIFIC FUNCTIONALITIES


JACQUEMUS

INVESTIGATION OF THE POWERS OF MECANOCHEMISTRY

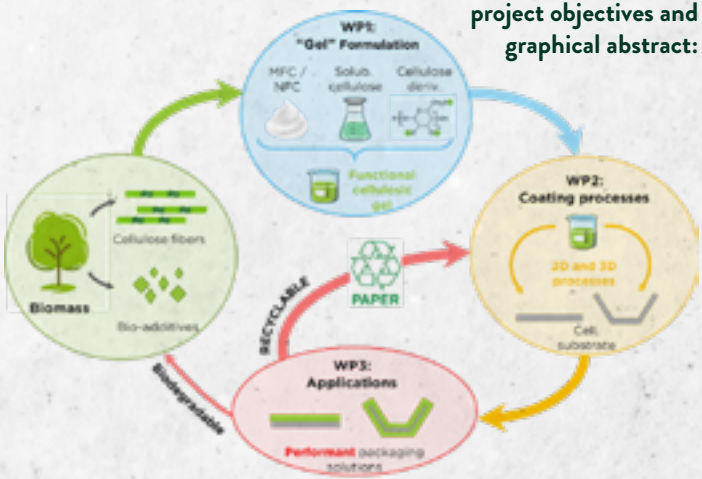
Julia Pescheux-Sergienko, *(Nov. 2021-Nov2024)* **PhD student. Co-supervision Pr Naceur Belgacem** *(Grenoble INP PAGORA)* **and Pr. Julien Bras, Chair Holder.**

"New cellulose process for high-barrier specialty papers and 3D cellulose materials"

Keywords: *cellulose gel, blends of cellulose derivatives, new mechanochemically functionalized fibers, gas and liquid barrier.*

The aim of this project is to investigate the different types of cellulose in order to maximise their barrier properties. The use of solubilised cellulose or nano-cellulose has the potential to act as a barrier to fats and oxygen. Chemical modification is envisaged as a solution for water and water vapour behaviour. The resulting materials will then be deposited onto different cellulose substrates and deposition techniques will be investigated as a function of substrate geometry and surface finish. The efficiency of the different «packaging» materials and their recyclability will be the focus of the project.

Background, project objectives and graphical abstract:



MATERIALS AND METHODS

- Chemical modification by mechanochemistry
- Solubilization of cellulose
- Various coating techniques
- Various characterizations *(Cobb, WVTR, OTR, etc.; FTIR, XPS, EA, DRX, UV, DPv, etc.)*
- Microscopy *(Optical, Alicona, SEM)*

MAIN RESULTS:

- Production of new cellulose derivatives
- Multilayer coating on special papers
- Investigation of coating on 3D objects *(dip-coating, spray, tempography)*
- Recyclability of samples

PROSPECT:

- Continue along the path of mechanochemistry
- Investigate the deposition of solubilized cellulose on cellulose substrates
- Propose packaging solutions that take into account industrial realities *(e.g. machinability)* and current legislation *(recyclability)*.

STUDY OF AN INNOVATIVE MULTILAYER MATERIAL DESIGN

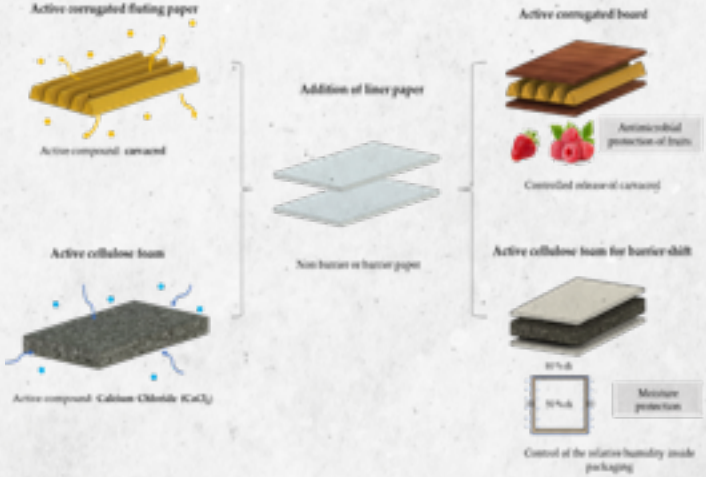
René Rafael Romero.Lezama *(Sept 2022-Sept 2025)*, **PhD student. Co-supervision Dr Jeremie Viguié** *(research engineer, LGP2)* **& Dr Isabelle Desloges** *(associate professor, Grenoble INP PAGORA)* **and Pr. Julien Bras, Chair Holder.**

"Multilayer cellulose process to produce high-value-added cellulose materials"

Keywords: *cellulose, adhesion, active layer, encapsulation, mechanical properties, ply strength, barrier properties, recyclability.*

CONTEXT AND OBJECTIVES:

This project, which is part of the Cellulose Valley Chair, aims to develop new cellulose-based multilayer structures for active packaging in collaboration with eight industrial partners. These structures consist of an active cellulose-based intermediate layer between two liner papers, which can be either barrier or non-barrier. The main objective is to study the effect of adding liner papers to these active layers to form two multilayer structures: active corrugated board and active cellulose foam for barrier shift.



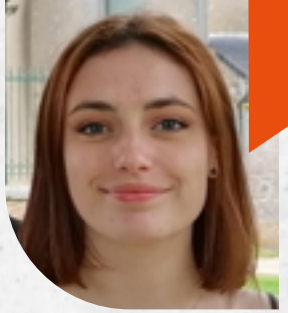
MATERIALS AND METHODS

- Fluting and liner papers
- Cellulose foams
- Size press
- UV spectroscopy
- Microbiology activity
- Water vapor transmission rate (WVTR)
- Wapor vapor absorption

MAIN RESULTS:

- Decrease of release when adding non-barrier and barrier paper
- Paper remains active after 10 days of release
- Decrease of WVTR when adding non-barrier and barrier paper.

IMMERSIVE ANALYSIS IN PROCESSES FOR 3D CELLULOSIC PACKAGING: WET MOLDED FIBER



Mathilde Bernard-Catinat *(Sept 2023-Sept 2026)*, **PhD student.**
Co-supervision: Pr Evelyne Mauret *(Grenoble INP PAGORA)* **and Pr. Julien Bras, Chair Holder.**

"Innovative process for the production of 3D cellulose complex materials"

Keywords: *cellulose, 3D proceed, Air-laid thermocompression, stretch paper, nanocellulose, barrier deposition on 3D form, spray, recyclability, life cycle analysis.*

Since the late 1950s, the shift to a throwaway culture has led to extensive use of plastics in food, cosmetics and pharmaceutical packaging, causing serious environmental problems such as threats to wildlife, contamination of the food chain and climate change. New legislation aims to reduce plastic pollution by limiting production and promoting recyclable materials. Rigid items currently made from plastic, such as trays, bottle caps and disposable cutlery, can be made from cellulose. This thesis aims to develop innovative processes for the production of three-dimensional cellulose materials by comparing and proposing new 3D shaping and surface functionalisation techniques.

MATERIALS AND METHODS

› Compact multifunctional pulp molding machine and thermopress *(WMF, DMF and WDD)*
› Hammer crusher *(DMF)*
› Handsheet machine *(WDD)*
› Paper pulp (several natural fiber sources).

MAIN RESULTS:

› Softwood pulp offers the best mechanical properties for WMF
› Higher water content offers better cohesion to DMF material
› Wet handsheet can be 3D formed at low deformation depth.

PROSPECT:

› Addition of new pulp tested
› Addition of moisture absorbing additives for DMF
› Addition of wet strength additives for WDD.

STUDY OF STRETCHABLE PAPER TO PRODUCE 3D CELLULOSIC PACKAGING

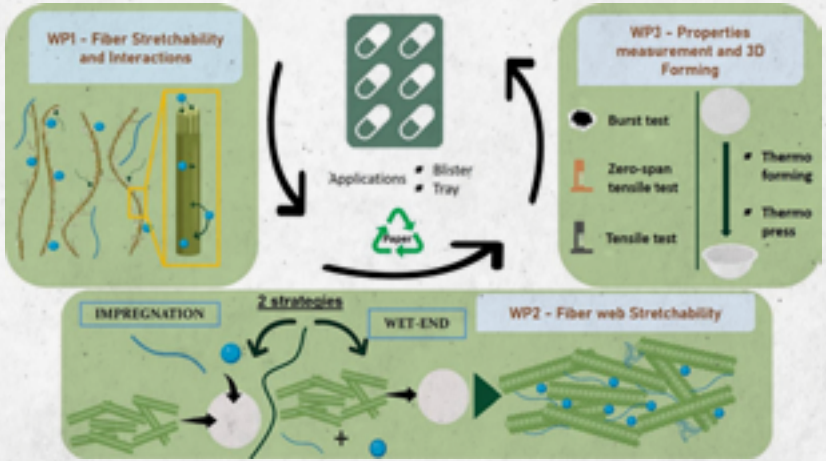
Salomé Damour, Study enginner *(2023-2024)*.
Co-supervision: Dr Jeremie Viguié, *(research engineer, LGP2)* **and Pr. Julien Bras, Chair Holder.**

"Investigation of paper with increased stretch potential for 3D forming"

Keywords: *cellulose, plasticizer, physico-chemical interaction, role of anisotropy and moisture in cellulose elasticity, functionalization of cellulose and multilayers.*

CONTEXT AND OBJECTIVES:

Plastic blisters are widely used for packaging pharmaceuticals, cosmetics and certain food products due to their lightweight and thermoformable properties. However, they pose significant environmental and health issues. Paper is a sustainable alternative as it is biodegradable, recyclable and reusable, but it has low extensibility which makes it difficult to thermoform for small deformations. This project aims to increase the extensibility of paper by influencing the fibres themselves, additives and the fibre network, in order to understand and control the operations required to produce extensible paper.



MATERIALS AND METHODS

- Paper pulp *(BSKP)*
- Additives *(Guar gum, Alginic acid, Glycerol, Cellulose Nanocrystals, PAE resin)* and enzymes
- Screen printer
- Various drying methods
- Thermopress.

MAIN RESULTS:

- Maximum elongation achieved by guar gum impregnation of an oven-dried handsheet.
- Possible thermoforming of guar gum handsheet on 1 cm deep mold.
- Possible 3D shaping of Screen printed CNC paper with defects.

PERSPECTIVES:

- Mechanical treatment of fibers to reach industrial paper extensibility
- Characterization of 3D formed substrates using topographical methods.

VALORISATION OF THE PROOFS OF CONCEPT

Candice Rey, Research engineer, *(2023-2026).*
Supervion: Pr. Julien Bras, Chair Holder.

Project coordinator for short term research, partners contact person and valorization of the Cellulose Valley research

Keywords: *proof of concept, scientific communication, project coordination, public knowledge diffusion, science valorization.*

This organisation provides a dynamic research environment conducive to the rapid and efficient progression of research. The objective is to investigate fundamental cellulose-related themes that require a greater investment of time and expertise. This is the objective of doctoral and postdoctoral students. Concurrently, the master's degree students will assist in the confrontation of established models and ideas with the reality of the contemporary market, while also exploring alternative avenues for innovative thinking.
The detailed research results are accessible to the public via the chair website, presented in the form of a poster or reports.

The main objective of all research projects consists in exploring the intrinsic properties of cellulose and optimize its use as a finished material.

«The necessity to transition towards sustainable materials is a pressing issue in the present era. The strength of the Cellulose Valley Chair lies in its capacity to align research with the requirements of industrial production, thereby facilitating an ecological transition in production methods. The Chair's research projects offer our partners significant time savings, while the various exchanges between partners give a very tangible meaning to our research.»

THE EXPECTED RESULTS
at the beginning of the chair are listed below:

- Improve the ***barrier properties*** of cellulose
- Explore ***multi-layer assembly*** of cellulose materials
- Investigate ***new industrial processes***
- Propose ***innovative, recyclable and biodegradable*** materials
- Question ***consumer habits*** in terms of packaging and put forward solutions based on the ***Life Cycle Analysis*** of the products studied.

Innovation and SHORT-TERM SOLUTIONS

On the other hand, the 23 masters will address the most topical issues in the field, with a focus on rapid solutions and proofs of concept.

The subjects of these master's programs will be decided in agreement with each of the Chair's partners and discussed at the steering committee. A research engineer will be on hand to supervise and promote these projects.

BELOW ARE EXAMPLES OF THE MASTER STUDENT'S SUBJECTS FORECASTED:

- MFC as a reinforcement in corrugated cardboard
- Molded cellulose and recyclability, upcycling of recycled cellulose fibers
- New cellulose beads for damping or high adsorption
- New cellulose injection prototypes
- Superhydrophobic solutions for e-commerce
- Super-light corrugated board for direct food packaging
- Alternative to fluorine for grease barriers
- Biomimetic approach to reusable board
- Intelligent molded cellulose with biopolymer coating
- Anti-counterfeiting with transparent conductive ink
- Adhesion measurement of multiple cellulose layers
- Heat sealing and filling of cellulose packaging
- Cellulose regeneration as a coating
- Direct coating of solid/paste materials, etc.

PROOFS OF CONCEPT FROM 2022

NEW 3D CELLULOSIC PACKAGING

February – June 2022, **Annabelle Julien**
Sponsoring: Chanel

Background, project objectives and graphical abstract:
This project is part of the anti-waste law and the European directive on single-use plastics *(AGEC, SUP law)*. Companies must quickly find an alternative to limit the production of plastic waste. In the cosmetics sector, there are 3 different levels of packaging *(product packaging, product protection secondary packaging, and tertiary transport packaging)*. The aim of this project is to propose a biodegradable, recyclable and bio-sourced alternative to secondary packaging for cosmetic products.

MATERIALS AND METHODS

› MFC foam obtained by enzymatic pretreatment
› Twin screw extrusion
› 3D PLA mold *(male and female parts)* for a cosmetic bottle
› Tests with several MFC suspensions
› Creation of 2D shapes for resistance testing
› Comparison between 2 and 5 extrusion passes for 3D shapes.

MAIN RESULTS:

› The more passes through the extruder the more tangled the fibers: *more cohesive part*
› Maximum 5 passes otherwise counter-productive
› Addition of HPMC = better rendering for 3D parts
› 2 passes + 20% HPMC = *better combination, better elastic modulus, appearance, less shrinkage.*

PROSPECT:

› Test other additives to improve surface state *(less sticky)*
› Test with fewer extruder passes *(2 seems better than 5)*
› Adapt a mold for 3D products and have repeatable parts
› Freeze drying: *calibrate drying time as a function of product thickness/mass*
› Process improvement through delignification and other drying processes
› Recyclability test *(ATICELCA standard)*.

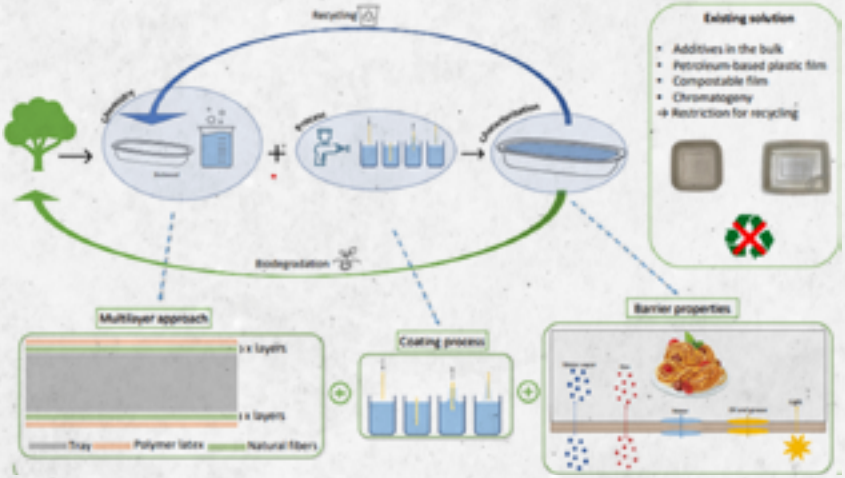
NEW PROCESS FOR BARRIER PROPERTIES OF MOLDED CELLULOSE TRAYS

February – June 2022, **Emma Colombari**

Sponsoring: Alphaform

Background, project objectives and graphical abstract:

Today, 40% of the world's plastic production is used for packaging. For this reason, the European directive on single-use plastics bans certain plastic consumables, such as trays. New companies are producing molded cellulose trays that can be an interesting alternative to existing plastic trays. The aim is to develop high-barrier, recyclable cellulose trays for the catering industry.



MATERIALS AND METHODS

› Two different types of trays with or without AKD
› Film casting and DIP coating
› Several coating sauces used: PVOH, HPMC, CNF and HPH8 *(SB latex)*
› COBB, roughness and air permeability measurements.

MAIN RESULTS:

› Latex SB: better barrier properties against water and grease
› CNF: *layer of the same material as the substrate, creating a barrier film*
› Non-homogeneous film deposition due to high substrate porosity: *less than optimal barrier properties*
› Multilayer for improved deposition with CNF and Latex SB: *2 layers of CNF + 1 final layer of Latex SB = optimum combination.*

PROSPECT:

› Recyclability test *(ATICELCA standard)*
› Food contact agreements test
› Mechanical resistance tests, such as abrasion, must be carried out
› A biobased coating to replace SB latex would reduce the carbon footprint of the final product. PLA is a good candidate, with good grease barrier properties but insufficient water resistance
› Improve operating parameters to get closer to orders of magnitude representative of the industrial field.

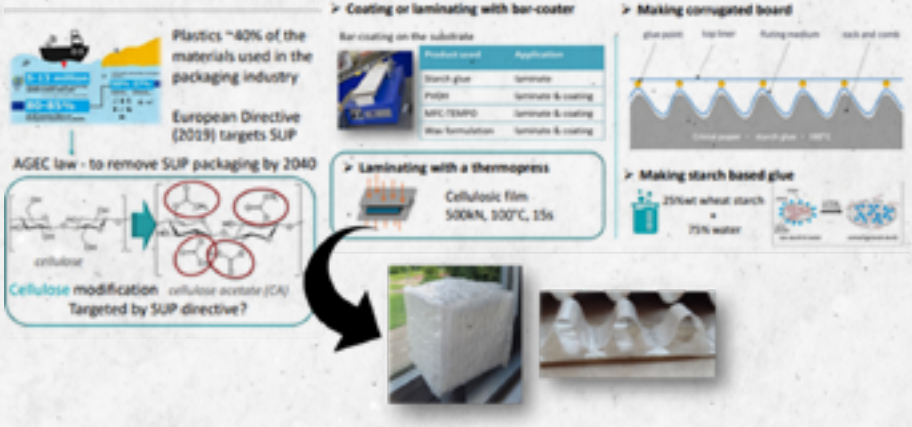
MULTILAYER AND TRANSPARENT NEW CELLULOSIC MATERIAL

February – June 2022, **Marie Segur**

Sponsoring: DS Smith

Background, project objectives and graphical abstract:

This project involves the development of two products based on the same translucent substrate, Cristal paper. The first case study is a transparent window that would replace cellulose acetate (CA) windows, possibly covered by the SUP directive on certain food packaging. The second case is completely innovative, since it would be a translucent corrugated cardboard. These two aspects of the project are linked by the substrate and its translucent nature. Translucency is therefore measured. Other properties such as adhesion, recyclability and anti-fogging are crucial to consider.



MATERIALS AND METHODS

- Utilisation de substrats : papiers cristal 32 et 50g.m^{-2}, Tracing paper, test liner, papier d'impression
- Bar coating de plusieurs sauces : MFC tempo, PVOH, cire, amidons
- Utilisation de plusieurs bio adhésifs pour la préparation de carton ondulé transparents
- Mesure de transparence *(spectrométrie à 550nm)*, de résistance mécanique, propriétés barrières.

MAIN RESULTS:

Case study 1:

- After coating with 32g.m^{-2} crystal paper: increased rigidity for all sauces
- As a replacement for AC windows, 32 g.m^{-2} glassine has the best anti-fog and recyclability properties

2nd case study:

- Crystal paper capable of being corrugated to make transparent corrugated board
- Corrugated 50g.m^{-2} crystal has better strength and stiffness properties than other substrates.

PROSPECT:

- For the first case study: perform tests on 32 crystal paper laminated with a bio-polymer film to increase transparency
- Adhesion between crystal paper and adhesives to be studied
- For the second case study: test other adhesives to make the paper even more transparent, and develop a repeatable method for producing samples
- Recyclability test in both cases.

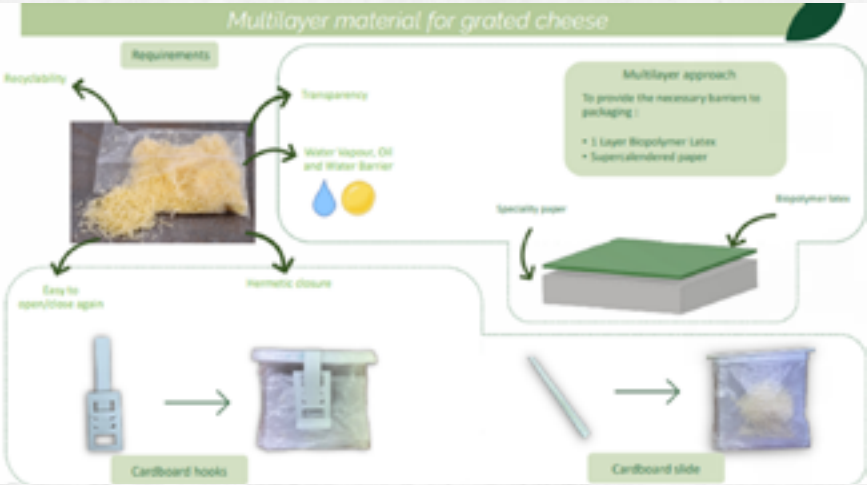
NEW TRANSPARENT PACKAGING AND DEVELOPMENT OF ECO-DESIGNED CLOSURES

February – June 2022, **Marion Delannoy**

Sponsoring: CITEO

Background, project objectives and graphical abstract:

Plastic packaging has been around for many years and has evolved over time, multiplying its negative impact on the environment. Single-use plastics have recently been largely banned in France, but the end-of-life of plastics and waste management poses problems. The growing demand for sustainable packaging materials has encouraged scientists to explore many unconventional materials. Biobased polymers are a sustainable alternative to conventional plastics. This is the background to this project..



MATERIALS AND METHODS

› Various papers: *32 and 50 g.m^{-2} crystal paper*
› Latex from PLA and Latex from Sun Chemical *(SPEF134)*
› Paper coated with 40 µm bar, 2m/min. Then dried at 90° for 3 min
› WVTR test, COBB oil test, COBB water test, qualitative fat hold test *(cheese placed on paper for 2 days)*
› Life cycle analysis.

MAIN RESULTS:

› 1 layer of PLA on crystal paper 50 g.m^{-2}: *best fat barrier properties*
› For water-barrier properties, 2 layers of PLA are required
› SPEF134 is less permeable to water vapor than PLA
› Comparison of different types of closure
› Greenhouse gas emissions of plastic packaging 2x higher than cellulose packaging.

PROSPECT:

› Ageing test to be carried out under conditions representative of use.
› Study of compatibility for food contact.
› Mechanical resistance tests on the closure system.
› Heat-sealing resistance test.

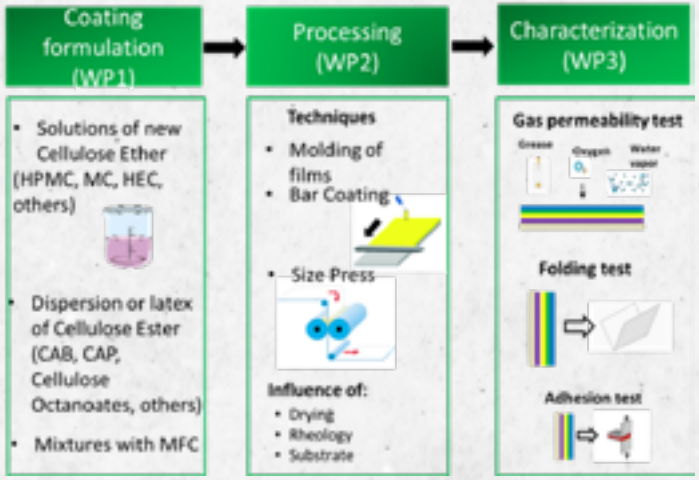
NEW TRANSPARENT PACKAGING AND DEVELOPMENT OF ECO-DESIGNED CLOSING SYSTEM

February – June 2022, **René Romero**

Sponsoring: Ahlstrom

Background, project objectives and graphical abstract:

Plastic packaging has played an important role in the food industry in recent years. Yet it is one of the main contributors to environmental pollution. The European directive on the single use of plastic is pushing the packaging industry to move towards a more sustainable industry and a circular economy. Cellulosic paper is a good solution for transforming the packaging industry due to its biobased nature, low cost, high availability, good mechanical properties and recyclability. The aim of this project is therefore to propose a packaging solution that meets the needs of a food product.



MATERIALS AND METHODS

- Gerstar paper, 60 $g.m^{-2}$
- Cellulose derivatives *(HPMC, HPC, EHM, CMC, cellulose acetates CA, Aquacoat CPD)*
- Preparation of coating sauces
- Bar coating *(24 µm bar, 2m.s^{-1})* and blade coating. Multilayer, from 1 to 4 layers
- Characterization by DSL, SEM images, COBB absorption measurements, WVTR, air permeability
- Bending strength test, sealability.

MAIN RESULTS:

- Films made with cellulose derivatives in casting film are highly grease-barrier: COBB 1800sec from 0 *(HPC, CAP, CAB, Aquacoat CPD)* to 1.6 $g.m^{-2}$ *(HPMC, CMC, EHM)* depending on the sauce used
- Blade coating deposits 4 times more material than bar-coating for HPMC sauce, with better coating quality observed
- Better grease barrier for increasing coating weights. Lower coating values with HPMC and CAB.

PROSPECT:

- Air permeability test
- Recyclability test
- Food contact compatibility study.

PROOFS OF CONCEPT FROM 2023

BARRIER PROPERTIES OF 3D CELLULOSIC OBJECTS BY DIP-COATING

February – July 2023, **Mathilde Bernard-Catinat**
Sponsoring: APTAR

Background, project objectives and graphical abstract:

In 2021, the European directive on single-use plastics is followed in France by the AGEC law (Anti-Gaspillage pour une Économie Circulaire). The aim of these initiatives is to reduce the production and consumption of single-use plastics in order to protect the environment. Today, 3D plastic objects such as bottle tops and disposable tableware are rarely recycled and are commonly found on European beaches. To combat this phenomenon, the use of cellulose would enable good recyclability. The main challenge for this material, and the aim of this project, is to bring grease, water and gas barrier properties to complex structures.

MATERIALS AND METHODS

- Artillery Sidewinder X2 3D printer
- Dip-coater with Arduino program and commercial coating sauces *(SBR latex and PLA)* and others *(MFC, carnauba wax, etc.)* on 3D printed parts and commercial WMF and DMF
- Barrier property tests: WVTR according to ASTM E-96A and ISO 2528, Cobb Oil and Water adapted from ISO 535:2014
- Surface study of samples with Alicona and SEM.

MAIN RESULTS:

- Drastic reduction in Cobb values with the addition of two layers of SBR, and even better with a pre-coating of MFC and a layer of SBR *(lower coated weight).*
- Drastic reduction in WVTR with SBR on all substrates
- Lower WVTR and Cobb oil with MFC-Cloisite + solubilized wax coating, but relatively constant Cobb water.

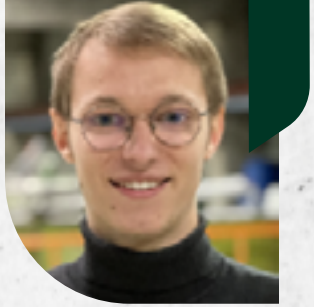
PROSPECT:

- Continue dip-coating tests with PLA latex, betulin and waxes
- Continue characterization and carry out the recycling test in accordance with the ATICELCA standard.

FORMULATION OF A MACHINABILITY-TOLERANT FLEXIBLE COATING

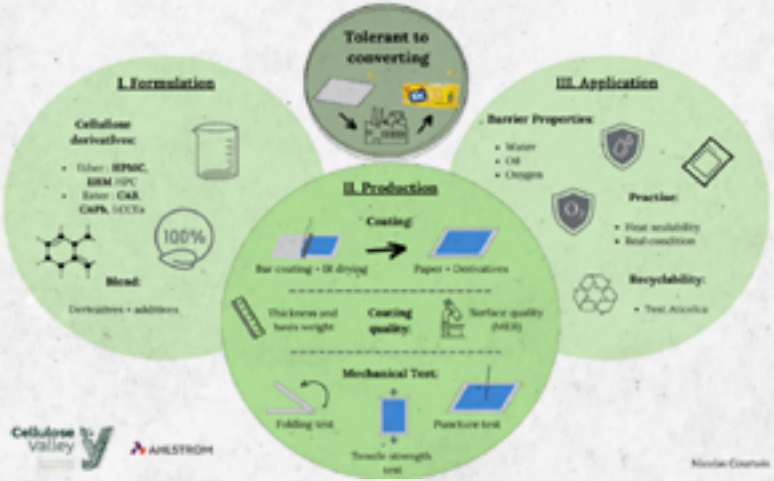
February – July 2023, **Nicolas Courtois**

Sponsoring: Ahlstrom



Background, project objectives and graphical abstract:

The European SUP directive and the French AGEC law regulate the use of single-use plastic. As a result, manufacturers need to find alternatives to plastic. The use of paper with a biosourced and recyclable coating to improve these properties could be a possible solution, particularly in food packaging. Will this coated paper be able to withstand all the mechanical stresses present in industry without losing quality? This is the question I'd like to answer by carrying out fold, friction and tensile tests to mimic industrial mechanical constraints and find the best coating formulation.



MATERIALS AND METHODS

› Coating sauces from cellulose derivatives *(DC, ether and ester, with or without plasticizer)*, bar coating and IR drying on Gerstar paper *(A4 format)*.
› Tensile tests with Instron 5965.
› Kodak stiffness tests.
› Fold resistance with ISIO 4 and WVTR oil resistance tests.
› Thermo-sealing of cellulose esters with different parameters *(time, temperature and pressure)*.

MAIN RESULTS:

› EHM and HPMC 4 layers, 1 for CAB and CAPh => 5g.m^{-2} coating
› Tensile mechanical properties vary slightly with DC
› Stiffness increases with the addition of DC, less pronounced for CAB
› Good fold resistance for CAB
› Addition of plasticizer *(≤5%)* for ethers improves fold resistance
› Good heat-sealing in less than 2s for CAB, unlike CAPh.

PROSPECT:

› Perform friction, bursting and recyclability tests *(ATICELCA standard)*
› Seal with ultrasound, apply elongation and test barrier properties, increase plasticizer quantity and observe impact on mechanical and barrier properties.

FLEXIBLE, HIGH-BARRIER, RECYCLABLE CELLULOSE PAPER FOR PACKAGING WET AND GREASY BAKING DOUGHS

February – July 2023, **Emna Hedhili**

Sponsoring: MARIE, LDC group

Background, project objectives and graphical abstract:

This Cellulose Valley Chair project focuses on paper coating as an alternative to plastic for food packaging. The aim of the study is to give paper, composed mainly of cellulose fibers, the same air, moisture and grease barrier properties as plastic.

MATERIALS AND METHODS

- *Coating of two types of paper with different sauces: Sunbar* (Sunchemical), PVOH, CNF, PLA, silicone
- Characterization and mechanical properties of paper for 1 layer of sauces.
- Multi-layer paper composition test: variation in the number of layers on both sides of the paper, up to a maximum of 6 layers
- Characterization of air permeability, water vapor transmission *(WVTR)*, oxygen transmission *(OTR)*.

MAIN RESULTS:

- Increased number of layers: improved barrier properties. Reduced WVTR and oxygen transmission
- The composition offering the lowest oxygen and water vapor transmission is: 3 layers on both sides of the paper with PVOH, PLA and Sunbar
- Analysis of transmission values obtained for plastic packaging: WVTR of the same order of magnitude as the best multi-layer but 2 times lower, lower OTR value for multi-layer.

PROSPECT:

- Improve multi-corking to achieve similar or lower WVTRs than plastic
- Roughness, mechanical strength and air permeability tests to be carried out
- Take SEM images to quantify multi-layer coating quality
- Ageing tests and positioning of packaging for intended use
- ATICELCA recyclability tests.

ACTIVE SECONDARY PACKAGING AS AN AROMA BARRIER AND INSECT REPELLENT

February – July 2023, **Thais Simoes Taveira**

Sponsoring: CITEO

Background, project objectives and graphical abstract:

The aim of this work is to develop secondary active cellulose packaging, based on two different active packaging strategies - release of active molecules and absorption of aromas - that can protect and prevent foodstuffs from deterioration due to the presence of insects or pests.

MATERIALS AND METHODS

- Essential oils *(EO)*: carvacrol, eugenol, thymol and limonene
- Paper coated with EOs *(release test)*
- Preparation of cellulose foams *(MC)* with EO *(salting-out test)*
- Preparation of MC with cyclodextrin *(β-CD) (absorption test)*
- Preparation of cellulose beads *(BC)* with HE *(release test)*
- HE release test in ethanol
- Flavor absorption test
- GA, SEM and qualitative test with strawberries.

MAIN RESULTS:

- EO evaporation temperature is between 120-180°C, except for limonene
- Paper: EO release fairly reproducible
- BC: more controlled release of EO than paper
- MC with HE: fast release of HE, but there is probably a huge loss of HE during the process
- Antifungal properties observed.

PROSPECT:

We need to look for strategies to better control the release of EO onto paper, as well as testing the release of EO into the air, and finally carry out a biological test with insects to validate the project.

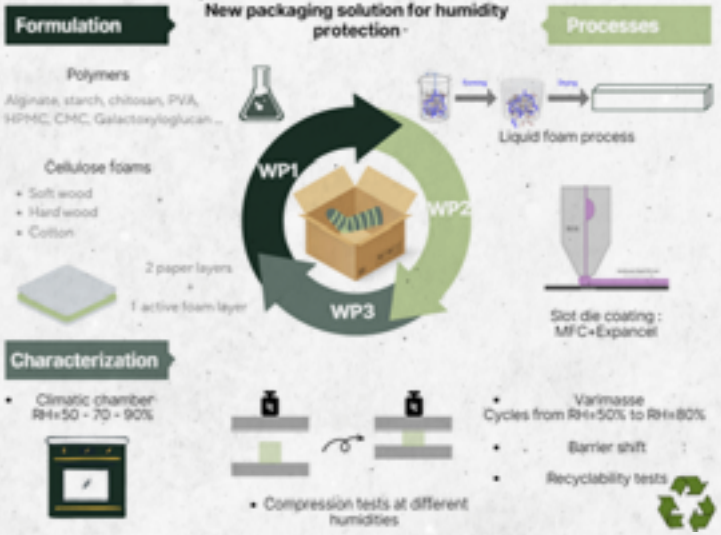
NEW PACKAGING SOLUTION FOR MOISTURE PROTECTION

February – July 2023, **Fiona Pichon**

Sponsoring: Decathlon

Background, project objectives and graphical abstract:

The aim of this project is to find a biosourced and recyclable alternative for moisture-resistant textile packaging. The AGEC *(anti-waste for a circular economy)* and SUP *(Single use plastic)* laws are motivating companies to find solutions for their packaging, which must be more respectful of the environment.



MATERIALS AND METHODS

› Varimasse measurement
› Climatic chamber
› Barrier shift test
› Foam simulation with various bio-polymers: CMC, Alginate, Sodium polyacrylate.

MAIN RESULTS:

› Increased moisture absorption over time: polymers and foams
› Delayed kinetics for barrier shift tests
› CMC and Alginate: best absorbers of all polymers tested.

PROSPECT:

› SEM morphology
› Slot die coating with MFC/Expancel foam.

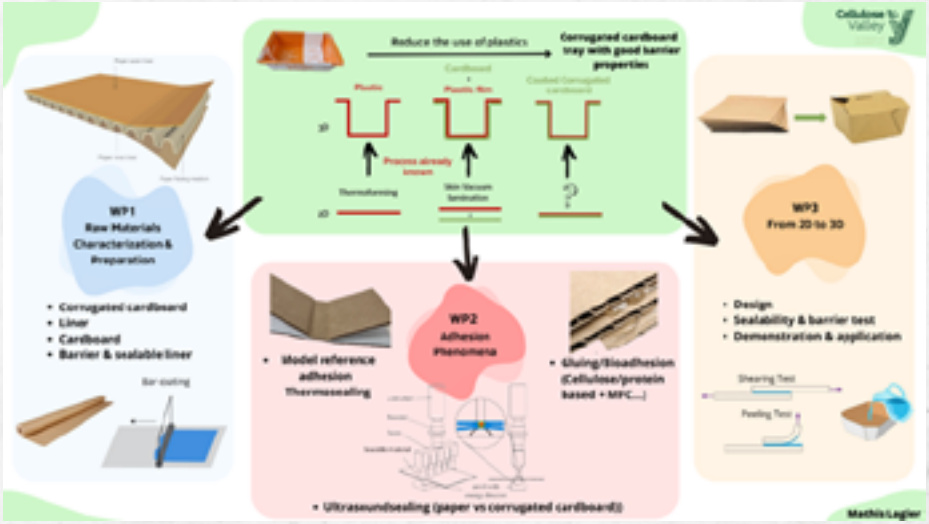
NEW SEALABLE CARDBOARD PACKAGING

February – July 2023, **Mathis Lagier**

Sponsoring: DS Smith

Background, project objectives and graphical abstract:

To provide food packaging plastic trays made by thermoforming have been widely used and this process is well-known. In order to reduce the use of plastic, cardboard covered by a plastic film giving good barrier properties is also used and made by a process called skin vacuum lamination. To replace this plastic film, DS Smith is working on the development of a barrier (gas, oil, water) coated corrugated cardboard primary tray. However, the process to make the tray from this new material is not established and ultrasound sealing or bioadhesives are solutions that need to be investigated.



MATERIALS AND METHODS

› Ultrasound sealing
› Heat sealing
› Bioadhesives
› Tensile test
› Bar coating

MAIN RESULTS:

› Formulation of bioadhesives made from cellulose derivatives and proteins
› Adhesiveness level of industrial glues reached with bioadhesives
› Improvement of adhesive strength with MFC
› Coated corrugated cardboard sealable with ultrasound sealing

PROSPECT:

› Check the impact of US sealing on the recyclability *(ATICELCA standard)*
› Influence of the amount of MFC added to the glue
› Optimization of US sealing parameters
› Design of a barrier corrugated cardboard tray

NEW 3D GAS-BARRIER CELLULOSE PACKAGING FOR COSMETICS

February – July 2023, **Aziza Mnallah**

Sponsoring: Chanel

Background, project objectives and graphical abstract:

This project aims to meet the requirements of the anti-waste law and the European directive on single-use plastics (AGEC, SUP law) by proposing an alternative solution to reduce the production of plastic waste. The aim of this project is to develop an alternative with high gas-barrier properties, being biodegradable, recyclable and of biological origin for cosmetics packaging. The barrier properties are developed through innovative surface coating techniques such as Atomic Layer Deposition.

MATERIALS AND METHODS

› Raw materials used: wet molded cellulose and dry molded cellulose. Use of several coating sauces: SBR, SunChemical, silicone
› Tests for water and oil absorption, water vapor resistance, roughness, surface energy, porosity
› Application of two coating methods: dip coating and atomic layer deposition
› Comparison of results with 1- and 2-layer coating of different sauces.

MAIN RESULTS:

› ALD reduces air permeability
› As the number of layers increases, air permeability decreases
› Coating reduces water absorption
› SBR latex gives lower surface energy than other sauces
› Water and oil absorption of dry molded cellulose < wet molded cellulose.

PROSPECT:

› Perform tests on DRY cellulose bedding
› Perform WVTR tests to test water vapor permeability
› Test recyclability and biodegradability
› Choose the best coating sauce for my final product
› Perform OTR test
› Vary DIP coating parameters.

SURFACE TECHNOLOGIES FOR APPLYING BARRIERS TO RIGID 3D STRUCTURES AND THE INFLUENCE OF SURFACE PREPARATION: SPRAY DEPOSITION

January – June 2023, **Suzy Ruano**

Sponsoring: Guillin Emballages

Background, project objectives and graphical abstract:

Plastic production and consumption are increasing year on year, leaving behind a significant amount of waste. This is why measures have been taken at European and French level: the SUP directive and the AGEC law to limit plastic accumulation and the use of single-use plastics. It is in this environmental and legislative context that this project was born. Indeed, the company. In the field of food packaging, plastic can meet specific needs in terms of barriers. The aim of this project is to offer a recyclable and potentially biodegradable alternative to laminated plastic using the spray technique.

MATERIALS AND METHODS

- Spray coating using Mecafer 400 HVP spray
- Water and grease absorption test using COBB
- Rheology test using MCR 302 rheometer
- Roughness measurement using Alicona
- Surface analysis using SEM.

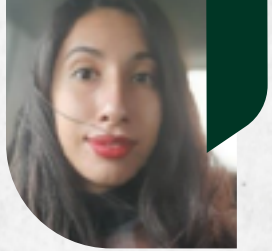
MAIN RESULTS:

- Latexes are not suitable for spray deposition
- Good barrier properties are achieved with bio-wax emulsion
- It's important to close the surface in order to apply a coating evenly and optimally
- The spray used does not allow perfect reproducibility.

PROSPECT:

To continue this project in the best possible way, we need to set up a laboratory-scale spray pilot to spray a known quantity of coating. In addition, it is essential to close the surface in order to deposit smaller quantities of coating and thus have a recyclable object.

PROOFS OF CONCEPT FROM 2024



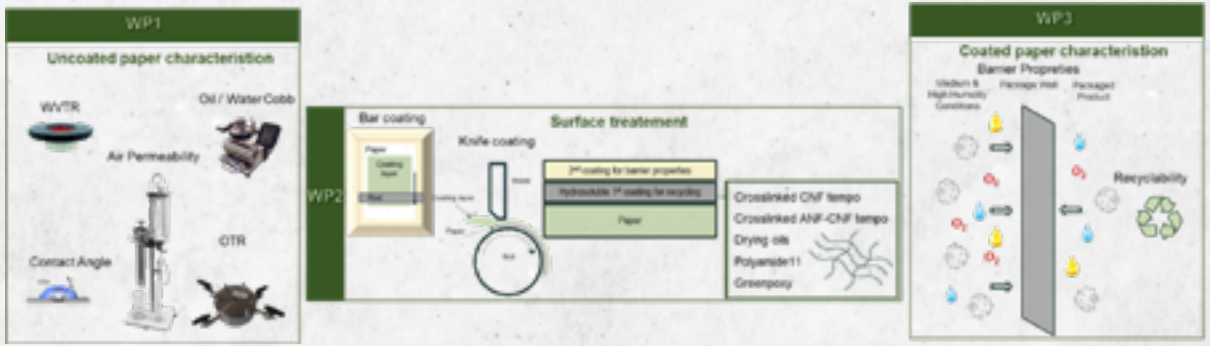
DEVELOPMENT OF EFFICIENT AND RECYCLABLE PACKAGING WITH BARRIER IN HIGH HUMIDITY

February – July 2024, **Eya Chaal**

Sponsoring: Ahlstrom

CONTEXT AND OBJECTIVES:

It is estimated that food and its packaging materials account for approximately 50% of municipal solid waste. While plastic has been widely used as packaging, its production has the dual disadvantage of depleting fossil resources and posing environmental hazards. The popularity of eco-friendly alternatives, such as paper-based packaging, is growing due to their renewability and recyclability. However, challenges remain in controlling water, gas, and oil absorption and transmission, especially in high humidity conditions. One promising solution is to coat the paper with biopolymers. Resins and cross-linked biopolymers like cellulose nanofibrils, amyloid nanofibrils, and drying oils represent an innovative coating strategy. The project aims to find a balance between barrier properties and environmental performance.



MATERIALS AND METHODS

- Ahltrom Rocalonde paper
- Water vapor tranmission rate
- Cobb water 60 seconds
- Cobb oil 60 seconds
- Air permeation
- Coating strategies: drying oil, Greenpoxy, crosslinked nanocellulose.

MAIN RESULTS:

- Rocalonde 40 has a WVTR of 1965 $g.m^{-2}.d^{-1}$ at 85% RH, 25°C, a cobb water of 24 $g.m^{-2}$ and a cobb oil of 6 $g.m^{-2}$.
- 7 gsm Greenpoxy coat decreased WVTR to 485 $g.m^{-2}.d^{-1}$ at 85% RH, 25°C, cobb water to 3 g/m^2 and cobb oil to 1 $g.m^{-2}$.
- 8 gsm ANF 4% coat decreased WVTR to 1415 $g.m^{-2}.d^{-1}$ at 85 % RH, 25°C, cobb water to 18 and cobb oil to 4 $g.m^{-2}$.
- Polyamide 11 film of 126 gsm showed a WVTR of 7 $g.m^{-2}.d^{-1}$ at 50% RH, 23°C.

PROSPECT:

- Optimize quantities for CNF tempo-oxidized and ANF crosslinking
- Find optimal technique for drying the papers coated with drying oils
- Find a 100% biobased epoxy resin.

DESIGN OF A BIO-BASED, RECYCLABLE AND TRANSLUCENT ALTERNATIVE TO THE FOOD PACKAGING FILMS FOR "CORDONS BLEUS"

February – July 2024, **Élodie Bouvet**

Sponsoring: Marie

CONTEXT AND OBJECTIVES:

The packaging industry is placing an increasing emphasis on sustainability, driven by regulations such as SUP, AGEC, and PPWR. This project is focused on the development of transparent, recyclable cellulose substrates, which represents a significant innovation due to the convergence of these three key features. Some of the substrates under consideration are still in the research phase and have not yet been coated or subjected to the tests I will employ. The primary objective of the PoC project is to develop a bio-based, recyclable, and transparent alternative for food packaging films used for "cordons bleus".

MATERIALS AND METHODS

- WVTR
- COBB oil and water
- UV spectrophotometer
- Oxygen Transmission Rate
- Heat sealability
- Different paper: UPM, Fedrigoni
- Cellulosic Films from VTT institute.

MAIN RESULTS:

- Raw materials already have good grease barrier and air permeability properties
- Water and moisture barrier properties need to be improved with coating
- Only Biocell, UPM and Sylvicta are compatible with size press
- Different drying have different effects on the paper *(IR, by contact, power...)*
- Following the type of coating, barrier properties are not the same
- Coating with bar coater (ENDUPAP) enhances transparency.

PROSPECT:

- Recyclability
- Puncture, abrasion.

INNOVATIVE BIO-SOURCED AND RECYCLED PACKAGING WITH HIGH BARRIER PROPERTIES

February – July 2024, **Ahmed Khalil Smaili**

Sponsoring: Decathlon

CONTEXT AND OBJECTIVES:

The issue of global plastic pollution is particularly acute in developing nations, where inefficient waste management practices have led to a significant accumulation of plastic waste. Despite the introduction of initiatives such as the EU Single-Use Plastics Directive, the current recycling rates remain low. The bioeconomy and projects like that of Decathlon with Cellulose Valley are exploring sustainable alternatives, such as cellulose nanofibrils, to replace plastic packaging. The objective of this project is to eliminate single-use plastics by 2026. To achieve this, we are focusing on developing bio-sourced and recyclable solutions that can withstand exposure to oxygen and humidity, which is particularly important for heaters.

MATERIALS AND METHODS

› Substrate & solutions : Cellulose base paper UPM Lucent 62g.m^{-2}, Solution Coating 01 : MFC - Solution Coating 02 : Sun Chemical “Latex”.
› Bar Coater with Handsheet Contact Dryer and Thermosceller.
› Water Vapor Transmission Rate & Oxygen Transmission Rate.
› Atomic Layer Deposition.
› Bendtsen Permeability & Intrinsic Permeability.

MAIN RESULTS:

› UPM Lucent 62g.m^{-2} with coating - WVTR 50% d’humidity, 23°C: 32 g.m^{-2}.d^{-1}.
› UPM Lucent 62g.m^{-2} with coating - WVTR 80% d’humidity, 25°C: 110g.m^{-2}.d^{-1}.
› UPM Lucent 62g.m^{-2} without coating and with coating - Bendtsen Permeability: 0 mL.min^{-1}.
› UPM Lucent 62g.m^{-2} - Intrinsic Permeability: 7,42E-14 m².
› UPM Lucent 62g.m^{-2} with coating - Intrinsic Permeability: 3,63E-14 m².

PROSPECT:

› Metallization
› Traction Test
› Test Oxygen Transmission Rate
› ORMOCER *(inorganic+organic coating solution).*

PREPARING NEW CELLULOSE- AND BIOPOLYMER-BASED MATERIALS FOR INNOVATIVE, HIGH-PERFORMANCE PACKAGING

February – July 2024, **Erin Cario**

Sponsoring: Guillin Emballages

CONTEXT AND OBJECTIVES:

In 2019, the EU introduced a ban on certain single-use plastics, followed in 2020 by France's AGEC law, which promotes the circular economy. The PPWR regulation, scheduled for implementation in 2024, will serve to reinforce these measures. In light of recent legislative directives, there has been a surge in the search for alternatives to plastic film for molded cellulose trays. The objective of this internship project is to develop an innovative paper process that offers barrier properties while being recyclable and compatible with molded cellulose. This will enable us to meet new standards and reduce the environmental impact of food packaging.

MATERIALS AND METHODS

- Cellulose molded tray
- Paper
- Bar coater
- Thermopressing
- Wet molding.

MAIN RESULTS:

- Porosity is important for good adhesion
- Certain coating bring plastic welding but not uniform adherence
- Extensibility is crucial for uniform adherence
- Barrier properties are lower with thermoforming
- Used of MFC as a glue is encouraging
- Low grammage, for substrate, give worst result.

PROSPECT:

Improve adherence for extensible paper and recyclability test.

CUSHIONING OBJECTS: BIO-BASED ALTERNATIVE IN RESPONSE TO END-OF-LIFE TREATMENT PROBLEM

February – July 2024, **Yasaman Ghasemi**

Sponsoring: Citeo

CONTEXT AND OBJECTIVES:

The primary objective of this project is to identify a sustainable alternative to expanded polystyrene cushioning with bio-based covered cellulosic foams that meet the necessary anti-abrasive and anti-humidity criteria. It is essential that these foams are multi-shock resistant, particularly during long transportation periods, and provide anti-humidity protection for exported products destined for tropical regions. The foams are designed for use with objects weighing less than 10 kg and must be biodegradable and recyclable in line with our commitment to environmental sustainability. The project's primary objective is to provide robust protection and demonstrate environmental responsibility, offering effective, eco-friendly packaging solutions for a range of shipping and storage requirements.

MATERIALS AND METHODS

- **Materials:** MFC 1%, Nomar 70, Nomar 73, PLA Latex, MFC1% + Expancel 30% powder
- **Methods:** Spray coating method, Dip coating method, Crock meter *(abrasion simulation)*, Compression test, Climatic chamber humidity analyzer.

MAIN RESULTS:

- The lighter the coated foam, the better
- Nomar 70 is showing the best anti-abrasion
- MFC 1% in 1 layer spray coating is good
- Spray coating method is better than dip coating
- Spray coating is good for abrasiveness
- Dip coating is good for mechanical properties.

PROSPECT:

- Between dip coating and spray coating, spray coating is showing better results in compression test and also in the appearance of the foam and also anti abrasiveness.
- The spray coating is suggested to be in 1 layer and all the foams should be fully dried.

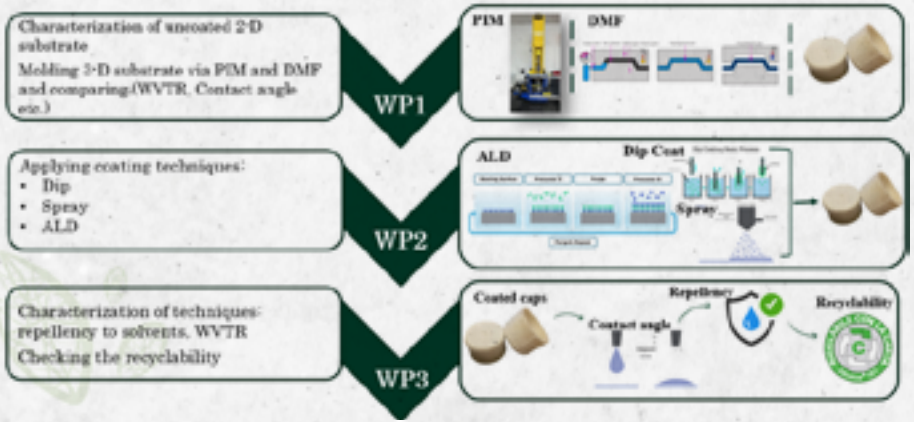
PROCESSES INVESTIGATIONS TO DESIGN BIO-BASED, HYDROPHOBIC AND RECYCLABLE CAPS: FROM 2D TO 3D OBJECTS

February – July 2024, **Waleed Mahmood**

Sponsoring: Aptar

CONTEXT AND OBJECTIVES:

Aptar, the leading producer of closures for food, beverages, beauty, and home care products, currently manufactures closures that are non-recyclable and thus unsustainable. The objective of this project at Cellulose Valley in LGP2 is to develop cellulose-based caps that are both sustainable and recyclable. Two innovative processes are being considered for potential industrial-scale application: dry molding of fibers and pulp injection molding. Furthermore, the project will assess three techniques for providing barriers: dip coating, spray coating, and atomic layer deposition.



MATERIALS AND METHODS

› Pulp injection molding
› Dip coating
› Spray coating
› Contact angle
› PVOH, PLA and biowax *(Topscreen from Solenis).*

MAIN RESULTS:

› Dry molded fiber caps having Topscreen showed least weight *(≈ 5%)* under 23°C and 80% RH.
› Dry molded fiber caps having Topscreen showed highest repellency to water *(Contact angle = 88°).*
› Dry molded caps alone seemed to have least WVTR *(≈ 240 $g.m^{-2}.d^{-1}$)* as compared to Pulp injection caps and DMF caps with Topscreen coating.
› Dip coating reduced WVTR from 297 to 95 $g.m^{-2}.d^{-1}$, while spray has around 134 $g.m^{-2}.d^{-1}$, Using PVOH and PLA as suspensions.
› Pulp injection caps coated with PVOH and PLA showed lesser angle of contact than one without coating

PROSPECT:

› Atomic layer deposition
› Recyclability test
› Dry molded fiber caps
› CNF-AKD-PCC based superhydrophobic suspension.

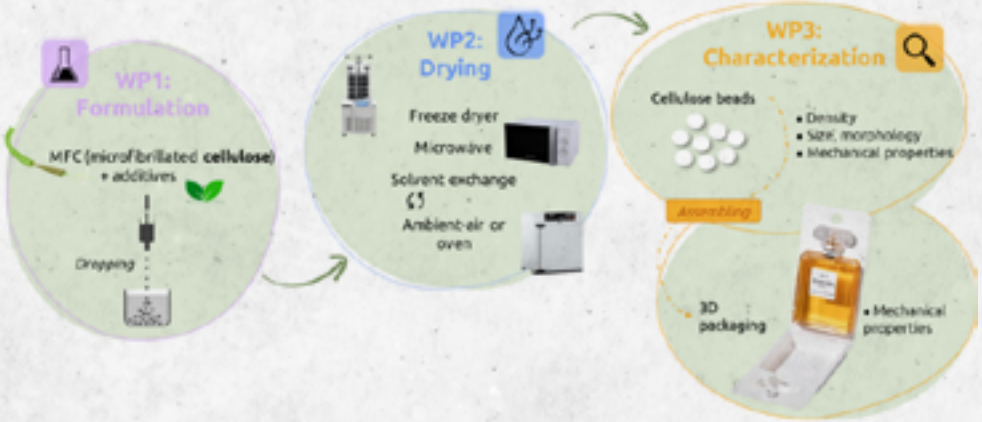
DEVELOPMENT OF AN INNOVATIVE, HIGH-PERFORMANCE AND RECYCLABLE CELLULOSIC SOLUTION FOR APPLICATION IN PACKAGING

April – July 2024, **Intissar El Mghibchi**

Sponsoring: Chanel

CONTEXT AND OBJECTIVES:

In light of the growing volume of waste plastic and the prevalence of single-use plastics such as cushioning packaging, this project was initiated with the objective of identifying a recyclable alternative. The objective was to develop a cellulosic solution for cushioning packaging applications by creating low-density beads. To achieve this, alginate and its gelling properties were combined with microfibrillated cellulose, as well as innovative drying methods such as freeze-drying and microwave drying. Furthermore, the internship concentrated on the assembly of these beads into a unified cushioning material.



MATERIALS AND METHODS

› Microfibrillated cellulose *(MFC)*
› Alginate
› Dropping
› Freeze-drying
› Microwave drying.

MAIN RESULTS:

› Comparison of different dryings
› Optimisation of formulation and process
› Demonstration of the use of a blowing agent combined with microwave drying
› Optimisation of microwave drying
› Increase in the mechanical strength of the beads
› Successful assembly of the beads.

PROSPECT:

› The product created is a promising solution for many applications
› It would be interesting to try drying and assembling the beads with a microwave blowing agent at the same time
› The formulation with chitosan as an additive could be tested more thoroughly.

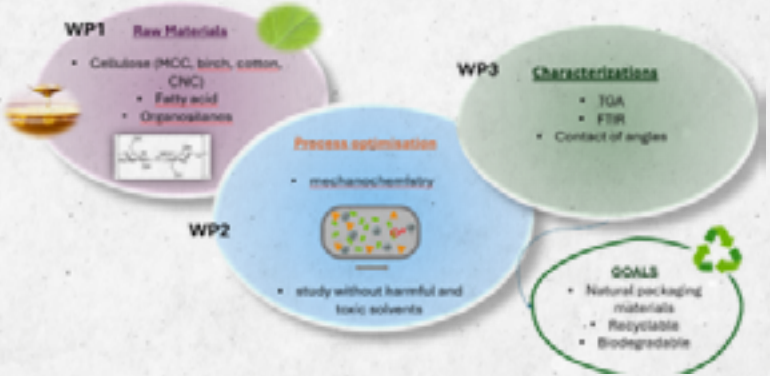
MODIFICATION OF CELLULOSE BY MECHANOCHEMISTRY

February – July 2024, **Laura Sabathier**

Partner: all

CONTEXT AND OBJECTIVES:

The primary environmental challenge facing us today is the reduction of greenhouse gas emissions in order to stabilise climate change. In 2022, global plastic production reached over 400 million metric tons, representing a 1.6% annual increase. The objective of this project is to enhance the hydrophobic properties of cellulose in order to create new recyclable and biodegradable packaging. To achieve this, we are utilising an innovative mechanochemical method, which offers significant environmental benefits. In the context of this project, the method enables cellulose to be modified without the use of harmful solvents or the wasting of energy, thus ensuring the greenest possible functionalisation of cellulose.



MATERIALS AND METHODS

› Cellulose *(Nanocrystals of Cellulose or Microcrystals of cellulose)*
› Aminosilane *(AMPS)*
› Isocyanate *(octadecyl isocyanate)*
› Fatty acids *(lauric and stearic acid).*

MAIN RESULTS:

› Increasing the hydrophobicity of cellulose by isocyanate grafting
› Confirmation of the presence of silica and amine in aminosilane-modified cellulose
› Reduction of cellulose hydrophobicity by adding aminosilane to cellulose
› Discovery of Si-O bonded grafting of aminosilane onto cellulose.

PROSPECT:

› Determines the nature of interactions between cellulose and reagents
› Test mechanochemistry with fatty acids on cellulose
› Set up a prototype to test the project in practice

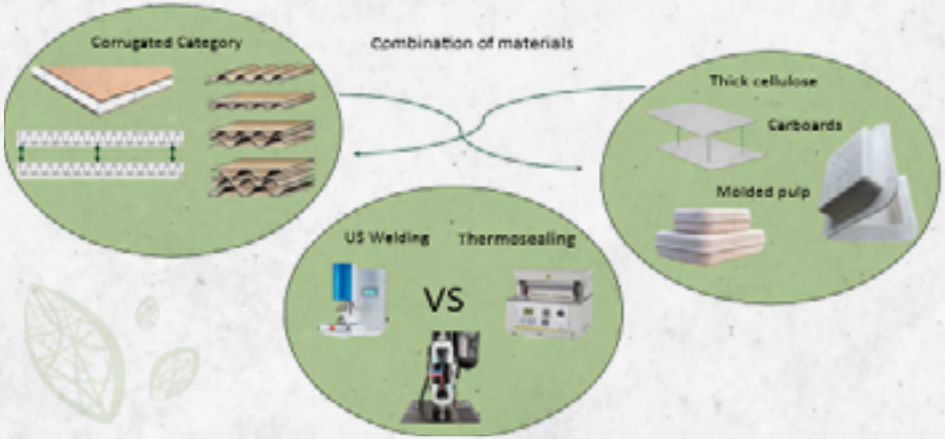
US WELDING: A NEW APPROACH FOR SEALING MOLDED CELLULOSE, CARDBOARDS AND PAPER

February – July 2024, **Abbass Taher**

Sponsoring: DS Smith

CONTEXT AND OBJECTIVES:

One of the available techniques on the market for assembling materials is ultrasonic welding. One of the most attractive features of this technique is its speed and efficiency, with a completion time of just 300 ms. Additionally, it lends itself well to automation, offering a high degree of flexibility in production. Furthermore, the technique increases the recyclability of materials, as it does not require the use of glue. This technique is typically employed in industrial settings for the assembly of metals and plastics. The objective of this project is to investigate the potential of ultrasound technology for the assembly of corrugated cardboard, molded pulp, and cardboard. Additionally, the project will explore the possibility of manufacturing corrugated cardboard from kraft paper, which represents a novel approach in the literature.



MATERIALS AND METHODS

- Bendsten *(Roughness)*
- Ultrasonic welding SC-500 *(FCT)*
- Instron *(shear & peel test)*
- Cardboard from DS SMITH.

MAIN RESULTS:

- Best Welding of corrugated cardboards depends on energy *(Max 400 E)*
- Welding of bare molded pulp not possible
- Welding of laminated and coated Molded pulp is possible at F_{set} 50 daN.

PROSPECT:

- Formation of corrugated cardboards
- Complete assembly of molded pulp trays.

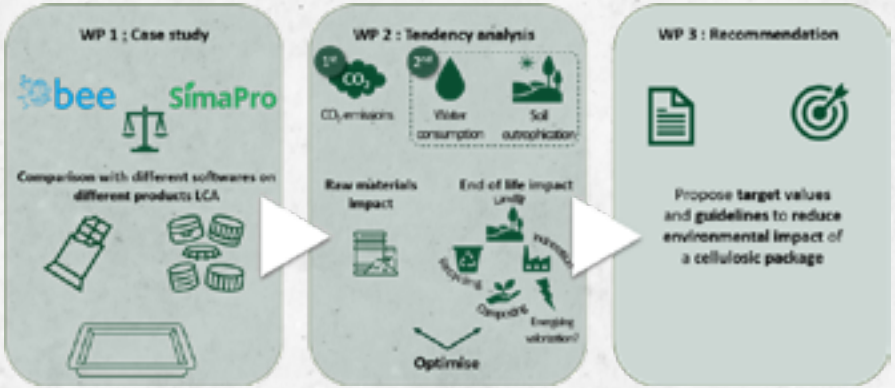
LIFE CYCLE ANALYSIS AND DEVELOPMENT OF A PERFORMANT AND RECYCLABLE CELLULOSIC PACKAGING

February – July 2024, **Marine Hernandez**

Partner: all

CONTEXT AND OBJECTIVES:

In response to growing interest in LCA *(Life Cycle Assessment)* and carbon footprint, the Cellulose Valley Chair has initiated a project to conduct an advanced LCA study on cellulosic packaging. The objective is to gain a deeper understanding of the influence of processes and raw materials on the environment. The objective of this project is to compare three different products for flexible and rigid applications, and identify the optimal raw material and process in terms of three environmental factors: climate change, soil eutrophication and water consumption. The innovation is to provide LCA values about cellulose packaging, which can then be used to inform eco-design in order to meet the SUP *(Single-Use Plastic)* regulation and the AGEC French directive requirements.



MATERIALS AND METHODS

- Simapro 9.6 – Ecoinvent 9.10
- BEE 3.4 – Ecoinvent 2.2 to 3.5
- Method EF 3.1, focus on climate change, soil eutrophication and water consumption
- Dataset creation for rigid processes: Dry and Wet Molded Fiber *(DMF and WMF)* and Pulp Injection Molding *(PIM)*.

MAIN RESULTS:

- **Hardwood** is the best option for flexible packaging.
- Contrary to expectations, **cotton** might be a good candidate for CNF production.
- According to literature, **DMF** shows better environmental impact than **WMF**, PP and PS foam.

PROSPECT:

- Provide data including waste scenarios.
- Propose other data for rigid processes, depending on created datasets.

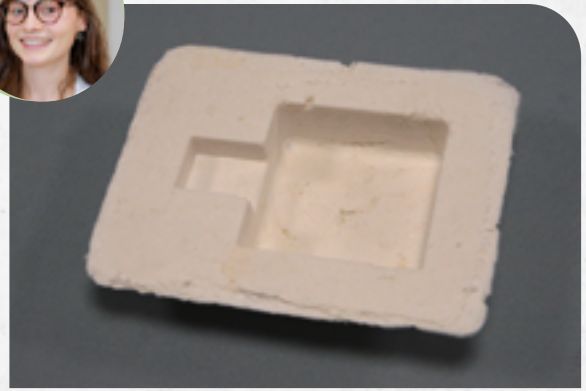
Demonstrator design

BY THE SHORT TERM INNOVATION STUDENTS TEAM

PROTOTYPE EXAMPLES FROM 2022

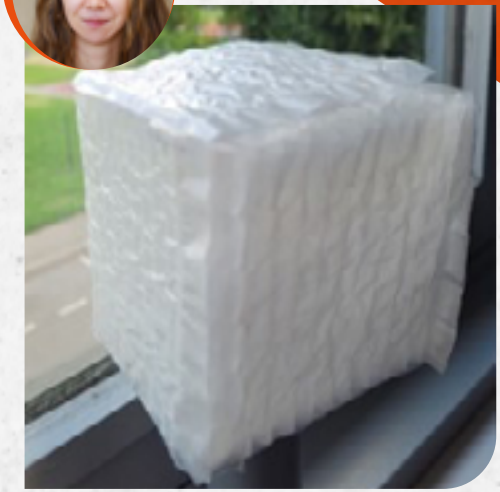
René

Annabelle



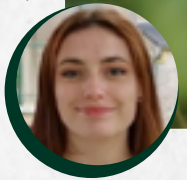
Emma

Marie



PROTOTYPE EXAMPLES FROM 2023

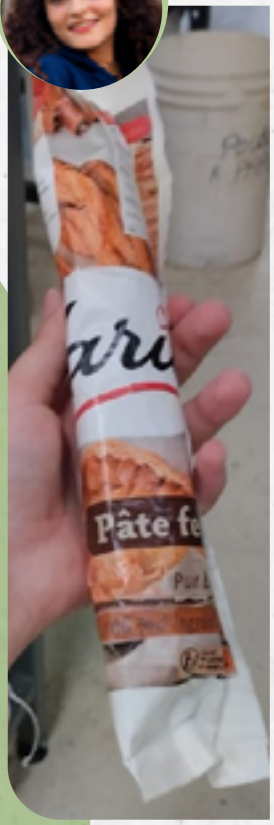
Mathilde



Aziza

Mathis

Emna

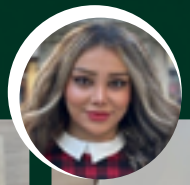


Thaïs

Sarah

PROTOTYPE EXAMPLES FROM 2024

Ahmed

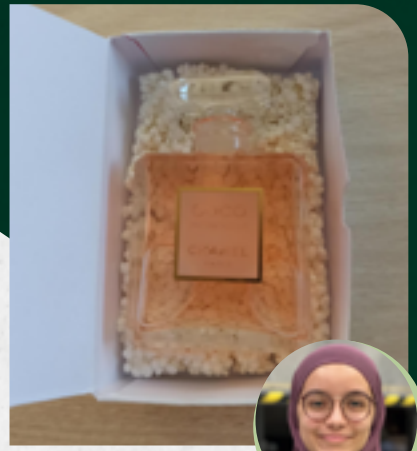


Yasaman

Elodie

Erin

Eya



Intissar

Waleed

International COLLABORATIONS

The Scientific Advisory Board proposed that the Chair should strongly considered scientific collaborations at international level.

The Chair would like to develop its partnerships by involving technical centers in its work. By the end of 2023, we plan to contact one of the following centers: EMPA, Innofibre *(Canada)*, Bioproducts Institute *(Canada)*, University of Maine *(USA)*, VTT *(Finland)*, Rise *(Sweden)*.

In this context, the Chair has hosted the VTT technical center on June 28th 2023, for a day of exchanges and visits to the LGP2 laboratory. From this meeting a collaboration was born between one of the POC project and the VTT center. The project linked to Marie group allowed the student to visit the VTT and make some characterization during 10 days in may 2024.

The chair received also Elisbeth Jahn, a research assistant from the FH Campus Wien, in Austria. She exchanged with us on the plastics recyclability problematics and had the occasion to make a presentation in front of the LGP2 public. She learned how to perform recyclability test for papers and cardboards.

THE CHAIR ALSO WELCOMED SEVERAL INTERNATIONAL PHD STUDENTS DURING THIS PERIOD:

Domenico
Santandrea

Università Foscari Venezi, Italy
January-July 2024

Chemical functionalisation of cellulose materials and their use in the preparation of protective films.

Pilar
Albaladejo

ITENE, Valencia, Spain
November 2023-January 2024

Manufacture of nanocelluloses.

Claire
Stuppa

Université du Québec
à Trois-Rivières, Québec, Canada
October-December 2024

Study of nano-suspensions / nano-wax emulsions

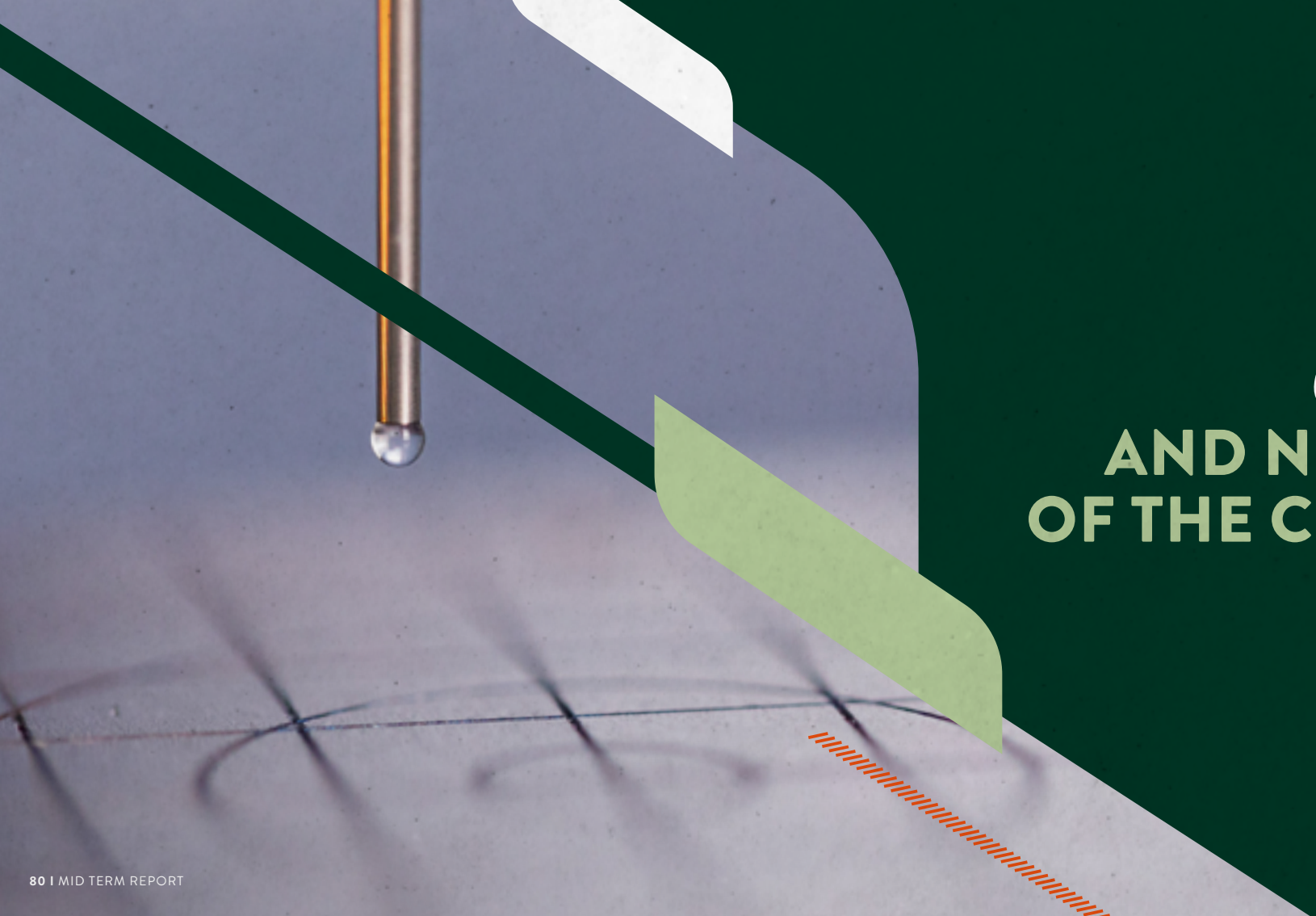
Ruby
Osei-Bonsu

University of British Columbia, Canada
September-November 2024

Improving the yield and colloidal stability of hydrolysed cellulose nanocrystals in subcritical water.

The visit of VTT pilot facilities, Graz University laboratories, Paper technical center in Ljubjana, embrapa facilities in Sao Carlos and department of paper in North Carolina State University has been useful to benchmarck our research and find complementarities.

A scientific exchange day was also organized at the University of British Columbia (UBC) in Vancouver on June 9, 2023, entitled "Not nano Cellulose". During this day, 5 UBC researchers and 5 Cellulose Valley members gave 30-minute presentations to share knowledge and advances concerning cellulose. The event was supported by the French Embassy in Canada.



Conclusions AND NEXT STEPS OF THE CELLULOSE VALLEY

The objective of the Cellulose Valley chair is to engage in research and innovation pertaining to cellulose in the context of packaging applications, and to disseminate the resulting knowledge to the wider public.

Regarding long-term innovation, all the PhD students have been launched with success, and some disruptive ideas are in progress. A benchmark with international research has been done with numerous conference participation.

Concerning the short-term innovation, already 23 proofs of concept have been launched with some positives results for most of them.

Strong relationships with the partners has been built via these short-term projects with more than 50 meetings with all the partners. The perspective for these proofs of concept is technology transfer with partners for the best projects.

Strong actions with the society have been done by the Chair members, at some exhibitions, student engagement, and some other scientific events.

The Chair is also involved in some student project like literature survey, or engineering projects.

The first two years the chair have been achieved as planned with lots of proactive actions and successful scientific discussions in agreement with the expectations of the Chair. Collaborations between some of our partners and with companies in contact with Julien Bras have been set up to scale up the proofs of concept developed by the Chair's students.

It is the Chair's hope that over the next two years, there will be a notable increase in interest in cellulose and a more sustainable industry among young engineers and students, with the objective of training the next generation for a successful environmental transition.

Aknowledgements & CREDITS

We would like to thank our partners and their involved colleagues for all the interesting discussions, guidances and advices into our commun projects. We are gratefull to our research colleagues from LGP2 and Grenoble-INP PAGORA for their scientific support and personal investigation into our different collaborations. The Chair members thank John Francis Kenwright, Francesco De Angelis and Perform platform for their support in our serious game project, Cellulose Valley – The Game.

The Cellulose Valley team would like to acknowledge Murielle Brachotte, Marie Dubrueil, Bernard Ugnon Coussoz, Benoit Giroud, and the Fondation Grenoble-INP for all their involvement and contributions. The Cellulose Valley is also gratefull to Grenoble-INP for their support in the process of creating the chair.

We thank Julia Pescheux-Sergienko, René Romero Lezama, and Mathilde Bernard-Catinat for being part of The Cellulose Valley's journey toward a sustainable future and making Science. We also thank them for their contribution to this report.

A special thanks to all the young researchers involved in the proofs of concept projects, who contributed to an important part of our research activities.

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Julien Bras

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